Andrea Malizia · Marco D'Arienzo
Editors

Enhancing CBRNE Safety & Security: Proceedings of the SICC 2017 Conference

Science as the First Countermeasure for CBRNE and Cyber Threats

Springer

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Scientific Board

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Introduction

Francesco d'Errico

This topical volume entitled "Enhancing CBRNE Safety and Security," published by Springer and edited by Dr. Andrea Malizia, University of Rome Tor Vergata, and Dr. Marco D'Arienzo, ENEA, constitutes the Proceedings of the First Scientific International Conference on CBRNe (SICC2017) which was held in Rome, Italy, on May 22–24, 2017. The conference was jointly organized by the University of Rome Tor Vergata and by the Health Safety Environmental Research Association Rome (HESAR), and it was sponsored by the European Space Agency (ESA) and by the Bruker Corporation.

While several workshops and meetings have been organized on protection against CBRNe events, this was the first major international scientific conference dedicated to all the aspects of this broad topic and will hopefully be held regularly. Indeed, the success of SICC2017 and the opportunity to organize it again in the future may be inferred from the following statistics: the conference had a total of 420 participants from over 50 countries, including 45 scientific delegates. A total of 235 abstracts were submitted, 193 were accepted after a double review, and 175 presentations were effectively delivered at the conference (100 oral and 75 poster presentations).

A sustainable solution to CBRNe threats will only be achieved when their root causes are addressed. However, our present efforts must also include developing and implementing preparedness and response techniques to prevent and mitigate the potential consequences of these events. All these topics were discussed in 12 oral sessions, opened by invited speakers, and in 2 poster sessions entitled Emergency System and Solutions; Modeling and Simulation, Diffusion, and Dispersion; Education and Training; CBRNe Policies, International Legal and Economic Framework; Medical Management and First Aid; Decision Support System; Cyber Security, CBRNe Intelligence, CBRNe Forensic, and Critical Infrastructures;

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Communication and Psychology; CBRNe-Related Geopolitical Issues; Centers of Excellence; Biological and Chemical Safety and Security, Protection, and Decontamination; and Detection and Identification.

The conference also included plenary sessions during which Prof. Leonardo Palombi, University of Rome Tor Vergata, discussed the issue of information systems and countries integration in conflict areas; Prof. Steve Johnson, Georgetown University, examined the development of international resilience; Amb. Ahmet Üzümcü, Director General of the OPCW and Nobel Peace Prize 2013, addressed the twentieth anniversary of the Chemical Weapons Convention; Mr. Dieter Rothbacher, Hotzone Solutions Group BV, discussed the central issue of training in CBRNE events; and Ms. Roberta Mugellesi, ESA ARTES-IAP, presented space-based services in support of CBRNe operations.

These proceedings provide a comprehensive account of the presentations delivered at the SICC2017 conference. The Editors and the Scientific Advisory Committee wish to thank the referees for their vital contribution to the scientific success of this endeavor. Our appreciation also goes to the members of the Springer editorial team for their highly professional and patient assistance in the publication of this volume. Finally, we wish to acknowledge the competence of the session chairpersons and the assistance of the secretarial and technical staff, which ensured the smooth running of the conference.

Part I
Detection and Identification

A Novel and Transportable Active Interrogation System for Special Nuclear Material Interdiction

Francesco d'Errico, Giuseppe Felici, and Raffaele Zagarella

1 Introduction

A key aspect in the effort to ensure national security is preventing special nuclear materials (SNM), i.e., U-235, Np-237, and Pu-239, from being introduced into our countries, hidden in the large containers entering through shipping ports and carrying the large majority of cargo. The possible presence in these containers of weapon components containing special nuclear materials is extremely difficult to detect through their faint radioactive signature. While radiation emitted by Pu-239 may be picked up by high-sensitivity devices, that of highly enriched U-235 (HEU) is virtually impossible to detect with passive interrogation techniques. In fact, the emission consists of an extremely low yield of neutrons and a weak emission of low-energy gamma rays which are strongly attenuated by surrounding materials. HEU is not only harder to detect but possibly also easier to obtain than Pu-239 and thus lends itself to improvised nuclear devices. For these reasons, active interrogation techniques (Fig. 1), using beams of neutrons or high-energy X-rays to trigger fission reactions, are considered the only viable option to detect the presence of HEU. These techniques are also effective in the detection of Pu-239, as illustrated in

It is an "Invited paper" and Prof. d'Errico was an "Invited speaker" of the conference.

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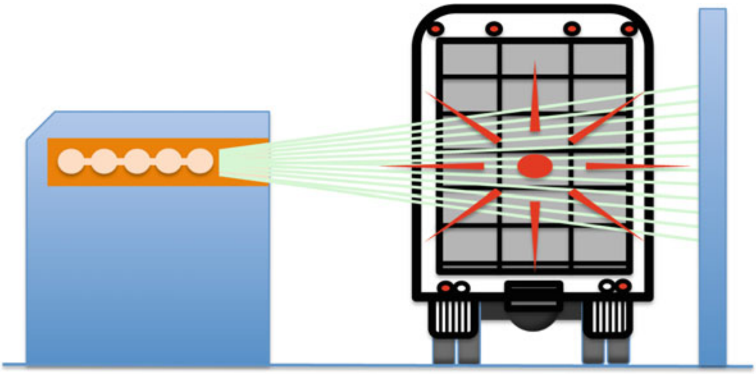

Fig. 1 Schematic of active interrogation system: an external beam of X-rays or neutrons (left-hand side) triggers the emission of fission neutron from special nuclear materials detected by a large detector (right-hand side)

a comprehensive DOE report [1] and in the reviews by Slaughter et al. [2] and by Medalia [3].

Historically, since the late 1960s [4], active interrogation for the detection of special nuclear materials has relied on the detection of delayed fission neutrons by means of moderator-type neutron detectors. These detectors can be blinded by the intense pulse of prompt gamma radiation that accompanies the fission process. In recent versions of the technique [5], a pulsed beam is used, and the detectors are gated off for a few milliseconds during and after the interrogation pulse, in order to allow them to recover from saturation. After this time, the moderator-type detectors can be used effectively to record delayed neutrons emitted with a half-life of up to 1 minute after the fission (see, e.g., Hughes et al. [6]). These neutrons carry a signature that is characteristic of special nuclear materials; however, both their emission energies and their yields are relatively low, which leads to a limited neutron flux emerging from cargo containers.

Alternative approaches have been developed relying on the detection of delayed high-energy gamma rays. These gamma rays are produced with yields about ten times larger than those of delayed neutrons, are not attenuated as intensely, and also carry a signature characteristic of special nuclear materials [7]. While providing a higher sensitivity, the technique still requires intermittent operation of the interrogation system, alternating between irradiation and detection. For improved duty cycle, novel active interrogation techniques focus on the detection of prompt fission neutrons, whose yield is over 100 times higher than that of delayed neutrons. A relevant implementation uses xylene-based liquid scintillators in conjunction with a low-energy neutron interrogation beam [8]. The system is highly sensitive to photons and requires advanced laboratory electronics for pulse-shape analysis and for the identification of the neutron signal against the prompt fission-gamma flash.

This work explores the potential of a complete AI system based on an ultracompact linear accelerator (LINAC) and on detectors developed in collaboration between the universities of Pisa and Yale. The system does not require complex electronics or special training in order to be operated and offers the possibility of simultaneous irradiation and detection, i.e., a 100% duty cycle. In fact, it relies on an extremely well-established accelerator technology and on detectors with an inherent threshold behavior and photon insensitivity in order to provide a "yes or no" answer as to whether prompt fissions are triggered by the active interrogation of a container.

2 Materials and Methods

2.1 Neutron Detector

The interdiction of special nuclear materials places heavy performance requirements on the detector systems. As was mentioned earlier, radiation beams are used to trigger fission reactions; then prompt and/or delayed fission neutrons and/or γ-rays are detected. Among the favored active interrogation approaches is using X-rays from 9 MV electron linear accelerators.

These X-rays have an effective energy causing adequate photofission in SNM (Fig. 2) while avoiding neutron production in most "innocent" materials, such as shipping container structures and legitimate contents. The photoneutron production threshold for these materials is typically above 10 MeV. An exception is the production of photoneutrons in naturally occurring deuterium; these neutrons can reach 3 MeV when produced by 9 MV X-rays. In order to record the intense prompt neutron emission, an ideal detector should not only discriminate X-rays but also

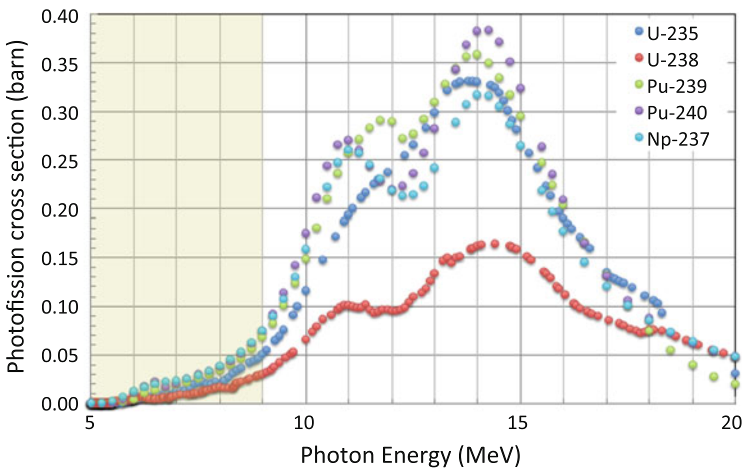

Fig. 2 Photofission cross sections for special nuclear materials of interest. The shaded area indicates the energy range of 9 MV X-rays typically employed for active interrogation

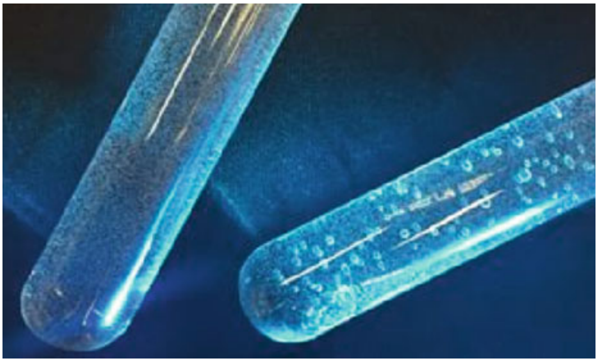

Fig. 3 Superheated emulsions of halocarbon C-318, before (left-hand side) and after (right-hand side) irradiation with fast neutrons

neutrons below about 3 MeV. Since the scan must be acquired and evaluated in real time, the detectors should be active and offer a rate-insensitive readout.

Superheated emulsions satisfy these requirements [9, 10]. They are suspensions of superheated halocarbon droplets in an inert medium [11]. Following irradiation with fast neutrons, these detectors develop bubbles, which can be recorded and then quickly reset to the liquid state (Fig. 3). Neutron-induced charged particles generate vapor cavities inside the droplets; when these cavities reach a critical size, the expansion becomes irreversible, and the whole droplet evaporates. The amount of energy and the critical size required for bubble nucleation depend on the composition and on the degree of superheat of an emulsion. By appropriate choice of the detector parameters, a selective response can be achieved to different types of ionizing radiations [12].

The detectors are manufactured in the form of emulsions placed inside glass containers, ranging from few-mL cartridges to several-liter tempered glass vessels. The metastable state of a superheated liquid is normally fragile and short-lived due to the microscopic particles and/or gas pockets present at the interface with container surfaces. However, fractionating a liquid into droplets and dispersing them in an immiscible fluid creates perfectly smooth spherical interfaces, free of nucleating impurities or irregularities. Thus, an emulsified superheated liquid may be kept in steady-state metastable conditions.

Superheated emulsions have become well-established among neutron detectors, and they are included in recent standards issued by ISO [13] and ANSI [14]. Several laboratories manufacture these detectors worldwide, and some make them available commercially (http://bubbletech.ca/) or within research collaborations (http://ocr.yale.edu/).

These detectors can be read out either postexposure, e.g., with commercial image acquisition devices, or in real time, e.g., with dynamic light scattering techniques [15].

Number, size, and composition of the droplets can be varied in the formulation of the detectors, and this permits a wide range of applications [12]. For example, highly superheated halocarbons can be used for the detection of sparsely ionizing

Table 1 Halocarbons used in the superheated emulsions for SNM interdiction

Halocarbon name and code	Chemical formula	Boiling point (°C)	Critical point (°C)
Octafluorocyclobutane, C-318	$C_4 F_8$	−7	115.2
Decafluorobutane, R-610	$C_4 F_{10}$	−1.7	113.3

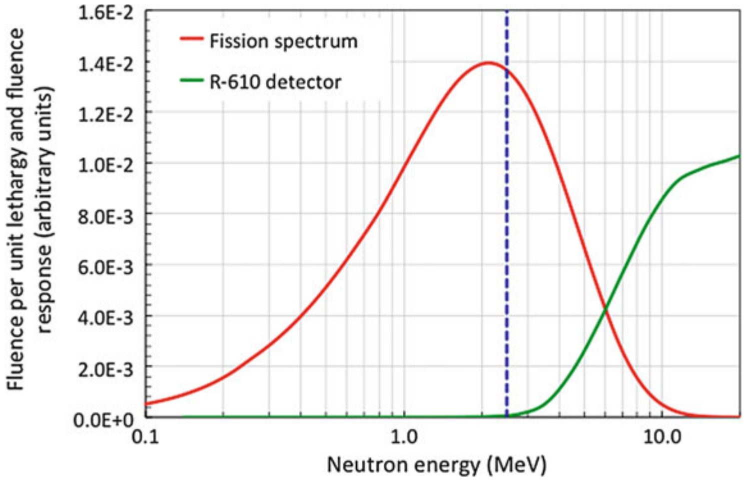

Fig. 4 Fluence response of R-610 emulsions vs a typical fission spectrum. The vertical dashed line indicates the threshold required to discriminate photoneutrons from deuterium

radiations, such as photons and electrons. In this work, halocarbons with a moderate degree of superheat were used (Table 1), since they are only nucleated by energetic heavy ions such as those released by fast neutron interactions (Fig. 4).

2.2 *Linear Accelerator*

In a close collaboration with the company S.I.T. S.p.A., we are developing a 9 MV light, compact, and mobile X-ray generator for active interrogation of cargo containers. The LINAC that we intend to adopt for the active irradiation system is based on the SIT-LIAC© machine (510(K) number K110840), which is already in use at several hospitals worldwide. The generator uses a linear particle accelerator (LINAC), whereby an electron beam is produced from a small thermionic cathode and accelerated up to 9 MeV. Radial focusing of the electron beam is achieved electrostatically; therefore, no external solenoid is required. This allows us to obtain an extremely compact and light LINAC system and virtually zero radiation leakage from the accelerating guide. A preliminary layout of the proposed LINAC system is shown in Fig. 5. LINAC, modulator, cooling unit, and RF power supply are assembled in the same enclosure. This is an innovative feature that makes our

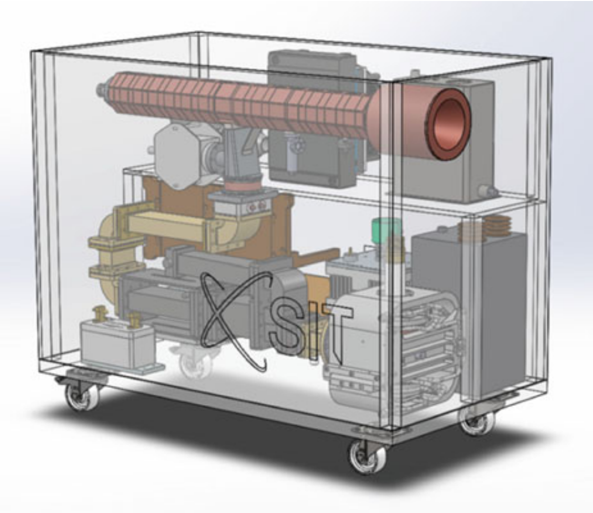

Fig. 5 Preliminary layout of the prototype LINAC system for active interrogation

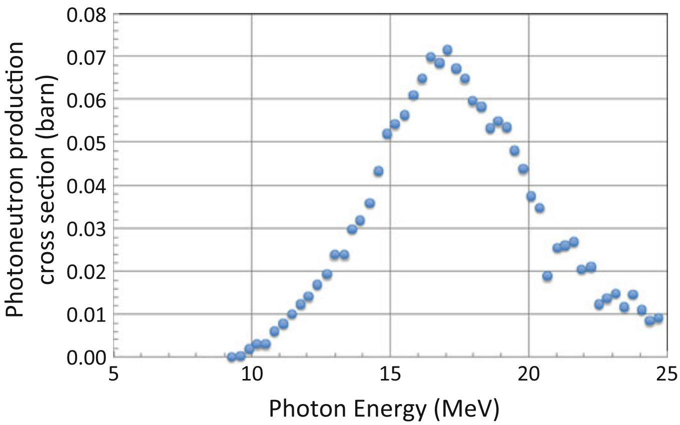

Fig. 6 Cross section for photoneutron production in copper showing that X-ray energies higher than 9 MeV are required to trigger the reaction

proposed LINAC system extremely compact and unique in its class. Only the control unit is provided separately.

A custom-designed X-ray production target was built to generate an intense and clean beam of photons, without neutron contamination. The target material is high-purity (beryllium-free) copper, whose photoneutron production cross section is shown in Fig. 6. The X-ray beam collimator is also built with high-purity copper and forms a single piece with the target. This ensures efficient heat removal during the generation of X-rays. Based on prior studies, for our first prototype, we chose a target thickness of 4.5 mm, while the internal geometry of the collimator is cylindrical.

Table 2 Stray radiation levels around the LINAC normalized to in-beam ion chamber readings

Angle (°)	Value (%)
90	<0.4
135	<0.3
180	<0.0003

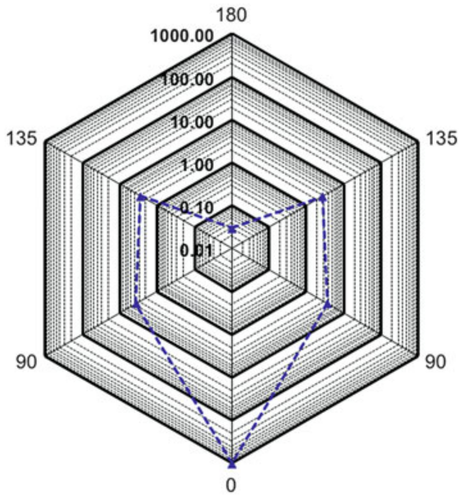

Fig. 7 Polar diagram of the leakage radiation levels around our LINAC

3 Results and Discussion

A series of experiments was carried out in order to characterize our active interrogation system. First, we investigated the radiation leakage levels around the unit, as this is a key aspect of its viability.

To determine the X-ray leakage radiation, the LINAC tube was placed horizontally at a height of approximately 170 cm from the floor. A PTW Semiflex cylindrical ionization chamber was placed in the beam at a distance of 1 m from the collimator to monitor the output of the accelerator, and two survey meters (Fluke 451P and Inovision 451B) were placed at several angular positions (90°, 135°, and 180°) to map the stray radiation around the LINAC. The results of the tests are given in Table 2 and shown as a polar diagram in Fig. 7.

Since the accelerating waveguide presents virtually zero leakage, the only source of stray radiation is the target itself. A lower leakage radiation may be easily achieved with some additional shielding around the copper collimator. Namely, a 1-cm-thick tungsten cylinder will reduce the 90° leakage from the measured value of 0.4% down to 0.04% with an additional weight of only 14.5 kg.

Next, we tested the system in terms of its ability to trigger photofission in special nuclear materials while producing negligible amounts of photoneutron contamination. A sample of military-grade depleted uranium was used along with our neutron detectors. The detectors were set to operate with a 3 MeV neutron threshold, and they were placed in the proximity of the X-ray beam, with and without depleted uranium in the radiation field. While full details will be provided in a separate publication, these tests clearly indicated that the system can trigger and detect fission neutrons while effectively discriminating against the possible presence of contaminant photoneutrons.

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Variations in Fluorescence Spectra of a Bacterial Population During Different Growth Phases

Lea Fellner, Florian Gebert, Arne Walter, Karin Grünewald, and Frank Duschek

1 Introduction

Most bacteria are harmless, but there are also pathogenic species which can be intentionally brought out. Once a person is infected, bacteria can be transmitted to other people and cause severe illness. Hence, it is crucial to detect harmful bacteria as fast as possible.

Fluorescence spectroscopy can be applied to detect and classify bacteria. This method may be used in a first step to scan large areas [1]. In the case of standoff detection, it is not necessary to collect and preprocess any samples, preventing direct contact to these materials. While the standoff detector recognizes a possible threat, in a second step, more accurate methods like mass spectrometry, immunological methods, polymerase chain reaction, and DNA sequencing for the identification of bacteria can be used to verify the detection.

Composition of bacteria and thus also fluorescence spectra of bacteria vary under different living conditions. If excited in the ultraviolet spectral region, the most prominent intrinsic fluorophores in bacteria are NAD(P)H and tryptophan. NADH and NADPH play an important role as coenzymes in metabolic redox reactions. NADH is essential for the energy metabolism of cells. Total NAD(P)/NAD(P)H and the ratio of the oxidized and reduced form vary in the bacterial cell depending on the metabolic status of the organism which is influenced by the availability of nutrients [2]. Only the reduced forms of NAD(P)H fluoresce [3]. Tryptophan is 1 of the 20 amino acids which are the building blocks of all proteins. In addition, *Bacillus* species form endospore when starving which can survive under harsh conditions,

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e.g., without nutrients, heat, and dryness [4]. They contain other fluorophores than vegetative bacteria, e.g., calcium dipicolinate (CaDPA) [5].

In order to evaluate these variations in one single bacterial strain, the fluorescence of a bacterial population during different growth phases of a batch culture was investigated. Therefore, a bacterial population of *Bacillus thuringiensis* with sufficient nutrients is compared with the same population with poor nutrients.

2 Experimental

Strain *Bacillus thuringiensis* (DSM 6102) was used. 800 ml Luria broth (LB) Miller (Sigma-Aldrich, Saint Louis, USA) in a shaking flask was inoculated with an optical density (OD_{565nm}) of 0.5 McFarland units measured by a densitometer (Grant Instruments Ltd., Cambridgeshire, GB). Bacteria were cultivated with limited nutrient supply in LB shaking at 26 °C for 9 days.

During the first 8 hours, OD_{565nm} and colony-forming units/ml (cfu/ml) were determined every hour and after that at larger time intervals. For evaluation of endospore content, bacteria were heated to 65 °C for 1 hour, and then the amount of cfu/ml was determined from cultivation of 100 μL serially diluted bacterial suspensions in phosphate-buffered saline (PBS) with 0.4% agar on nutrient agar I (Sifin Diagnostics GmbH, Berlin, Germany) at 26 °C overnight.

For sample preparation, a volume of bacteria, which resulted in a final (theoretical) OD_{565nm} of 22 McFarland when concentrated to 5 ml, was taken from the culture flask at the same time intervals the cfu/ml was determined. Samples were centrifuged 10 min, 3500×*g*, 4 °C, and washed once in 4 °C 50 ml PBS. After another centrifugation, pellets were suspended in 5 ml PBS. Final samples had an OD_{565nm} between 10 and 20 McFarland units corresponding roughly to 10^8 cfu/ml. Fluorescence of samples was measured instantly after sample preparation. Fluorescence measurements were conducted in 3500 μL cuvettes (117-QS, Hellma GmbH & Co. KG, Müllheim, Germany), while the samples were continuously stirred with a magnetic bar and stirrer. As reference for fluorescence intensity, fluorescence of a solution containing 8.5×10^{-5} M NADH disodium salt and 3×10^{-4} M tryptophan was measured instantly after each bacterial sample.

The membrane integrity of bacteria was tested by dyeing the bacteria with SYTO® 9 green-fluorescent nucleic acid stain and the red-fluorescent nucleic acid stain, propidium iodide. Therefore, LIVE/DEAD® BacLight Bacterial Viability Kit (Thermo Fisher Scientific, Waltham, Massachusetts, USA) for microscopy was used. Bacterial samples were observed by phase contrast microscopy (CFI Achromat DL-100x oil Ph3/1.25/0,23) and fluorescence microscopy (CFI E P-Achromat 100X oil/1.25/0,23) using a (DIS) ECLIPSE E200-F microscope (Nikon, Chiyoda, Tokyo, Japan). For excitation, a high-pressure mercury vapor arc-discharge lamp (HBO lamp) and a spectral filter for 450–490 nm were used. Pictures were taken with a DS-Vi1 color microscope camera (Nikon).

Laser-induced fluorescence (LIF) of bacterial samples in cuvettes with alternating excitation wavelengths of 280 nm and 355 nm was measured as described previously [6]. Laser pulses with a pulse width of 7 ns and pulse energy of approximately 10 mJ were used for excitation. One hundred background corrected single spectra were averaged. Averaged fluorescence spectra were smoothed using Origin (Adjacent Averaging, points of window 10, OriginLab, Northampton, Massachusetts, USA).

3 Spectral Results and Interpretation

Growth of bacteria was carried out with limited nutrient supply. The bacterial population was growing exponentially during the first 5 hours as indicated by the increasing OD_{565nm} (Fig. 1). After 1–2 days, the viability of bacteria decreased due to depletion of nutrients, and the number of cfu/ml declined. After 6 days, the membrane of some vegetative bacteria was damaged, as an increase in red fluorescence due to penetration through the bacterial membrane of the fluorescence dye propidium iodide was observed. Phase microscopy and heat-resistant cfu indicated that after 7 days, the endospore content had increased to over 50% of the total number of bacteria.

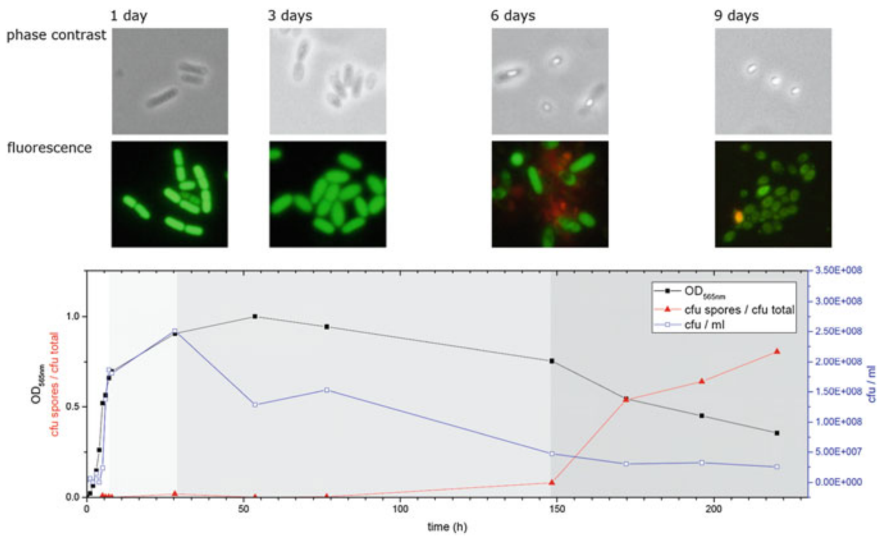

Fig. 1 Growth of a *Bacillus thuringiensis* population in LB medium at 26 °C. Optical density normalized to one, fraction spores, and cfu/ml of the bacterial population are shown after different times of incubation in the lower graph. Microscopic pictures (1000×) of the 1-, 3-, 6-, and 9-day-old bacterial population are shown in the top part of the figure. Phase contrast microscopy shows vegetative bacteria as dark rods and spores as white ovals. For fluorescence microscopy, bacteria were treated with LIVE/DEAD® BacLight Bacterial Viability Kit. Alive bacteria are shown in green, whereas dead bacteria are red

3.1 280 nm Excitation

Figure 2 shows spectra of bacterial samples measured at different living phases of the bacterial population. Fluorescence spectra measured in the time interval between 1 hour and 3 days (samples do not show significant endospore content) are very similar with a strong, single fluorescence peak at 325 nm. Fluorescence spectra of the older, 6–9 days, bacterial population with significant endospore content show an additional peak at about 500 nm. Figure 2d shows that the fluorescence emission at 500 nm is increasing with respect to the fluorescence emission intensity at 325 nm. This may be attributed to endospore formation.

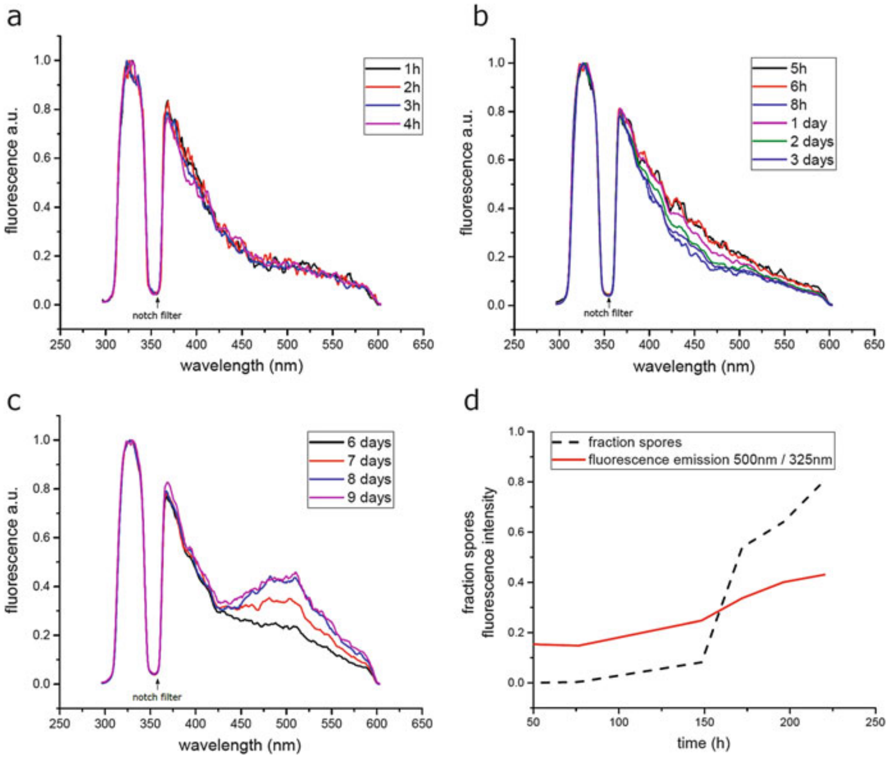

Fig. 2 Fluorescence emission for excitation with 280 nm laser pulses (**a**), (**b**), (**c**). Normalized fluorescence emission spectra of a *Bacillus thuringiensis* population during different growth phases. The maximum was set to one. (**d**) Intensity of fluorescence emission at 500 nm divided by fluorescence emission at 325 nm is shown in red for a bacterial population at different living phases. The endospore fraction of the bacterial population is shown in black

3.2 355 nm Excitation

Fluorescence spectra of bacteria excited at 355 nm sampled from the exponential growth phase differ slightly from aging bacteria and samples containing endospores (Fig. 3a–c). Total fluorescence emission seems to increase when the bacterial culture is aging (Fig. 3d).

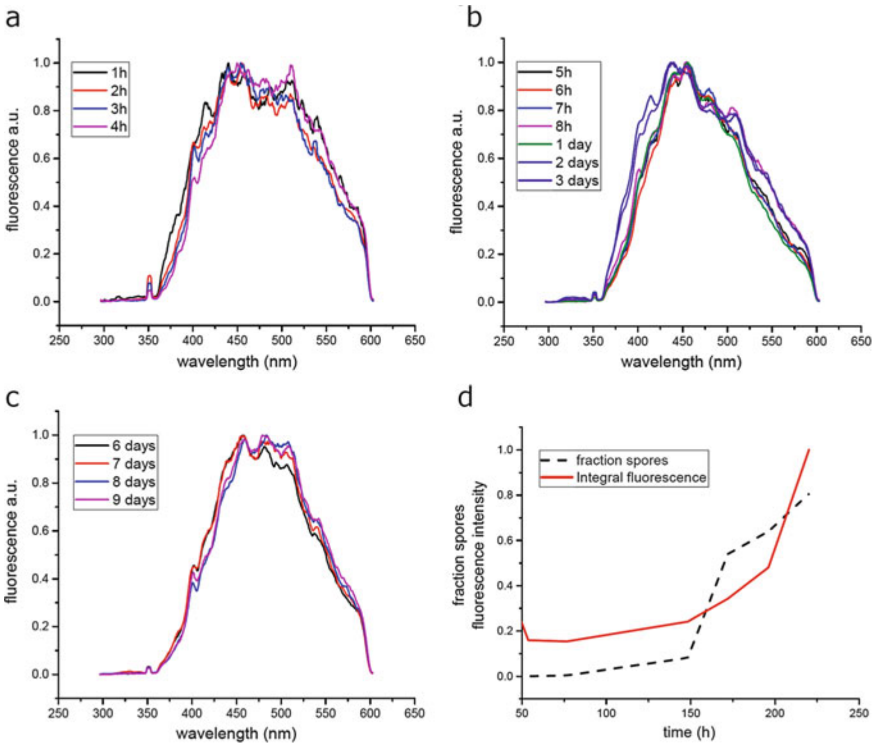

Fig. 3 Fluorescence emission for excitation with 355 nm laser pulses (**a**), (**b**), (**c**). Normalized fluorescence emission spectra of a *Bacillus thuringiensis* population during different living phases for 355 nm excitation are shown. The maximum was set to one. (**d**) The red curve shows total intensity of fluorescence for 355 nm excitation for a bacterial population at different living phases. The integral of fluorescence emission was divided by the OD_{565nm} of the bacterial sample (concentration) and the fluorescence emission at 489.38 nm of an 8.5×10^{-5} M NADH disodium salt and 3×10^{-4} M tryptophan solution measured instantly after the bacterial sample. Then values were normalized, maximum = 1. The black curve shows the fraction of endospores in the bacterial population

4 Discussion

NAD(P)H is probably the main contributor to fluorescence emission of bacterial samples when excited at 355 nm [5, 7]. Differences in spectra can be caused by the contribution of a change in abundance of absorbing and fluorescent molecules, while bacteria adapt their composition to their living conditions. In addition, fluorophores can be bound to proteins or not. NAD(P)H occurs reduced or oxidized depending on the metabolic status of the cell.

Total intensity of fluorescence emission for excitation at 355 nm seems to increase for the aging bacterial population. However, concentration of bacterial suspension was quantified from OD_{565nm}, which might be problematic since the shape and size of vegetative bacteria are different to the endospore form of bacteria. It might be more accurate to determine the bacterial concentrations from, e.g., dry mass of the bacterial material for quantitative investigations of fluorescence intensity.

When excited at 280 nm, the fluorescence spectrum of a bacterial sample with significant fraction of endospores shows a peak at 500 nm which is not seen for a sample with vegetative bacteria. For this excitation, wavelength fluorescence emission below 500 nm is most likely due to tryptophan fluorescence and some tyrosine. Fluorescence emission around 450–500 nm excited at 280 nm might be caused by NAD(P)H, but it does not seem likely that endospores contain more reduced NAD (P)H than vegetative bacteria since NADH plays an important role in energy metabolism and endospores are practically metabolic inactive [8]. One hypothesis is that in endospores, calcium dipicolinate (CaDPA) contributes to fluorescence emission. According to Hill et al. [5], dry weight vegetative *Bacillus* contains 0.15% NAD(P)H and 0% CaDPA. *Bacillus* dry weight endospores contain 0% NAD(P)H, 0.008% NAD(P), and 10% CaDPA. For dry and wet DPA, a maximum emission at 440 nm for 360 nm excitation was shown [9], but the fluorescence emission we observe occurs for higher wavelengths.

In Pan et al. [10, 11], fluorescence spectra for excitation at different wavelengths (266, 273, 280, and 365 nm) of aerosolized endospores from *Bacillus atrophaeus*, *Bacillus thuringiensis*, and *Bacillus anthracis* and the vegetative bacteria *Escherichia coli*, *Pantoea agglomerans*, *Yersinia rohdei*, and *Yersinia pestis* are shown. Strong fluorescence emission for *Bacillus anthracis* and *Yersinia pestis* at 400–600 nm is shown, whereas they found little fluorescence above 400 nm for the other samples. There, no clear difference between the endospores and the vegetative bacteria was observed. We measured bacteria in suspension, whereas Pan et al. measured aerosolized bacteria which might explain differences in spectra. Stronger fluorescence emission at wavelengths between 400 and 600 nm, as we observed, has been reported previously for *Bacillus* endospores compared to vegetative *Bacillus*. In Hill et al. [12], a similar peak with fluorescence emission between 400 and 550 nm is shown for aerosolized *Bacillus subtilis* endospores when excited at 260 nm. This peak was not observed for vegetative *Bacillus subtilis*. Alimova et al. [13] describe an increase of fluorescence emission around 410 nm for a starved *Bacillus subtilis* population compared before starvation with 270 and 340 nm excitation. The authors state that this is due to an increase of DPA in endospores.

5 Conclusion and Outlook

When exciting bacterial samples from different growth phases at 280 nm and 355 nm, the variation in the fluorescence emission spectra is quite small. This facilitates the detection of bacteria using LIF; nonetheless, one should take the changes of the spectra for different growth phases into account when creating a reference database of fluorescence spectra [14]. Both spectra of vegetative bacteria and endospores should be included in a database used for classification and identification purposes, since the spectra for these two living forms differ strongly.

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A Mobile Complex System for Fast Internal Contamination Monitoring in Nuclear and Radiological Terrorism Scenarios

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1 Introduction

The possibility of using radiological weapons (both real and to create panic) designed to spread radioactive material or deliberate terrorist attacks on nuclear power plants stresses the necessity of arranging suitable facilities and preparing and testing procedures in order to conduct a large-scale individual monitoring of internally contaminated public. Difficulties in implementing such monitoring on field can be represented, besides considerable organizational and logistical issues, by the need to arrange suitable mobile measurement systems to be quickly assembled, easily transportable, and usable in contaminated environments for a long period, also in critical conditions.

Such systems must moreover have an optimal energy resolution in order to identify each emission line of unknown spread radionuclides and be able to acquire useful data in a very short time in order to monitor a large group of contaminated people [1, 2].

The common internal contamination measurement systems to be used on field consist of high-resolution detectors and handheld NaI(Tl) instruments, both shielded and unshielded [3]. All these systems have disadvantages: shielded detectors are difficult to transport and very expensive, unshielded detectors could be affected by environmental contamination resulting from the incident, whereas NaI(Tl) detectors

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aren't sufficiently accurate in cases of incidents involving mixtures of radionuclides [3].

In this paper we propose a mobile complex system (MCS), composed of a collective protection (Col. Pro.) apparatus and a portable spectrometer HPGe trans-SPEC-DX-100. The Col. Pro. can be used at the same time both for scientific laboratories and outpatient clinic and allows thus to give prompt medical treatment for decorporation therapies to internal exposed individuals identified by the spectrometer therein installed. Moreover, being the Col. Pro. coupled to a decontamination station, the spectrometer allows to correctly select really internal contaminated individuals after their shower, avoiding therefore administering unnecessary medical therapies. Such features, together with appropriate counting geometries hereafter described, make the **proposed** MCS particularly suitable for fast monitoring on field of internal contamination by gamma emitters in radiological-nuclear emergencies from malicious acts.

2 Materials and Methods

2.1 Collective Protection Apparatus

The Col. Pro. is formed by high-pressure inflatable deployable tents (Fig. 1) provided with connecting passageways. This apparatus is characterized by a quick deployment, light weight, and good behavior in extreme weather conditions (e.g., −20 to +49 °C, strong wind, rain, and snow). The Col. Pro. is composed of an access area fitted with an overpressured air lock, a decontamination area based on showering systems to remove any type of Chemical–Biological–Radiological–Nuclear (CBRN) agents and some living areas (clean areas) equipped with a positive-pressure CBRN filtration. The CBRN filtration system allows relief from the continuous wearing of masks and coverall equipment and, together with closed-circuit climate control, provides a safe mobile environment to be used both for scientific laboratories and outpatient clinic.

Fig. 1 Outside (left) and inside (right) view of the Col. Pro. deployed on open ground field

2.2 Trans-SPEC-DX100 Spectrometer and Calibration Procedures

The trans-SPEC-DX-100 portable gamma spectrometer [4] uses a P-type crystal HPGe detector ($\Phi = 66$ mm and $h = 50$ mm). The instrument is cooled by a miniature, high-reliability Stirling mechanical cooler that runs, in absence of power supply, from internal lithium-ion battery (3 hours operation life) or supplemental external batteries; thus no liquid nitrogen is required. The detector has a 41% relative efficiency and a 0.15% energy resolution at 1332 keV. Considering its weight (11.5 kg) and its moderate size, the spectrometer is particularly suitable for direct measurements on field, and thus it is usually used to measure radioactive contamination of large areas. Through a customized support, the spectrometer can be mounted on a variable length tripod, provided as standard equipment, whether tilted to a desired angle or horizontally: in such arrangements we have the chance to carry out direct in vivo measurements.

Energy and efficiency calibrations were performed in two arrangements: for whole-body (WB) measurements by means of an anthropomorphic adult BOMAB (BOttle Mannikin ABsorption) phantom and for thyroid (T) measurements by means of a neck phantom. In all cases, in order to maximize efficiencies, no shielding was used.

The used BOMAB phantom [5] simulates a male adult individual of 70 kg weight and 173 cm height and consists of ten polyethylene independent bottles, reproducing the size and the shape of the external anatomical characteristics of the ICRP reference man [6]. Each section is filled with a gelled homogeneous solution (0.987 kg/dm^3) containing a known amount of certified mix radionuclide source (^{60}Co, ^{137}Cs, and ^{241}Am). Concerning the BOMAB positioning, we adopted the seated geometry: it guarantees the highest accuracy of the methodology, allowing both to optimize counting efficiencies and to reduce the variability due to the size and the height of the individuals under investigation. In addition, this geometry allows individuals to undergo WB scans in a stable and comfortable position, improving, in situations of high emotional tension, the reproducibility of the theoretical measurement geometry ensuring hence a better applicability of the calibration coefficients. For these reasons, the BOMAB phantom was placed on a chair, and the spectrometer was placed in this optimized WB configuration: its sensitive area at a distance of 87 cm from the phantom chest (navel), with a height from the ground level of 120 cm with its longitudinal axis lying on the BOMAB sagittal plane and sloping of $-36°$ (see Fig. 2 – left). Treating nuclear and radiological terrorism scenarios, where it's very probable the need of measuring even injured or shocked persons, we also performed calibrations placing the BOMAB phantom laid on a stretcher (see Fig. 2 on the right): in this case the sensitive area surface of the spectrometer was positioned at a distance of 44 cm from the phantom chest (navel), at a height of 133 cm from the ground level with a slope of $-26°$.

The used neck phantom was proposed in a recent project called Child and Adult Thyroid Monitoring After Reactor Accident (CAThyMARA) [7]. It consists of a

Fig. 2 Geometry calibration in sitting WB (left) and in supine WB (right) configurations

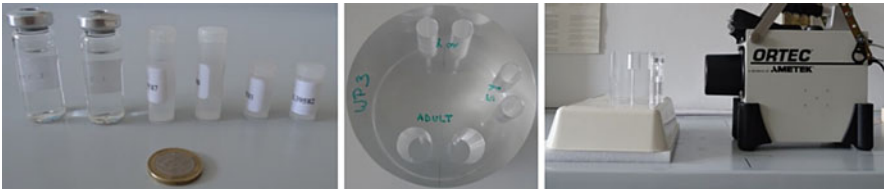

Fig. 3 Three pairs of vials in liquid form simulating different thyroid sizes (left) to be inserted in the neck plexiglass phantom (center) for calibration in T configuration (right)

plexiglass cylinder [8], shown in the middle in Fig. 3, representing the neck ($\Phi =$ 13 cm and h = 12 cm) with three pairs of holes with different dimensions for inserting the vials in liquid form, shown on the left in Fig. 3. In particular the two vials of volume 1.6 ml each simulate the thyroid lobes of a 5-year-old child, the two vials of volume 3.75 ml each simulate the thyroid lobes of a 10-year-old child, and the two vials of volume 9.5 ml each simulate the thyroid lobes of an adult [8]. Aiming to detect and to quantify ^{131}I in thyroid, the filling solution contains a liquid certified ^{133}Ba source, being the most suitable radionuclide because of its long half-life (10.5 years) and its gamma-ray energy at 356 keV which usefully simulates the main gamma emission of ^{131}I. The sensitive area surface of the spectrometer was positioned at 10 cm far from the neck phantom, with its longitudinal axis parallel to the ground level. Such arrangement, shown on the right in Fig. 3 and replicable on the tripod, is called T configuration. This entire T procedure (efficiencies, positioning, and choice of 100 s hereafter indicated for acquisition time) was successfully tested in the CAThyMARA project [7].

2.3 MCS Performance Evaluation

Arranging the Col. Pro. on open ground field (see Fig. 1) and the spectrometer in an inner area dedicated to scientific laboratories, the MCS performance was determined by means of ten soldiers' acquisitions of 180 s counts each in sitting WB configuration and 100 s counts each in T configuration. Realizing no child thyroid scans, in order to be conservative, all evaluations related to 5-year and 10-year thyroids were carried out using adult WB acquisitions. In parallel with the acquisitions, we were estimating the rate of ambient dose equivalent H*(10) by means of a calibrated scintillator portable probe.

Concerning radionuclides, supposing deliberate attacks on nuclear power plants or malicious acts with radiological weapons, we considered the main gamma-emitting radionuclides in presence of a nuclear release (^{95}Zr, ^{95}Nb,^{99}Mo–^{99m}Tc, ^{103}Ru, ^{131}I, ^{132}Te–^{132}I, ^{134}Cs, ^{137}Cs, ^{140}Ba,^{140}La, and ^{141}Ce) and ^{60}Co, ^{137}Cs itself, and ^{192}Ir, being the ones more easily stolen from hospitals and industries. Detection limit (DL) values expressed in terms of Bq were evaluated on averaged parameters on the ten soldiers' acquired spectra (GammaVision Version 6.08) using the ISO 28218 methodology [9], considering the relative efficiency uncertainties $\Delta\varepsilon/\varepsilon$ constant for all efficiency values and equal to 20% [10]. Owning just punctual in vivo efficiency values ε expressed in terms of $s^{-1}/(\gamma/s)$ (the used radionuclides don't allow to create an accurate calibration curve), in order to be conservative, we chose to use for energy peaks lower than 662 keV the punctual efficiency registered for ^{137}Cs, ^{95}Zr, and ^{95}Nb and the punctual efficiency registered for the first peak of ^{60}Co and for ^{140}Lathe efficiency obtained by means of linear extrapolation.

Concerning doses, DL intakes (i.e., the intake corresponding to an in vivo amount equal to a DL value) expressed in terms of kBq and related committed effective doses E(50) and equivalent doses in thyroid H_T (thyroid weighting factor equal to 0.05), expressed both in terms of mSv, were evaluated for members of the public with particle AMAD equal to 1 μm using the MONDAL3 software [11, 12] and, when the retention curves are not available for members of the public, the RiPhyKo German regulations [13] for workers, always with 1 μm particle AMAD, assuming an acute inhalation intake occurred 5 days before the measurement. Since it is least likely to lead to a large overestimate or underestimate of E(50), type M absorption behavior was assumed as a default for environmental exposure of members of the public to all radionuclides in particulate form, excluding^{131}I, ^{134}Cs, and ^{137}Cs whose data indicate that many of the principal forms of the element likely to be encountered exhibit behavior characteristic of type F [14]. For ^{99}Mo–^{99m}Tc, instead, type S absorption behavior was assumed since their retention function for type M is not available.

3 Results

The overview of the MCS characterization is shown in Table 1, where are reported for each radionuclide the nuclear yield of the main gamma emission, the relative efficiency ε, the DL value, the assumed absorption type of the compound of the inhaled aerosol, the related intake, as well as the corresponding E(50) and H_T values. All reported values in Table 1 are related to acquisitions carried out in sitting WB configuration (see Fig. 4 on the left), excluding ^{131}I-adult values which are related to acquisitions in T configuration (see Fig. 4 on the right). Efficiency values related to the supine WB configuration (see Fig. 2 on the right) were evaluated about 70% higher than the ones obtained in sitting WB configuration (e.g., 6.5E−05 s^{-1}/[γ/s] at 662 keV).

The MCS shows, with an average rate of H*(10) in Col. Pro. equal to 92 nSv/h, DL values of the order of thousands of Bq for acquisitions of 180 s in sitting WB configuration and of the order of 100 Bq for acquisitions of 100 s in T configuration, resulting in a maximum E(50), due to an acute inhalation of a single radionuclide that occurred 5 days before measurement, equal to 1.1 mSv (^{140}Ba) and a maximum H_T due to ^{131}I in the same exposure scenario equal to 1.3 mSv (related to a 5-year thyroid).

4 Discussion

The MCS in supine WB configuration shows in vivo efficiencies higher than those obtained in sitting WB configuration: this advantage is only due to the lower distance detector-body surface, but on the contrary, as previously explained, the supine geometry implies an increment of measurement uncertainties due both to the distribution of the contaminant in the body and to the variation in body size. However, in order to be conservative, we suggest the use of the sitting WB calibration also when analyzing scans of individuals placed on the stretcher. This approach can significantly avoid underestimations of human body activity and simplifies the procedure for a first estimation of WB radionuclide concentrations in a public monitoring.

The MCS in T configuration shows in vivo efficiencies decreasing with thyroid volume increment (i.e., age); being the efficiency range not particularly wide, the same adult calibration is suggested when scanning and analyzing thyroids of all ages.

The site, where the Col. Pro. is set up, takes on particular importance. As previously cited, values illustrated in Table 1 derived from measurements carried out on open field with an average rate of H*(10) equal to 92 nSv/h. Similar measurements on asphalt surface, with an average rate of H*(10) equal to 170 nSv/h, provided DL values 30% higher than the ones reported in Table 1. In order to optimize MCS capabilities, it is opportune to identify the most suitable site by in situ ambient dose measurements.

Table 1 Overview of the MCS characterization with the Col. Pro. apparatus on open ground field with recorded rate of H*(10) equal to 92 nSv/h

Radionuclides	Main emission (keV)	Yield (%)	Eff. ε [$s^{-1}/(\gamma/s)$]	DL (Bq)	Absorption type	Intake (kBq)	E(50) (mSv)	H_T (mSv)
^{99}Mo–^{99m}Tc	141	90	3.8E−05	18,000	S	470	0.46	–
^{141}Ce	145	48	3.8E−05	33,000	M	260	0.82	–
^{132}Te–^{132}I	228	88	3.8E−05	12,000	M	230	0.51	–
^{192}Ir	317	83	3.8E−05	9100	M	75	0.37	–
^{131}I (adult)	364	81	3.4E−03	120	F	1.8	0.01	0.27
^{131}I (10 years)	364	81	3.9E−03	110	F	1.7	0.03	0.63
^{131}I (5 years)	364	81	4.2E−03	105	F	1.8	0.07	1.3
^{103}Ru	497	90	3.8E−05	6100	M	51	0.12	–
^{140}Ba	537	25	3.8E−05	21,000	M	220	1.1	–
^{134}Cs	605	98	3.8E−05	4500	F	15	0.10	–
^{137}Cs	662	85	3.8E−05	4800	F	16	0.07	–
^{95}Zr	757	54	2.8E−05	9800	M	74	0.35	–
^{95}Nb	766	100	2.8E−05	5400	M	45	0.06	–
^{60}Co	1332	100	2.6E−05	3300	M	25	0.25	–
^{140}La	1596	95	2.3E−05	4000	M	240	0.26	–

Fig. 4 Trans-SPEC-DX-100 spectrometer in sitting WB (left) and T (right) configurations

From the dose point of view, the (high) E(50) value equal to 1.1 mSv, observed for ^{140}Ba, mainly derives from the small yield value (24.6%) related to its principal emission line. However, since ^{140}Ba decays to various excited levels of ^{140}La, it is possible to detect ^{140}Ba also by analysis of ^{140}La main emission line(s). Assuming the same retention function both for ^{140}Ba and its daughter ^{140}La, the in vivo activity of the two radionuclides is roughly identical 5 days after a pure ^{140}Ba acute intake (their equilibrium is reached 19 days after the intake). Therefore the E(50) value can be evaluated to be 0.21 mSv for ^{140}Ba, associating the same DL value as the one related to ^{140}La. Same approach can be applied for ^{132}Te–^{132}I (equilibrium reached 1 day after the intake): it is possible to detect ^{132}Te also by analyzing the main emission line(s) of ^{132}I, obtaining a E(50) value equal to 0.17 mSv for ^{132}Te. Finally, for ^{99}Mo–^{99m}Tc and ^{141}Ce, the two E(50) values mainly derive from the use of the punctual efficiency registered at 662 keV(supposed to be at least 2 times lower than the one at 143 keV).

Considering previous arguments, all the evaluated E(50) values are lower than the annual limit of effective dose equal to 1 mSv for public exposure reported on [15], and the evaluated H_T values are lower than the lowest 10 mSv reference level for consideration in planning stable iodine prophylaxis, as recommended on [16]. The observed performance level makes the MCS a very useful tool to be used for fast internal WB and T monitoring in nuclear and radiological emergencies, both in case of accidents and as a consequence of malicious acts. Supposing a logistical organization allowing an implementation of measurements every 5 minutes and a H24 workability, we can estimate a monitoring capability up to 250 individuals per day for each detection system setup (in a Col. Pro. it is possible to install up to three portable spectrometers).

5 Conclusions

In this paper a mobile complex system has been proposed for in vivo measurement on field, in nuclear and radiological terrorism scenarios, both for scientific laboratories and outpatient clinic. The system, allowing to operate in contaminated environment, can be used when a large number of individuals has to be quickly internally monitored and potentially medically treated. The system, coupled to a decontamination station, avoids the overlapping between external and internal contaminations, reducing the risks of unnecessary medical therapies. The adopted counting geometries guarantee a reduction of mistakes in activity evaluations due to the variability of the individuals under investigation and an assessment of committed doses greater than 1 mSv due to gamma emitters if monitoring is carried out within 5 days after intake.

It is recommended, before starting any kind of in vivo acquisitions, to carry out measurements of ambient dose equivalent rate to identify the most suitable site to set up the collective protection apparatus on and to acquire a prior background spectrum in order to reevaluate DL values, to be related to each specific scenario.

The system together with the current procedure can be also a valid tool to be used to evaluate nuclear danger in national or transboundary nuclear accident.

As for the procedure related to measurements of ^{131}I in thyroids, the participation in the next EURADOS WBC intercomparison (Working Group 7) is planned in order to validate our entire WBC procedure.

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Field-Based Multiplex Detection of Biothreat Agents

Christopher Pöhlmann and Thomas Elßner

1 Introduction

Recent bioterrorist events, such as the anthrax letters in 2001 or the ricin letters in 2003–2004 and 2013, demonstrate the need to immediately detect and identify biothreat agents. Beside these deliberately caused outbreaks, naturally occurring outbreaks of infectious diseases such as Ebola outbreak in West Africa 2014–2016 or cholera outbreak in Yemen 2016–2017 describe another likely scenario of the release of biothreat agents. Rapid and reliable detection of biothreat agents is of utmost importance not only to confirm that a bioterrorism event has occurred but also to initiate appropriate organizational as well as medical countermeasures [1]. The analytical method must be able to detect minute quantities of a biothreat agent because a countless number of similar microorganism or substances are constantly present in the environment. Furthermore, due to the high lethality or toxicity, respectively, of biothreat agents [1], reliable detection technologies require an extraordinary sensitivity to make a reasonable statement about the presence of threatening amounts of biothreat agents. Beside sensitivity and specificity, the various natures of possible biothreat agents are a challenge for on-site detection platforms. Initial symptoms of an active infection are generally nonspecific (fever, malaise, fatigue) [2]. These unspecific symptoms constitute an immanent diagnostic challenge, because an intentional release of biothreat agents needs to be identified rapidly and reliably for effective diagnosis and treatment.

In general, nucleic acid-based detection platforms relying on polymerase chain reaction (PCR) or isothermal amplification technologies offer a higher sensitivity than antibody-based detection technologies. However, PCR requires a clean sample and, therefore, elaborates sample preparation steps prior to analysis. Furthermore,

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PCR is unable to detect proteinaceous toxins such as ricin or botulinum neurotoxins (BoNTs) [3]. Hence, immunoassay-based detection systems offer a technology for universal detection of bacteria, viruses, as well as toxins. However, the currently most widely applied immunoassay-based detection technology, the conventional 96-well format enzyme-linked immunosorbent assay (ELISA), is not suitable for resource-limited settings because it requires trained personnel and is time-consuming and labor-intensive. In contrast, lateral flow assays are easy to use and can be applied in the field but often suffer from limited sensitivity and specificity needed to facilitate unambiguous diagnosis [4]. Electrochemical biosensors have been the subject of basic and applied research for many years as particularly attractive because of their high sensitivity and selectivity, low cost, and ease of automatization [5–7]. Furthermore, advantages include low energy consumption, small fluid volume requirement, short assay time, high portability, and multiplexing ability [8]. In general, a biosensor relies on highly specific recognition events between biological receptor molecules such as antibodies, aptamers, peptides or nucleic acids and their target molecules generating substances for detection by the physicochemical transducer resulting in a measureable signal. Electrochemical sensors exhibit electrodes such as gold or graphite electrodes as transducer elements. Electrochemical biosensors specific for nucleic acids mostly rely on hybridization between a target nucleic acid and complementary DNA oligonucleotides immobilized on the electrode [5]. Electrochemical immunosensors for detection of proteinaceous analytes mostly apply the highly specific interaction between immobilized antibodies and corresponding antigens. Often the robust and sensitive sandwich format is used. In this format the analyte is bound between a capture antibody and a detection antibody labelled with a reporter enzyme such as alkaline phosphatase or β-galactosidase generating an electroactive product [9].

Here, an electrochemical detection platform for multiplex detection of up to six biothreat agents such as *Bacillus anthracis*, *Yersinia pestis*, *Francisella tularensis*, *Brucella melitensis*, *Burkholderia mallei*, and *Variola major* virus applying a total assay time of 20 min in a fully automated procedure is presented. The detection platform is integrated in a robust, lightweight case offering a fully deconable housing allowing application for on-site detection in resource-limited settings.

2 Experimental Procedures

2.1 The Biodetection Platform

The pBDi instrument is 21 cm long × 41 cm wide × 41 cm high, weighs 14.2 kg, and runs on battery or 19 V DC power, respectively (Fig. 1). The pBDi is fully portable and deconable due to integration into a robust, lightweight case (Ingress Protection class 65). The pBDi communicates with Control software installed on a ruggedized tablet PC through USB cable or wireless via Bluetooth. The instrument manipulates all required fluids to perform electrochemical ELISA on the biochips in

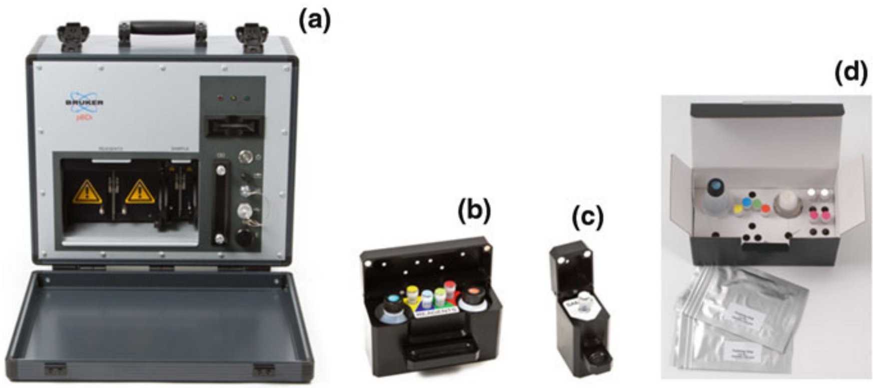

Fig. 1 The pBDi open (**a**) with reagents (**b**) and a sample holder (**c**) as well as a training kit (**d**)

a fully automated manner. Therefore, pBDi contains a rotary valve for connection of assay reagents as well as sample to the biochip cartridge. The reagents are aspirated selectively by the pump movement in combination with the proper triggering of valves. All reagents are introduced via the reagents' holder, whereas the sample is introduced via a sample holder (Fig. 1).

2.2 Electrochemical Biochip

Chips were manufactured in an industrial semiconductor production line on standard 8″ silicon wafers. Each chip (9 × 10 mm) has 16 electrode positions, each with 500 μm in diameter [10]. The electrode positions consist of interdigitated gold electrodes exhibiting two comb-type structures with 204 fingers, each 800 nm wide with a 400 nm gap distance between anode and cathode fingers [10]. The biochip itself is inserted into a biochip cartridge consisting of polycarbonate for convenient handling (Fig. 2). An incubation chamber with approximately 10 μL is formed over the electrode area of the biochip.

2.3 Workflow of Biochip-Based Biothreat Agent Detection

A wide range of sample types such as liquids, solids, environmental swabs, or powders can be analyzed by the pBDi. A dedicated Sample Preparation Kit (Bruker Daltonik, Leipzig, Germany, article no. 1848504) makes the assay robust to a large number of sample matrices. The time to prepare samples is kept to a minimum (approximately 2–5 min); no centrifugation steps are necessary. In general, sample preparation consists of two main steps: (1) resuspension of sample matrix in a

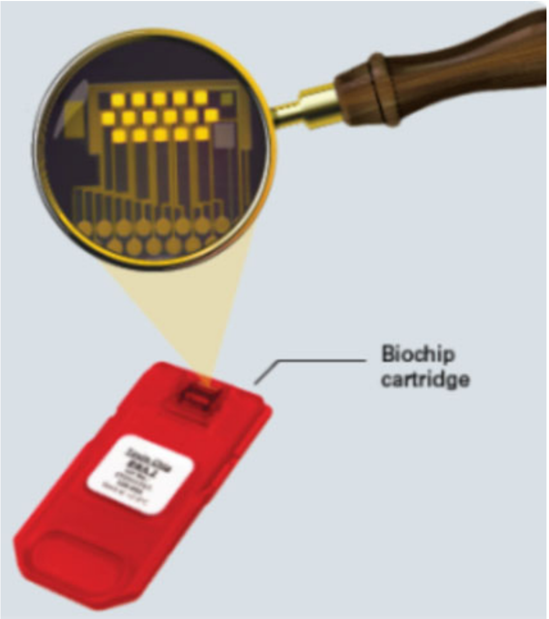

Fig. 2 Biochip cartridge with mounted electrical biochip

sample buffer for adjustment of sample pH and (2) filtration through a syringe filter for removing of particles. For liquid samples such as water, apple juice, or milk, a 1 mL sample and 1 mL sample buffer (Bruker Daltonik; article no. 1854824; included in Sample Preparation Kit) were mixed. The sample was spiked with different biothreat agents and incubated for 2 h at room temperature. The samples were then filtered via a syringe filter (pore size of 5.0 μm; Millex® syringe filter, Merck Millipore, Darmstadt, Germany) to remove solid particles. Subsequently, 0.5–1.0 mL filtrate was used for analysis with the pBDi. For solid and semisolid samples, approximately 0.5 g sample was mixed with 5 mL sample buffer (Bruker Daltonik; article no. 1854824), and the biothreat agent to be examined was added. Further processing is analogue to the sample preparation procedure for liquid samples.

3 Results

3.1 Assay Principle

The pBDi employs a sensitive electrochemical biochip technology for multiplex fully automated ELISA-based detection of biothreat agents (Fig. 3). Capture antibodies immobilized on gold electrodes facilitate the specific binding of corresponding biothreat agents. Detection of bound biothreat agents is realized by application of a

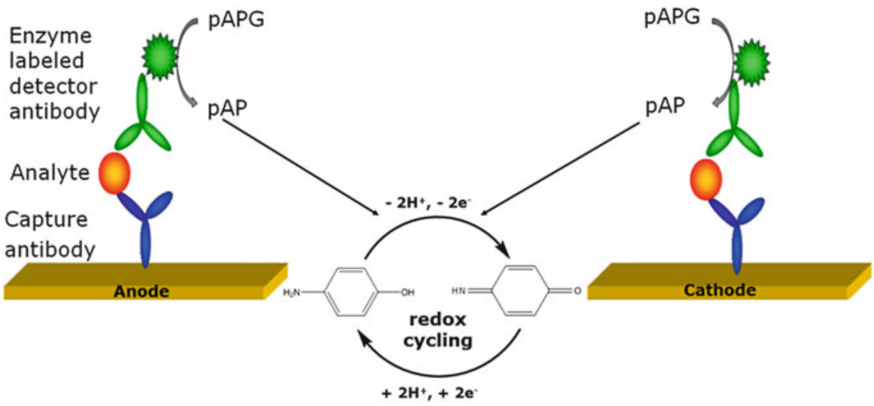

Fig. 3 Principle of immunoassay-based detection of biothreat agents using electrochemical biochip technology with redox cycling signal amplification. For further details see explanations in the text

biotin-labeled detector antibody conjugate enabling binding of streptavidin-β-galactosidase conjugate and measurement of the electrical current of an enzymatic redox reaction on interdigitated ultramicroelectrodes [10]. The reporter enzyme converts an electroinactive substrate (*p*-aminophenyl-β-D-galactopyranoside, pAPG) into an electroactive product (*p*-aminophenol, pAP) leading to a detectable signal (Fig. 4). Unique biochip cartridge design and small reaction volume on electrochemical biochips favor rapid reaction kinetics allowing biothreat agent identification in approximately 20 min. High sensitivity is achieved due to the high turnover of enzymatic reaction, and, in addition, the redox cycling procedure between pAP and quinoneimine due to interdigitated electrode structure [11] built into the experimental procedure significantly contributes to the signal amplification [12].

3.2 Assay Panels for Toxins, Bacteria, and Viruses

All test kits contain optimized reagents to perform multiplex electrochemical ELISA in a stable, easy-to-use format. Table 1 shows available multiplex assay panels for detection of bacteria such as *B. anthracis*, viruses such as *Orthopoxvirus*, or proteinaceous toxin such as botulinum neurotoxins (BoNTs) or staphylococcal enterotoxins (SEs). Furthermore, on request test kits for immobilization of customer-specific antibodies are feasible. The application of electrochemical biochip technology was recently demonstrated for detection of toxins such as ricin or staphylococcal enterotoxin B (SEB) in unknown samples [13, 14]. These results demonstrated that limits of detection (LOD) for toxins are in the low ng mL^{-1} range as well as high specificity of toxin detection. In the following chapters, analytical parameters for bacteria and virus detection are presented.

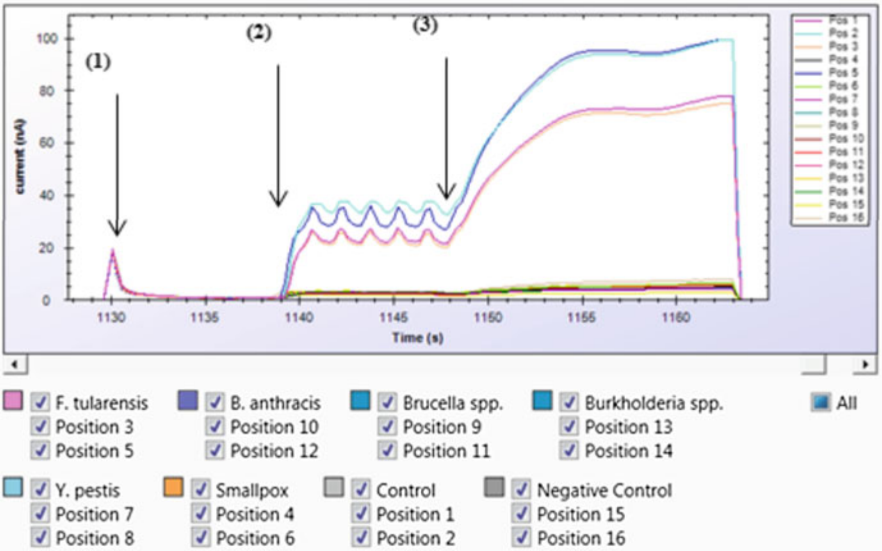

Fig. 4 Result analysis with Control software. As sample 10^7 colony-forming units per mL *F. tularensis* subsp. *tularensis* (heat-inactivated) was applied. The graph shows current versus time course of all 16 electrode positions. Buffer flow through the chip chamber (1) was followed by addition of substrate (2). After reaching a plateau of current, flow was stopped, and the change in current versus time was determined for each electrode position (3). The two positive control electrodes (position 1 and 2) as well the two electrodes with anti-*F. tularensis* antibodies immobilized (positions 3 and 5) showed significant positive signals, whereas all other electrode positions showed no increase of current after stop flow

Table 1 Assay panels for pBDi instrument

Biothreat test kit	Toxin test kit 1	Toxin test kit 2	Food test kit	Training kit
B. anthracis *Y. pestis* *F. tularensis* *Brucella* spp. *Burkholderia mallei/ B. pseudomallei* *Orthopoxvirus*	BoNT/A BoNT/B BoNT/F SEB Ricin	BoNT/C BoNT/D BoNT/E SEA Abrin	*Vibrio cholerae* *Escherichia coli* O157:H7 *Salmonella* spp. *Shigella dysenteriae* *Listeria monocytogenes* *Campylobacter jejuni*	Training sample (IgG)

3.3 Sensitivity of Microorganism Detection

The limit of detection (LOD) for microorganism detection was determined applying serial dilutions of pure cultures of target pathogens. The minimum concentration detected above a threshold value (mean blank plus three times standard deviation of blank value) was defined as LOD. The test revealed that the LOD of the assays is in the range of 10^3–10^5 colony-forming units per mL (CFU mL^{-1}) or approximately 10 ^{4} plaque-forming units per mL (PFU mL^{-1}) depending on target pathogens.

3.4 Specificity of Microorganism Detection

Specificity of simultaneous detection of bioterrorism-relevant pathogens is demonstrated in Fig. 5. Specificity was assessed individually with high concentrations ($\geq 5.0 \times 10^6$ CFU mL^{-1} or 5.0×10^6 PFU mL^{-1}) of the relevant species of biothreat agents. Each target pathogen produced significant signals only on electrodes immobilized with the respective specific capture antibodies. No significant cross-reactivity of the antibodies with analyzed target substances was observed. These results indicate that each electrode position on the biochips specifically detected its target with no cross-reactivity with the other bacteria tested on the multiplex biochip, confirming high specificity of the assay.

3.5 Robustness of Biothreat Agent Detection

Biothreat agent detection has been successfully demonstrated in environmental samples (e.g., aerosol samples, soil, dust), food samples (e.g., milk, apple juice, mineral water), as well as powder samples (e.g., talc, bentonite) applying a standardized sample preparation procedure. For majority of tested sample matrices, excellent recovery rates ([signal of analyte in artificially contaminated sample

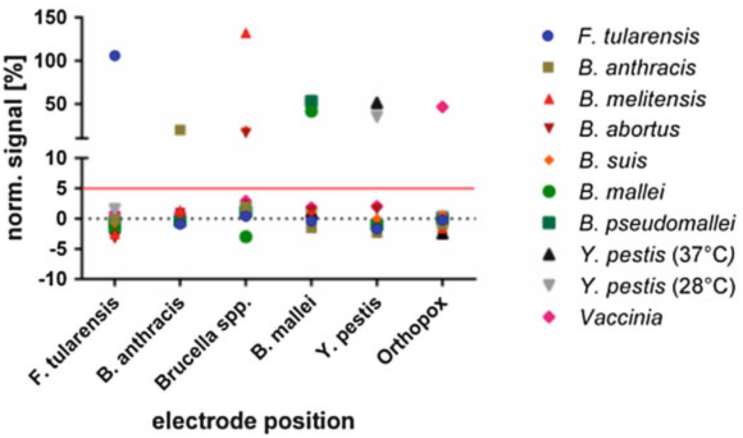

Fig. 5 Specificity of biothreat agent detection using pBDi. The x-axis refers to the six different electrode positions of the biochip, whereas the y-axis refers to the normalized signals [%] obtained for the corresponding bacterial or viral solutions applied. Results were defined as positive when the normalized signal exceeds the defined threshold value (red line)

matrix/signal of analyte in buffer] × 100) between approximately 70% and 100% were determined. Recovery rates of artificially contaminated liquid sample matrices (contaminated with 5×10^5 CFU mL^{-1} heat-inactivated *F. tularensis*) such as mineral water or apple juice were determined as $81.4 \pm 1.1\%$ or $89.9 \pm 0.4\%$ ($n = 3$), respectively. Analogous recovery rates for artificially contaminated solid sample matrices (contaminated with 5×10^5 CFU mL^{-1} heat-inactivated *F. tularensis*) such as bentonite, soil, or milk powder were determined as $103.0 \pm 0.9\%$, $102.0 \pm 0.9\%$, or $69.3 \pm 0.5\%$ ($n = 3$), respectively. These results demonstrate high robustness of electrochemical biochip technology toward a wide range of sample matrices applying a rapid and minimal sample preparation procedure.

4 Conclusions

The pBDi is a portable detection platform for rapid and sensitive on-site multiplex identification of up to six biothreat agents such as bioterrorism-relevant bacteria, viruses, and toxins. Fully portable and operating from internal batteries, pBDi can be used for testing the field.

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Experimental Real-Time Tracking and Numerical Simulation of Hazardous Dust Dispersion in the Atmosphere

Stefano Parracino, Jean François Ciparisse, Michela Gelfusa, Andrea Malizia, Maria Richetta, and Pasquale Gaudio

1 Introduction

Given the growing concerns of national/international authorities on air pollution and terrorist attacks, it could be useful to deploy, in areas where safety and security are crucial (e.g. city centre, airports, railway stations, industrial plants, etc.), stand-off tracking systems, able to give a rapid alert if something strange is detected in the atmosphere, and also, advanced software frameworks, able to predict the spatio-temporal evolution of the hazardous dust/particles dispersion.

Since the mid-1960s, LiDAR/DIAL techniques have been considered well-established methods for environmental remote sensing, in particular, for atmospheric physics studies [1–4]. Given the high sensitivity for both long- and short-range detection, they are ideal for the detection and monitoring of particles and gases in air, over large areas, from one single observation point [5–8]. By contrast, conventional measurement systems can typically evaluate the concentration of substance, for which the system has been calibrated, only in a limited area close to the detector. Therefore, to cover large areas, these fixed monitoring stations have to be deployed in large numbers and connected in suitable networks [9].

In this context, the QEP Research Group has recently developed compact, mobile and fully automated LiDAR/DIAL systems (e.g. the Compact LiDAR—COLI, whose results are reported here), for the real-time tracking of hazardous substances and polluted particles in urban/industrial areas. These systems have been recently shown their potential in field campaigns [9–13]. Despite the progress achieved in the last years, in both miniaturization/setup [9, 12] and data processing [11, 13], their

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deployment in the field, for prolonged periods of time, still remains difficult, due to economic and technical implications [9, 13]. For these reasons, efforts have been spent over the last 15 years to integrate existing data processing routines with simulation tools for atmospheric dispersion modelling [14, 15]. Nowadays, enormous progress has been made in this field, and by means of software such as COMSOL [16], it is possible to recreate, in the lab, refined and robust simulations [17]. This would allow us to reduce significantly LiDAR operating costs and the deterioration of the system components.

Therefore, in this work an integrated approach is proposed for real-time identification and tracking, by means of LiDAR/DIAL techniques, and numerical simulation, by means of COMSOL, of hazardous particles/dust dispersion in air. This framework could be useful, in particular, to the end users (Civil Protection, Fire Brigade, etc.) in real scenarios (e.g. CBRNe attacks, heavily polluted areas or wildfires, etc.) in order to take effective countermeasures aimed at mitigating the risks for the population/environment.

The paper is structured as follows: firstly, an overview of the system and the implemented dispersion modelling software will be shown. Then, the results obtained from experiments and simulations will be presented and discussed in detail. In the conclusions, a flowchart relative to the proposed integrated approach, for both data processing and numerical simulation, will be reported.

2 Materials and Methods

2.1 LiDAR/DIAL Systems

As already stressed, QEP Group has recently designed, procured and assembled two different systems for environmental monitoring. The first one consists of a compact, robust, stable, scanning mobile LiDAR (COLI), based on monostatic configuration with a biaxial arrangement. COLI, whose specifications are reported in [9], has been conceived for real-time detection and tracking of particles emitted by vehicle/industrial emissions (e.g. PM10) or by wildfires. Further details about the system setup, the results obtained and the measurement uncertainty are reported in [9, 12]. The second one consists of a compact, multiwavelength mini-DIAL, based on monostatic configuration with a monoaxial arrangement, whose specifications are reported in [13]. Thanks to a fine laser-grating tuning, it is possible to select the measuring wavelength from 64 spectral lines in the range of 9–11 μm (9R, 9P, 10R, 10P bands). First tests, carried out to assess the potential of this system, have shown promising results, concerning the rapid and simultaneous identification of several greenhouse gases and other volatile organic compounds (whose absorption spectra fall under the investigated spectral range) in a suburban area of Rome [13].

It should be noted that, once deployed in the field, both the systems are completely autonomous since they are remotely controlled by our own software package written in LabVIEW and MATLAB. These routines have been explicitly developed for the mechanical handling of laser-telescope block, the data acquisition and processing. Moreover, a wireless connection makes it possible the stand-off and real-time analysis of LiDAR profiles from a remote workstation [9, 13]. Furthermore, during the experiments, preventive measures [18] were taken to guarantee the safety of both operators and civilians [9, 12, 13].

Finally, COLI is based on the well-known Klett-Fernald's inversion method [5–8] to retrieve the range-resolved backscattering coefficient, a parameter strictly linked to the concentration of particles and aerosols in atmosphere [4]. Instead, the mini-DIAL system is based on the idea of differential absorption measurement [5–8] that allows one to measure the range-resolved gas concentration. More details about the LiDAR/DIAL data processing steps are available in previous works [9, 13]. Here, only for illustrative purposes, the attention has been focused on COLI and the tracking of smoke particles, produced by a chimney, during the campaign carried out at Lamezia Terme (CZ) in 2014 [12].

2.2 Computational Fluid Dynamics Modelling Software

COMSOL Multiphysics is a cross-platform finite element analysis, solver and multiphysics simulation software [16]. It allows to solve, by the use of several modules, many physical problems (fluid mechanics, heat exchange, electromagnetic fields, structural mechanics and so on). In this work, a multiphase flow has been considered, as solid dust particles are dispersed in a fluid (e.g. air). The models describing the problem are the following:

- Mixture model for multiphase flow
- Constant densities of the two phases
- k–ε turbulence model

Given its flexibility in term of use and the interoperability with MATLAB, COMSOL has been considered to be integrated into a unique framework, for the monitoring of hazardous particles dispersion in heterogeneous areas. Then, its performances have been tested in the experimental scenario described in the previous section. Since at the time of LiDAR experiments the use of COMSOL was out of our purpose, here the software has been used only in the post-processing step. In the near future, platform integration and data sharing could be possible by installing the software on a further remote workstation, connected within a wireless local area network (e.g. via Wi-Fi) with the one used for real-time LiDAR data processing.

In this work, COMSOL has made it possible to develop refined particles dispersion prediction models on the basis of the data acquired by COLI and other useful information, concerning both the system setup (e.g. the laser pointing angle, the maximum operative range, etc.) and the current weather conditions of the investigated area (e.g. the wind speed and direction). It should be noted that the processing time to develop these prediction models could vary from several hours to several days, depending on the computing power and both the complexity and duration of the simulation. Further details of these numerical simulations are provided in Sect. 3.2.

3 Results and Discussions

3.1 LiDAR Experimental Results

As already mentioned in Sect. 2.1, here a brief summary of the data acquired by COLI is reported and analysed. Experimental results are referred to the measurement session performed on 10 June, 2014 in the industrial area of Lamezia Terme (CZ), nearby the local international airport. In order to test the system performances, a controlled fire, produced by the combustion of a known quantity of vegetables, was lighted into a chimney at a distance of about 400 m from the system [12]. In Fig. 1, both COLI and chimney positions are marked with different colours.

During the campaign weather pattern disturbances were excluded. In the absence of precipitations, the attention was focused on the north-west wind that, during the experiments, was almost blowing towards the line of sight (LOS) of the laser beam path, with an average value of wind speed of about 3 m/s (see Fig. 1) [12]. To observe two-dimensional temporal and spatial distribution of smoke particles, horizontal scans were executed. The elevation angle of the laser beam was set approximately to 3°, and the azimuth angle was changed in 1.234° steps in counterclockwise direction from 270° (west) to 263.83° (south-west), covering a range of about 6.2° (see Fig. 1). At each step, 100 laser shots were averaged (this improved the signal to noise ratio), and each scan took approximately 1 minute to complete [12].

An example of COLI signal's maps resolved in space and time is visible in Fig. 2. The scans (a), (b) and (c) have been extrapolated from a measurement session lasting about 1 hour (during which COLI acquired data without any interruptions). Each scan has been reported in the form of polar diagram. The red dotted boxes highlight

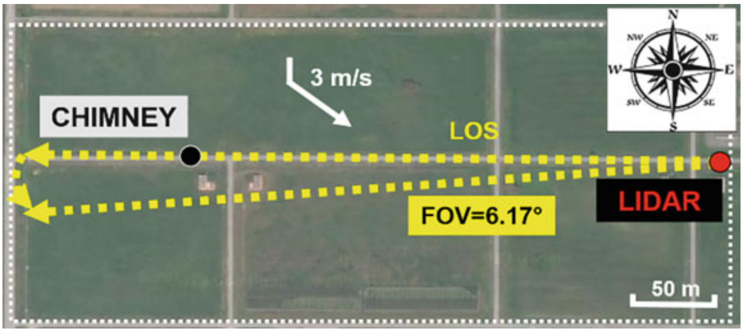

Fig. 1 Experimental area (white dotted box) during the campaign of Lamezia Terme (CZ). The LiDAR position, its field of view (FOV), and the chimney are reported and marked with different colours

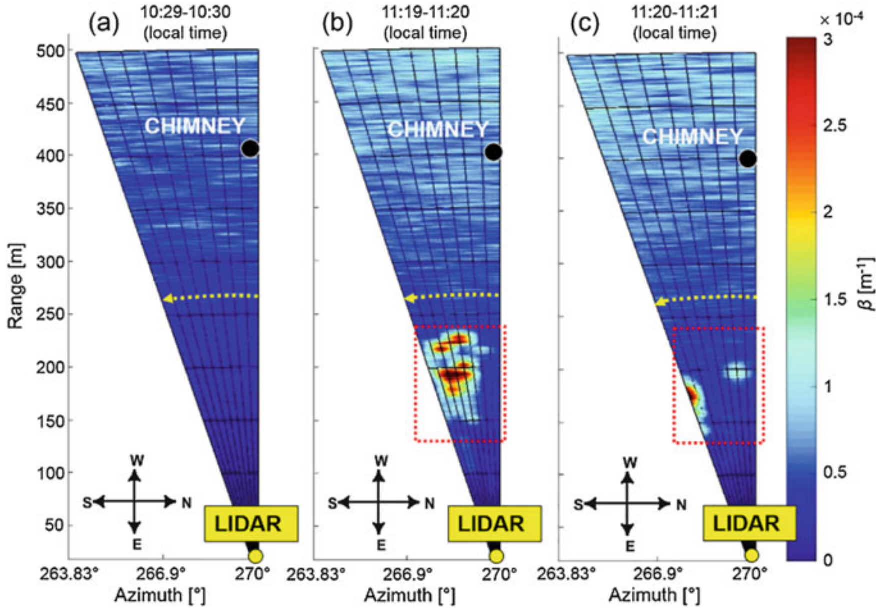

Fig. 2 Example of scans (1 minute long) carried out by our LiDAR system during 10 June, 2014. The scan (**a**) shows the situation in the absence of smoke, before the lighting of the chimney. Scan (**b**) and (**c**) are referred to the presence of scattered smoke particles. The measurement uncertainty was estimated to around 14% [9]

the increase of backscattering level linked to the particles smoke concentration in the investigated area. It is possible to notice that red spots rapidly change their position from the source of smoke even hundreds of meters. This was probably due to the presence of wind blowing from the north-west direction [12].

The experimental results confirmed the sensitivity and effectiveness of COLI that was able to provide a fast, automatic detection and monitoring of particles dispersion into the atmosphere over extended regions. It should be noted that both the LiDAR/DIAL systems and the related data processing approaches are fully general, and basically, they could be applied to any type of scenario (e.g. industrial air pollution, CBRNe attack, etc.) for the tracking of any substance in air.

3.2 COMSOL Post-processing Results

In this section, the results of numerical simulations performed using COMSOL are reported. These simulations refer to the previously cited campaign, and they have been performed to demonstrate the potential of the fluid dynamics software, within the perspective of a future integration with LiDAR/DIAL measurements, for the long-term monitoring of hazardous particles dispersion in air. As already stated, both

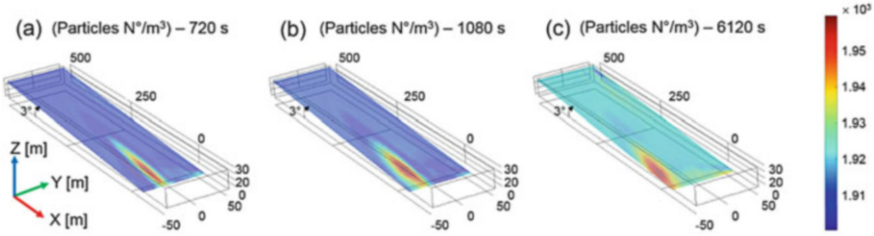

Fig. 3 Examples of simulated particles volume fraction dispersion scans carried out by COMSOL. The scan (**a**) shows the situation after 12 minutes. Scan (**b**) and (**c**) show the situation after 18 and 102 minutes, respectively

the LiDAR system setup and the local weather conditions (e.g. wind speed/direction) have been taken into account to create a plausible scenario and, then, to obtain three-dimensional models that describe, with a satisfactory level of accuracy [16, 17], the spatio-temporal evolution of particles in the investigated area. It should be noted that the whole numerical simulation has been completed within about 1 day with the technical resources at our disposal, but in the future, this processing time could be significantly reduced by improving the computational power. Therefore, the results provided here have been made available only in the post-processing step (see Sect. 2.2), so as to simulate the forwarding of these data to the end users (e.g. Civil Protection, Fire Brigade, etc.). The potential of the software is exemplified in Fig. 3, where, for example, only three screenshots of the whole numerical simulation have been reported. These scans show the time evolution of particle dispersion in the investigated area, within 3 hours after the end of the LiDAR measurement session.

In previous examples, due to the lack of further weather information, the mean values of wind speed and direction retrieved during the campaign have been assumed as constant values and used as input to our COMSOL routine. However, once available the current values of wind speed/direction, it is generally possible to perform more accurate and robust simulations. Even though a cross-comparison with LiDAR results has not been possible due to the different data analysis approaches (the LiDAR technique is unable to give the absolute measurement of particles/dust concentration, but it is able to evaluate the particles' density variation respect to the atmospheric background [7], whereas in the numerical simulation, the absolute particle volume fraction is given at each point), a plume lying in the stream generated by the north-west wind has been observed with both methods. These results are in line with in-field observations. Moreover, with respect to the LiDAR results, it should be noted that COMSOL provides further information since it simulates the particles dispersion in more realistic and easy-to-read three-dimensional grid planes. In addition to this, starting from just a few inputs, it is possible to perform, in principle, long-term (e.g. lasting days or weeks) prediction models without any additional costs, with the only exception of a further computational effort.

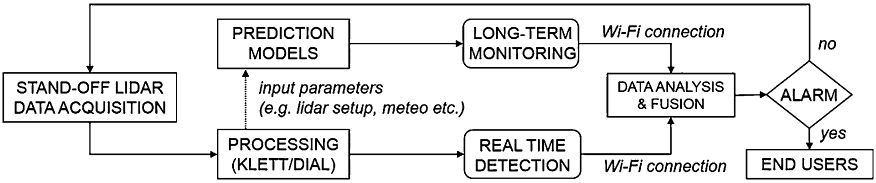

Fig. 4 Flowchart of the proposed integrated approach for both real-time detection and numerical simulation of particles/dust dispersion into the atmosphere

4 Conclusions

In this paper, an integrated approach for both the real-time detection and long-term monitoring of hazardous particles/dust in air has been proposed and first numerical tests presented. Thanks to LiDAR/DIAL systems and MATLAB routines, developed by the QEP Group, it is possible to perform stand-off detection and tracking of polluted particles or hazardous substances in heterogeneous areas. Unfortunately, the deployment in field of laser-based techniques, for prolonged periods, still remains difficult, due to economic and technical implications. For these reasons, a routine based on COMSOL, a computational fluid dynamics software, has been considered to be integrated with existing tools to perform rapid and robust assessment of hazardous particles/dust dispersion also in the long term. The main goal of the routines, once implemented to work alongside (see the flowchart reported in Fig. 4), will be to provide an early warning to the competent authorities, in case of anomalous or accidental release of harmful substances in the investigated area (e.g. CBRNe attacks).

The great advantage of this combined approach will be the high level of flexibility of use, since it could be deployed in any type of scenario for the detection and monitoring of any substance. At the present time, further efforts are needed, in order to refine the whole method (e.g. by implementing the data fusion step shown in Fig. 4), and a wide investigation of experimental data are necessary to validate the framework. In the near future, it will be desirable and useful to deploy this software-based integrated approach in critical areas. This could reduce the LiDAR operating costs and represent, at the same time, a valuable option to the end users, so as to take effective countermeasures aimed at mitigating the risks for the population and the environment.

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Comparison of Classification Methods for Spectral Data of Laser-Induced Fluorescence

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1 Introduction

A fast detection of hazardous substances can save human lives. Many techniques have been developed, more are in progress, and the demand is still growing. The setups vary widely and so do the subsequent classification methods [1–3]. This paper compares the performance of three different algorithms applied to two datasets, collected with two experimental setups, in which LIF spectra of seven bacterial samples are discriminated. On the one hand, there is a noisy signal; on the other hand, there is a lower resolution, but the classification procedure is similar.

For investigations in this paper, the following bacterial species are used: *Bacillus subtilis*, *Bacillus thuringiensis*, *Brevibacillus brevis*, *Escherichia coli K12*, *Micrococcus luteus*, *Oligella urethralis*, and *Paenibacillus polymyxa*. For each bacterial strain, the measurements performed with both setups were made with samples originating from the same cultures, and the suspensions were measured within few hours after preparation.

The first setup utilizes two alternating laser pulses with excitation wavelengths of 280 and 355 nm. The cuvettes are placed outdoors at a distance of 22 m, and the fluorescence signal is recorded by an intensified CCD camera with 1024 channels [1]. The second setup is based on a simultaneous emission of two laser pulses with wavelengths of 266 and 355 nm, the latter temporally shifted by an optical delay line. In this case, the samples are placed indoors at a distance of 3.5 m, and the signal is gathered by a photomultiplier tube array with 32 channels [4]. The experimental setups (Fig. 1) and data acquisition are fully described in [1] and the proceedings of *SICC 2017* [4]. Figure 2 shows the spectra after the preprocess described in Sect. 3.1.

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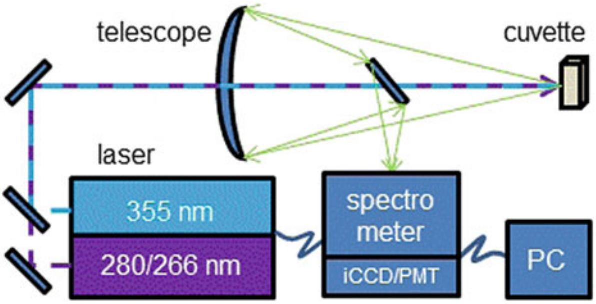

Fig. 1 The spectra were recorded with two different setups using two excitation wavelengths, each, both illustrated in this simplified schematic view

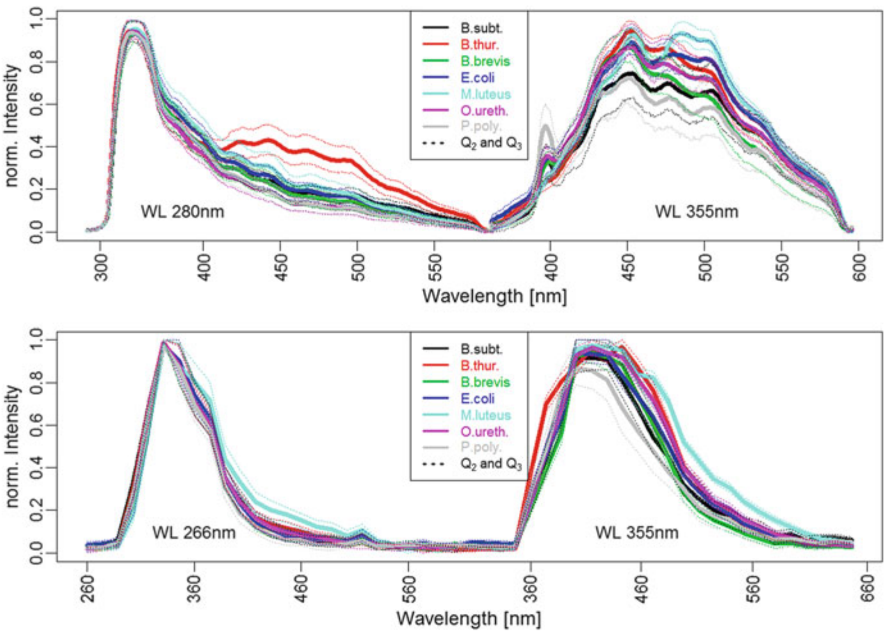

Fig. 2 The resulting signals of both setups: reduced to important ranges, rescaled, and corresponding data merged. The dotted lines enclose 50% of the spectra (second and third quartiles)

For statistical computing the free software environment R [5] is used, especially the *caret* package [6]. This combines classification packages, i.e., [7–11], which were used individually for some illustrations of this contribution. A detailed description of the algorithms and their mathematical background can be found in [12, 13].

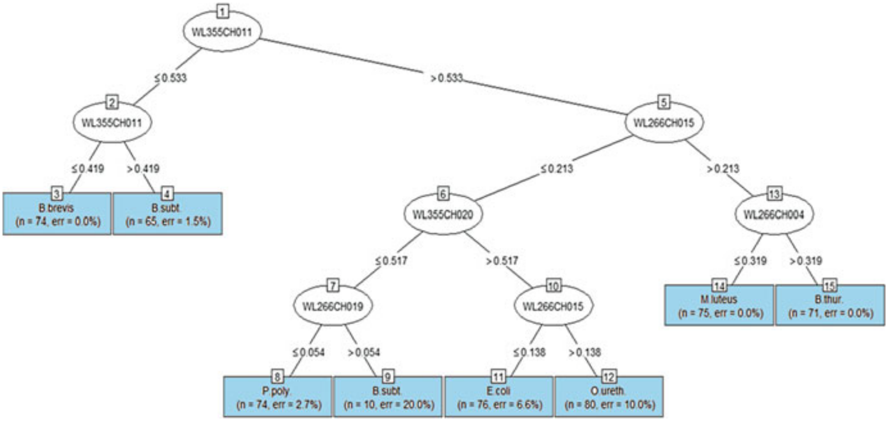

Fig. 3 Decision tree example demonstrating the classification principle

2 Classification Algorithms

2.1 Decision Tree

A decision tree is used to divide sets in several subsets until there is no more splitting needed to accomplish a distinct classification. The investigation of single features (channels) leads to a couple of benchmarks to make a binary decision at each node saying if feature X is bigger than a value Y, go to the next node A; otherwise go to node B. Following these instructions, each single dataset is guided along the branches until it is associated at the leafs to a specific class.

The model construction is done in multiple steps where the tree is rearranged based on the information entropy of every channel, like single features that discriminate a whole class from the rest. In addition, the placement of a border separating two classes is varied within the gap between. The one which has the least mean squared distance to both classes is used. The result is a more effective model regarding to its size and evaluation time. Figure 3 shows a small model which classifies the data in a few steps observing five features from setup 2.

2.2 Support Vector Machine (SVM)

Decision trees imply the ability of linear separation, but in many times, this is not possible. One can make an additional transformation of the data by mapping them into a hyperspace (commonly with the radial basis function [13]). This procedure is called *kernel trick* and enables a linear division in higher dimensions. The closest points to the boundaries are the *support vectors*, and only they take effect on the border's shape (see Fig. 4).

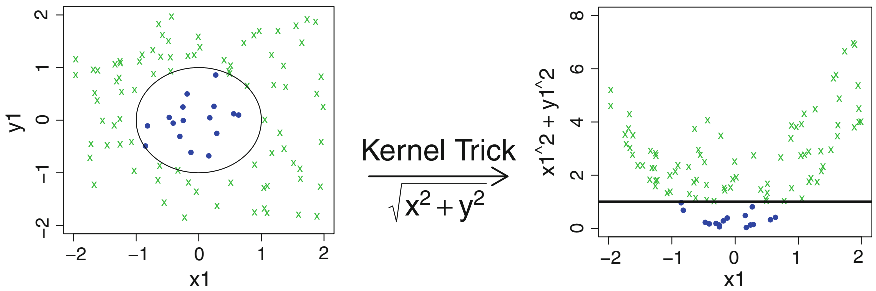

Fig. 4 This example of a SVM classification divides two classes using the distance from the origin as kernel function. After the transformation a simple linear separation is possible

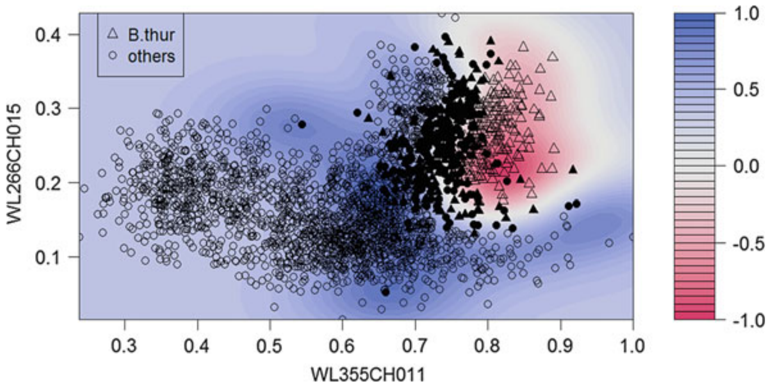

Fig. 5 This SVM model shows the classification of one sample versus the others focusing on only two features. A combination with all pairs of channels generates the model

Figure 5 shows a binary classification with only two features, and *Bacillus thuringiensis* is the one we want to detect. The model is defined just by the *support vectors* marked with filled black symbols. Many of the spectra are classified correctly using only two detection channels.

2.3 *Artificial Neural Network (ANN)*

Classifying is a function, mapping the feature space (*input I*) onto a "class space" (*output O*). ANNs use two functions: a linear combination maps features to an additional space (*hidden units H*) and then maps this to the classes. Connections are weighted by the coefficients of the linear function, changing with every iteration step, influenced by the coefficients of the previous second mapping.

Figure 6 shows a 10-7-7 ANN: *I* are ten features with large variance, *H* is one hidden layer with seven variables, and *O* are the seven species. The bias terms *B* with

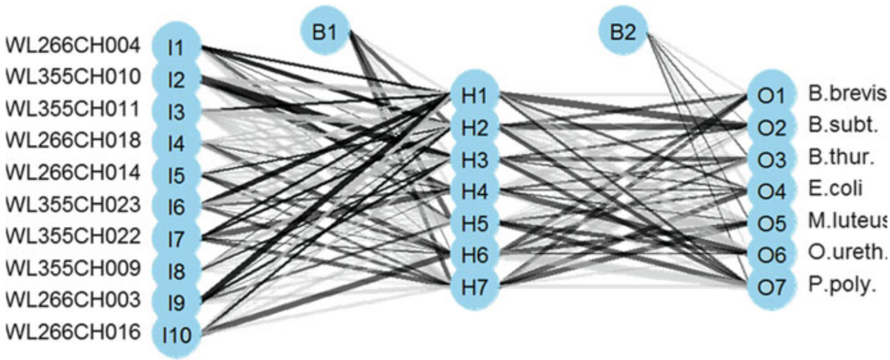

Fig. 6 This ANN has ten features and seven hidden units showing the weights after 1000 iterations. Dark connections represent positive, bright ones negative coefficients, and the widths represent the absolute values of the coefficients for the linear combination

a constant influence represent simulated noise. The amount of inputs and hidden units can be varied as well as the maximum of iteration steps.

3 Data Processing

3.1 Preprocess

After background correction and outlier removal, each spectrum of setup 1 was smoothed by running median due to a lower signal-to-noise ratio. Features were eliminated which cannot yield useful information like channels beyond the lower wavelength, where no fluorescence can occur, or the filter range at about 355 nm. The Raman peak of water, still shown on the right side of Fig. 2 at about 400 nm, was removed for further operations because of its misleading intensity. Every single spectrum was rescaled by setting its minimum to 0 and its maximum to 1. The corresponding data of both wavelengths were concatenated to construct one dataset for the classification process.

Each bacterial sample was measured five times gathering 100 spectra per measurement and wavelength. Thus we obtained a total set of 3500 records per setup. The upper half of Fig. 2 displays the averaged spectra acquired with setup 1 and the boundaries of the second and third quartiles containing 50% of each class. The lower part visualizes the data of the second setup accordingly. Detailed descriptions of the spectra are given in [1, 4].

3.2 Training and Test

The data were randomly split in two parts. In order to have a verification the training has been repeated by resampling methods like cross validation and bootstrapping, 75% of the data were used to train the algorithms with different parameters to find those with the highest *accuracy*, the ratio of correctly classified spectra, and the total. The remaining 25% were assigned with the generated models to test their goodness of fit.

To prevent overfitting the training parameters are set not too exactly. For example, the minimal number of spectra in the leafs of a decision tree could be too small, and so the algorithm tries to match even those terms which are noisy and only therefore belong to the area of another class. This will lead to misclassifications applying the model on unknown data.

4 Results and Discussion

The three presented algorithms discriminated seven bacteria samples better than 92% only by observing their LIF spectra. Table 1 shows the performance for the test datasets from both setups and the three different methods from above. Decision trees gained an *accuracy* of 92.1% and 97.7%, dependent on the setup. The SVM obtained the best results of 96.5% and 99.5%, respectively. Also the ANN provided a very good classification (*accuracy*: 92.6% and 99.1%).

The rather noisy signal of setup 1 and the low resolution of setup 2, both yield enough information for different methods of machine learning. The same data can be used to generate other models with even better performance depending on the preprocess as well as on tuning parameters for each method.

Due to the lower dimensionality of the data acquired by setup 2, the training process is much faster without using any type of feature selection. Instead of some hours, it only takes several minutes and allows a wider search for optimal tuning parameters in the same runtime.

Grouping the bacteria in two classes like “harmless” and “harmful” and using the same models, the *accuracy* could not be worse. There are no new misclassifications, but some of the so-called false positives and false negatives now belong to the same group and are correct. Therefore, the performance values would increase compared to the previous prediction.

5 Conclusion and Outlook

The results show that it is possible to distinguish between seven different bacteria by analyzing single spectra of LIF. LIF is a technique with several possibilities for the stand off detection of organisms due to the presence of special amino acids.

Table 1 Correlation matrices for both setups and three classification models: the six diagonals are constituted by the correctly classified spectra

		Setup 1							Setup 2						
Classified as →		*B. brevis*	*B. subt*	*B. thur.*	*E. coli*	*M. luteus*	*O. ureth.*	*P. poly.*	*B. brevis*	*B. subt.*	*B. thur.*	*E. coli*	*M. luteus*	*O. ureth.*	*P. poly.*
Decision tree algorithm															
				92.1%				Accuracy		97.7%					
Actual sample	*B. brevis*	114	3						125						
	B. subt.		102				1	14	2	122					1
	B. thur.			123	1		1				124			1	
	E. coli	2	2		114		6	1	1	1		119			4
	M. luteus					123	1	1					125		
	O. ureth.	2			3	1	119				1	3	1	120	
	P. poly.	5	6		2		1	111		2		2		1	120
Support vector machine															
				96.5%				Accuracy		99.5%					
Actual sample	*B. brevis*	120	1				1	3	125						
	B. subt.		119					6	1	124					
	B. thur.			124			1				125				
	E. coli				121		4					124		1	
	M. luteus					123		2					125		
	O. ureth.	2					123							125	
	P. poly.	4	2		5			114				2			123
Artificial neural network															
				92.6%				Accuracy		99.1%					
Actual sample	*B. brevis*	114	4				5	2	125						
	B. subt.	2	112		2	2	2	5	1	124					
	B. thur.			125							125				
	E. coli	3			113		5	4				123		1	1
	M. luteus	1	2			121		1					125		
	O. ureth.	1			3		120	1				2		123	
	P. poly.	6	8		4		2	105		2		1			122

Latest studies of bacteria in different growth phases show the changing characteristics of their LIF spectra [14]. This behavior has to be taken into account during the process of model generation.

The preprocess could include more steps like principal component analysis or feature selection. This reduction would lead to a faster model generation and less overfitting and will be part of future examinations. Taking the average of five consecutive spectra would obtain even better values, but we aimed for a single-shot classification.

It is promising that a combination of at least three models would increase the validity and help to eliminate samples which were mismatched in a minority of cases. Investigating other algorithms, e.g., random forests, a pool of models could be generated, each assigning the spectra for its own. Having used every model an ambiguity may still exist which is solved by a *hybrid* model choosing the classification appearing more often.

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Part II
Protection and Decontamination

Fast Response CBRN High-Scale Decontamination System: COUNTERFOG

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1 The CBRN Threat

Recent CBRNE episodes have raised the level of awareness of this kind of threats. Crowded railway carriages and stations, metro tunnels, or airports have been tragically targeted by terrorists to generate massacres with conventional explosives all

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along Europe. Subsequent fire, smoke, saturation of responder capability, and—overall—confusion have demonstrated to impose critical limitations to an optimal response. A few liters of 30% sarin just evaporating—without any means for dispersion—killed 12 and injured more than 5000 in Tokyo subway that absolutely collapsed the local responder's capability. Relatively weak chemical attacks in Hamburg and London City airports injured tenths of people and/or paralyzed their operation very recently. There have been evidences of terrorists manipulating biological agents like botulinum toxins or Black Death. Evidences that terrorist try to use explosives to disperse the agents have been published as well. Additionally, thousands of radiological sources are used in health, research, and industry being not always appropriately secured. Cesium-137, cobalt-60, and iridium-192 may be used to make a dirty bomb. Therefore, a theft of one of them becomes a quite serious concern. Moreover, it is not only terrorist attacks that may create a serious CBRNE incident. Thousands of deaths caused by Bhopal disaster demonstrated a terrifying capability of industry to produce deadly accidents. Moreover, the effects of exposition to toxic clouds like that of Seveso may remain for decades. Please note that the first paragraph of a section or subsection is not indented. The first paragraph that follows a table, figure, equation, etc. does not have an indent, either.

Transport accidents proved to be as deadly as industries. They present the aggravating circumstance that freight routes and railways usually run close to or even throughout large populated areas. Dispersion is always a key factor that multiplies the impact and effects of these incidents, and fire is often present cooperating to extend and worsen the effect of all these kinds of attacks and disasters. This is particularly the case in nuclear disasters, but it may also become the single protagonist as single origin of CBRNE events, killing people or creating huge toxic clouds.

The technology for counteracting a CBRN toxic cloud called COUNTERFOG has been recently developed under the 7th Framework Program of the European Commission as a general-purpose counteraction tool that has demonstrated to be effective against a broad spectrum of agents including C, B and RN and additionally to wash out smoke. Additionally, it is harmless that makes activation in case of false alarms not a particular concern itself.

1.1 Fog Clouds and Smoke

Dispersed matter includes smoke, clouds, fog, mist, and dust. Micron- and under-micron-sized solid particles and liquid droplets float in air for minutes, hours, or days due to the scaling of the forces acting on them. Gravity is proportional to the mass that essentially scales with the cube of the size, while the viscous drag force of a flow of a fluid around a particle scales with the size and the velocity of the fluid relative to the particle. Stokes derived an expression for the fall final speed of a particle of density ρ_{p} and radius R which can be written as

$$\vec{V}_{\mathrm{p}} = \frac{2}{9}\frac{R^2 g\left(\rho_{\mathrm{p}} - \rho_{\mathrm{a}}\right)}{\mu} \tag{1}$$

where g is the gravity and ρ_{a} is the density of air—of the order of one thousandth of that of water. This gives for a water droplet of diameter 2 μm falling in air at room temperature and a final speed of about $1.2 \times 10 - 4$ m/s = 0.72 cm/min, while for a diameter of 10 μm, it will be around $3{\cdot}10 - 3$ m/s = 18 cm/min which is 25 times faster. The most dangerous particulate matter will be sized around 2.5 μm. They are too big to diffuse as gas molecules or to suffer Brownian motion but too small to be dragged by gravity. They essentially are driven by the air even into bronchi and bronchiole.

2 COUNTERFOG Principle

COUNTERFOG is based on the large-scale generation of water-based fog to counteract the dispersed agents. A nozzle able to provide a large amount of fog was engineered requiring only compressed air and water supply to work. Water droplets sized 5–10 micron diameter are the only that are small enough to catch up the 2.5 micron ones, and simultaneously they are big enough to fall down in a few minutes. The principle of COUNTERFOG is to provide a fog, mainly made of water droplets sized between 2.5 and 20 μm. This fog will interact with the dispersed agent providing chances for collapsing and neutralization.

A way to interact is pure mechanical collision. Droplets of different sizes will fall down at different speeds in air—a viscous fluid—according to Stokes law. Trajectories of small droplets seen from the frame of reference of the big droplet are shown in Fig. 1. In this case, water droplets sized 0.1 μm radius are driven around a 10-μm-radius droplet observed in the frame of reference fixed to this last one as integrated with MATLAB. 0.1 μm droplets are driven around by the airflow not being caught up even if they were well under the big droplet. It can be calculated [1] that only 0.1 μm droplets with its center in a cylinder of radius 0.5 μm below the big droplets will collide.

It is therefore clear that the size of droplets is a key parameter for a fog to catch up and wash out particles from air. In the case of agents in the gaseous state, a fog composed of liquid droplets floating in air will expose its surface to solve and eventually hydrolyze the agent. Droplets of radius R will slowly fall down with terminal velocity.

$$\vec{V}_{\mathrm{p}} = \frac{2}{9}\frac{R^2 g\left(\rho_{\mathrm{p}} - \rho_{\mathrm{a}}\right)}{\mu} \tag{2}$$

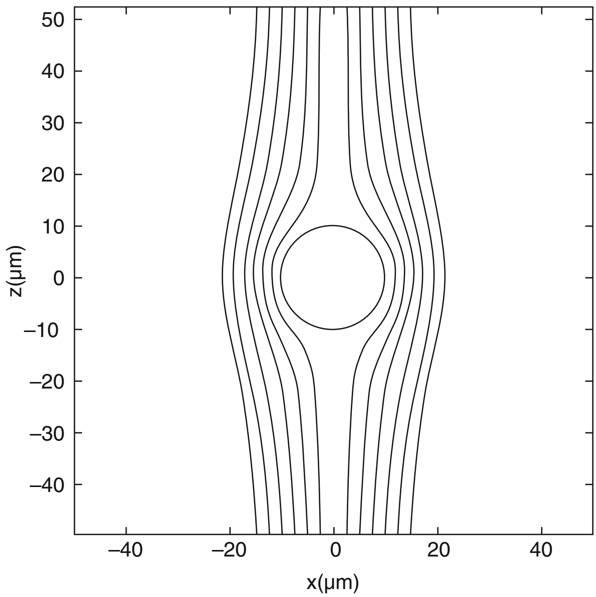

Fig. 1 Trajectories of small droplets of 0.1 μm seen from the frame of reference of the big droplet of 10 μm radius

where g is the gravity acceleration, $\rho_{\mathrm{p}} - \rho_{\mathrm{a}}$ is the difference between the density of the particle and the density of the air, and μ is the dynamic viscosity. They will expose a surface $S_R = 4\,\pi\,R^2$ each, and therefore the product of surface times the time of fall t_f from a height h will be

$$S_R \cdot t_f = S_R \cdot \frac{h}{V_{\mathrm{p}}} = \frac{18}{g \cdot \left(\rho_{\mathrm{p}} - \rho_{\mathrm{a}}\right)} \pi \cdot \mu \tag{3}$$

which is independent of the radius of the droplet. This fact makes equally effective a large droplet than a small one for decontamination of gaseous agents. However, the amount of water—and eventually waste—used scales with the volume of the droplet:

$$V_R = 4/3\,\boldsymbol{\pi}\,R^3 \tag{4}$$

This means that a set of N droplets of, for instance, 1 μm will provide a washing effectiveness similar to a set of N droplets of 100 μm, typically provided by sprinklers, but the amount of water used is 1 million times lower. Again, small droplets are better than large ones. The limit comes only because of the evaporation rate that makes droplets to vanish.

3 COUNTERFOG Technology and Fog Dynamics Laboratory

There are many techniques to produce fogs and mists, including ultrasound, thermal generation, and high-pressure ejection. The washing out principle described in the previous paragraph stands valid for all of them provided the fog is made of the right size and number of droplets. However, for COUNTERFOG a series of nozzles combining compressed air and water supplies were designed to provide a system suitable to be installed with conventional industrial elements and capable of large fog production. Among the several nozzles designed, the so-called B1/2 nozzle was demonstrated to provide a good-quality fog consuming up to 0.11 l/s of water and between 25 and 34 Nm^3/min of air at pressure under 12 bars.

A laboratory for testing fogs and their dynamics has been created. This laboratory is provided with a double test room, a control room, and a technical room. Insulated from the environment, temperature is controlled throughout thermally controlled walls, ceiling, and floor providing a very good thermal stability. Water and airflow as well as humidity in the room and actual pressure in pipes are registered. Other instruments measure the number of particles floating in air, living microorganisms, or chemical concentration.

An airborne particle counter Fluke model 985 based on optical counting complying ISO21501–4, JIS B9921, IEC/EN 60825–1:2007, and 21CFR1040.10 is used to measure the concentration of particles floating in air. Counting efficiency is 50% for 0.3 μm and 100% for particles greater than 0.45 μ/JIS. Concentration limit is 1.41×10^8 particles/m^3 with 5% coincidence loss. An air sampler MAS-100 NT and Petri plates cultivated 24 hours at room temperature are used to measure the biological agents in air.

4 Fog Dynamics

After 30 s of actuation of a B1/2 nozzle under working parameters (water and air pressure under 12 bars), a fog is generated with diameter distribution centered in 5 μm as it can be seen in the figure below. Values greater than 10^9 droplets/m^3 (with only 5 ml of liquid water per m^3) are typically obtained. Note that for 10 μm-sized droplets, only 8×10^8 droplets/m^3 store 3.4 ml of liquid water per m^3. This means that a relatively large amount of water is collected on walls, ceiling, and floor during activation of the nozzle. In fact, tests with smoke demonstrate that soot is collected on walls, ceiling, and floor. Therefore, a direct washing out effect and the falling down washout are provided.

Typical fog dynamics include falling down, evaporation, and the subsequent reduction of droplet size. Figure 3 shows the evolution of 5 and 10 μm-sized droplets for several temperature conditions both of the environment and the water of which the fog is made. It is clearly observed a twofold behavior. In the first part, the particle counter is saturated showing almost a horizontal straight line. Only when levels are

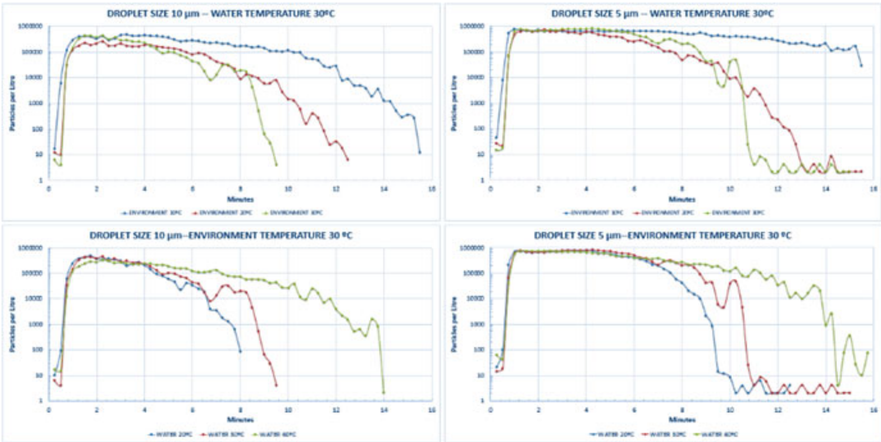

Fig. 2 Measurement of the colliding time of droplets of different sizes and temperatures

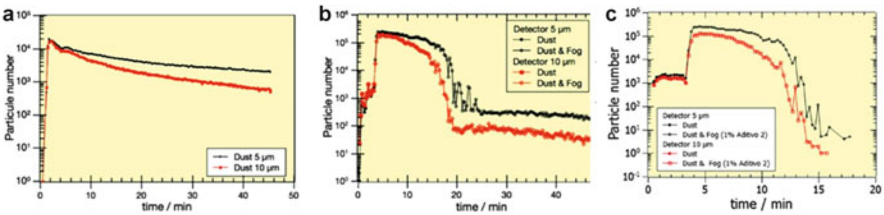

Fig. 3 Comparison of the evolution of different Fog compositions. (**a**) Talcum dispersed in air and naturally falling down. (**b**) COUNTERFOG released with just water. (**c**) COUNTERFOG released with a surfactant additive

lower than 10^8 particles/m^3 data are more accurate. An extrapolation of the evolution can be done to estimate that the original concentration of droplets is over 10^9–10^{10} particles/m^3.

According to the expression for the terminal speed, the time it takes all the droplets up to the ceiling to fall down the particle counter should be inversely proportional to the density of water and directly proportional to the viscosity of air. As it can be seen in Fig. 2, the higher the temperature of water, the lower the density (decreasing about 0.7% from 10 to 40 °C) that makes 40 °C water fog to remain in longer time than 10 °C water fog in the same environment. In the same way, the higher the temperature of air, the lower its viscosity is and therefore the faster the droplets fall down. Paradoxically, the hotter the water, the longer the droplets remain. Experimental results: radiological salt surrogates.

A typical scenario of RN incident is a radioactive salt in the form of a powder dispersed in air. Surrogates tested up to now in the COUNTERFOG Fog Dynamics Laboratory include $NaHCO_3$, KH_2PO_4, talcum, urea, and C_sC_l. If any kind of dispersion method is used, a natural fall down of powder is expected depending on the size and density as previously described.

The activation of the COUNTERFOG nozzle for 30 s creates a fog that should wash out the particles in a much shorter time. Figure 3a shows the number of particles in air for 10 and 5 μm when talcum is dispersed in air and it is let naturally to fall down. Figure 3b shows particles in air when, in addition to dispersed talcum, a COUNTERFOG is released made with just water. As it can be observed, there is no reduction of the number of particles in air after the dissipation of the water fog.

However, if an additive is added to reduce surface tension, then the effect of COUNTERFOG is then evident. In Fig. 3c the evolution is shown when the fog is made of 99% water and 1% surfactant additive. Note the time scale is much shorter in the figure below than in the previous ones. As a conclusion it is clear that hydrophobic powders require additives to be added to the water in order to be washed out effectively. More details on radiological tests may be found in [2].

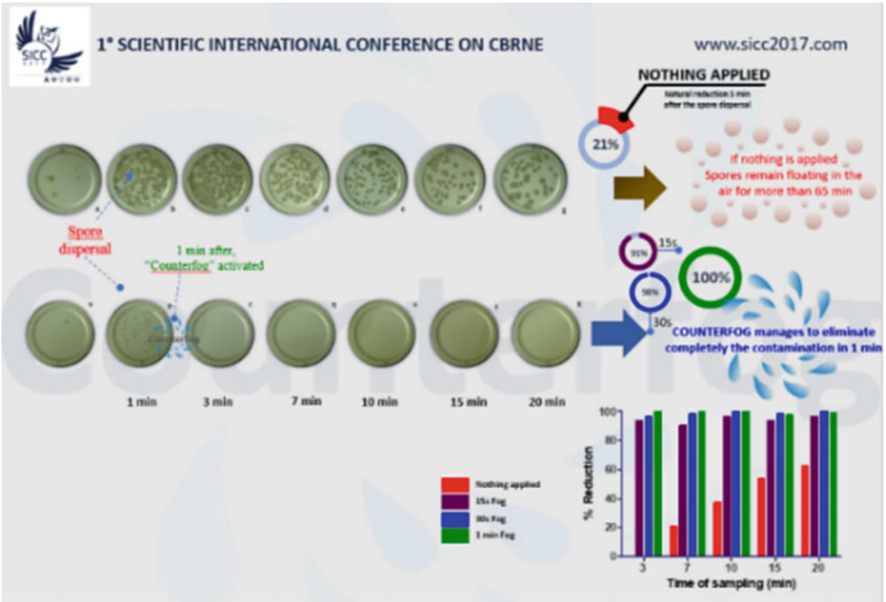

Fig. 4 Impact air sampler plates obtained from the air of the room where the spores have been disseminated with an aerograph. (a) Sample 0: taken 1 min after the releasing of spores. (b) Sample t1: taken 3 min after the releasing of spores. (c) Sample t2: taken 7 min after the releasing of spores. (d) Sample t3: taken 10 min after the releasing of spores. (e) Sample t4: taken 15 min after the releasing of spores. (f) Sample t5: taken 18 min after the releasing of the fog. (g) Sample 0: taken 1 min after the releasing of spores. (h) Sample t1: taken 1 min after the releasing of the fog. (i) Sample t2: taken 4 min after the releasing of the fog. (j) Sample t3: taken 8 min after the releasing of the fog. (k) Sample t4: taken 13 min after the releasing of the fog. (l) Sample t5: taken 18 min after the releasing of the fog

5 Experimental Results: Biological Surrogates

Tests with *Bacillus thuringiensis* were performed. Spores of *B. thuringiensis* CECT 4454 were set 0.3 U of McFarland scale and serially diluted 10^{-2} in a volume of 20 ml, and then these suspensions were heat-shocked by incubating at 80 °C for 45–60 min to kill vegetative cells. Then the solution was sprayed in the Fog Dynamics Laboratory (Fig. 4).

Comparison of the natural fall down rates and those after application of COUNTERFOG was systematically repeated for several actuation times of COUNTERFOG. Just 15 s of application of COUNTERFOG removes 91% of spores, and 30 s removes 98%, while there is only 21% of reduction by natural fall down after 5 min [3].

6 Experimental Results: Chemical Surrogates

Tests with methyl salicylate (MS), dipropylene glycol methyl ether (DPGME), and triethyl phosphate (TEP) show that a reduction is also achieved when a water fog is applied. However, the initial dispersion of TiO_2 and TiO_2–Al_2O_3 nanostructured microparticles which are powerful catalysts [4] and afterward removal of the particles by COUNTERFOG provide a much faster method with minimum environmental impact [2].

7 Toxicity Tests

Finally, in vitro and in vivo short-term toxicity tests were done to check if any of the fogs or nanostructured particles + fog were toxic. The list included water fog, TiO_2, and TiO_2–Al_2O_3 nanostructured microparticles plus water fog, an additive plus water fog, and Bio-Sel fog.

None of them had any relevant negative effect on blood oxygen saturation in any animal. This showed that the respiratory capacity of animals was not affected in the short-term studies.

8 Discussion

It is therefore obvious that a general-purpose water + an additive fog may be applied just in case that any potential anomaly is detected irrespective of the kind of agent that is producing it. Spores, microorganisms, and powder or smoke particles will be washed out, while gases will be solved. The preventive application of nanostructured microparticles just previously to the fog production seems as well to be recommended to counteract chemical agents.

The new COUNTERFOG technology based on the use of fogs has demonstrated a potential for rapid counteraction and decontamination of large-scale facilities and areas in case of CBRN incidents. The relatively low-cost, low toxicity, general purpose, and extremely low amount of waste are key advantageous characteristics that make it worthy to further research on their use.

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Safety in the Transport of Hazardous Substances in Residential Areas: Cases of the Release of TIC (Chlorine, Propane, and Butane) at Low Temperatures

Mario Ciccotti, Ferdinando Spagnolo, and Maura Palmery

1 Introduction

In the recent history, the release of chemicals provoked huge catastrophes. The most cited example is the Bhopal incident (December 3, 1984) that caused thousands of casualties due to the release of methyl isocyanate (40 tons, 7000–10,000 casualties up to 3 days after the disaster, and between 15,000 and 20,000 within 1985 and 2003) [1]. In Europe Seveso represents an example in terms of land reclamation costs [2] and impact on animal life involved [3]. The transportation of chemicals is a high-level risk process. Nowadays in other parts of the world, chlorine, a typical hazmat assumed to have a dual-use nature, becomes a widely used chemical weapon in theaters such as in Syria [4]. Another risk concern is liquefied petroleum gas (LPG) transport (propane and butane blends), for example, in Viareggio railway station 33 people died in an accident with LPG [5]. Also, the Major Hazard Incident Data Service (MHIDAS) database covering all types of transport related to hazardous substances has shown that there have been a significant number of accidents involving the transport of dangerous substances [6]. To contrast this trend, the regulations on the transport of substances increased. An example is the adoption of Regulation 1907/2006 and Regulation 1272/2008, both increased toxicological information, that can be provided in the event of a health emergency.

It is a paper coming from the best POSTER AWARD of SICC2017 conference.

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2 Aim

The aim of the following study is to analyze various risk scenarios to describe the possible consequences given by the voluntary release of propane, butane, and chlorine, after a hypothetical terrorist attack in a railway station where the materials are released in the form of aerosol, boiling liquid expanding vapor explosion, or explosion.

3 Materials and Methods

ALOHA software (Environmental Protection Agency, EPA) was used to simulate the dispersion; Google Earth was used for geographic information system (GIS) visualization. All the toxic industrial chemical (TIC) releases are estimated at the same condition of hotspot dimension (all simulation used a 40 feet tank) and conditions of tank loading (90% full tank, 49.9 m^3 volume) and aperture dimension (15 cm of diameter). Same weather conditions have been used during the simulations. Toxicological information was retrieved from the EPA, the European Chemicals Agency (EChA), and the National Institute for Occupational Safety and Health (NIOSH) toxicological databases. Additional information was retrieved from the Safety Data Sheet and the international railway transport regulation.

4 Scenarios

All the releases were simulated in a railway station, we considered four scenarios: chemical release without flames (chemical spread after atmospheric release with a distance of 50 m from the hotspot, indoor and outdoor concentrations considered); boiling liquid expanding vapor explosions (BLEVEs) for butane and propane and relative fireball diameter (10 kWm^2 of thermal gradient); lower explosion limit at 50 m from the hotspot; and triggered shock wave explosion (butane and propane). Different colors are used in GIS visualization for different levels of danger.

4.1 Chemical Release Without Flames

When the chemical compound is released without flames, chlorine and propane expand quickly and extensively, while, in the case of butane, low temperatures favor the formation of a puddle with constant gas release. Different colors are visualized in GIS representation in function of different gas concentrations, red for the higher

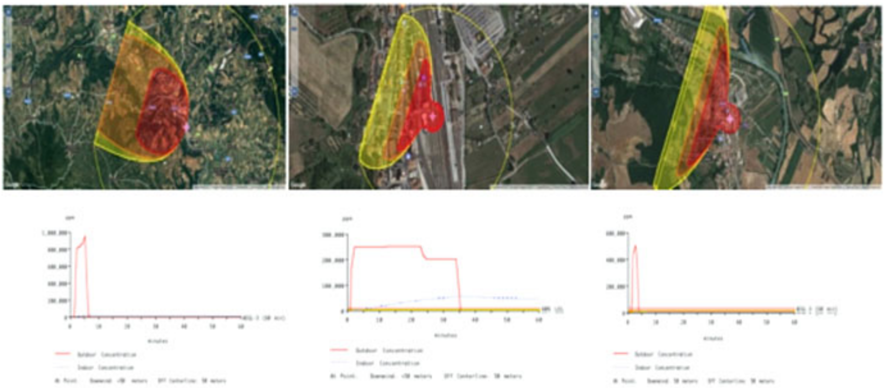

Fig. 1 Releases in order from the left to the right: chlorine, butane, and propane

Table 1 Result of simulation

Parameters		Conc. out + 50	Conc. ind. + 50	Perimeter (km)	Area (km^2)
AEGL 3 (red) 20 ppm	Chlorine			21.7	33.1
AEGL 2 (orange) 2 ppm				34	80.7
AEGL1 (yellow) 0.5 ppm				37	90.6
Conc. in ppm		952,000	28,100		
AEGL 3 (red) 53,000 ppm	Butane			0.664	0.015
AEGL 2 (orange) 17,000 ppm				0.853	0.031
AEGL 1 (yellow) 5500 ppm				1.13	0.067
Conc. in ppm		246,000	56,600		
AEGL 3 (red) 33,000 ppm	Propane			3.38	0.347
AEGL 2 (orange) 17,000 ppm				4.14	0.578
AEGL1 (yellow) 5500 ppm				5.46	1.21
Conc. in ppm		7,580	502,000		

levels of concentration (in ppm) and yellow for the lowest concentration, as reported in Fig. 1 and Table 1.

4.2 *Boiling Liquid Expanding Vapor Explosion (BLEVE)*

In this section, we analyzed BLEVEs caused by propane and butane.

In case of BLEVE generated by butane and propane, we obtain similar thermal waves on intensity and size; the areas are divided in different colors by different

Fig. 2 BLEVE generated by butane and propane

Table 2 Result of butane and propane simulation

Parameters	Thermal radiation lethal in 60″ (red) 10 kW (m^2)	Thermal radiation second-degree burns in 60″ (orange) 5 kW (m^2)	Thermal radiation-caused burns in 60″ (yellow) 2 kW (m^2)	Thermal radiation lethal in 60″ (red) 10 kW (m^2)	Thermal radiation second-degree burns in 60″ (orange) 5 kW (m^2)	Thermal radiation-caused burns in 60″ (yellow) 2 kW (m^2)
	Butane			Propane		
Area (km^2)	0.555	1.11	2.70	0.518	1.03	2.52
Perimeter (km)	2.64	3.73	5.83	2.55	3.61	5.63
Diameter (m)	420	593	927	406	573	896

thermal intensities, color red for 10″ of lethal thermal radiation, orange for second-degree burns after 60″ of explosion, and yellow for third-degree burns in 60″, as results reported in Fig. 2 and Table 2.

The results are listed below.

4.3 Lower Explosion Limit at 50 M from the Hotspot

The presence of vapors with a concentration over 60% of the saturation limit is considered one of the possible triggers of a catastrophic explosion. High concentration of gases or vapor combined with an ignition could be enough to initiate a domino reaction that put at risk rescuers' life and structures. We simulated both the flammable area for propane and butane and the concentration of vapors at 50 m from the release area. For butane and propane, ALOHA simulated the lower explosive limit (LEL) 60% and LEL 10% concentrations to identify dangerous zones; the results are reported in Fig. 3.

For butane LELs are 0.043 km^2 (60% red colored in Fig. 3) and 0.154 km^2 (10% yellow colored in Fig. 3). For propane LELs are 0.711 km^2 (more than 10% and up to 60% red colored in Fig. 3) and 2.07 km (up to 10% yellow colored in Fig. 3).

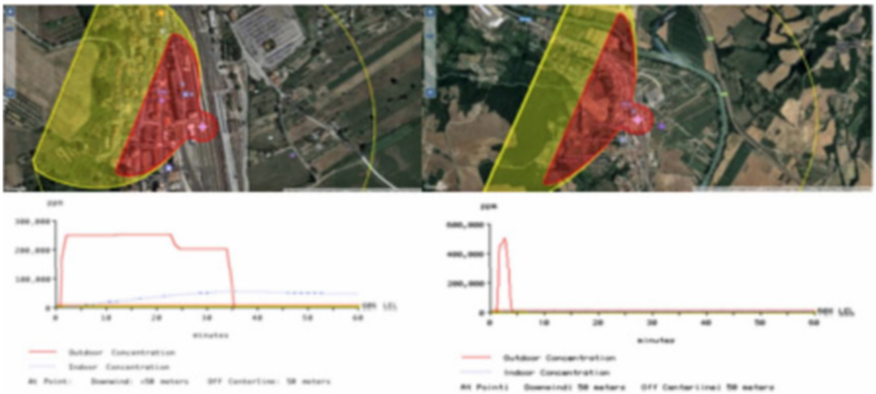

Fig. 3 Dynamic of release of butane (left) and propane (right): in red the area with LEL >60%, in yellow the area with >10% LEL

For butane, we have a maximum outdoor concentration of 260,000 ppm and indoor concentration of 56,000 ppm. In indoor and outdoor simulation, we have a concentration over the limit of 9600 ppm (>60% LEL) for outdoor concentration and 1600 ppm (>10% LEL) for indoor concentration. Moreover the vapor persistence is high (over 60% LEL) both considering 36 min for outdoor concentration and more than an hour for indoor concentration. This is due to the physical properties of butane (boiling point between −0.5 and −0.7 °C). At this temperature butane outflows from the tank in liquid form, forming a puddle with toxic and dangerous vapors. For propane, we obtained a maximum of 502,000 ppm in outdoor concentration and 7850 ppm maximum indoor concentration. The release lasts 4 min. All the concentrations are over 12,600 ppm (>60% LEL) outdoor limit and 2100 ppm (>10% LEL) indoor limit. The shock wave was generated by an explosion triggered by the tank.

4.4 Triggered Shock Wave Explosion

In this section, we simulate the shock wave generated by tank explosion 90% loaded with butane or propane. Propane and butane develop a different shock wave. The impact wave generated by propane is greater in terms of area and diameter.

In Fig. 4 the shock waves are depicted as follows: in red the pressure is over 8 psi (damage of buildings), in orange over 3.5 psi (serious damage), and in yellow over 1 psi (glass breaking). All data is reported in Table 3.

For butane, at 50 m from the point of explosion, we have an overpressure of 17.5 psi; for propane at 50 m from the point of explosion, we have an overpressure of 34.1 psi.

Fig. 4 Shock wave generated by detonation (left butane, right propane), different colors with different intensity, from the highest (red) to the lowest (yellow)

Table 3 Results after explosion of butane and propane

Parameters	Pressure over 8 psi (red) able to destruct buildings	Pressure over 3.5 psi (orange) able to inflict serious injury	Pressure over 1 psi (yellow) able to shatter glass	Pressure over 8 psi (red) able to destruct buildings	Pressure over 3.5 psi (orange) able to inflict serious injury	Pressure over 1 psi (yellow) able to shatter glass
	Butane			Propane		
Area (km^2)	0.026	0.078	0.521	0.186	0.431	2.63
Diameter (m)	166	237	488	572	672	1200

5 Exposure Rates and Toxicological Considerations

The exposure rates were estimated using the Green Book [7] using the Probit generic formula (1):

$$\mathrm{Pr} = a + b\ \ln\left(\mathrm{C}^{n}\mathrm{t}\right) \tag{1}$$

The percentage of incidence was obtained interpolating the Probit rates in standard incidence matrices. In the Green Book, some of these parameters are determined, for example, in case of chlorine, we have all the parameters (a, b, and n). For the other substances (butane and propane), we calculated all the parameters with vulnerability models through qualitative analysis [8]. To identify all the parameters, we consulted a toxicological dossier in different databases such as ECHA and EPA. Then the toxicological parameters were estimated for all three substances. For chlorine, we selected all three parameters ($a = -9$, $b = 0.92$, and $n = 2$) for an average population standard activity, and we use it to calculate the exposition rates with the Probit formula. The simulations of butane release included an acute e chronic inhalator toxicological assessment and thermal and shock wave exposures. All parameters were retrieved from the Environmental Protection Agency database [9]. To quantify the toxicity of the butane, we utilized the LC_{50} for 30′ in mice. This case is of 285.000 ppm, and after a conversion from ppm to mg/m^3, we obtained a concentration of 676,073 mg/m^3. To infer human toxicity levels, we used a factor

Table 4 Percentage of mortality at different levels of toxicity

Parameters	% Mortality Chlorine	% Mortality Butane	% Mortality Propane
AEGL 3 for 60′ exposure	0%	0%	0%
AEGL 3 for 10′ exposure	0%	0%	0%
Maximum indoor conc. at 50 m of distance	100%	0%	0%
Maximum outdoor conc. at 50 m of distance	100%	33%	26%

correction (mice-human) of 0.5 leading for human a LC_{50} of 338,036 mg/m^3. For butane Probit function, we assumed $b = 1$ and $n = 2$. To determine parameter a, we utilized the formula from the Green Book [Eq. (2)]:

$$a = 5 - \ln\left\{\left[338{,}036\ \mathrm{mg/m^3}\right]^2 \times 30'\right\} = -23.86 \tag{2}$$

obtaining −23.86 value. For propane, we determined parameter a from the toxicological information that we found in ECHA dossier, where the LC_{50} after 15′ of exposition in rats is 1,443,000 mg/m^3. For humans, we utilized a factor of conversion from rats to man which is 0.25, and we obtain an inhalator toxicity of 360,000 mg/m^3. Assuming $b = 1$ and $n = 2$, we obtained the value −23.2999 for parameter a [Eq. (3)]:

$$a = 5 - \ln\left\{\left[360{,}750\ \mathrm{mg/m^3}\right]^2 \times 15'\right\} = -23.2999 \tag{3}$$

Results for inhalator exposure are as listed in Table 4.

As a result, we have a high inhalation toxicity of chlorine, in terms of mortality and dimension of the exposure (able to kill people after 1′ exposure in an area of 1.73 km^2 and with a perimeter of 7.41 km). Butane is able to kill 33% of population due to its physical properties; it forms toxic persistent vapors for 36 min. We have a relevant outdoor toxicity considering only 4 min of exposure with 26% mortality. Furthermore, the area has been divided in three different thermal exposure zones: 10 kWm^2 as potentially lethal in 60″, kWm^2 for second-degree burns in 60″, and 2 kWm^2 able to cause pain in 60″. We estimated the damage for each zone using a formula reported on the Green Book available in two versions, one for the mortality rate and the other for the burns assessment. The formula (4) for hydrocarbons exposure is:

$$\mathrm{Pr} = -36.38 + 2.56\ \ln\left(t^*\ q^{4/3}\right) \tag{4}$$

where t is the time of exposure in seconds and q is the intensity of thermal wave in kWm^2; the only variation between the first version and the second version in the q parameters is $q^{4/3}$ for the mortality rates and $q^{4/3} = 1.25$ for the not mortal burns.

For a 10 kWm^2 exposure, the results are 70% mortality, 99% of first-degree burns, 16% of second-degree burns, and 9% of third-degree burns. We estimated also the damage after an explosion, in particular the damage generated by shock wave after explosion. The following Probit formula (5) was utilized to estimate hearing damage (e.g., number of perforated eardrums):

$$\mathrm{Pr} = -12.6 + 1.524\ \ln Ps \tag{5}$$

Ps is the pressure in pascal, in the simulation we estimated the area over 8 Psi, after an operation of conversion we passed from 8 Psi to 55,158 Pa, and the result is 4.038 that means 18% of incidence. For butane, we evaluate the shock wave at 50 m from the point of explosion (17.5 psi). With this pressure value, we obtained a Probit of 5231 meaning that 60% of eardrums were injured after the explosion. The mortality ratio after thermal exposure was simulated revealing a lethal area of 0.555 km^2 for butane and 0.518 km^2 for propane. For propane, in the case of explosion, the incidence accounts for 18% incidence by shock wave in an area of 0.186 km^2. At 50 m, the overpressure is estimated in 34.1 Psi potentially capable of perforating 90% of eardrums of the exposed personnel.

6 Conclusions

In this study, we simulated three types of toxic industrial materials at low-temperature release close to residential areas. We analyzed four scenarios with different toxicological or physical implications. Chlorine showed indoor and outdoor toxicity, also after a short time exposition, and a high dispersion after release. We simulated also the toxicity of propane in outdoor. The toxicity of butane at low temperature is important, due to its vapors originating from a puddle. In this condition butane forms constant, toxic vapor (for 36′) able to increase indoor and outdoor toxic concentrations very dangerous for people and rescuers. We simulated also BLEVE scenario for butane and propane and the high level of danger faced by rescuer approach in case of butane at low temperature due its vapors. Eventually we considered damages after explosion and the physical damage after a shock wave. The aim of this article was to focus the attention on the risk related to transport of TIC. We analyzed how much the release of chemical substances in gaseous or vapor forms could be dangerous and how triggered explosion of the tank could be dangerous especially at low temperatures.

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Fog Dynamics

Juan Sánchez García Casarrubios, Francisco-José Llerena-Aguilar, and José-Luis Pérez-Díaz

1 Introduction

The lethal power of CBRN agents and their power to cause massive fatalities rely on their ability to disperse and propagate. In this sense, the most dangerous agents are those which are dispersed in the air and penetrate the lungs. For example, casualties caused by inhaling anthrax spores dispersed in the air are two orders of magnitude greater than those caused by a cutaneous infection of the same spores. This is also true for chemical and radiological agents [1].

The activity of a dispersed agent is many times greater than that of the same agent in a bulk or aggregate state. This is a general law and is due to the exponential increase of the surface-to-volume ratio for decreasing sizes of particles, spores, or drops. This principle is also well-known in medicine, i.e., a patient inhales sprayed medicaments to affect the respiratory system quickly [2]. It is also well-known in other fields: for example, coal powder suspended in the air makes an explosion in the atmosphere much worse than any other explosion in mines; even flour suspended in the air makes an explosive mixture that can often cause serious accidents in factories. On the other hand, fog and mist devices have been developed to fight fire with minimum water use. These systems are now becoming very common—for instance, to protect escalators from fire. They have the great advantages of using the optimal amount of water compatible with electric hardware and of being harmless to humans.

Taking this into account, a priority for any rapid response against a CBRN attack should be to collapse any kind of dispersion, fog or smoke, into a physically bulk state. This would avoid further propagation and drastically diminish the lethality and therefore the impact of the attack.

It is a paper coming from the best POSTER AWARD of SICC2017 conference.

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The main objective of COUNTERFOG project is to design, build, and test a rapid response system for collapsing all kinds of dispersed agents (smoke, fog, etc.) by using a fog made of a solution that could eventually also contain any kind of neutralizing component. It is intended for use in large atriums and buildings as well as in outdoor conditions. It is intended to provide a very fast and early response.

2 Fog Dynamics

Although most solid particles will be far from being spherical, liquid droplets are supposed to be approximately spheres, provided the air velocity around it is not large enough to modify its shape. Therefore, a dynamics model for spheres floating in the air will be a first approach to deal with. The dynamics of the fog may include mechanical and thermal phenomena including mass and heat transport and changes of phase. In this last case, evaporation will shift the size distribution toward smaller diameters, while condensation will do the opposite.

Mechanics of a sphere in a viscous flow is determined by Stokes law [3]. The force exerted by a fluid onto a sphere can be written as in Eq. (1):

$$\vec{F} = 6\,\pi R\mu\,\vec{V} \tag{1}$$

where R is the radius, μ the viscosity of the fluid (air in our case), and V the fluid velocity.

As a well-known consequence of this, the fall of final speed of a particle of density ρ_p and radius R can be written as in Eq. (2):

$$\vec{V}_p = \frac{2}{9}\frac{R^2 g\left(\rho_\mathrm{p} - \rho_\mathrm{a}\right)}{\mu} \tag{2}$$

where g is the gravity and ρ_a is the density of air—of the order of one thousandth of that of water.

It means that for a water droplet with a diameter of 2 μm falling in the air at room temperature, the final speed is about 1.2×10^{-4} m/s = 0.72 cm/min, while for a diameter of 10 μm, it will be around 3×10^{-3} m/s = 18 cm/min which is 25 times faster. This means that for a 3-m-high room, it will take around 15 min for all the 10 μm droplets to fall down to the floor.

3 Fog Dynamics Laboratory

As a part of the COUNTERFOG project [4], a laboratory for the study of fog dynamics has been designed and built. This laboratory is provided with a double test room, a control room, and a technical room. Insulated from the environment, temperature is controlled throughout thermally controlled walls, ceiling, and floor providing a very good thermal stability. Temperature can be statically controlled through its walls, ceiling, and floor in a range from 0 °C up to 45 °C with a precision ± 0.1 °C. Water and airflow as well as humidity in room and actual pressure in pipes are registered.

Provided with IP-65 lighting, thermal insulation, compressed air and pressurized liquid pipelines, air filtering, and collecting pool drainage, it can withstand still humid air even in condensing state. It is as well provided with sensors for air and water pressure and flow, temperature, humidity, droplet/particle size, and opacity as well as CO_2, CO, SO_2, CHx, and O_2 concentrations. Dynamics of fog, suspensions in the air and smoke, as well as their interaction can be experimentally measured.

An airborne particle counter Fluke model 985 based on optical counting complying ISO21501–4, JIS B9921, IEC/EN 60825–1:2007, and 21CFR1040.10 is used to measure the concentration of particles floating in air. Counting efficiency is 50% for 0.3 μm and 100% for particles greater than 0.45 μm per JIS. Other instruments measure number of particles floating in the air, living microorganisms, or chemical concentration.

4 Experimental Tests

The COUNTERFOG system for decontamination is based on the generation of a water-based fog. As a part of the mentioned project, the dynamics of water fogs has been experimentally studied for different temperature conditions for air and water.

After 30 s of actuation of a B½ nozzle under working parameters (water and air pressure under 12 bar), a fog is generated with diameter distribution centered in 5 μm as it can be seen in Fig. 1.

Values greater than 10^9 droplets/m^3 (with only 5 ml of liquid water per m^3) are typically obtained. Note that for 10-μm-sized droplets, only 8×10^8 droplets/m^3 store

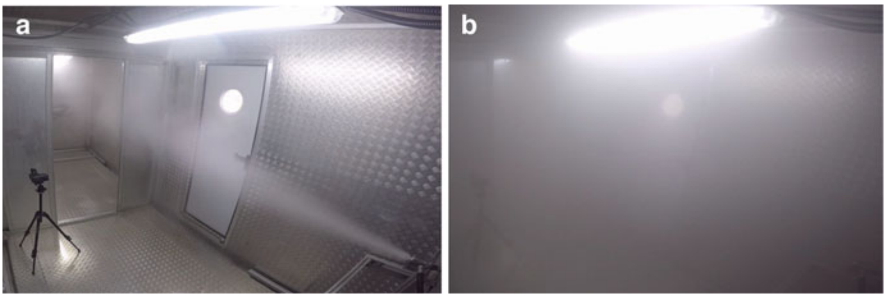

Fig. 1 Test room of the fog dynamics laboratory. (**a**) Test room before the fog was released. (**b**) Test room after 30 s of actuator

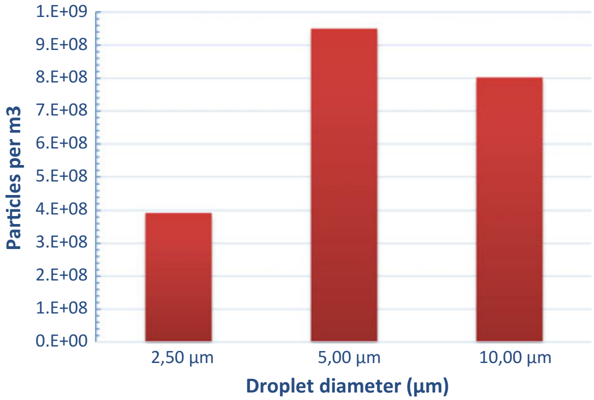

Fig. 2 Evolution of a 5- and 10-µm-sized droplets for several temperature conditions both of the environment and the water of which the fog is made

3.4 ml of liquid water per m^3. This means that a relatively large amount of water is collected on walls, ceiling, and floor during activation of the nozzle.

Typical fog dynamics include falling down, evaporation, and the subsequent reduction of droplet size [5]. Figure 2 shows the evolution of 5- and 10-µm-sized droplets for several temperature conditions both of the environment and the water of which the fog is made. A two-fold behavior is clearly observed. In the first part, the particle counter is saturated showing almost a horizontal straight line. Only when levels are lower than 10^8 particles/m^3 data are more accurate. An extrapolation of the evolution can be done to estimate that the original concentration of droplets is over $10^9 - 10^{10}$ particles/m^3.

According to the expression for the terminal speed, the time it takes for all the droplets from the ceiling to fall down the particle counter should be inversely proportional to the density of water and directly proportional to the viscosity of air. Paradoxically, the hotter the water is, the longer the droplets remain. The higher the temperature of water, the lower the density (decreasing about 0.7% from 10 to 40 °C) that makes 40 °C water fog to remain longer time than 10 °C water fog in the same environment. In the same way, the higher the temperature of air, the lower its viscosity is, and therefore the faster the droplets fall down.

5 Conclusion

As a conclusion it is demonstrated that a fog generated by COUNTERFOG is relatively stable with a droplet size distribution centered 5 µm in diameter. As it was theoretically expected, they slowly fall down while washing out the air. The system and dynamics have demonstrated to be stable from 10 to 40 °C for both water temperature and environment temperature as it can be seen in Fig. 3a–d.

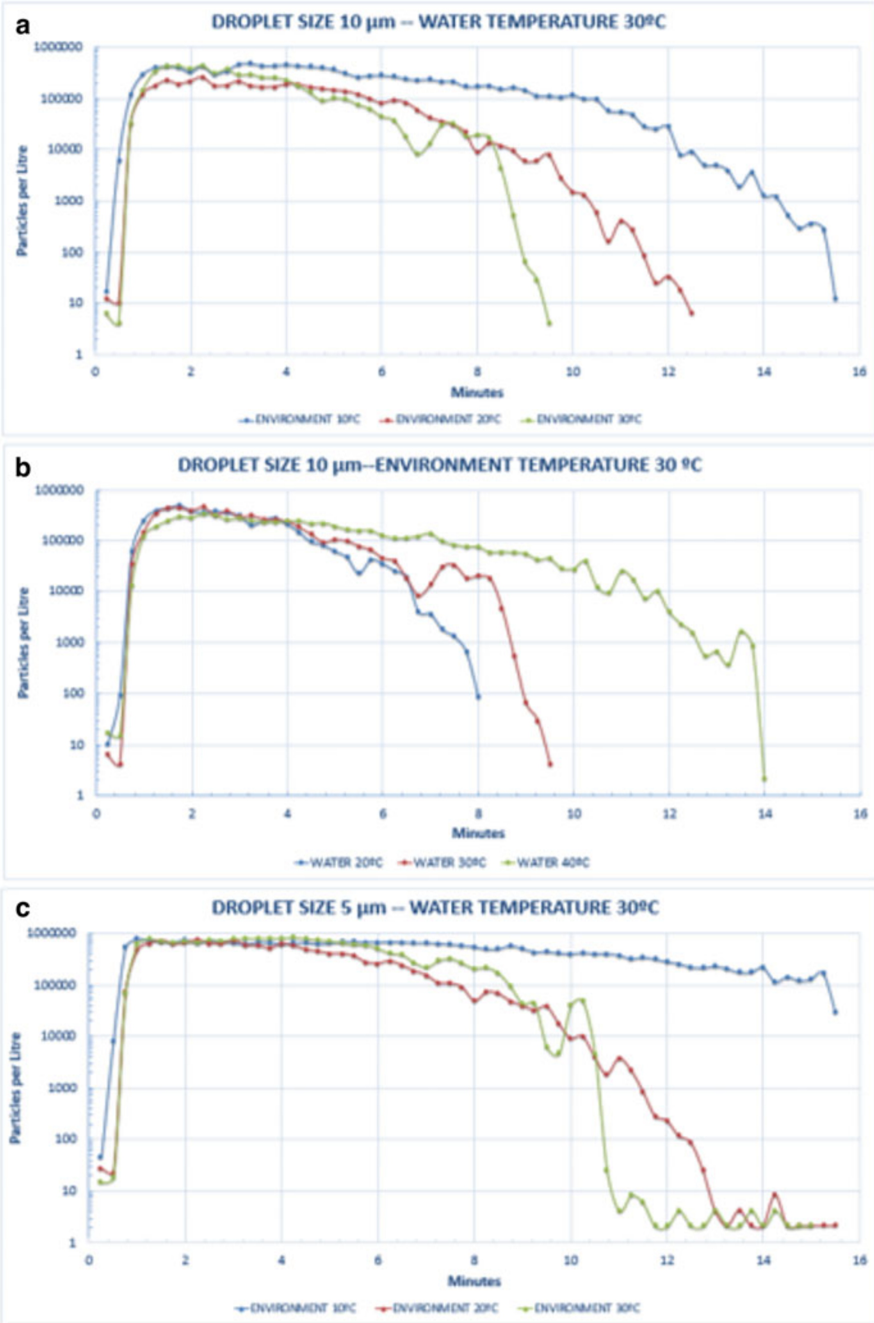

Fig. 3 (**a**) Measurement of the colliding time of droplets of 10 µm at different temperatures without COUNTERFOG application. (**b**) Measurement of the colliding time of droplets of 10 µm at different temperatures with COUNTERFOG application. (**c**) Measurement of the colliding time of droplets of 5 µm at different temperatures without COUNTERFOG application. (**d**) Measurement of the colliding time of droplets of 10 µm at different temperatures with COUNTERFOG application

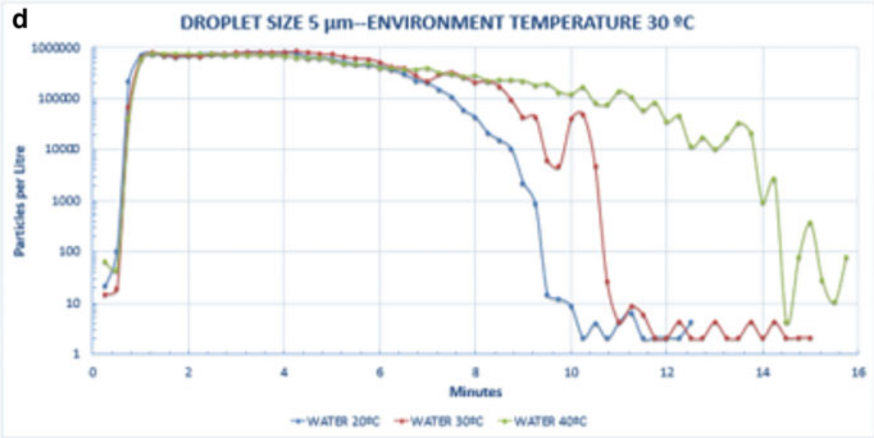

Fig. 3 (continued)

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Thymol and Bromothymol: Two Alleys in Biological Weapons Defeat

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1 Introduction

Since 1915, the World has become sadly aware of the chemical weapons employment in war. As far as last century, the Chemical Weapons Convention has established to banish this type of military equipment promoting their whole demolition till 2012. At today, approximately the 72% of declared chemical weapons has been destroyed, however the development of biochemistry, molecular biology and gene engineering has been raising new concerns in that field [1]. While some lectures consider chemical weapons as ancient tools in warfare, the latest scientific-technical

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developments are getting more appeal not only among the major world powers but also in terrorism. These types of molecules, compounds or even bacterial strains are difficult to pursuit but, at the same time, suitable for mass spreading and easy in reproducing. Furthermore, several strains are able to resist to a wide range of drugs and can intake foreign genes, which allow them to synthesize wide amount of toxins, enzymes and inhibitors [2–4]. Thus, finding new compounds or drugs able to defeat engineering bacteria, or resistant once as well, is an impellent issue [5]. Keeping an eye on environmental safety drugs, essential oils are considered a new begin in the fight against microorganism [6]. These compounds are naturally present in plants acting as natural antimicrobial drugs and preventing pest infections or invasions. Often, essential oils are characterized by intense smell, to which their name is due, and they might be volatile or non-volatile. In the first family there are several familiar odours such as limonene, camphor, eucalyptol, lavender, but one of the more active on bacterial inhibition growth is thymol [7]. Thymol belongs to terpene family, it is a monoterpene phenol showing a wide panel of activities [6]. Currently, it is recognised by European Union as natural preservative and additive in food storage [8] but in literature there are a huge amount of studies on its application in medicine (i.e. headache, coughs, heart attach) [6]. As mentioned above, it is the main molecule found in Laminacee family herbs [9] and its antibacterial activity is in the micro or nanomolar range. It can act at different level in killing pathogens. As reported by Trombetta [10] and co-workers, thymol is able to interfere with cell membrane changing its structure and inhibiting ions-pumps for electrolytes carriage. More recent studies, however, suggest that thymol way of action is extremely tuning [11]. Briefly, this terpene goes through cell membranes allowing its binding to DNA [11]. This starts a path leading to cell death. Because the use of thymol in bacterial defeating is a new challenge, nowadays, only negligible types of strains have shown a specific resistance mechanism. As summarised by Marchese et al. [6], Thymol is able to kill, or at least to inhibit, both Gram positive and Gram negative bacteria [12]. Furthermore, its efficacy has been studied towards pathogen, which might have an interest as biological weapons. Some examples are the capability in defeating *E. coli* O157:H7, *Y. enterocolica*, *S. thyphimurium*, *E.coli* O157:H7 CECT, *K. pneumoniae*, *Brucella spp* and *Clostridium perfrigens*. Thus, every time the monoterpene goes through cellular membrane it triggers the cell death [6, 7, 11]. Because its potentiality, the interest in this compound is further corroborate by it is low toxicity toward human cell (fibroblast and human gastric cells [2]), commonly use as control in drug efficacy/side-toxicity ratio. Data collected in this field show that thymol has a slight and non-statistic significant side effects on human cells at the concentrations used in bacterial treatments [12, 13]. Summarising, essential oils have been arousing a great interest in pharmaceutical application due to their wide panel of effectiveness. Furthermore, several basic compounds have been modified with the aim of achieving a better dose/response ratio. Starting from these evidences, our group has developed a new eco-friendly and economic sustainable process to obtain bromothymol. In the present work, the antibacterial efficacy of the drug is deeply analysed and a comparison with the non-functionalised thymol is disserted. In our investigation bromothymol has a greater dose/response ratio than thymol alone

Table 1 Comparison between thymol and bromothymol efficacy towards a wide panel of bacterial strains

Bacterial Strain	Thymol (MIC μg/ml ± SD)	Bromothymol (MIC μg/ml ± SD)
E. coli strains*	450 ± 1	300 ± 100
S. areus strains**	423 ± 74	41 ± 14
P. aeruginosa	900	–[a]
*A. baumannii***	250 ± 75	126 ± 64

MIC minimum inhibitory concentration, *SD* standard deviation
Statistical analysis are performed using T-Student: *$P < 0.02$; **$P < 0.001$
[a]Resistance

toward three bacterial strains. From our current knowledge, it is the first time that this kind of antiseptic molecule is employed in pharmaceutical application, as well.

2 Material and Method

Bromothymol has been synthetized following the literature procedure [14]. Biological test and activities are previously described [15].

3 Result

3.1 *Bromothymol vs Thymol: Efficacy on Bacteria and Negligible DNA Toxicity*

To investigate the antibacterial efficacy of bromothymol, experiments have been conducted in parallel with thymol on *E. coli*, *S. aureus*, *P. aeruginosa* and *A. baumannii*. Data were collected and a statistical analysis performed as described. Results are shown in Table 1. According with our finding, the compound is one order of magnitude more active than thymol against *P. aureus* (41 μg/ml vs 421 μg/ml) while there is not a greater difference versus *E. coli*. Despite thymol, bromothymol shows no toxicity on *P. aeruginosa*, though the natural compound has a very high MIC dose (900 μg/ml). Furthermore, our drug has no genotoxicity in QSAR simulation. In fact, despite other compounds in which bromine is weakly bound to an sp2 carbon, in the presence of intracellular enzymes [16], inducing the covalent linkage between DNA and the drug, our results show no chromosome aberration during treatments.

3.2 Assessment for Skin Treatment

In order to deeply investigate the possibility in applying BT as sanitizers in topic resource, studies have been performed on keratinocytes cultures. It is a common practise, indeed, using in vitro this kind of cells to mimic and foresee skin response at irritant agents [17]. Indeed, focusing on the possibility to use BT as element in bulk soaps production, it is necessary that this substance avoid doing skin morbidity. According to this purpose, the comparison between thymol and BT on aforementioned cells has been performed and, while thymol is corrosive, implying an irreversible damage on the skin, BT is irritant. This property suggests a reversible condition without permanent side effects.

4 Discussion

Essential oil has been considered new allies in the fight towards bacteria resisting to common drugs. They are characterized by eco-friendly processes of extraction and negligible side effects. Essential oil capability of action is due to a wide panel of compound belonging to different families. Terpene one is the more representative and, among all, thymol is the one showing the more appealing property. Starting from that evidences, our group has applied a functionalized analogue testing its antibacterial activity. Our results highlight how BT has a MIC toward *P. aureus* one order of magnitude lower than thymol. In addition, both compounds are toxic on *E. coli* in equal concentration. QASAR investigation has revealed that BT does not affect chromosome aberration in vivo, executing its efficacy with a different path in respect to that suggested by Lang-Hong and co-workers [11]. Moving on this data and that reported in literature previously [6], we judge that BT way of action ought to be in agreement with Marchese et al. [6]. Embracing this theory, BT is capable of interfering with cellular membrane stability as well as ion channels. That arouses the breakage of membrane and the loose of cellular homeostasis causing cell death, Fig. 1.

5 Conclusion

World has become aware of chemical weapons since 1915. In parallel with the development of technology and biology also these kinds of mass destruction tools have been upgraded. Furthermore, while in the past terrorism used to use gases, (i.e. nerve agents) up today, biological agents are the more common in their assaults. Indeed, bacteria can be modified with foreign genes able to synthetized a wide spectrum of protein having very different activities. Because of this critical scenario, the need of new compounds able to defeat engineering organism is required. In

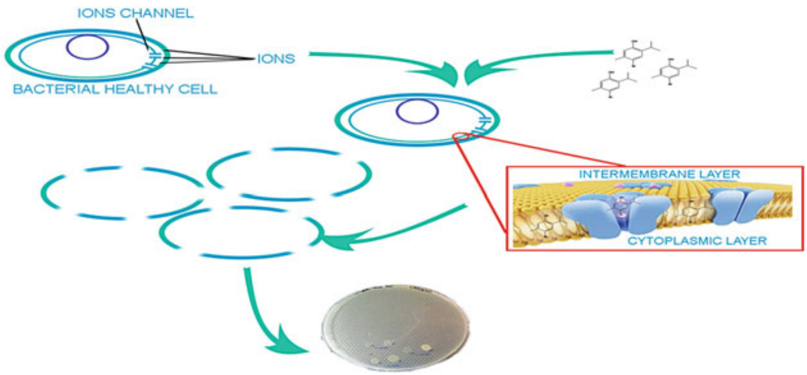

Fig. 1 Mechanism of action of BT. *In bona fide*, our data suggest that the compound is able to cause the breakage of cellular membranes

doing so, scientists have investigated the efficacy of artificial and natural compounds, as well. Keeping advantage from natural substances, essential oils have been revealed as perfect candidates for that aim. Especially volatile substances, belonging to terpene family, are taking into account. Among that, thymol is one of the more suitable for the use. It is safe for human health and it can easy penetrate microorganism cellular membrane, inducing cell death. This activity is also present in a molecule preserving the aromatic ring but having a bromine as substituent. Bromothymol is commonly used in laboratory application but, in bona fide, it is the first time that it is used as drug against bacteria. As far as, it was very difficult to purify in laboratory but our group has developed a easy and eco-friendly protocol. BT is more power than thymol and it has a lower toxicity on skin application inducing no aberration in chromosomes. Certainly, a huge amount of studies have been requested to further investigate and disclose in detail the mechanism of action and the whole potentialities of that compound. For this reason, our group has already started investigation on fungal activity. Promising results are obtaining in that field. Furthermore, an optimization in vehicular process let us to suppose that BT ought to be a suitable candidate in biological weapons defeat.

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First Measurement Using COUNTERFOG Device: Chemical Warfare Agent Scenario

Laura Pascual, Marta Fernández, José Antonio Dominguez, Luis Jesús Amigo, Karel Mazanec, José Luis Pérez, and Javier Quiñones

1 Introduction

In order to analyze and study the behavior of chemical warfare agents (CWA) in the context of the COUNTERFOG project experiments and due to their toxicity and restrictions of use, the so-called surrogates, simulants, or mimics are used [1]. A chemical warfare simulant is considered ideal if it mimics all significant chemical and physical properties of the agent without its associated toxicological properties. Although a number of compounds have been used as surrogates, no individual compound is ideal because a single simulant cannot satisfactorily represent all properties of a given CWA; so if a surrogate resembles an agent in molecular structure or physicochemical properties, then the simulant's performance may offer guidance for handling the CWA. Thus, a number of different chemicals have been used as CWA simulants depending on the physical-chemical property of interest, such as hydrolysis, sorption, bioavailability, and volatilization [2].

The goal of the present research work is to develop an experimental procedure to assess the effectiveness of the COUNTERFOG device in cleaning contaminated atmospheres in order to use it either under emergency scenarios, produced by dispersion of CWA, or in the collapse and cleaning of chemical agents dispersed in the environment.

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Table 1 Physicochemical properties of CWA and its potential surrogates

Abbrev.	Molecular weight (g/mol)	K_H°	Boiling point (°C)	P_v (mm Hg)	S (mg/l)
GA	**162**	$\mathbf{6.5 \times 10^{-7}}$	**248**	**0.057**	$\mathbf{7.2 \times 10^{4}}$
GB	**140**	$\mathbf{3.8 \times 10^{-4}}$	**158**	**2.1**	$\mathbf{1.0 \times 10^{6}}$
GC	**182**	$\mathbf{1.9 \times 10^{-4}}$	**198**	**0.4**	$\mathbf{2.1 \times 10^{4}}$
DIMP	180	1.8×10^{-3}	121	0.277	1.5×10^{3}
DMMP	124	5.3×10^{-5}	181	0.96	1.0×10^{6}
DPGME	**148**	$\mathbf{4.7 \times 10^{-8}}$	**188**	**0.55**	$\mathbf{1.0 \times 10^{6}}$
DFP	184	5.3	183	0.58	1.5×10^{4}
TEP	**182**	$\mathbf{6.1 \times 10^{-5}}$	**215**	**0.39**	$\mathbf{5 \times 10^{5}}$
HD	**159**	$\mathbf{9.8 \times 10^{-4}}$	**218**	**0.11**	**684**
CEES	125	1.5×10^{-2}	157	3.4	1062
CEPS	173	3.0×10^{-3}	257	1.9×10^{-2}	84
MS	**152**	$\mathbf{4.0 \times 10^{-3}}$	**223**	**0.04**	**700**
VX	267	1.4×10^{-7}	292	7×10^{-4}	3×10^{4}
Malathion	330	2.0×10^{-7}	156	3.4×10^{-6}	143
Parathion	291	1.8×10^{-5}	375	6.7×10^{-3}	11

Highlighted in bold are the CWA of each group

2 Experimental Procedure

2.1 CWA Surrogates Selection

In the context of the COUNTERFOG project, the selection of chemical surrogates was done by experts in the Advisory Board, the Defense Ministry of Spain, and the Consortium itself according to the proposed objectives. Sets of agents were selected as the most important and their corresponding surrogates usually accepted in the North Atlantic Treaty Organization (NATO) (Table 1).

To select the surrogates, the following variables have been considered: boiling point, solubility, Henry's law constant (K_H), and chemical structure, i.e., functional group and molecular weight [3].

To perform the study for the group of G agents, two surrogates were selected: triethyl phosphate (TEP), having a core molecular structure similar to these agents with the P–O functional group (Fig. 1), and dipropylene glycol monomethyl ether (DPGME), whose physical parameters cover the range of boiling point, K_H, and solubility.

With regard to distilled mustard (HD), methyl salicylate (MS) has been selected as it has a boiling point, K_H, and solubility very close to the target compound (Fig. 1).

CWA Dispersion Method The method of dispersion established was the generation of the vapor. For that, 5–10 ml of surrogate was evaporated by means of porcelain capsule located onto a hot plate (180–240 °C).

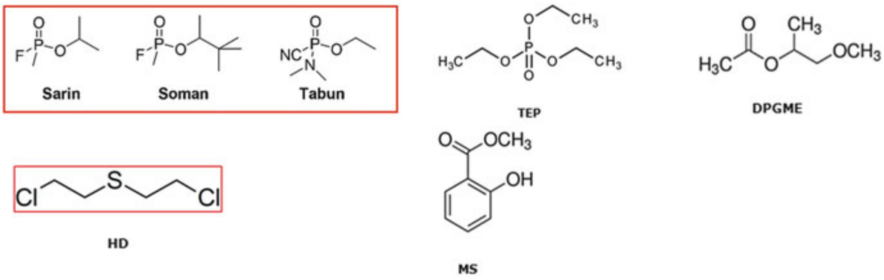


Fig. 1 Chemical structures of different CWA considered and the surrogate selected

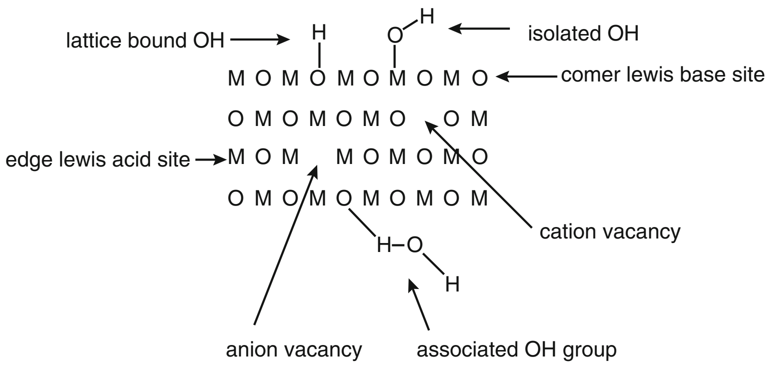


Fig. 2 Reactive sites on surface of metal oxides

CWA Sampling, Detection, and Measurement Methods Compounds were sampled in active mode by drawing the air of laboratory directly into organic solvents (ethanol and hexane) using small suction pumps. Gas chromatography with flame ionization detection (GC-FID) was the analytical technique used to detect and quantify the CWA surrogate [4, 5].

2.2 *Nanomaterial Selection*

Due to large surface area, nanomaterials (NMs) have enhanced the capacity to strongly adsorb CWA, trapping them in pores and dragging them down, increasing the fog efficiency and accelerating the time necessary to remove the agent from the atmosphere. Moreover, CWA trapped in NMs may undergo reactions in reactive sites of NMs that neutralize its hazardous properties rendering the agent nontoxic (Fig. 2). Proposed decomposition mechanisms are based on reactions of oxidation and/or hydrolysis taking place after the adsorption of functional groups of the CWA or surrogate at Lewis acid (metal atom) or at Brönsted acid (hydroxyl) sites of metal oxides [6].

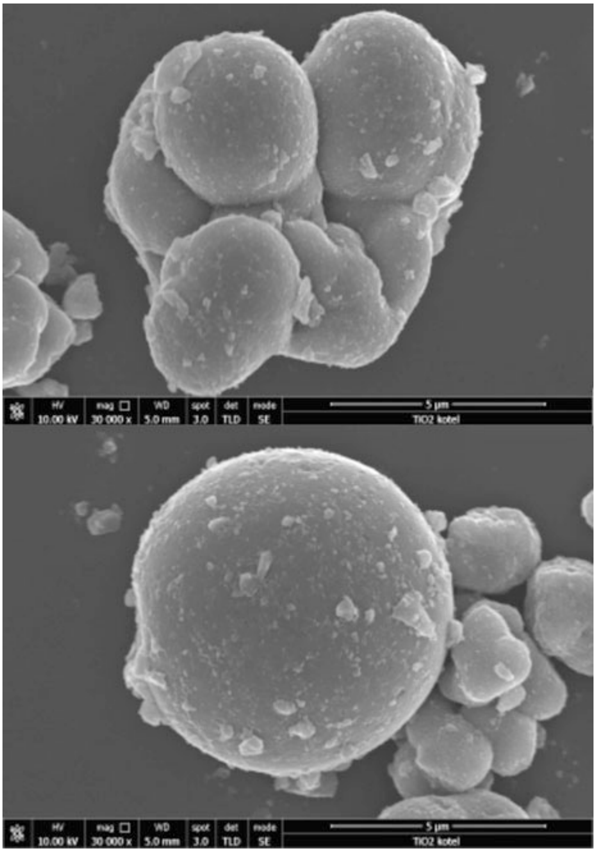


Fig. 3 SEM images of TiO_2 nanoparticles

For our purposes, nanomaterials of TiO_2 and TiO_2–Al_2O_3 were finally selected and used for the trials after being conveniently characterized (see Sect. 3.1).

3 Results and Discussion

3.1 Nanoparticles Characterization

The properties of nanomaterials depend largely on its surface area, which determines the number of active sites and interactions with other substances. Surface area is related to particle size, particle morphology, and porosity. To assess the possible interactions of NMs and CWA surrogates, these parameters were studied. The particle size distribution was determined by laser diffraction technique. Nanoparticle porosity and specific surface area were measured by physisorption. The NMs were provided by IIC (Institute of Inorganic Chemistry) with the following pictures (Figs. 3 and 4).

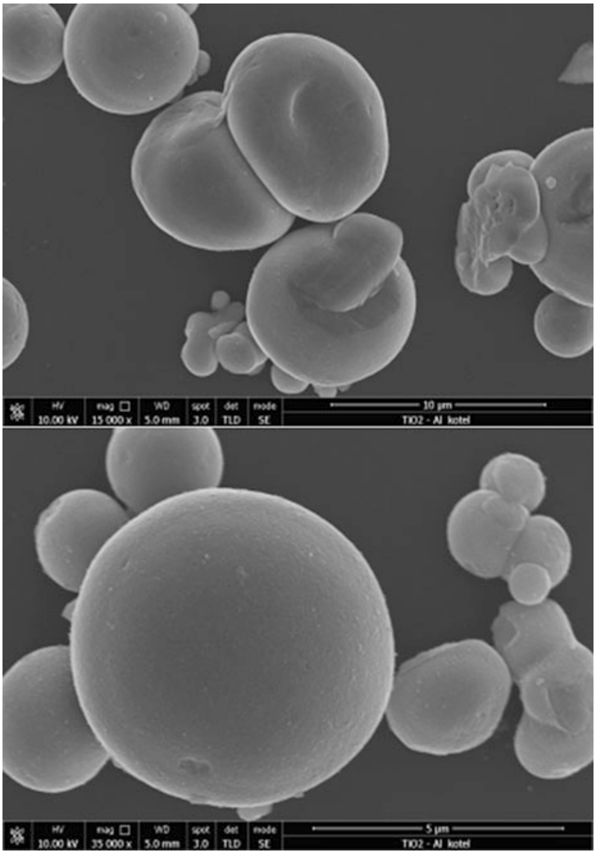


Fig. 4 SEM images of TiO_2–Al_2O_3 nanoparticles

Table 2 Summary of the diameters measured for nanomaterials

Nanomaterial	D_m [v,0.9]/µm	D_m [v,0.5]/µm	D_m [v,0.1]/µm
TiO_2	16 ± 1	12 ± 1	7 ± 1
TiO_2–Al_2O_3	38 ± 1	28 ± 1	19 ± 1

Particle size measurement distribution results for TiO_2 and TiO_2–Al_2O_3 are displayed in Table 2 and Fig. 5. The measurements of the particle size distribution show a high repeatability which supports the evidence of the high homogeneity and stability of nanoparticles.

Specific surface area will have a strong influence on the layer interaction between solid particle, fog, and contaminant agents. The results obtained for specific surface area of the two nanomaterials determined by Brunauer, Emmett, and Teller (BET) method (Fig. 6) jointly with pore size and volume of each one appear in Table 3. Geometrical surface (S_{geo}) calculated for both nanoparticles is also summarized in Table 3.

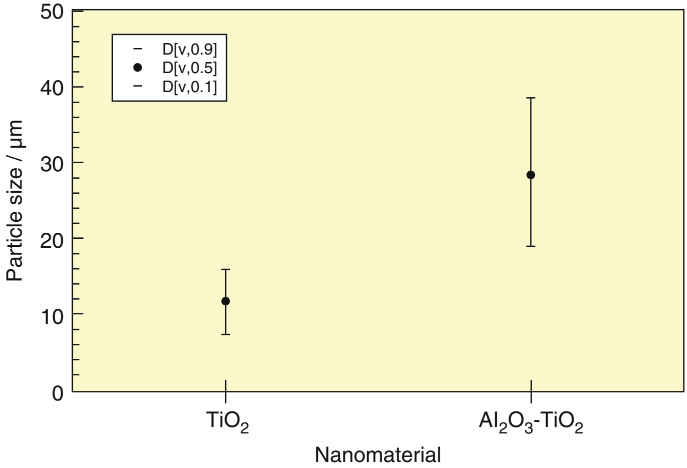


Fig. 5 Comparison of the diameters of the considered nanomaterials

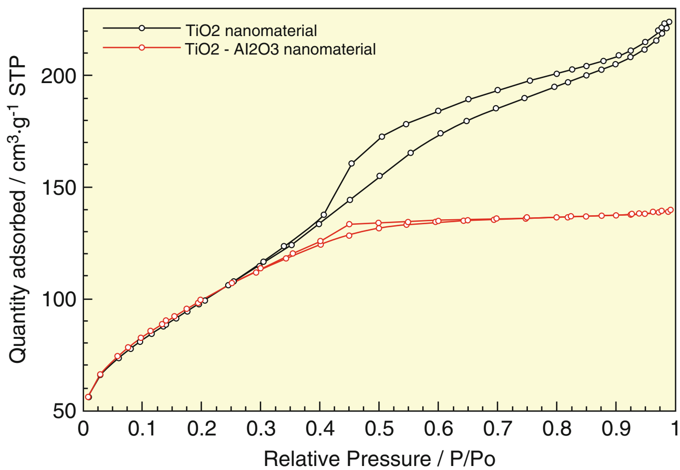


Fig. 6 Specific surface analysis of nanomaterials used

Table 3 Specific surface and porosity measurements

Nanomaterial	S_{BET}/m^2 g^{-1}	Pore volume/cm^3 g^{-1}	Pore size/Å	S_{geo}/m^2 g^{-1}
TiO_2	296.34 ± 2.30	0.22	29.77	0.12
TiO_2–Al_2O_3	361.79 ± 0.91	0.21	23.74	0.05

Both nanomaterials have a high specific surface area, which increases the layer of interaction between chemical agent, fog, and solid particles, making it faster.

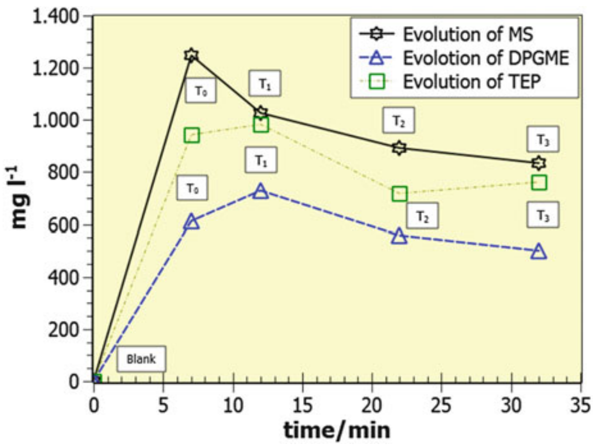


Fig. 7 Evolution of the concentration of MS, DPGME, and TEP without neither fog nor NPS delivery

3.2 Comparative Analysis

Since the methodology applied contemplates the use of nanomaterials, chemical surrogates, and fog, an important aspect to consider is the interaction of dispersed nanomaterials with the surrogates and fog and its ability to deposit them.

At this point it is highlighted a significant difference between the effectiveness of cleaning the test room atmosphere through the COUNTERFOG system method versus evolution of the chemical warfare agent surrogate in the case where no cleaning means is being used.

In Fig. 7, it is shown the evolution of MS, DPGME, and TEP altogether without the participation of a countermeasure mean (fog and nanoparticles) resulting in a low decrease of the compound concentration during the experiment. Blank samples were taken at the beginning of the trials, and the data results obtained from GC-FID analysis are displayed as a starting point of reference.

In Figs. 8, 9, and 10, it is depicted the evolution for each CWA surrogate concentration in laboratory atmosphere in the course of a trial with fog and NM release. The synergic effect of dispersed nanomaterials and fog improves the cleaning of the test room atmosphere. The trials were developed in four consecutive phases taking samples in every stage at a previously predetermined time. Resulting data show how the dispersed contaminants were behaving and evolving in every fixed step:

- T_0: contaminant delivery.
- T_1: NMs delivery.
- T_2: concentration after shot of the COUNTERFOG nozzle.
- T_3: a decrease in concentration is observed in checking times. TiO_2 exhibited slightly higher removal efficiency since its nanoparticles show a larger geometric surface and pore volume favoring interaction between NPs and CWA surrogates and increasing the cleaning efficiency [7, 8].

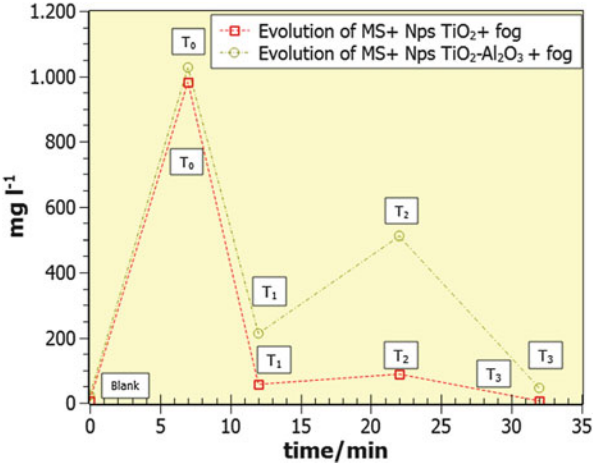


Fig. 8 Evolution of the MS concentration along four steps (T_0, T_1, T_2, and T_3) with NPs and fog

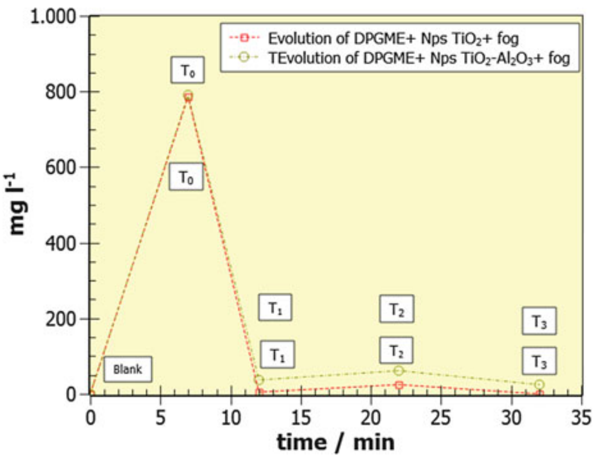


Fig. 9 Evolution of the DPGME concentration along four steps (T_0, T_1, T_2, and T_3) with NPs and fog

From the data obtained in the tests, it could be concluded that after 5 min from the surrogate dispersion and the performance of NPs, the concentration of the surrogates is reduced by 95% for MS (Fig. 11) and DPGME (Fig. 12) and by 67% for TEP (Fig. 13). The fog helps to deposit the dispersed particles and keeps decreasing the chemical agent concentration in the laboratory room until it reaches concentrations next to 0 after 30 min. Under normal conditions and after 30 min, the contaminant still persists in the atmosphere in concentrations around 600–1000 mg l^{-1}.

Fig. 10 Evolution of the TEP concentration along four steps (T_0, T_1, T_2, and T_3) with NPs and fog

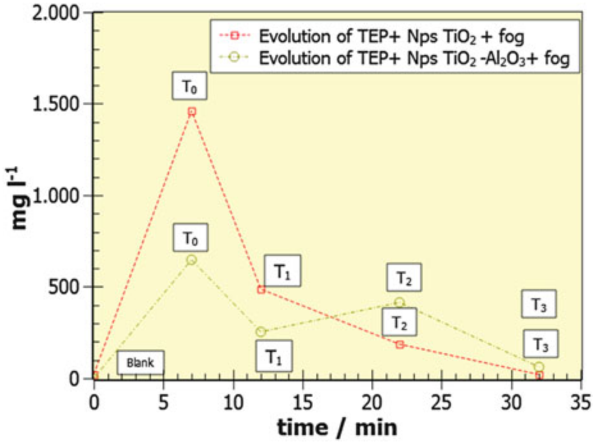


Fig. 11 Percentage evolution of the cleaning of SM

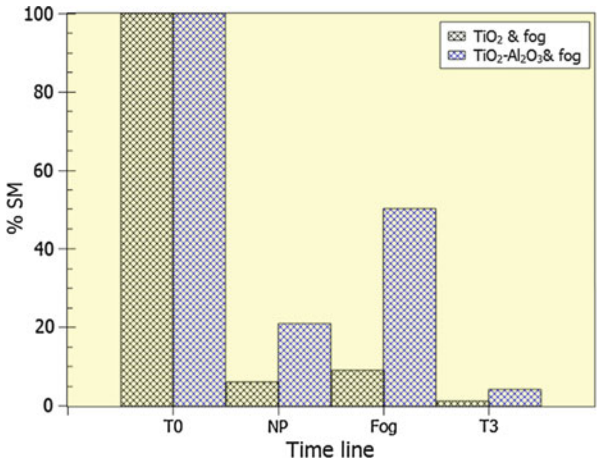
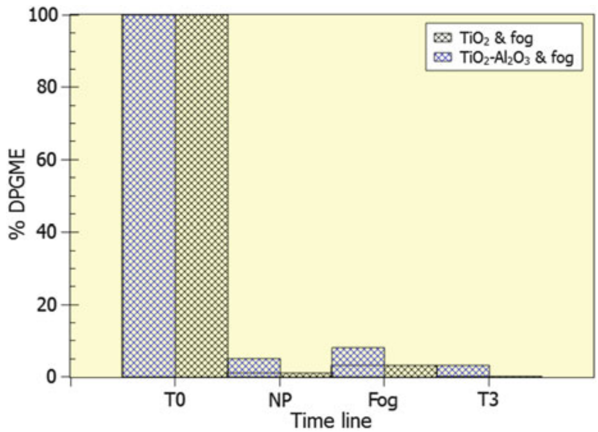


Fig. 12 Percentage evolution of the cleaning of DPGME



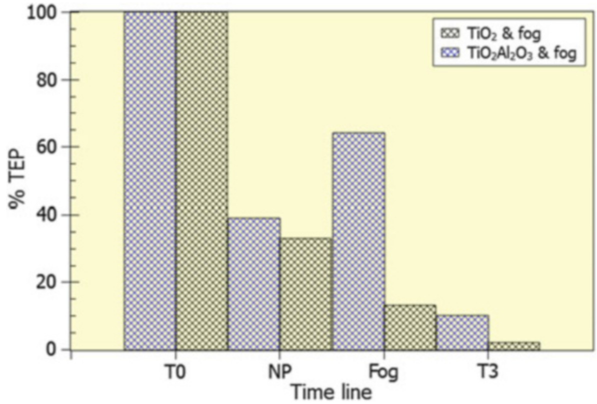


Fig. 13 Percentage evolution of the cleaning of TEP

4 Conclusions

Operational procedures to test and evaluate the effectiveness with CWA surrogates have been accomplished.

In summary, by the use of metal oxide nanoparticles and the COUNTERFOG system, it has been achieved the cleaning of contaminated atmospheres with chemical agent surrogates.

Based on the results obtained, TiO_2 nanoparticles exhibited slightly higher cleaning efficiency.

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The Potentiality of Improvised Explosive Devices to Trigger Domino Effects

Ernesto Salzano and Valerio Cozzani

1 Introduction

Industrial facilities where relevant quantities of hazardous chemicals are stored or processed may be possible targets for malicious acts of interference due to terrorist attacks. To this regard, an important aspect is that external attacks may damage one or more process units or even neighbouring industrial sites aiming at triggering domino effects, hence producing large-scale accidents as fire, explosion or toxic dispersion, starting from minor, primary scenarios.

To this aim, primary (as detonator or igniter) and secondary explosives are wished by terrorists, as trinitrotoluene (TNT), pentolite, RDX and similar. Nevertheless, these substances, or their mixtures, are very difficult to obtain without permission or military organizations. Hence, either tertiary explosives as mine blasting substances, or home-made explosives, or even modified pyrotechnic and propellants, in one word improvised explosive device (IED), are typically adopted [1].

The most common IEDs are ammonium nitrate-fuel oil (AN/FO) produced from fertilizers; black powder-based "pipe" bombs, which in turn may be considered as a tertiary explosive when produced from pure components; or home-made triacetone triperoxide or peroxy-acetone, which is often used for suicide bombing.

Despite the apparent, similar effects (shock waves, fragment, heat radiation), explosives and IEDs are completely different from the phenomenological point of view. The overall reaction of standard explosives may be sketched in two sequential steps. The first step is a primary reaction between the oxygen-donor (oxidizer) and the fuel. Hence, in a second step, the secondary reactions (after-burning) of the

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unreacted fuel or partially oxidized products with surrounding air occur. The overall energy release is the sum of the proper (primary) explosion energy and that related to the combustion with air of reaction products, which can be twice the explosion energy, thus resulting in more severe hazards than expected. If a highly energetic substance as TNT is considered, the primary step may proceed as a detonation: the reaction completes within microseconds and is not dependent upon external chemical environment. On the other hand, the deflagrative burning of the early time products of detonation in air, although in the well-distributed regime rather than typical convectional/diffusive mechanism typically observed in flammable gaseous/air mixture, may last milliseconds. Due to this relatively long characteristic time, the secondary reaction is unable to produce any increase of the shock wave overpressure produced by the detonation even if it may affect the total impulse. The effects of afterburning increase with oxygen deficiency, and indeed heavily oxygen-deficient substance as TNT (73.9%) may continue to drive the blast wave away from the charge for longer period than other high explosives with good oxygen balance, thus resulting in higher impulse [2].

If a substance or mixture with relatively low reactivity is considered, as in the case of tertiary explosives (AN/FO) or IEDs, the primary explosion proceeds as a deflagration, and the produced shock wave is significantly less intense than TNT. However, the effects of secondary reactions may be dramatic with respect to the overall explosive phenomenon for closed or partially closed environment. Eventually, explosives as TNT reach a high pressure very quickly resulting in a directional shock wave, which is characterized by relatively small impulse, which is imparted to contingent walls in the case of confinement. On the other hand, IEDs, home-made tertiary explosives, propellants or pyrotechnic substances are characterized by larger impulse and lower rates of pressure rise. Consequently, the criteria normally required for the evaluation of hazard of high-energy solid explosives as TNT are not directly applicable for the evaluation of the hazards of low-energy compositions.

The present study investigates the possibility that a shock wave and fragments generated by improvised explosive device (IED) may damage process equipment and/or trigger the escalation sequence, thus resulting in a domino scenario. Furthermore, it is intended to give some insight for the consequence and vulnerability assessments of industrial plants (hence equipment) when subjected to shock waves produced by IED. To this aim, the calculation of the pressure history (maximum pressure, positive duration, impulse) with respect to the distance from the explosion point is needed. In order to obtain this information, the amount of explosive and its efficiency with respect to an equivalent amount of TNT (WTNT) are required. Hence, the Hopkinson-Cranz function is adopted to calculate the mass-scaled distance (Z):

$$W_{\mathrm{TNT}} \cdot \Delta H_{\mathrm{TNT}} = k \cdot W_{\exp} \cdot \Delta H_{\exp} \tag{1}$$

where $W_{\exp}$ is the net mass of the explosive; ΔH_{TNT} is the TNT explosion energy, which is typically 4.6 MJ/kg; $\Delta H_{\exp}$ is the explosion energy of the material of interest, related to the primary explosion only (decomposition or detonation energy) and not to the overall combustion energy; and κ is a coefficient which depends on the confinement or, more specifically, on the mechanical energy adsorbed for the deformation and failure of the containment system [3]. For explosives contained in low-strength enclosure, a factor $\kappa = 0.7$ could be adopted; however, we used unitary values in order to obtain safe-side evaluations. At this stage, if unconfined explosions are considered, the ratio of the explosion energy and TNT energy may be defined as an efficiency factor η if the first is considered as the primary (decomposition or detonation) energy:

$$\eta = \left(\frac{\Delta H_{\mathrm{exp}}}{\Delta H_{\mathrm{TNT}}}\right)_{\mathrm{primary}} \tag{2}$$

This value is of crucial importance for domino effect analysis and will be analysed in the following.

2 Improvised Explosive Device

Several substances and mixtures can be used for the realization of home-made or improvised explosive device, starting from chemicals sold in markets and pharmacies [1]. Two explosives, among others, are often adopted for terrorist attacks, suicide bombing and other malicious uses: ammonium nitrate (AN)-fuel oil (AN/FO) and TATP. Other IED may be based on black powder or many other pyrotechnic substances, which may be easily collected and used in cased systems, as in pipe bombs. A description of these materials and their deviation from standard explosives when produced by nonskilled person from non-pure substance is given for the sake of discussion.

2.1 AN/FO (Ammonium Nitrate-Fuel Oil)

The AN/FO is typically composed of 94% of AN prills and 6% of adsorbed fuel oil. It is extensively used for several, authorized purposes, mainly mine blasting. This mixture has a TNT equivalence of about 80%, with an ideal explosion (detonation) energy of 3890 kJ/kg [4]. When the IED is produced, fertilizer AN prills may be adopted. However, these prills are different from those used in the mining applications. Indeed, the commercial ammonium nitrate prills used for mine blasting have a 20% void fractions. The main difference of the home-made AN/FO produced by using AN prills for fertilizers is then reflected in the bulk density, which is approximately 840 kg/m^3, hence much lower than AN/FO produced for mining applications, which has a density of about 1300 kg/m^3. Overall, a lower explosive efficiency in the case of IED may be certainly predicted. If commercial AN (containing about 50% of inert, as dolomite) and diesel fuel are used, a detonation energy of about

1071 kJ/kg is obtained, much less than pure AN/FO. And it is worth noting that when amounts of dolomite higher than 30% are present, no detonation is observed.

Nevertheless, the potentiality of explosion is still actual. Hence, the new European regulations for fertilizers state that they must contain less than 45% of AN (16% N) for being traded to the public.

2.2 TATP (Triacetone Triperoxide)

TATP is a primary explosive, which is notable because it does not contain nitrogen. Thus, it is used to avoid conventional chemical bomb detection systems, and it is almost undetectable by either analytical system or by sniffer dogs. It can be obtained from common household items such as sulphuric acid, hydrogen peroxide and acetone. TATP is very unstable: it can be ignited by touch and can explode spontaneously. It is actually composed by isomers and conformers, the dimer being more stable but having lower decomposition energy. The density of the pure molecule is typically considered to be 1220 kg/m^3. However, home-made TAPT formulations are in the range of 450–500 kg/m^3. Finally, TATP is often stabilized with carbonaceous liquids and waxes so that the net charge is even lower [5].

Home-made TATP can be a primary explosive and very sensitive to impact or friction, although the strength of explosion may strongly vary since the quality of the final product is very sensitive to the temperature during its synthesis. Furthermore, it is highly volatile and deteriorates rapidly forming, thus lowering its explosive effect, as it is occurred in the London tube attack of 15/09/2017. Acetone and ozone are predicted to be the main decomposition products, along with oxygen, methyl acetate, ethane and carbon dioxide.

2.3 Black Powder and Other Pyrotechnic Substances

If a pyrotechnic substance or mixture with relatively low reactivity is considered, the primary explosion proceeds as a deflagration, and the produced shock waves are significantly less intense than typical TNT explosion.

Napadensky and Swatosh [6] have produced several experimental tests for black powder. The efficiency factor reached maximum values of 24% and 40%, respectively, for pressure and impulse, hence half of that expected by energy comparison (about 0.6), which is however usually adopted, conservatively, by authorities. In the case of unconfined storage, most of hazards are related to the distance reached by the fireball, which however is not analysed in this paper because we are here interested in domino effects. Further details on black powder can be found elsewhere [7].

3 Methodology

Provided the corrected efficiency factor for home-made explosive, the peak overpressure may be estimated by adapting the following literature correlation [8]:

$$P_S = \frac{W_{TNT}^{\frac{1}{3}}}{r} + 4.4\frac{W_{TNT}^{\frac{2}{3}}}{r^2} + 14.0\frac{W_{TNT}}{r^3} \quad (3)$$

where P_s (bar) is the peak overpressure, r (m) is the distance from the centre of the explosion and W_{TNT} is the equivalent mass of TNT expressed in kg.

When domino effects and direct attack on equipment shell are of concern, the escalation of scenarios may be then evaluated by considering the threshold values for escalation [9], namely, the radii of overpressure with 22 kPa (atmospheric equipment), 16 kPa (pressurized equipment) and 32 kPa (for elongated equipment). Both choices are conservative and can be considered a first reference data for the risk assessment.

4 Results

Several previous publications provide data, references and correlations for the shock wave produced by AN/FO, TATP, BP and other pyrotechnical devices. What is relevant for the present study is that (a) the explosion energy gives a good reproduction of the destructive power of the substances at constant, atmospheric pressure; (b) light confinement may double the severity of the explosion; (c) high-strength confinement as the steel case adopted for bombs and military explosive devices has been only considered for pipe bomb (2 kg of explosive); and (d) the energy output from nonideal explosives is dependent on charge size.

4.1 Shock Waves

Table 1 reports the TNT efficiency (η) obtained from specific studies and calculated as the ratio between the explosion energy of the mixture of interest and the explosion energy of TNT (namely, detonation energy ratio) for different types of explosives.

In the case of nonideal mixtures, the property values have been calculated by using the chemical equilibrium model, CEA [10]. Quite clearly, discrepancies can be found with respect to the reaction heats given in the open literature. However, the figures obtained by the CEA model are at least indicative of the explosion energies involved. Details of calculation can be found in Salzano and Basco [7, 12] and Landucci et al. [5].

Table 1 Experimental heat of explosion (ΔH_{exp}) [4] and TNT efficiency (η) for the analysed explosives

Explosive	ΔH_{exp}, kJ/g	η(-)
Ammonium nitrate/dolomite(50/50)+diesel[a]	1.1	0.24
Ammonium nitrate/dolomite(90/10)+diesel[a]	3.2	0.68
AN/FO (ammonium nitrate/fuel oil)[a]	3.9	0.83
Black powder (KNO_3, C, S)[b]	2.8	0.60
Flare (Mg, $NaNO_3$)[b]	8.4	1.79
Flash powder ($KClO_4$, Al, $Ba(NO_3)_2$)[b]	7.3	1.56
RDX	5.4	1.15
TATP (triacetone triperoxide, trimer)	2.8	0.60
TNT	4.7	1.00

[a]Ratio between the explosion energy of the mixture of interest and the explosion energy of TNT (namely, detonation energy ratio)
[b]Mixture of isomers

Table 2 Stand-off distances for domino effects (threshold value = 16 kPa) with respect to three different amounts of explosives

Explosive mass	1 kg	50 kg	500 kg
Ammonium nitrate/dolomite (50/50)+diesel	6.3	24.0	50.0
Ammonium nitrate/dolomite (90/10)+diesel	7.0	26.0	55.0
AN/FO (ammonium nitrate/fuel oil)	7.5	27.0	58.0
Black powder (KNO_3, C, S)	6.3	24.0	50.0
Flare (Mg,$NaNO_3$)	7.5	27.0	58.0
Flash powder ($KClO_4$, Al, $Ba(NO_3)_2$)	9.0	33.0	70.0
RDX	8.7	32.0	68.0
TATP (triacetone triperoxide, trimer)	6.5	24.0	51.0
TNT	7.8	29.0	61.0

It is worth noticing that the efficiency of pure AN/FO is consistently larger than that of possible home-made explosives based on fertilizers, in which some inert material as dolomite is used and diesel fuel and non-porous AN as explosive component are employed. Reduction to very low values of TNT efficiencies can clearly be observed for both 90% and 50% non-porous AN in mass with dolomite as inert material mixed with fuel oil (respectively, "AN/dolomite (90/10) + diesel fuel" and "AN/dolomite (50/50) + diesel fuel").

Table 2 gives the stand-off distances for domino effects (reference threshold value = 16 kPa), calculated for three different amounts of explosives (efficiency as in Table 1), namely, 1 kg, 50 kg and 500 kg, which are considered the maximum value transportable by a single individual or by car, in the proximity of industrial equipment.

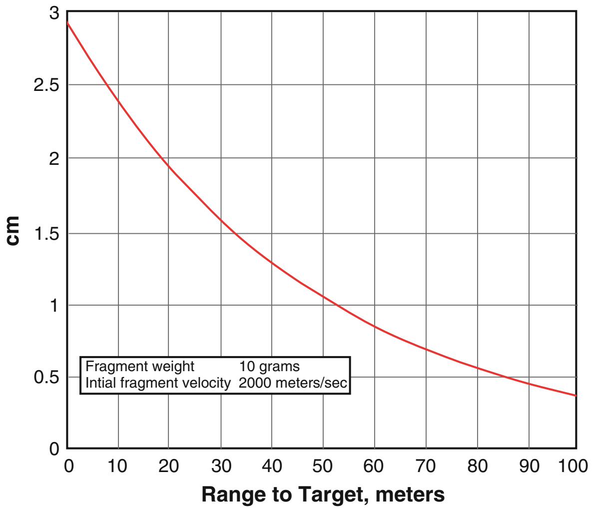

Fig. 1 Fragment penetration (in cm) into mild steel of modelled pipe bomb filled with AN/FO, $w = 2$ kg

4.2 *Fragment*

In Fig. 1, a typical penetration plot of explosion fragment in mild steel, where the pipe bomb is composed of 2 kg of pure AN/FO as calculated by the US Army Corps of Engineers code, ConWep [11], is given. Similar results can be obtained for any of the IEDs analysed in this work.

From the figure, it is clear that the considered representative fragment and a wall thickness of 1 cm can produce domino effect only at 50 m, which is much more effective than damage produced by shock waves if considering the potentiality of damage with respect to the total mass of the explosive [12].

5 Conclusions

Improvised explosion devices are nonideal substances with low explosion energies with variable density, composition, humidity and other chemical and physical parameters, which may strongly affect their efficiency. Their potentiality with respect to the attack against individuals has been proven. However, when considering the same devices for the aims of escalation of effects (domino effects) through the structural failure of pipelines, tanks or other industrial equipment containing hazardous materials, the probability of occurrence of accidental scenarios is very low or however limited. The fragment projected from IED may be however potentially damaging any equipment shell. These aspects will be further evaluated in future works.

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Eco-friendly Air Decontamination of Biological Warfare Agents Using "Counterfog" System

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1 Introduction

Human exposure to bioaerosols can occur by inhalation, dermal contact, and ingestion, but inhalation is the most common route that results in adverse health effects [1]. Thus, aerosol exposure has become one of the major concerns for the residential, healthcare, and government sectors [2]. To counter the threat of terrorist attacks or accidental release, an effective decontamination defense is required to minimize the consequences of biological attacks. Raber et al. [3] developed a decision-making framework that guides sequential actions after a terrorist attack. The framework identifies four phases: notification, first-responder, characterization, and restoration (decontamination). During the initial notification phase, an operation center identifies an event based on sensors. The first-responder phase is likely to include hazardous material (HAZMAT) actions or other emergency actions aimed at stabilizing and isolating the incident. The characterization phase focuses on determining key site parameters, including time since release, extent of contamination, and assessment of potential risks to human health and environment. The final restoration phase involves selection of site-specific decontaminating reagents, if required, and sampling to verify that all long-term environmental issues have been addressed.

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Despite advances in these areas, many problems still limit the ability to prevent, prepare for, detect, and respond to biological terrorism.

Since terrorists are unlikely to announce what type of agent has been deployed, the ideal approach is the development of broad-spectrum decontaminants that are simple to use, are active against both chemical and biological agents, and do not destroy the environment into which they are deployed. The traditional decontamination methods for biological agents are chemical liquids and vapors; the traditional room fumigation has been conducted by using formaldehyde or ethylene oxide gas. These methods have been given up due to their toxicity and carcinogenicity [4]. The same is true also for quaternary ammonium compounds, even though these materials have been investigated less [5]. Apart of their toxicology, these hazardous chemicals need to meet special guidelines for storage, transport, and disposal during and after usage. Moreover, "green" decontaminants are preferred because these chemicals are released into the environment. Moreover, the decontamination methods are focus in the surfaces instead in the air, which is the way of infection [6–9]. The "Counterfog" system is a decontamination technology that can clean the air of spores, preventing the inhalation of them, only releasing a fog made of water and air.

2 Materials and Methods

2.1 Test Organism

Spores of *B. thurigiensis* CECT 4454 which is a surrogate of *B. anthracis* were obtained as follows. A culture of *B. thurigiensis* was grown for a week at 32 °C in nutrient broth (Scharlau) supplement with 1% of $MnSO_4{\cdot}H_2O$ on an orbital shaker set at c. 150–200 rev min^{-1}. Culture was centrifuged at approx. 9000–10,000× *g* for 30 min at 2–8 °C. The resultant pellet was washed twice and resuspended in PBS 1×. The suspension was set 0.3 U of McFarland scale and serially diluted 10-2 in a volume of 20 ml, and then these suspensions were heat-shocked by incubating at 80 °C for 45–60 min to kill vegetative cells.

2.2 Fog Dynamics Laboratory

The tests were carried out at the Fog Dynamics Laboratory, located within the enclosure of the Center for Energy, Environmental and Technological Research (CIEMAT) in the city of Madrid. This installation consists of an isolated room of dimensions 2.46 m × 3.10 m × 2.13 m equipped with a ventilation system that allows both the introduction and extraction of air. In addition, the room has equipment that allows the temperature and humidity control (Fig. 1). These test rooms are separated from each other by a door which can be kept open and closed according to the type of test to be performed.

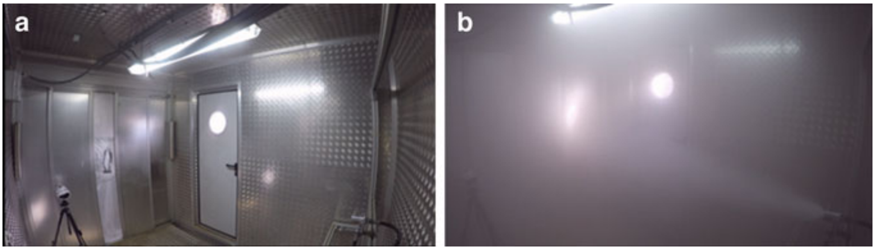

Fig. 1 Test room of the Fog Dynamics Laboratory. (**a**) Test room before the fog was released. (**b**) Test room when the nozzle is shooting the fog

For the heating and cooling of the room, there is a hot/cold water circuit installed inside the floor, walls, and roof that provides the homogeneity and smooth variation of the thermal conditions required in the tests. Moreover, sensors are placed to measure the pressures of shooting of water and air during the generation of the fog, as well as the flows and the temperature of the shooting water.

2.3 Air Contamination Procedure and Sampling

The suspension of spores was dispersed in the air of laboratory. At different times since the dispersion of spores (1, 3, 7, 10, 15, 20, 30, 40, 50, and 60 min), a sample of 50 l of air was taken by a particle impactor (Merck, MAS-100 NTTM). The plates obtained were incubated at 30 °C for 24 h, and CFU/50 ml was then counted by "Automatic Colony Counter Scan® 1200" (Interscience Ref.: 437000). This procedure was performed by triplicate.

2.4 Air Decontamination Procedure and Sampling

The spores' suspension was released in the air of the room, and after 2 min of the releasing, the Counterfog system was activated during 15 s, 30 s, and 1 min in different assays. The Counterfog system consists in a nozzle which expels water and air in order to create a cleaning fog. At different times since the dispersion of spores (1, 3, 7, 10, 15, and 20 min), a sample of 50 l of air was taken by a particle impactor (Merck, MAS-100 NTTM). The plates obtained were incubated at 30 °C for 24 h, and CFU/50 ml was then counted by "Automatic Colony Counter Scan® 1200" (Interscience Ref.: 437000). This procedure was performed by triplicate.

2.5 Efficacy Calculations

To calculate the efficacy of the air contamination and decontamination, the number of viable spores counted in each time was compared with the number of viable spores extracted immediately after the releasing of the spores. In order to know the natural reduction of the spores in the air, the log reduction was calculated using the following equation:

$$\text{Log Reduction} = \log\left(N/N'\right) \tag{1}$$

where N is the mean number of viable organisms recovered from the samples at different times or samples subjected to Counterfog system and N' is the number of viable organisms recovered immediately after the dispersion of the spores or before decontamination. For plates where viable organisms were not detected, the efficacy was calculated as the log of the mean number of viable organisms recovered from the plates took before the decontamination. Using the calculated log reduction for each test, the mean (±SD) log reduction was calculated.

Also, the reduction percentage was calculated for each of the samples by comparing the number of colonies in the first sample with the number of colonies in the rest of the samples.

3 Results

3.1 Air Contamination

The released spores' suspension remained in the air for 60 min at least. The percentage reduction over the time is shown in Table 1. After 2 min of the releasing of the spores, the totality is in the air. Moreover, after 6 and 9 min, only 20.60 and

Table 1 Contamination efficacy of *Bacillus thurigiensis* spores in the air. Values are expressed as mean ± SD from triplicates of three different experiments

Time of sampling after the release of the spores (min)	Total of spores recovered without fog (CFU/m^3)	Log reduction	% Reduction
1	3.56E+03 ± 1.47E+03	NA	NA
3	3.81E+03 ± 1.65E+03	−0.030	−7.12
6	2.83E+03 ± 1.35E+03	0.100	20.60
9	2.23E+03 ± 9.09E+02	0.202	37.27
14	1.63E+03 ± 8.93E+02	0.338	54.12
19	1.33E+03 ± 5.46E+02	0.426	62.55
29	9.73E+02 ± 6.29E+02	0.563	72.66
39	6.00E+02 ± 2.99E+02	0.773	83.15
49	4.93E+02 ± 3.03E+02	0.858	86.14
59	3.87E+02 ± 2.08E+02	0.964	89.14

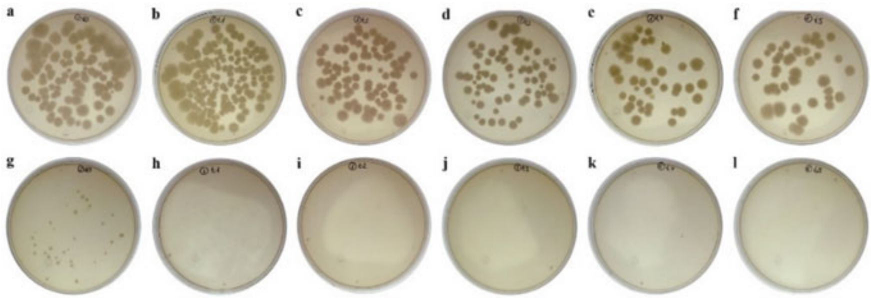

Fig. 2 Impact of air sampler plates obtained from the air of the room where the spores have been disseminated. (**a**) Sample 0: taken 1 min after the releasing of spores. (**b**) Sample t1: taken 3 min after the releasing of spores. (**c**) Sample t2: taken 7 min after the releasing of spores. (**d**) Sample t3: taken 10 min after the releasing of spores. (**e**) Sample t4: taken 15 min after the releasing of spores. (**f**) Sample t5: taken 18 min after the releasing of the fog. (**g**) Sample 0: taken 1 min after the releasing of spores. (**h**) Sample t1: taken 1 min after the releasing of the fog. (**i**) Sample t2: taken 4 min after the releasing of the fog. (**j**) Sample t3: taken 8 min after the releasing of the fog. (**k**) Sample t4: taken 13 min after the releasing of the fog. (**l**) Sample t5: taken 18 min after the releasing of the fog

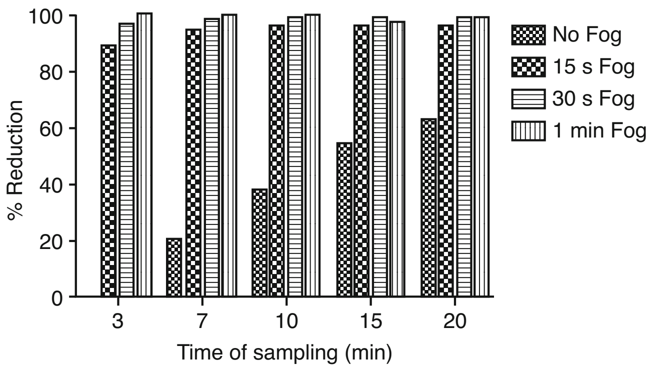

Fig. 3 Percentage reduction graph

37.27% of the spores have fallen down, whereas after 14 min, the half of the spores are in the air (Fig. 2).

3.2 Air Decontamination

A total of nine decontamination runs were conducted of which the Counterfog system was active for 1 min and 30 and 15 s. In all tests, the relative humidity reached levels of 90–100% during the decontamination phase with Counterfog system. Exposure of spores to this new system resulted in a reduction of spores in the air that varied according to the time of the releasing fog (Fig. 3, Table 2). The

Table 2 Decontamination efficacy of *Bacillus thurigiensis* spores in the air. Values are expressed as mean ± SD from triplicates of three different experiments

Time of sampling after the release of spores (min)	Total of spores recovered with 1 min of fog (CFU/m^3)	Log reduction with 1 min of fog	% reduction with 1 min of fog	Total of spores recovered with 30 s of fog (CFU/m^3)	Log reduction with 30 s of fog	% reduction with 30 s fog	Total of spores recovered with 15 s (CFU/m^3)	Log reduction with 15% of fog	Reduction with 15 s of fog
1	5.73E+02 ± 1.22E+02	NA	NA	8.67E+03 ± 6.13E+03	NA	NA	3.10E+03 ± 2.19E+03	NA	NA
3	0.00E+00 ± 0.00E+00	2.758	100.00	3.07E+02 ± 2.17E+02	1.451	96.46	3.50E+02 ± 2.47E+02	0.947	88.71
6	0.00E+00 ± 0.00E+00	2.758	100.00	1.33E+02 ± 9.40E+01	1.814	98.47	1.70E+02 ± 1.20E+02	1.261	94.52
9	0.00E+00 ± 0.00E+00	2.758	100.00	9.33E+01 ± 6.60E+01	1.968	98.92	1.20E+02 ± 8.49E+01	1.412	96.13
14	1.33E+01 ± 1.15E+01	1.633	97.67	8.00E+01 ± 5.66E+01	2.035	99.08	1.10E+02 ± 7.78E+01	1.450	96.45
19	6.67E+00 ± 1.15E+01	1.934	98.84	6.67E+01 ± 4.72E+01	2.114	99.23	1.10E+02 ± 7.78E+01	1.450	96.45

percentage reduction is directly proportional to the releasing duration of the fog: 96.88 %, 100 %, and 98.84 % for 15 s, 30 s, and 1 min, respectively, after 19 min of the releasing of spores and after 16 min of the fog releasing. Meanwhile, the percentage reduction of viable spores in the air without the decontamination fog is 54.12 %. Moreover, after 1 min of the Counterfog activation, the percentage reduction is 93.75, 96.36, and 100 % for 15 s, 30 s, and 1 min, respectively.

4 Discussion

During the last years, great advances of the technologies for decontamination surfaces have been done. Whereas, there are a few systems which are focused on air decontamination. The last ones usually work with disinfectants like peroxide hydrogen which effectiveness has been proved; however, its use is limited to specific and certain situation and could not be applicated in the presence of persons. Hence, the use of harmless products which can be used in a wide range of scenarios in the presence of persons is needed. The advantage of Counterfog is that the decontamination is done only with water to wash out the microorganisms' resistance form of the air as it is demonstrated with our results. Thus, this technology can be used in the presence of human beings because water inhalation is not toxic.

Moreover, it is a rapid system because the time of actuation is just 1 min, and 2 min after the release of the fog, the reduction is 100 %. In the case of the other technologies of surface decontamination, the time of actuation is 1 h, and the room must be closed at minimum of 3 h before the entrance of persons [10]. There are devices like "ASP GLOSAIRTM" (Advance Sterilization Products Norderstedt, Germany) able to decontaminate the air of a room. ASP GLOSAIRTM sprays H_2O_2 [11]; thus, it can be used in the presence of persons, while our system as is only a water-fog can be used in presence of persons. Counterfog is also able to wash out chemicals and radiological agents which make it the perfect technology to be used as first responder in a terrorist attack.

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A Micro-propulsion System to Widen CubeSat's Applications to Security

Angelo Minotti

1 Introduction

Adoption of nanosatellite (nanosats) monitoring for security reason is an idea that is starting to spread among scientists [1].

In fact, new nanosat infrastructures are of interest for their low cost and because these infrastructures are easy to manufacturing and can be potentially deployed as swarms in order to act as a single orbiting constellation.

In particular, in 1999 [2], California Polytechnic State University and Stanford University developed a concept of satellite designed to utilize a standardized platform. Those satellites, known as CubeSat (belonging to the nanosatellite family), are cubic modular satellites of "10 cm sides—1 kg weight"—for each module/unit. Defined for academic purposes and necessities (low-budget projects), a fundamental boost has been impressed by the MEMS fabrication technology (MicroElectricalMechanical Systems), which has permitted component miniaturization [3].

Moreover, CubeSats become of interest in the government and industry communities, since the benefits of swarm satellite technologies have become more apparent [4].

A swarm of CubeSats would mean a group of dozens, up to hundreds, of satellites able to act as a single orbiting constellation, providing greater coverage and faster update rates than can be achieved using conventional single satellite operations.

Nowadays, that accomplishment is hampered by the absence of a CubeSat independent propulsion system.

In fact, most of the CubeSats operate in orbits determined by the deployment of the main payload of the launch vehicle [5], and none have incorporated propulsion

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capable of substantial ΔV (delta velocity) to extend their operability to orbit control, formation flying, proximity operations, fine attitude control or lifetime extension and de-orbiting. To realize these manoeuvres, a propulsion system beyond the current state of the art is required. Such a propulsion system must be consistent with the CubeSats cost and mass-volume limitations. Attitude control is generally addressed adopting magnetic control, and only few operational small satellites are equipped with an orbital control system [6] (the most popular is a cold gas propulsion system that is limited by low specific impulse, low impulse density propellants, low ΔV and thrust). Only one small satellite, currently in orbit as of 2010, has a chemical propulsion system [6]. Simultaneously, a high-pressure bipropellant micro-rocket engine is already being developed [7]. High-pressure turbo pumps and valves are incorporated onto the rocket chip, but this combustor plans to operate at 12.7 [MPa].

Unfortunately, high operating pressures are not practical for nanosatellite systems.

Past [8] and actual [9] investigations try to solve those issues and/or to suggest solutions, but all of them present drawbacks or are not still ready to be mounted on satellites.

The present paper reports a possible solution that consists in an innovative micro-propulsion system, patent pending [10], which adopts H_2/O_2 as fuel/oxidizer, obtained by water electrolysis and introduced into a micro-swirling combustion chamber, which characteristic dimensions are of the order of millimetres. The relative hot gases are expanded in a sub-supersonic micro-nozzle to optimize the thrust.

This miniaturized system would overcome the current nanosat limits, accomplishing orbit manoeuvres and lifetime extension, maintaining high combustion efficiency. Benefits in the security fields as intelligence, disaster monitoring, CBRNe observation and identification are evident.

The paper is structured as follows: Sect. 2 reports the propulsion system's main technologies, and Sect. 3 reports the thrust chamber and a system analysis, while Sect. 4 reports the conclusions.

2 The Micro-propulsion System: Main Technologies

The present innovative nanosatellite propulsion system merges three main technologies: electrolysis [9], a micro-swirling combustion chamber and eventually catalysis [11]. In particular, liquid water is used as propellant and separated, by electrolysis, in H_2–O_2 flows that are introduced into a swirling combustion chamber (eventually with internal catalytic deposition) (Fig. 1).

This tech idea presents many benefits:

1. Water is unpressurized and safe during launch, poses no risk to the rocket or primary payload, can operate in very low power modes and leads to a relatively inexpensive system.

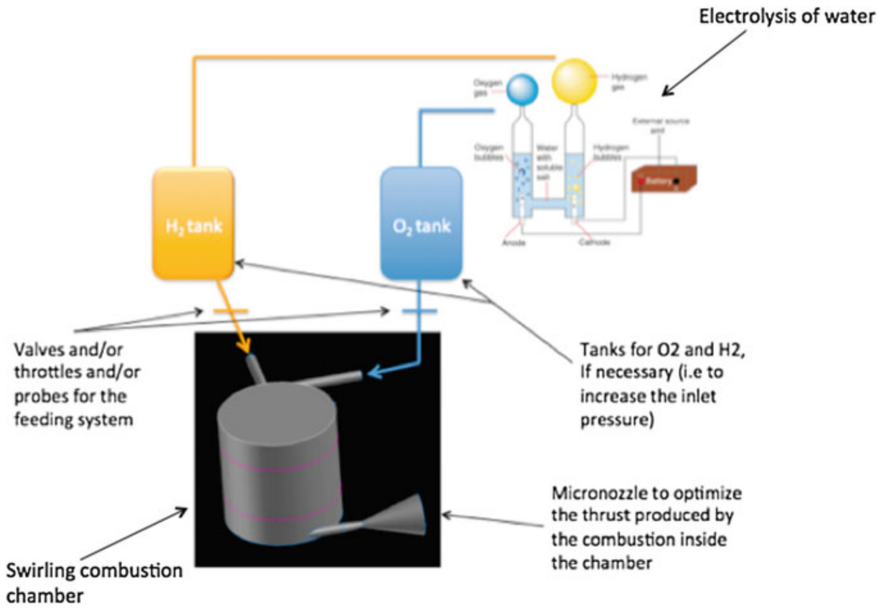

Fig. 1 Micro-propulsion system: overall structure

2. Electricity for the electrolysis is generated by the solar cells. Moreover, the propellant may serve as a battery, storing the electrical power with far greater mass efficiency, and none of the electrical losses associated with batteries.
3. Electrolysis provides gaseous hydrogen and oxygen at stoichiometric conditions; this means to obtain the highest flame temperature and almost exclusively steam, as products of combustion.
4. Swirling combustion chamber permits to overcome the intrinsic limitations of miniaturized chambers [12] (flame quenching, unstable combustion, low residence time and low combustion efficiency) and then to realize a combustion chamber of the order of millimetres with high combustion efficiency and, potentially, no spark ignition.

3 The Thrust Chamber

The core of the system is the micro-swirling combustion chamber (Fig. 2).

The swirling motion is imposed by the position of the inlet/outlet ducts; they oblige the internal flow to define a helical path and create recirculation before passing through the nozzle [13].

All that increases, significantly, the residence time and the mixing, permitting very high combustion efficiency in very small devices [14].

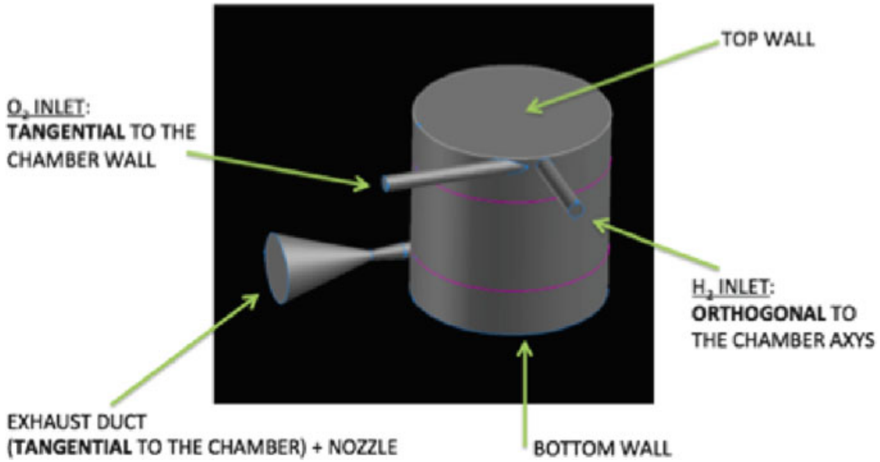

Fig. 2 Rendering of the thrust chamber

Hot products are then expanded in a sub-supersonic micro-nozzle to generate the required thrust (bipropellant thrusters, as opposed to monopropellant thrusters, offer higher specific impulse, Isp $>$ 300[s]). Combustion chambers, smaller than 10 [mm] of characteristic dimensions, may deliver thrust of the order up to 10[N] (the upper limit is defined by the inlet velocities, which can be tuned modifying the operating pressure and the inlet section area).

Numerical simulation, carried out by the author [15], demonstrates that a thrust chamber[1] providing about 3×10^{-2}[N] is characterized by a maximum internal temperature of about 3200[K], an exhaust velocity greater than 3300[m/s] and, therefore, a specific impulse approaching 350[s].

In the light of the above, the propulsion system, with a 500[g] of water propellant, would provide a $\Delta V > 400$[m/s].

The order of magnitude of the ΔV is suitable for orbit changing (Fig. 3), from a typical 700 km deployment.

In particular this would permit constellation forming (Fig. 4), moving to specific "hot-sensitive zones", even at low altitude (Figs. 5 and 6), and extending the relative satellites' lifetime, according to mission requirements.

[1]Simulation main data: (1) chamber 6x6[mm] (D $\times$ H), (2) ducts' diameter equal to 0.5[mm], (3) oxygen-hydrogen inlet mass flow rates equal to 8×10^{-6}[kg/s] and 1×10^{-6}[kg/s], (4) inlet pressure equal to 3[atm] and (5) micro-nozzle's throat and exit section radius equal to 0.15[mm] and 1[mm] (area expansion ratio equal to about 49).

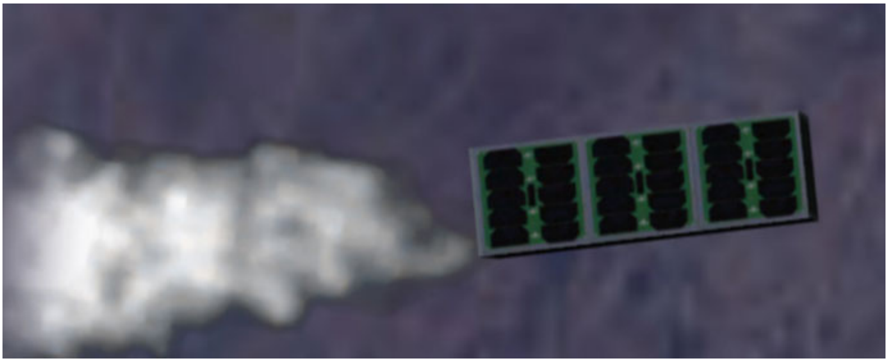

Fig. 3 Rendering of a 3U propelled CubeSat

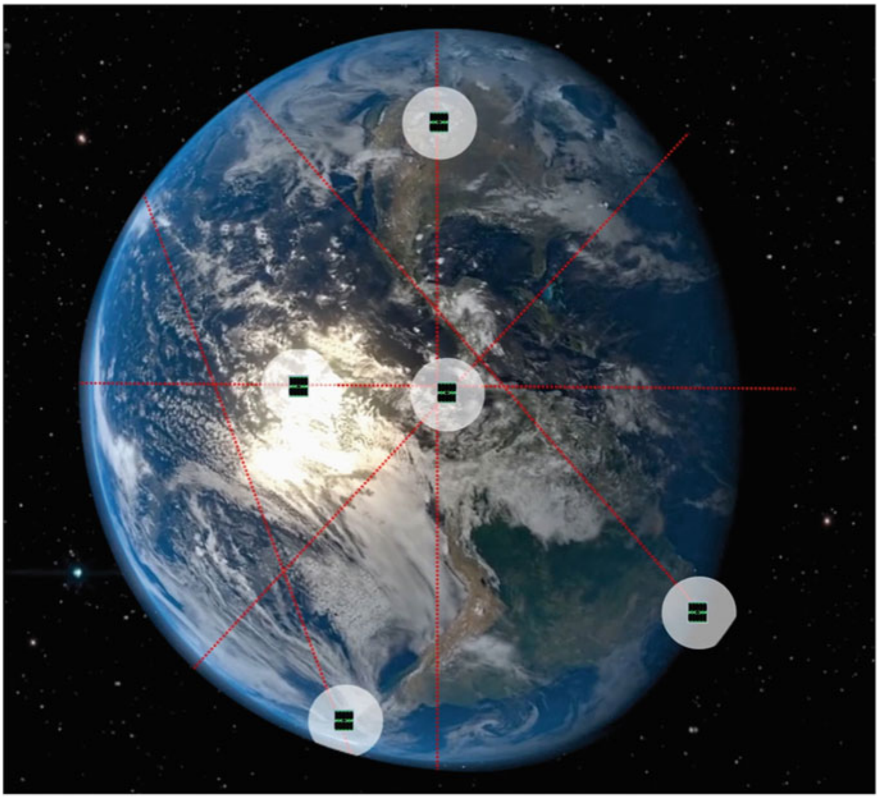

Fig. 4 CubeSat swarm constellation

Fig. 5 "Hot zone" observation

4 Conclusions

Adoption of nanosat monitoring for security reasons (intelligence, disaster monitoring, climate and CBRNe observation, etc.) is a technique that is starting to spread among scientists. New satellite infrastructures (nanosats) are of interest for their low cost, ease of manufacturing and their potentialities to be deployed as swarms in order to act as a single orbiting constellation.

That accomplishment, which would provide greater coverage and faster update rates, than can be achieved using conventional single satellite operations, is hampered, nowadays, by the absence of an independent propulsion system that must be simultaneously miniaturized, efficient and performing.

Many technological solutions are currently under investigations, but all of them present drawbacks or are not still ready to be mounted on satellites.

This manuscript presents an innovative miniaturized propulsion system, patent pending, that would overcome the limits of the current solutions, permitting, then,

Fig. 6 Climate observation

both orbit constellations and fast manoeuvres, if requested by security operations (intelligence, disaster monitoring, climate and CBRNe observation).

Even though the system is based on apparently simple technologies, it fulfils the following design requirements: miniaturized dimensions, high combustion efficiencies, scalability and high performance.

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Part III
Decision Support System, Modeling and Simulation

Image/Data Transmission Systems of the Italian Fire and Rescue Service in Emergency Contexts: An Overview of Methods and Technologies to Support Decision-Making

Luigi Palestini and Giorgio Binotti

Acronyms

IFRS	Italian Fire and Rescue Service
CDV	Local documentation and video centers
CSF	Fixed service center
CRF	Fixed transmission center
SRF	Fixed receiving station
CRT	Mobile radio center (truck for satellite transmission)
CON	National Operation Center
TAS	Topography Applied to Rescue
NIS	Special interventions task force
DICOMAC	Coordinating Office of the Civil Protection Department
GIS	Geographic information system
UAS	Unmanned aircraft system
UAV	Unmanned aerial vehicle

1 Emergency Communication

1.1 Emergency and Communication: A Model Analysis

A disaster can be defined as a critical situation that occurs as a result of an event, of a fact, or of a circumstance (such as fire, earthquake, the release of harmful substances, a blackout, a CBRN event) that results in a potentially dangerous situation for the

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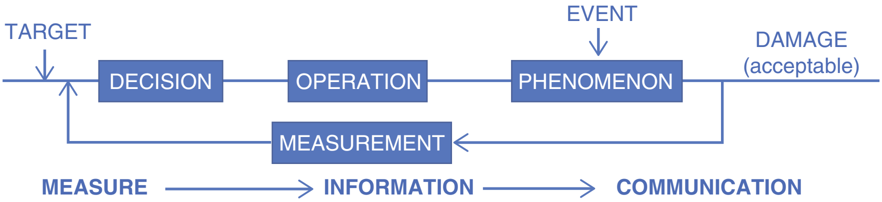

Fig. 1 The feedback approach

safety of persons and/or goods and facilities and requires exceptional and urgent interventions in order to be handled and brought back to normal.

A model of study for emergencies should understand the phenomenon/event, predict the evolution in order to provide the best possible response, and appropriately "measure" (through technologies and sensor systems), in order to implement the best solutions (feedback approach).

As shown in Fig. 1, feedback (measurement) is information about the gap between the actual level and the reference level of a system parameter, which is used to alter the gap in some way. Information on the gap when used to alter the gap (most probably to decrease the gap) becomes feedback [1]. In our case, the parameters could be, for example, severity of damages, position of rescuers and persons to be rescued, and road and weather conditions, while the feedback information could be, for example, photos, videos, aerial shots, GPS coordinates, measurements with sensors, and radio communications.

In this context, the need for information in emergency scenarios is therefore a key element of emergency management and emergency communication. It therefore represents a key component of the study process and even then a method of controlling, measuring, and monitoring the response of the system of aid and support.

1.2 Emergency Communications: Aspects, Tools, and Features

Emergency communication activities include information and communication in emergency situations (e.g., natural disasters, technological accidents, extensive fires, collapses, etc.). Operationally, the path of emergency communication derives from careful design, performed by the emergency response system, and should consider the following three main aspects, typical of each form of communication:

1. Formal characteristics of the message ("how" and "to whom" is it being communicated).
2. Relationship of trust between communicators (especially between the issuer and the source of the message).

3. Contents of the message ("the topic" and "the reason why"); the contents of the message can, for example, be reduced to the definition of events and actions.

The instruments to implement communication strategies are:

1. The press release
2. The press conference
3. Direct imaging from the disaster scenario (video and image transmission)
4. The interview
5. The mailing list
6. The production of photographic prints

Television pictures are real means of communication; images have some important characteristics; in fact, a picture of a scenario can be purely descriptive (documentary), or it can have, through its own characteristics and with few components, an emotionally expressive tone, related to the context it is documenting [2]. The image can be transmitted directly or can be created and presented on a supporting device, such as a DVD, through a process of elaboration in studio (editing).

2 Communication in the Italian Fire and Rescue Service

In the Italian Fire and Rescue Service (IFRS), communication is entrusted to the Public Relations Office, managed by the head office of the Department of the Ministry of Internal Affairs. This Office develops and implements specific communication strategies for both routine events and emergency management. Communication in emergency settings is implemented by the IFRS and focuses on:

1. Communication activities with mass media, press, and TV, related to the current situation, the evolution of the scenario, the continuous and constant monitoring of urgent technical assistance operations, and a general update of the situation (press releases, interviews, press conferences, diffusion of images).
2. Communication activities for the management of the Italian Fire and Rescue Service and the Ministry of the Interior and the Civil Protection System, relating to the updates of the scenario and the ongoing rescue operations. This is achieved either through verbal communication or data and image transmission.
3. Communication activities directly from the emergency scenario to the relevant operating facilities in the territory, in order to illustrate ongoing situations in real time, to optimize management decisions for rescue operations.
4. Communication activities to document events in progress, for educational purposes, and to assist the police in their investigations (through the acquisition and recording of images).

The images are acquired by local documentation and video centers (CDV) and later transmitted generally through satellite technologies to receiving screens/monitors at other offices and in the National Operations Center (the transmission is done by the National Telecommunication System, with central and peripheral offices using satellite systems as SkyplexNet).

The Italian Fire and Rescue Service has been one of the first civil entities in Italy to equip itself with a satellite transmission system. The system SkyplexNet was designed and realized together with the Telespazio company, and it is an analogic satellite transmission system. This system has been fine-tuned and mainly used for the delivery of data and teleconferences.

Over the years, due to the growth of video's length and quality and the diffusion of digital equipment, this system for image transmission has started to present a number of limitations. After thorough research on the transmission of high resolution images and a number of tests, the Tooway system was born.

This system uses the connection to the Internet via the satellite connection and is not a live transmission system but allows access to the Internet even when the usual connection system cannot not be used. The frequency, which can be used, is guaranteed and is available in 1 Mb, 2 Mb, 4 Mb, and 8 Mb. In order to open the connection, a request is necessary. Once a request has been made, the timing between the request and the possibility to use the frequency has been assessed as 30 s at the most.

The system is made up of a parabolic antenna, a transmitting/receiving illuminator, a connection cable, and a modem. Right now these systems have been activated in 16 Italian regions.

3 Image Transmission Technologies

The SkyplexNet network of the Italian Fire and Rescue Service consists of the following elements (ground segment):

- # 1 Fixed service center (CSF), primary, installed at the Ministry of Home Affairs (Rome)
- # 1 Fixed service center (CSF), secondary, installed at the "DC-75" building (Montelibretti)
- # 16 Fixed transmission centers (CRF), located at the regional facilities of the Italian Fire and Rescue Service
- # 103 Fixed receiving stations (SRF), located at the headquarters of the local Italian Fire and Rescue Service offices
- # 2 Mobile radio centers (CRT trucks), with many services available, such as audio/video streaming, distance learning, video conferencing, and data/image transmission

A network element is defined as a satellite station (or a terminal) with receiving/transmitting or only receiving equipment. The CSF, the CRF, and the CRT are transmitting network elements, while the SRF is only receiving network element.

The CSF is the main element of the network, dedicated to the preparation, management, and provision of services to the users of SkyplexNet network (SRF, CRF, and CRT).

4 Examples of Image Transmission Systems

Over the years 2009 and 2010, different image transmission systems were implemented in the context of a natural disaster, the earthquake in L'Aquila of 2009, and the G8 event of the same year, using the abovementioned technologies.

The system was structured as follows:

1. # 5 Cameras fixed/mobile in the various areas to follow (transitions of foreign delegations); this section uses the "analog chain."
2. # 2 Mobile director trucks, # 1 truck for satellite transmission (CRT).
3. # 1 Quick assembly station at one of the mobile director trucks for direction.
4. # 1 External monitor to display images.
5. Microwave radio links for analog video transmission/reception.
6. Video transmission with video cables in local connections, remote transmission by satellite, and two CRT trucks.
7. # 25 Staff people of Italian Fire and Rescue Service, from the National Telecommunication System and CDV facilities.

The system produce the following materials: live images at the Ministry of Home Affairs and Italian Fire and Rescue Service offices (stakeholders) and, on the external display, DVDs post production for TV and photographic prints. The diagram shown in Fig. 2 describes the system.

Scanned images, as they arrived at the mixer, were processed, chosen, characterized with the Fire and Rescue Service logo, and made ready for satellite transmission in one-way direction, in other words from the CRT to the fixed positions. Also the fast assembly of images and recording of quick mounted DVDs were done in the same mobile director trucks.

5 The TAS Service

Firefighters always use cartography. When a team of firefighters intervenes in an emergency, not knowing which way to go, they need a road map, if they are within the city limits, or a topographic/touristic/hiking map, if they need to move out of town.

Today the area of operations is directly visible on screen with the help of various cartographic management computer programs. The management of rescues from the operation room at the on-site command post is therefore substantially facilitated.

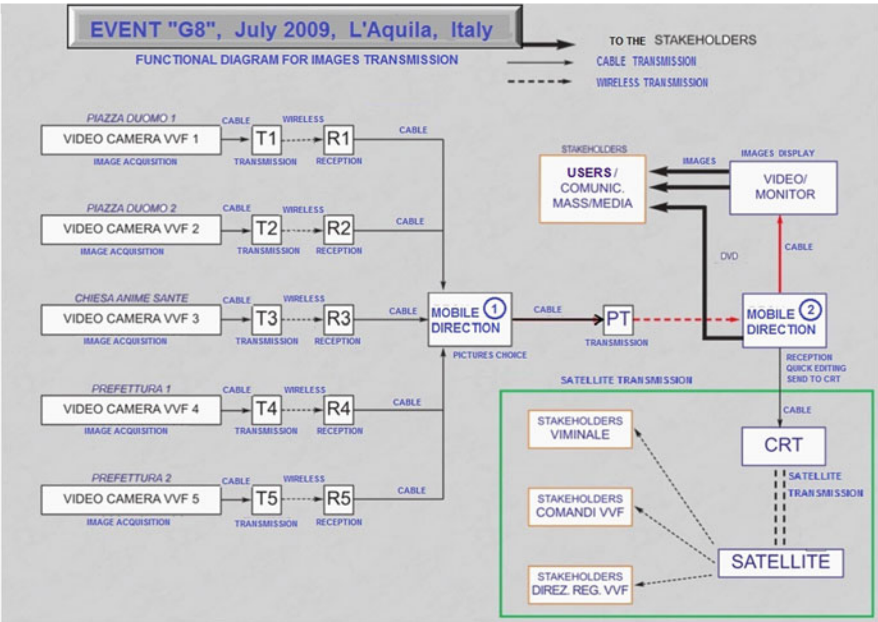

Fig. 2 Functional diagram of the Italian Fire and Rescue Service image transmission system

It can be fundamental in various situations: searching for missing people; containing, controlling, and extinguishing forest fires; CBRN scenarios; emergency assistance in water-based environments, floods, earthquakes, and landslides; actions taken by helicopters; interventions at industrial sites at risk; etc.

With a computer, the headquarters can also manage the GPS devices in the field, control the position of the operating units at all times, and proceed with order and rationality in carrying out the rescue operations.

The scope of the Topography Applied to Rescue (TAS) service is to regulate and optimize the use of geographic information in the activities of the Italian firefighters of the IFRS, first of all in assisting the urgent rescue phase and then in the management of tasks in the early emergency phases of events, which require the intervention of the Italian System of Civil Protection.

The TAS service objectives are aimed at improving the effectiveness and efficiency of the emergency services and other activities of the Italian firefighters, through the integrated use of human and material resources, for the production, analysis, and use of geo-referenced data. These data can be used to facilitate the search of solutions to complex problems relating to the planning and management of emergencies and other reporting transactions.

TAS service is articulated in territorial structures, in the provincial commands and in regional offices with a central reference, the Central TAS Service, which hosts the coordination and relations management functions and cartographic databases of the Italian territory.

In the context of the management of technical rescues, TAS function provides decisional support to the control function. TAS operators are placed in on-site command posts, working near the emergency scenario, mapping and identifying the critical areas with a clear benefit in terms of optimizing the use of resources.

5.1 TAS and Earthquake

The earthquake that struck Central Italy in August 2016 has been a difficult task for the Italian firefighters, with 4 regions involved, 6 provincial commands, and up to 1600 men and 600 vehicles deployed in the field. In this complex scenario, the monitoring of operations and resources was the key to enable headquarters to have full knowledge of the situation.

In order to do this, TAS operators have been employed at Advanced Operating Commands (COA) and at the IFRS Regional Directorates. TAS service was also activated at the Coordinating Office of the Civil Protection Department (DICOMAC), at the firefighter's special interventions task force (NIS), and at the National Operation Center (CON). This has ensured a stream of data and information on all activities carried out by the Italian Fire and Rescue Service, as emergency interventions, mapping of the triage of roads and buildings, monitoring of remedial measures of buildings, surveys of sites containing asbestos, etc.

In the course of the emergency caused by the earthquake, a system of sharing geographic data WebGIS[1] type was also used for the first time, by creating a portal that proved to be very useful too because it can be integrated with WebApp[2], taken by TAS staff, which allowed the detection of a significant amount of geographic data. This tool proved strategically useful for the management of the different stages of the emergency, to the point that the Central Directorate for Emergency and Technical Rescue chose to use it even in ordinary and relief planning activities [5] (Figs. 3 and 4).

5.2 UAS Support

An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot aboard. UAVs are a component of an unmanned aircraft system (UAS), which includes a UAV, a ground-based controller, and a system of

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[1] A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. A web map on the World Wide Web is a service by which consumers may choose what the map will show. WebGIS uses web maps, and end users who are web mapping are gaining analytical capabilities for decision-making [3, 4].

[2] A WebApp is a powerful dedicated GIS app that can run on any device, sharing geographic data to achieve specific tasks.

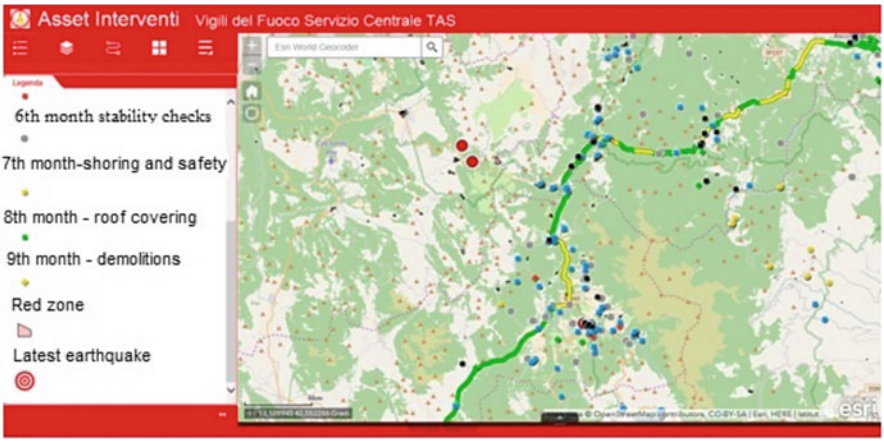

Fig. 3 Rescue activities on the map after the earthquake

Fig. 4 Quick triage of buildings on the map after the earthquake

communications between the two. The kind of UAV most used by the Italian firefighters is the quadcopter, a multirotor helicopter that is lifted and propelled by four rotors [6].

The use of UAS proved to be useful, as the fixed-wing aircraft was utilized to complete aero mapping and 3D rendering of buildings in the territory. TAS staff processed the photographic surveys carried out through the use of quadcopters, to complete the planning activities and create orthophoto base maps [7, 8] of the areas hit by the earthquake (Fig. 5).

Quadcopters are also used for documentation during rescue operations and to complete the documentation overview of the places affected by the earthquake. This kind of UAS is used also to support teams engaged in research in crumbling

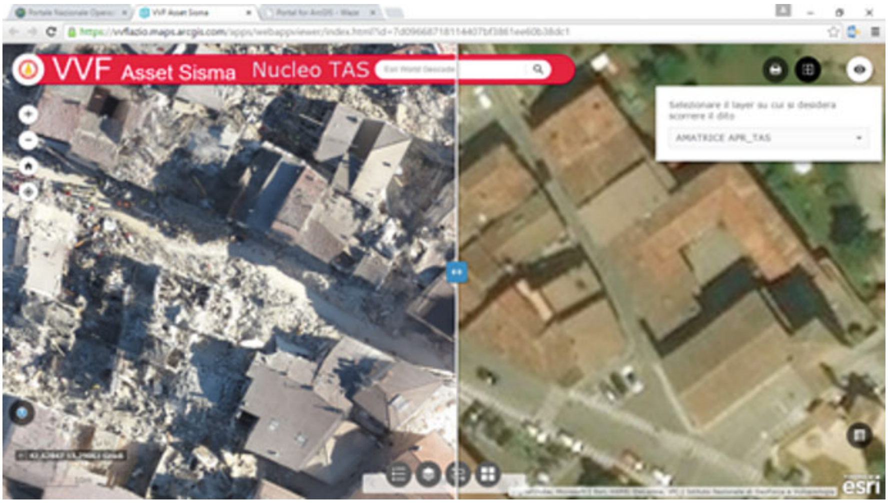

Fig. 5 Damage assessment after the earthquake, with photographic surveys, carried out through the use of UAS (quadcopter)

buildings, to safeguard the safety of personnel, and for timely inspections in hazardous environments or vertical development.

Activities are managed by the office coordinating air rescue of the Central Directorate for Emergency and Technical Rescue. The images are handled by the centers and transmitted to the National Operation Center (CON).

5.3 TAS and G7

On the occasion of the recent political forum of the major governments of the world, the service was active in mapping the deployment of TAS vehicles and Italian Fire and Rescue Service staff, which were present on-site [9].

The adopted WebGIS is a tool which allowed the sharing of data collected from TAS staff in Sicily and integrating it in the processes carried out by Central TAS personnel with the purpose of creating a comprehensive tool to help manage the event even remotely.

6 Conclusions

After examining the main technologies and methods for the transmission of remote images in use in the Italian Fire and Rescue Service and the main features of the innovative discipline of Topography Applied to Rescue, it is possible to draw a general overview of the aforementioned themes, having regard of the latest applications in the field.

For the development of the Italian Fire and Rescue Service urgent technical rescue activities, especially in contexts of the recent major calamitous events (earthquake in Central Italy of 2016–2017), both image transmission technologies, the Tooway and the Satellite Transmission, are constantly used, with plant layouts of operators, video machines, and transmission systems similar to those previously mentioned and used during the earthquake in L'Aquila in 2009. These plant solutions have undergone a constant and progressive evolution, compared to what has already been described, especially from the strictly technological point of view, including for image acquisition, the use of full HD equipment, and adding to the layouts already discussed also transmission backup systems, through streaming video procedures or interconnected streaming—Tooway systems.

As far as the Topography Applied to Rescue technologies are concerned, important evolutions are being developed, on one side technological, with the adoption of remote-piloted equipment (UAS, drones), which allow more and more acquisition of images and frames at higher altitudes, and on the other managerial, by implementing TAS techniques in an increasing number of activities. Today, therefore, during a disaster or a significant rescue operation, through the use of TAS techniques, it is possible to view in real time at the operating rooms of the Italian Fire and Rescue Service head offices the complete picture of the events in progress, the vehicles intervened and those available, as well as the changes in the operating scenarios, thus providing exhaustive and correct information and being able to provide reliable forecast of the developments of the scenario.

We can conclude that the documentation and emergency communication activities will guarantee to the Italian Fire and Rescue Service in the near future an important and increasing support for the management of rescue operations, especially in the context of civil protection events. They therefore provide an important support to decision-making and have allowed the technological and procedural evolution of the urgent technical rescue activities, succeeding in guaranteeing a faithful and precise remote overview of the events in progress.

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Modelling and Optimization of the Health Emergency Services Regional Network (HES-RN) in Morocco: A Case Study on HES-RN of Rabat Region

Ibtissam Khalfaoui and Amar Hammouche

1 Introduction

The effective management of emergency services has become a critical issue in the hospital sector in Morocco. It is well known that these services are often congested, under-equipped and suffering from a degraded image with performance levels below those set by international standards. To bring solutions of improvement of the organization and the functioning of such services at a territorial region level, their structuring and management are considered as part of the HES-RN of RSZZ (Rabat–Salé–Zemmour–Zaer).

Considering an Occurrence of an event of Health Emergency (OHE) in the global context of HES-RN of RSZZ and the local neighbourhood of this OHE as shown in Fig. 1, we construct a GIS-based decision support system to manage it as optimally as possible. After a brief literature review, the rationale and the methodology of this construction are presented in the following.

2 Literature Review

There are many researches which deal with the problem of the shortest path between any node pair of a traffic network. Few ones are addressing the issue of the fastest path [1] proposed three algorithms; (1) for recalculating shortest path (SP) and its

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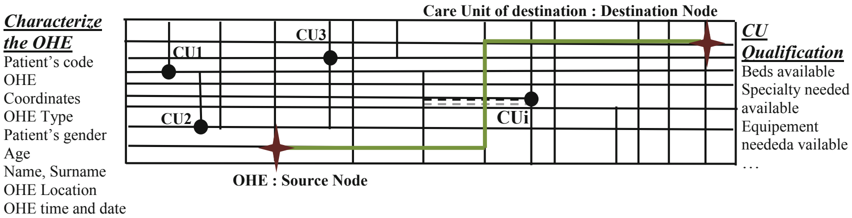

Fig. 1 OHE representation inside a road network

related minimum travel time (T_{min}) when the travel time of the road (i, j) changes (FG_A), (2) an algorithm to find alternative paths both in free-flow regimes (FG_B) and (3) in congested flow regimes (FG_C). This latter is the most interesting one. The researchers took into consideration the shockwave propagation from the congestion point. That means that a list of roads, whose travel times will change due to the accident, at time t_k in a given interval, from the one related to the free-flow regime to the one pertaining to the congested flow regime, will be determined and taken into consideration when computing the fastest path.

Both FG_B and FG_C algorithms use the FG_A algorithm.

For the same purpose, [2] presents an adaptive fastest path algorithm. This one is based on the hierarchy of roads that can be used to partition the road network into area to limit the search space, as well as the historic traffic data. The algorithm proposed by the researchers gives preference to fast routes that have high support, i.e. that are frequently travelled, over those, though fast, rarely taken by drivers.

A query contains the start point, the end point and departure time or some other information. The fastest route is computed based on additional conditions, such as weather forecast or road construction/closure information.

Other researchers [3] propose a solution to finding the fastest path among multiple simplest routes with greatly varying length. They associated a road network with two cost functions: the length function L that assigns to each edge a cost representing its length and the complexity function $C(\rho)$ of a route ρ, equal to the sum of complexities for each turn the road contains. The study present four algorithms: (1) fastest simplest route BSL, (2) simplest fastest route, (3) fastest near-simplest route and (4) simplest near-fastest route, based on both functions mentioned above.

3 Methodology

The basic ideas of this study are modelling the HES-RN-RSZZ and optimizing its functioning.

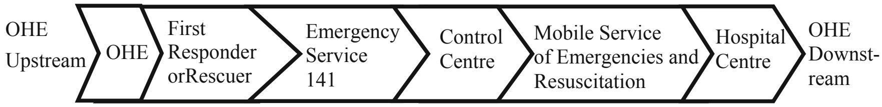

Fig. 2 OHE process

Thanks to a GIS model, the studied network is represented by a graph. This later is composed by a finished number of vertices (health institutions), which are connected by edges and characterized by events, OHEs.

The HES-RN's GIS was accomplished in several layers, each one having its own data, necessary to manage and regulate well such a network. This mapping determines the best care units adapted to the needs of the concerned patient; it also indicates the closest to reach the OHE, in terms of distance and road traffic. Much more, it is a tool allowing the communication, the coordination, the transparency and the data sharing between all HES-RN's nodes.

Once the OHE takes place, it will be associated with a supply chain (SC-OHE) on one hand and with a service process on the other hand (SP-OHE), as shown in Fig. 2:

The OHE chain (C-OHE) defines the logistics and the necessary resources for the corresponding OHE process (P-OHE), while this one specifies the prehospital process of a medical urgency treatment.

3.1 HES-RN-RSZZ Structuring and Organization

To model the HES-RN structure, data were collected from several organizations (hospitals and ambulatory care direction, regional health office, health delegations of RSZZ regio, etc.) and from QGIS open-source database. Then, the HES-RN's mapping was developed, from the digital map of the studied region, under a GIS platform, with all geographical, healthcare offer, road networking and transportation, real-time road traffic and patients' data pertinent to the management of OHEs in the considered region.

3.2 Functioning and Management of the HES-RN-RSZZ

In this section, we study the functioning of the HES-RN, and we are interested in particular in the dynamic routing of the patient concerned by the OHE of this HES-RN. This routing depends on the length of the considered road and also on the traffic flow along this road. This flow can be characterized by the road density varying in time and in space. The GIS that we use has a tool, which allows us to

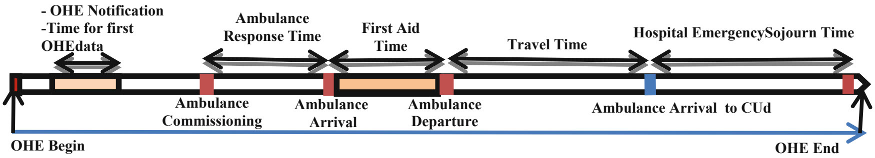

Fig. 3 OHE cycle time

determine, in a given radius, the Care Units of destination (CUds) and the shortest path which lead there. Yet, in our decision support model, in order to transfer the patient as quickly as possible to the CUd, we are looking for the fastest path between the OHE and the CUd.

In order to model the network in all its aspects, we resorted to Unified Modelling Language (UML) [3]. This allowed us to model (1) the structure of the network as UML classes, (2) the use of the network as use case diagram and (3) the dynamic aspects of the network through (a) the activity diagram that represents the behaviour of a use case and (b) the sequence diagram which describes how the elements of the system interact with each other and with the actors interacting with network.

The OHE cycle time is represented in Fig. 3:

Unique Patient Dossier This paper is interested in managing only what is measured. The traceability is a strategic asset that provides the visibility, got by the access to continuous and measurable data. In the absence of an effective traceability system, it is not possible to monitor and trace patient flows nor to objectively measure the effectiveness of the activities of medical staff.

In this study a patient dossier was created using a GIS software. This dossier contains all the important information about the concerned patient.

It is therefore a matter of codifying each of the OHEs processed, of collecting all the information relating to it, of archiving the OHE Dossier and of consulting the history of the dossier whenever it is necessary.

Patient's Transfer The problem of finding the fastest path to ensure a transfer from point A to point B of a road network is well known. Its formulation remains simplified, and its resolution is complex especially at the mathematical level [4, 5]. Even the exact solutions developed for the simplified models provide only local optimality. Furthermore, the stochastic nature of the road traffic only complicates things. In the absence of having an optimal global solution for this problem, we settle for a meta-heuristic that allows us to provide a good approximate solution. For this we built and added the layer "real-time traffic conditions" to our HES-RN's cartography, to have quantification and meta-visualization of road traffic at quasi real time in this HES-RN (see Fig. 4).

There are four levels of traffic quantification adopted by ArcGIS Online. These levels are qualified as follows: [stop and go] for the densest (average minimum

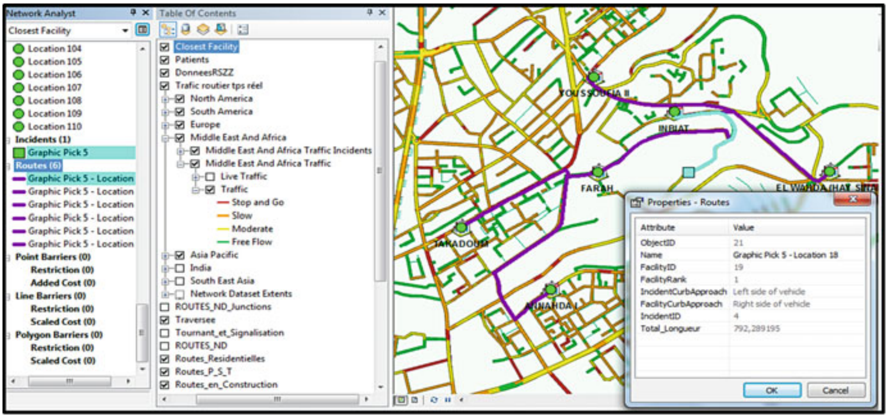

Fig. 4 HES-RNGIS mapping with near real-time meta-traffic

speed: v_{min}), [slow] with average speed v_1, [medium] with average speed v_2 and [fluid] with maximum speed v_{max}.

Thus, on the basis of this information and the GIS data of the modelled HES-RN-RSZZ, the following algorithm procedure is proposed, to obtain the fastest possible transfer of the patient between the OHE and the CU of destination:

1. Pinpoint the OHE location (geographical coordinates) and characterize it.
2. Determine which CUds are qualified (feasible points) to process the OHE.
3. Classify these qualified CUds (depending on OHE severity) according to their qualifications.
4. Determine all paths connecting OHE location to the qualified and classified CUds, within a given radius (this latter is determined on the OHE severity).
5. Among these paths, determine the path that optimizes the transfer time of the patient according to its length and its traffic:

   (a) Insert in a table all the segments of the paths found.
   (b) Characterize and classify these edges <edge_id, Time, Condition, average speed>.

The steps in this procedural heuristic that have some complexity are steps 2, 4 and 5. The difficulty for step 2 is to determine the qualification elements of a CUd and to qualify the severity levels of the OHE.

As for step 4, the problem faced concerns the graph theory, which consists in finding all the possible connection paths between two given nodes of a graph. In our case, these nodes are the OHE location and the chosen CUd. In this paper, we will determine several paths linking two nodes of the network, in a given radius, in order to simplify the algorithm and reduce its time of simulation.

As for step 5, its complexity is to find, dynamically, the shortest path (fastest in our case) between two nodes. In our research, we focus on these three steps.

We consider that a path is composed of a finite number of sections (edges).

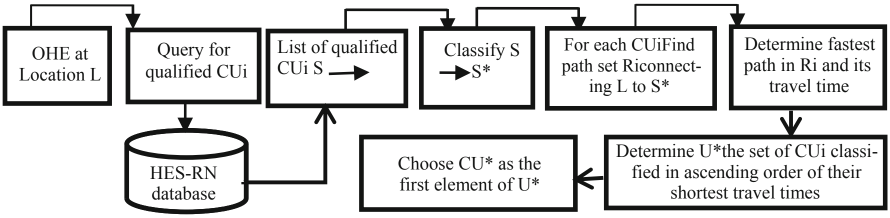

Fig. 5 The second, third and fourth steps of the algorithm

Let Vg be the average speed of the path and S be the non-empty set of these qualified CU, with $S = \{\text{CU}i/i = 1, n\}$.

Set $Ri = \{r_{\text{ik}}/k = 1 \ldots m\}$ the non-empty set of paths connecting the OHE location to the CUi such as:

t_{ik} = travel time of the path r_{ik} = (total length of path with fluid flow)/$V_{\max}$ + (total length of path with slow flow)/V_1 + (total length of path with medium flow)/V_2 + (total length of path with stop and go flow)/$V_{\min}$

Set $t_{\text{iki}} = \min\{t_{\text{ik}}, k = 1 \ldots m\}$ for $k = k_{\text{i}}$.

Then $r_{\text{iki}} \in Ri$ is the fastest path between the OHE location and the CUi, and t_{iki} is its travel time.

Then steps 2, 3 and 4 become as shown in Fig. 5:

On the other hand, and considering the dynamic of traffic road in real time, we adopt dynamic optimization by section method: at iteration i and at the current node, the objective is to find the next connected node on the optimal path of the remaining network.

In the general case of the road network, modelled as a non-oriented graph with circuits, reaching the destination node (the CUd in our case) is not guaranteed. We therefore, make the assumption that the nodes cannot be revisited. In this case, our problem is formulated as a *DiscreteDynamic One to Some Shortest Paths* (D2OS2P) problem. It is dynamic, because in our modelling we consider system state change, particularly road travel times and availability change of the CUd in time. It is discrete, because changes in the system states will be considered only at the next node on the travelling path.

Our dynamic optimization method for this D2OS2P becomes:

- Iteration 0: initial graph G_0 = road network between the OHE location (source node) and the CUd (destination node).

New initial node = next connected node on the optimal path of G_0

New remaining road network $G_1 = G_0 - \{\text{source node of } G_0\} - \{\text{arcs connected to the source node of } G_0\}$

- Iteration i: initial graph G_i = road network between the initial node of iteration i and the CUd, with eventually new weights (travel times), and/or new eventual CUd ranking.

New initial node = next connected node, located on the optimal path of G_i.

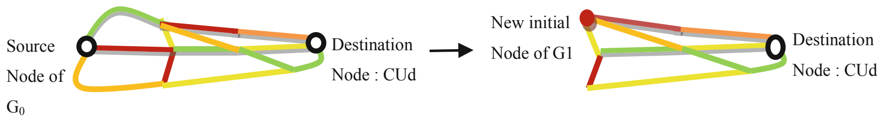

Fig. 6 Iteration 0 and iteration 1

New remaining road network $G_{i+1} = G_i - \{\text{initial node of } G_i\} - \{\text{edges connected to the initial node of } G_i\}$.

- Repeat iteration i until the new initial node is the CUd.
- As an example of application of this method, see Fig. 6.

To implement this algorithm, we need at the next node (1) to determine the new travel times following any perturbations in subgraph G_i, and/or the new eventual CUd ranking, and (2) to propose an algorithm to find the optimal path of G_i.

Concerning point $n°1$, we know that the segment travel times is a function of time, speed and traffic flow.

Finding a real-time solution for it necessitates the resolution of an ill-formed problem that involves differential equations. A lot of research has been done [4, 5] to solve this hard problem. But only approximate and incomplete solutions have been proposed.

Therefore, and for practical reasons, we will adopt the averaging method by segment to compute an average segment travel time as a function of its average travel speed. For this we consider that car speeds may span four regimes as proposed in [1]: (1) regime I for city streets, (2) regime II for city streets and suburban area, (3) regime III for lower speeds in city streets and suburban area and (4) jammed regime for congested streets.

As for the ranking of the different CUds, any change in this ranking will require an update of S^*.

Concerning point $n°2$, we resorted to the algorithms FG proposed by Faro et al. [1], which deal with the APSP problem, considered as a generalization of our case study (D2OS2P).

They are used (1) to determine the shortest path (SP) of the considered APSP, in case the travel time of a given road changes (FG_A), and (2) to find alternative shortest paths both in free-flow regimes (FG_B) and in congested flow regimes (FG_C).

In our case, we are working on the adaptation of these algorithms to our D2OS2P, in order to find the new U^*, at the next node.

4 Decision Support Model

In order to analyse and evaluate the activity of healthcare institutions and to respond to the needs of decision-makers, within the network, a pilot dashboard is used. It is a tool of control, diagnostic, dialogue and communication.

The objective of the dashboard is to pilot the health organization through key performance indicators (KPI). There are two types of KPI: (1) prehospital KPI, such as call waiting time, response time, vehicle kilometres travelled, number of calls processed, average call processing time, survival rate during transfer, transfer time, number of vehicles used per day and number of transfers performed per day, and (2) intra-hospital KPI, such as number of urgent consultation, number of expected outpatient surgeries, number of surgical interventions scheduled, number of day hospital activities, number of examinations (scanner, Echo & Doppler, etc.), number of explorations, full hospitalization, day hospital, average occupancy rate, average duration of stay, turnover rate, mortality rate, number of deliveries per year, number of medical consultations per year, total admission, emergency room, etc.

Furthermore, to achieve optimal decision-making and to act quickly and efficiently in the emergency sector, when there is an OHE, we propose a decision support model, using:

- A HES-RN GIS mapping able to provide real-time data and information needed to determine the most appropriate CU of the HES-RN to receive the patient concerned with the OHE and to select the fastest routing for the transfer of this latter, taking into account the possible routing times to the unit care of destination.
- An algorithm allowing to determine the fastest routing of the patient, in real time, according to the candidate routings, their lengths and their traffic flows.
- A global modelling of the OHEs within the HES-RN, using UML diagrams, allowing to represent the functioning of the network in a precise and complete way.

This decision support model assumes that the HES-RN nodes work autonomously with provided regulation by the control centre node, insuring the access to the most effective care in the shortest possible time, with a sustainable quality of service, level of service and the best possible and with the least possible costs.

5 Conclusion and Perspectives

In this work, we have studied the structuring and the functioning of an HES-RN using both GIS platform and UML modelling. This has allowed us to propose a comprehensive framework for the modelling, simulation and optimization of a health network.

The optimization of the network's administration and management concerns in particular its OHE management, especially the complex problem of its dynamic routing optimization.

If there is a risk of death of the patient, subject of the OHE management, any nonoptimal decision can have fatal consequences on the patient's survival. That is why in this paper we propose an algorithmic decision procedure for the optimization of OHE cycle time in particular and of the critical decision processes through the HES-RSZZ-RN network in general.

The algorithm proposed deals with *DiscreteDynamic One to Some Shortest Paths* (D2OS2P) problem, in order to obtain the fastest possible transfer of the patient, between the OHE and the CU of destination, taking into account road congestions and the consequent flow perturbation that propagates over the network.

We also introduced a guideline protocol for the decision support of the HES-RN-RSZZ, assuming that the HES-RN nodes work autonomously with provided regulation by the control centre node.

As to our future works, we are working on (1) the adaptation of Faro et al.'s [1] algorithms to our D2OS2P, (2) the translation of our GIS/UML model into a simulation model, to be deployed on a computer platform using a GIS Software in combination with visual basic for applications and (3) the validation of that model.

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3D Numerical Simulation of a Chlorine Release in an Urban Area

Jean-François Ciparisse, Andrea Malizia, and Pasquale Gaudio

1 Dispersion Models

The release of harmful substances in the environment is a concern which has led in the last years to a deep investigation, carried out experimentally and numerically [1–5]. The elaboration of dispersion models is crucial to predict the effects of an accidental or intentional diffusion of such agents and therefore to take countermeasures.

1.1 Simplified Models

Those models, often based on experimental data, take as inputs the information about the position and the magnitude of the chemical release, as well as the environmental conditions (wind speed and direction, temperature, humidity, atmosphere stability, etc.), and give as an output the local concentration of the substance taken into consideration, so that the dispersion plume can be determined.

The main advantages of those models are:

- Fast response: very short computational time, so they can be used infield to support first responders.
- Easiness of use: only few operations need to be performed to get the results.

The main disadvantages of the simplified models are:

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– Low/medium level of accuracy
– They are more suited for open spaces than for closed/geometrically complex areas.

So, when accurate predictions are required, simplified models cannot be applied. The full set of equations governing mass, species, momentum, energy and turbulence quantity transport must be solved.

1.2 CFD Simulations

The full set of equations describing the behaviour of the flow is numerically solved on a discretized domain, i.e. the area where the phenomenon occurs is divided into subdomains, called cells, and the aforesaid equations are linearized and solved as an algebraic problem.

The advantage of this approach is its accuracy, much greater than the one reached by simplified diffusion models (errors on each quantity are typically less than 10%). Complex geometries can be drawn, and a number of phenomena can be coupled to the one describing the flow (e.g. chemical reactions).

However, this approach is very time-consuming and is therefore not usable infield but is good for predicting scenarios.

2 Models and Settings

The leakage of a tank containing chlorine at high pressure was considered as the case study. An urban area consisting of 15 buildings, each of them having a height of 10 m and a width of 6 m is considered as case study. The computational domain has a length of 200 m, a width of 100 m and a height of 50 m. The wind blows at 3 m/s, and the chlorine source, shown in Fig. 1 with a green star, is modelled as a sphere having a radius equal to 0.2 m and staying at 5 m above the ground level and at 20 m behind the face from which the wind enters. The speed Cl_2 is 150 m/s on the surface of the sphere.

The models used are:

– Compressible gases mixture
– Kinetic theory for gas property calculations
– $k - \varepsilon$ turbulence model
– Steady-state simulation

The software used is Comsol Multiphysics, a finite element code able to simulate many physical phenomena (fluid mechanics, heat transfer, solid mechanics,

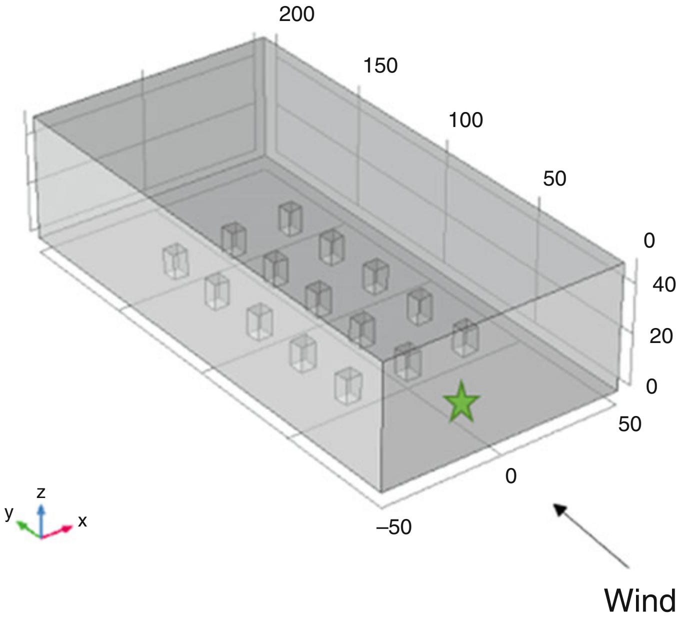

Fig. 1 Computational domain

electromagnetic fields, etc.) and even to couple them when a complex problem is to be modelled.

The full set of equations is reported below [6]:

$$\vec{\nabla}\cdot\left(\rho\,\vec{V}\right)=0 \tag{1}$$

$$\rho\cdot\left(\vec{V}\vec{\nabla}\right)\vec{V}=\vec{\nabla}\cdot\left(\left(-p-\frac{2}{3}(\mu+\mu_{\mathrm{T}})\left(\vec{\nabla}\cdot\vec{V}\right)-\frac{2}{3}\rho k\right).I+(\mu+\mu_{\mathrm{T}})\left(\vec{\nabla}\vec{V}+\left(\vec{\nabla}\vec{V}\right)^{T}\right)\right)+\rho\cdot\vec{g} \tag{2}$$

$$\rho\cdot C_p\cdot\left(\vec{V}\cdot\vec{\nabla}T\right)=\vec{\nabla}\cdot\left(\lambda\vec{\nabla}T\right)+\mu\cdot\left(\vec{\nabla}\vec{V}+\left(\vec{\nabla}\vec{V}\right)^{T}-\frac{2}{3}\cdot\left(\vec{\nabla}\cdot\vec{V}\right)\cdot I\right):\vec{\nabla}\vec{V}+\vec{V}\cdot\vec{\nabla}p \tag{3}$$

$$\rho\cdot\left(\vec{V}\vec{\nabla}\right)k=\vec{\nabla}\cdot\left[\left(\mu+\frac{\mu_{\mathrm{T}}}{\sigma_k}\right)\vec{\nabla}k\right]+P_k-\rho\epsilon \tag{4}$$

$$\rho\cdot\left(\vec{V}\vec{\nabla}\right)\varepsilon=\vec{\nabla}\cdot\left[\left(\mu+\frac{\mu_{\mathrm{T}}}{\sigma_{\epsilon}}\right)\vec{\nabla}\epsilon\right]+C_{\epsilon 1}\frac{\epsilon}{k}P_k-C_{\epsilon 2}\rho\frac{\epsilon^2}{k} \tag{5}$$

$$\vec{\nabla} \cdot \vec{j}_i + \rho \cdot \left(\vec{V} \cdot \vec{\nabla}\right)\omega_i = 0 \tag{6}$$

where ρ is the density of the mixture, $\vec{V}$ is the speed vector, μ is the molecular viscosity, μ_T is the turbulent viscosity, $\vec{g}$ is the gravity acceleration vector, k is the turbulent kinetic energy, ε is the turbulent kinetic energy dissipation rate, T is the temperature, C_p is the specific heat at constant pressure, λ is the thermal conductivity, P_k is the production rate of k, ω_i is the mass fraction of the ith species of the mixture and $\vec{j_i}$ is the flux vector of the ith species.

The steady-state flow was simulated numerically, in order to estimate the local severity of the chemical contamination. On the basis of the LD_{50} of Cl_2, the computational domain was divided into risk zones.

The effects on human health of chlorine inhalation depend on the poisoning power of this chemical and on the breathing rate. As reported in [7], LD_{50} for chlorine is 850 mg/kg, so that the mean lethal dose for a person (whose average mass, m, is about 60 kg) will be 51 g.

The mortality is assumed to be of the form:

$$\omega = \mathrm{e}^{-\frac{a}{m\_\mathrm{Cl}_2}} \tag{7}$$

where a is a constant to determine and m_Cl_2 is the inhaled mass of chlorine. The latter can be calculated as follows (assuming that all the inhaled chlorine is absorbed):

$$m_{\mathrm{Cl}_2} = Q * \rho * \omega_{\mathrm{Cl}_2} * \Delta t \tag{8}$$

where $Q = 10$ L/min is the breathing rate ([8]), ω_{Cl_2} is the chlorine mass fraction and $\Delta t = 60$ s is the exposure time.

By setting $\omega = 0.5$ to determine a, we get:

$$a = LD_{50} \cdot m \cdot \ln 2 = 35.35\ g \tag{9}$$

Finally, the mortality is:

$$\omega = e^{-\frac{LD_{50} * m * \ln 2}{\rho \cdot Q \cdot \omega_{\mathrm{Cl}_2} \cdot \Delta t}} = 2^{-\frac{LD_{50} * m}{\rho \cdot Q \cdot \omega_{\mathrm{Cl}_2} \cdot \Delta t}} \tag{10}$$

To calculate the mortality caused in an urban area due to the chlorine release, the followings steps were followed:

1. CFD simulation of the chlorine release and calculation of its local concentration
2. Application of a clinical model during the post-processing phase taking into account the harmfulness of chlorine

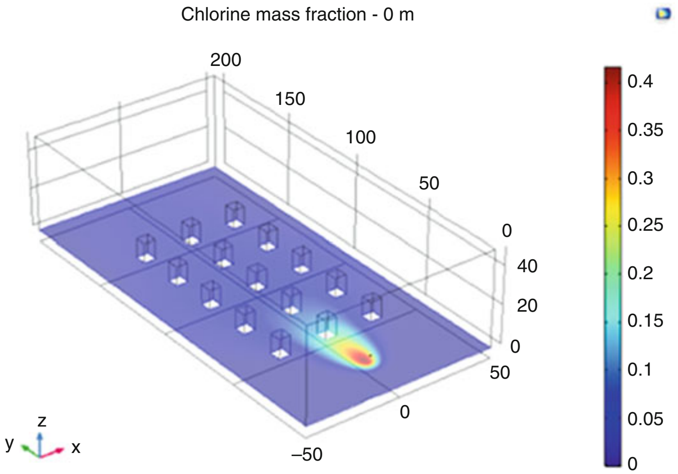

Fig. 2 Chlorine mass fraction at 0 m

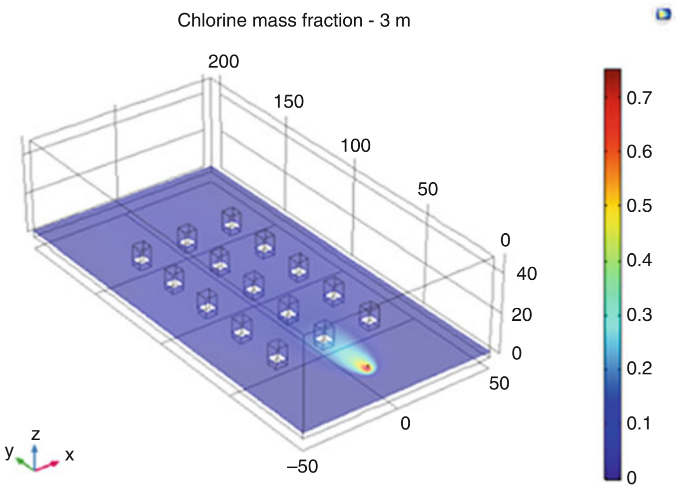

Fig. 3 Chlorine mass fraction at 3 m

3 Results

In Figs. 2, 3, 4, 5, 6 and 7, the chlorine mass fraction is shown on horizontal planes lying at 0, 3, 5, 10, 15 and 20 m above the ground level:

As it can be seen, a plume of Cl_2 forms from the release point. The chemical spreads mainly in the wind direction, and the concentration of chlorine is obviously maximum at the height of the source and on the *y*-axis. A significant contamination level is observed at all heights, even above the level of the roofs of the buildings. It

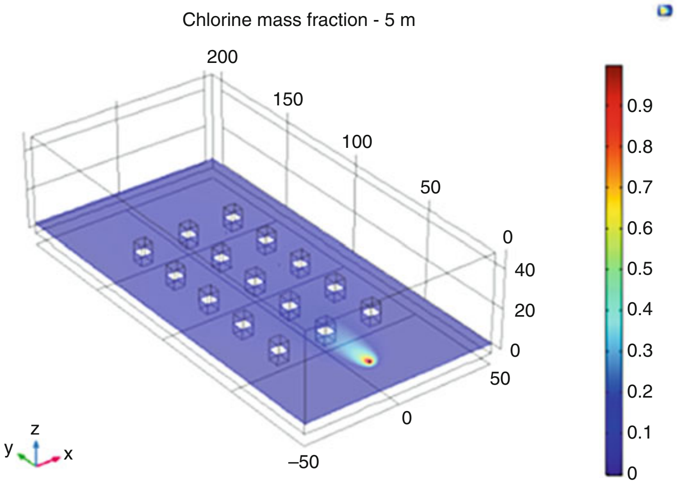

Fig. 4 Chlorine mass fraction at 5 m

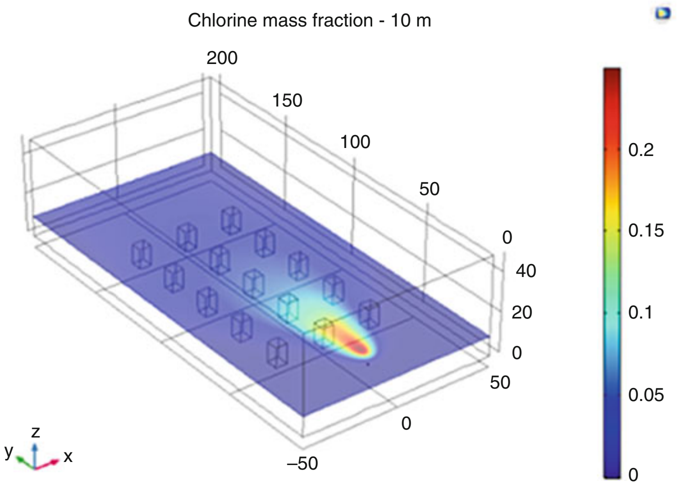

Fig. 5 Chlorine mass fraction at 10 m

has also to be noticed that the plume spreads laterally more quickly at heights greater or equal to the one of the roofs. This is due to the fact that each building acts as a huge bluff body which generates vortices at its sides, in front of it, behind it and over it. At heights below the one of the roofs, only the side, frontal and rear vortices act on the flow, and this already produces an acceleration of the convective mixing of air and chlorine. But at heights above the one of the roofs, the vortices forming above them act too. As the zone where the building is an area where the flow is partially obstructed, the wind tends to deviate upwards, so the zone immediately above the

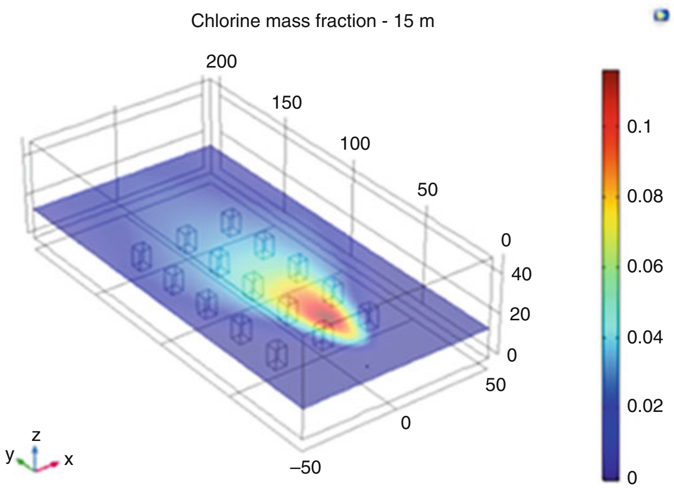

Fig. 6 Chlorine mass fraction at 15 m

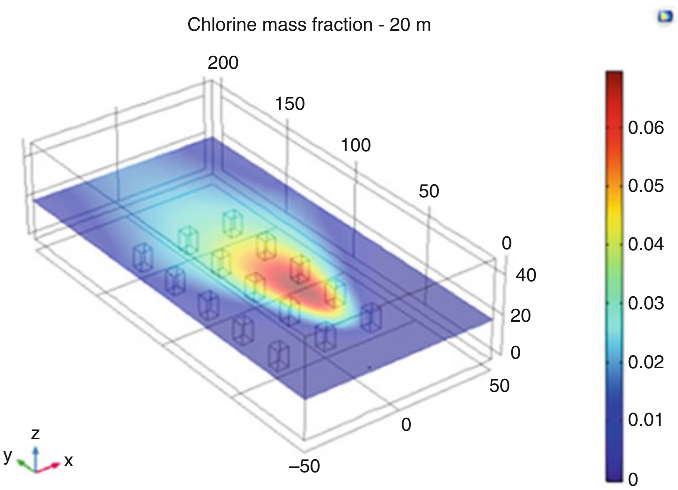

Fig. 7 Chlorine mass fraction at 20 m

roofs has a higher velocity than the wind at infinity. When this high-speed flow encounters the vortices just above the roofs, a lot of turbulence is generated, so the mixing is improved. In Fig. 5, a change in the aperture angle of the plume is noticed when the latter encounters the first central building; in Fig. 6 the same is observed around the second central building, and the same happens at 20 m around the third central building (Fig. 7).

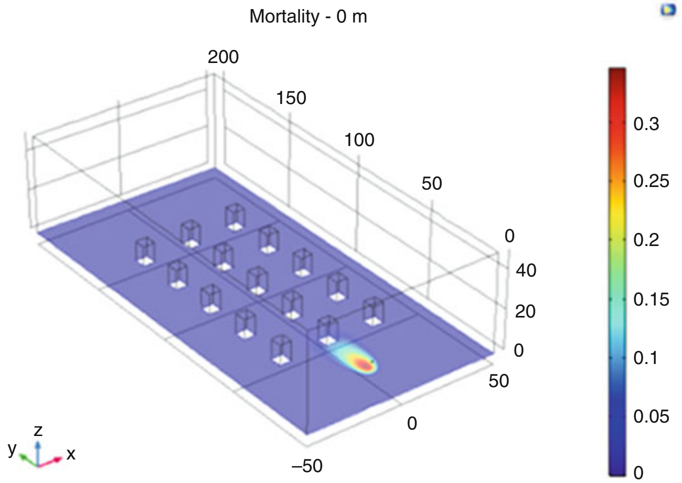

Fig. 8 Mortality at 0 m

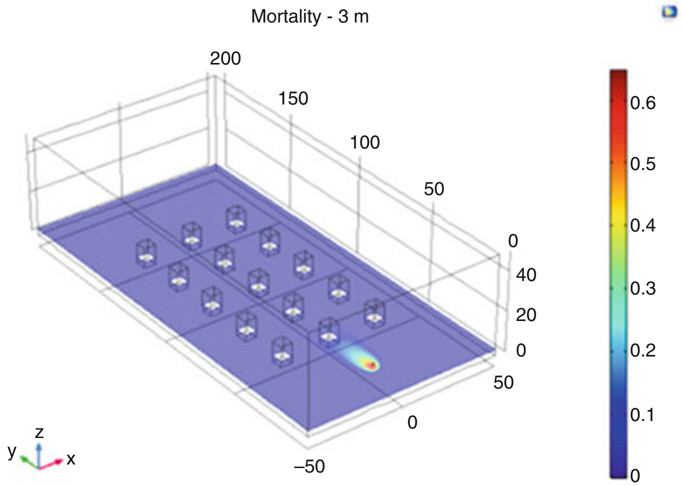

Fig. 9 Mortality at 3 m

Once the mass fraction of chlorine has been calculated, it is possible to determine the local mortality at several heights. Figures 8, 9, 10, 11, 12 and 13 show ω at 0, 3, 5, 10, 15 and 20 m above the ground level:

As it can be seen, the mortality peak is reached at 5 m above the ground level (height of the release point) and decreases when moving upwards or downwards, due to the spread of the plume and therefore to the dilution of Cl_2. Anyway, the area

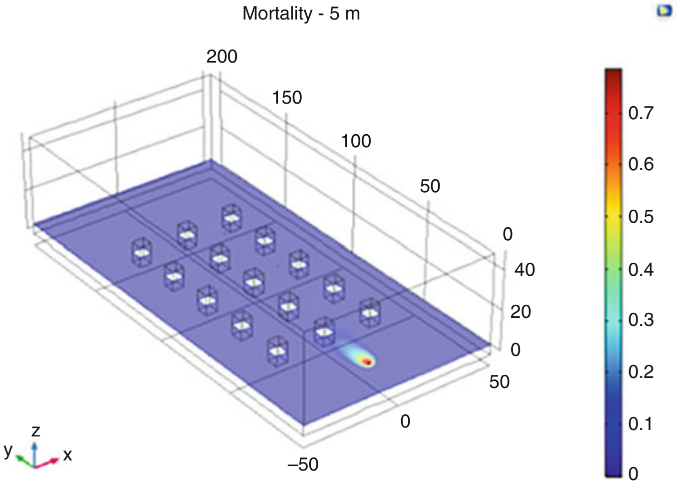

Fig. 10 Mortality at 5 m

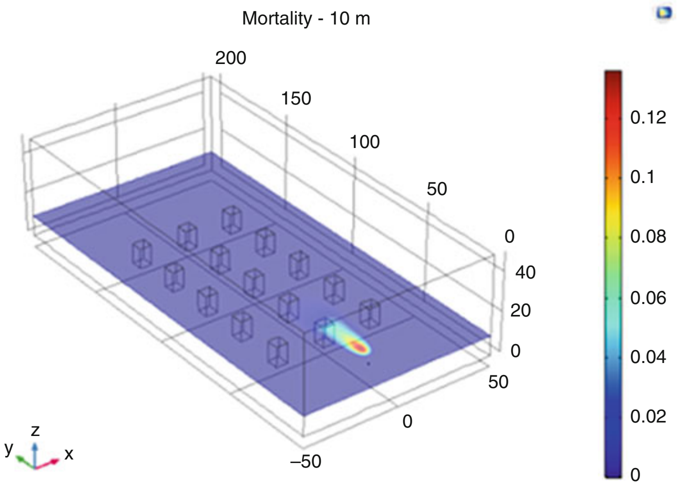

Fig. 11 Mortality at 10 m

where ω is really high is the one in the surroundings of the chlorine source. This means that, in case of an outdoor release of this gas, the effects are great only in a small area near the source of the gas. This is due to the low harmfulness of chlorine, if compared to one of the chemical weapons (Sarin, Tabun, VX, and so on [9–13]).

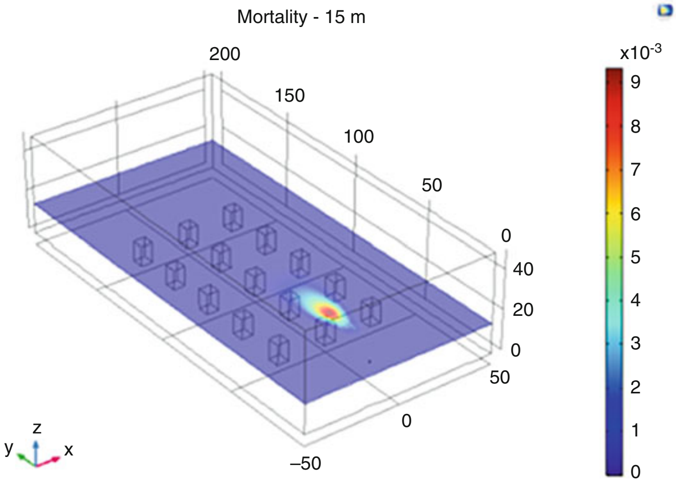

Fig. 12 Mortality at 15 m

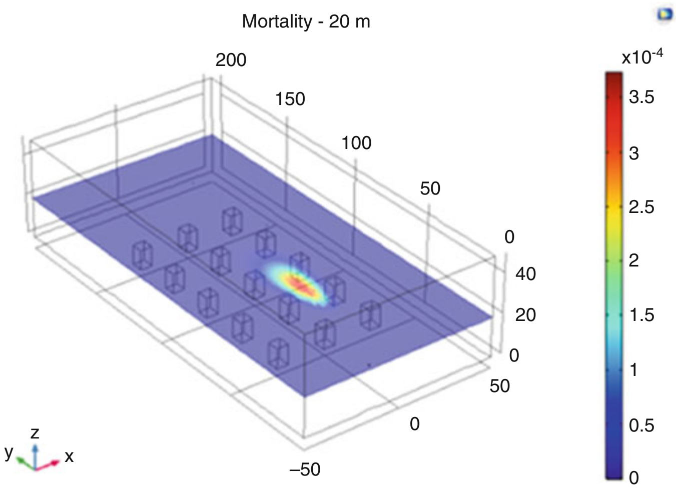

Fig. 13 Mortality at 20 m

4 Conclusions

In this work, a scenario of contamination with chlorine of an urban area was considered as the case study. The continuous and steady-state dispersion of Cl_2 by a wind blowing over the above-mentioned zone was simulated with a CFD code to get the local mass fraction of this gas and to determine the local mortality rate by applying a clinical model. It was found that, due to the limited toxicity of chlorine (lower than that of other poisonous gases used as chemical weapons), an outdoor attempt is effective only at short range [14, 15]. It was also shown that the buildings improve the dispersion of the gas: this leads to an increase of the extension of the area struck by the contamination but also to a reduction of the mean mortality in the plume. This implies that when a low toxicity substance is released, an area with natural or artificial obstacles is likely to be safer than an area without them, whereas when a highly toxic chemical is dispersed, the opposite is likely to happen. That's why it is very important, when first responders have to go on the field, that the nature of the contaminant is known.

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Numerical Analysis of Natural Outbreaks and Intentional Releases of Emerging and Re-emerging Pathogens: Preliminary Evidence

Alessandro Puleio, Jean-François Ciparisse, Orlando Cenciarelli, Valentina Gabbarini, Andrea Malizia, Pasqualino Gaudio, Laura Morciano, Sandro Mancinelli, and Leonardo Palombi

1 Introduction

1.1 Emerging and Re-emerging Infectious Diseases

Frequently associated with war and famine, infectious diseases have for centuries represented a threat to human health [1] and still rank among the leading causes of deaths in the world [2]. Despite the enormous progress achieved by biomedical research, the microorganisms continue to emerge and re-emerge and spread around the world without any possible prediction as a never-ending challenge [3].

The critical importance of emerging and re-emerging infectious diseases in global public health is quite evident considering that more than 25% of the annual deaths worldwide are caused by infectious diseases [4].

The emergence of new infectious diseases or re-emergence of old ones is a direct consequence of modification of host-pathogen interactions: these involve rapid microbial adaptation, human susceptibility to infections, and changes in host behavior, as well as environmental, social, political, and economic factors that condition the relationship between host, pathogen, and environment [4]. Many re-emergences have been tightly related to dramatic changes in the population status, such as wars or natural disasters, which often undermine public health response capacity and compromise host immune defenses [4].

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While most of the public health efforts on this matter are focused to face naturally occurring diseases, the infections that can be intentionally introduced to cause deliberately emerging diseases as a mean of bioterror cannot be underestimated [3].

1.2 Biological Warfare Agents

The use of biological agents (BAs) with the purpose to spread illness and terror is a reality since ancient times and has become a major concern during the last years [5]. The peculiarity of bioterrorism is to have a wide range of actions ranging from false alarms to the use of biological weapons by small terrorist groups up to biological weapon creation programs adopted by individual states throughout history to create mass destruction weapons [6].

Microorganisms such as viruses, bacteria, fungi, protozoa, or toxins produced by them fall into the category of biological warfare agents (BWAs) [7]. Normally, these agents cause severe disease in humans, animals, or plants; they can cause large-scale mortality and may incapacitate a large number of people in a short period of time [8, 9].

BWAs strongly attract many terrorist groups because of different characteristics. BAs aerosols are invisible, silent, odorless, and relatively easily dispersed. They can also be produced in a very easy and cost-effective manner with existing and obsolete technologies. The consequences of using BWA are many. They can quickly produce a mass effect that goes beyond the services and health system [9].

1.3 Measles: The Model for Natural Outbreak

Measles is a serious disease that, before the widespread vaccination program started in 1980, was estimated to cause globally about 2.6 million deaths per year [10]. The susceptible host for measles infection is restricted to humans, and viral transmission implies direct contact or aerosol droplets [11]. The symptomatic manifestation of the disease appears usually after a period between 7 and 14 days after the infection [11]. Typical symptoms include high fever, cough, runny nose, and red watery eyes. These are followed by the onset of rashes that begin on the face and then extend to the whole body and concomitant increase in fever, which spikes to more than 40 °C [11].

Thanks to the widespread diffusion of measles vaccination programs, the incidence of lethal cases associated with the disease has been significantly reduced [10]. During 2000–2015, measles vaccination prevented an estimated 20.3 million deaths. Nevertheless, according to WHO, 134 200 measles deaths globally have been recorded during 2015 [10]. Measles is a highly contagious disease; infectivity is possible from 4 days prior to the onset of the rash to 4 days after the rash erupts [10].

According to CDC, measles is so contagious that an infected individual can likely infect about 90% of the people close to him, who are not immune [11].

The population at risk to develop measles infection includes any nonimmune person, who is not vaccinated or was vaccinated but did not develop immunity, or immunocompromised individuals, whose immune system has been weakened by HIV/AIDS or other diseases [10]. Statistics estimate that severe measles is more likely among poorly nourished young children, in populations with high levels of malnutrition and lacking adequate health care; in these conditions, up to 10% of measles cases result in death.

Normal treatment for measles is based on supportive care that ensures good nutrition, adequate fluid intake, and treatment of dehydration, as well as vitamin A supplement, which can avoid severe complications from the disease [10]. Measles is still common in many developing countries—particularly in parts of Africa and Asia. More than 95% of measles-related deaths occur in poor countries with weak health infrastructures. However, the decrease in vaccination rates in the latest years resulted in a re-emergence of this disease also in developed countries, with a concerning dramatic increase of infection cases [10].

1.4 Anthrax Spores: The Model for Intentional Release

Anthrax is a severe infectious disease that can affect humans and animals. The etiological agent is *Bacillus anthracis*, a gram-positive rod-shaped endospore-forming bacterium. Despite anthrax is a not a contagious disease, individuals can become infected when exposed to infected animals or to anthrax endospores [12]. The severity of the disease is related to the type of infection; three kinds of anthrax infections can occur: cutaneous, inhalation, and gastrointestinal. The cutaneous form is the most common and is usually acquired by direct contact with animal products contaminated with anthrax endospores [12]. Untreated cutaneous anthrax can become systemic, and it is fatal in 5–20% of cases [13]. Gastrointestinal and inhalation forms are less common [12]. Some vaccines are available and can be administered to prevent the disease [12]; after infection, antibiotics can be effective.

The resistance of anthrax spores in the environment is one of the characteristics that make it a suitable BWA. Anthrax endospores are resistant to drying, heat, ultraviolet and ionizing radiation, and chemical disinfectants. They can survive in the environment, especially in the soil, for several years [13]. Anthrax has already been used as BWA [13]; the most recent bioterrorist attack using anthrax spores happened in 2001, in the USA. The delivery of letters containing anthrax spores, addressed to the press and to government officials through the US postal system, resulted in 22 confirmed cases—12 cutaneous and 10 inhalational. The 12 cutaneous patients responded positively to antibiotics, while of the 10 inhalational cases, 4 were fatal [13].

2 Materials and Methods

2.1 STEM

STEM (Spatiotemporal Epidemiological Modeler) software is an open-source program designed to create time-space model of epidemics; STEM is designed to be a flexible software provided with validation tools for the study of outbreaks of infectious diseases under a global perspective [14]. The program is conceived as a series of compartment models, such as the SEIR model by which it is possible to calculate the most likely scenario of an infectious disease outbreak. This is possible thanks to the ability to define the parameters playing a role in the epidemic. The STEM application is provided with geographic information (known as GIS) for any country [15]. STEM treats the world as a graph with a layered and modular structure, in which the program shows the scenario's trend and its filterable results for the compartment of interest in the population. The construction of the scenario involves the creation of three models: geographic, population, and disease model.

For this preliminary work, the simulation using STEM software was played in the West Azerbaijan region in Iran, one of the regions constituting the Kurdistan geographical region. Among the various epidemic mathematical models in the software, we have chosen, according to the software tutorial [14], the epidemic model SEIR. In this model, the population (N) can be divided into four categories: (1) susceptible (S), healthy population at risk of contracting the disease; (2) exposed (E), infected but not yet infectious; (3) infectious (I), infected and infecting others, capable of transmitting disease; (4) removed and recovered (R), population that dies or recovers from the disease [15]. Other epidemiological features of the SEIR model are ε, incubation rate; γ, recovery rate; δ, infectious mortality rate; β, transmission rate; $1/\gamma$, average recovery period; $1/\varepsilon$, average incubation period; μ^*, population birth rate, μ, population mortality rate; and α, immunity loss.

During the simulated epidemic, it was assumed that the population was closed, meaning that demographic changes of births and natural deaths were minimized.

The following data were used for the simulation: (a) size of the population (N), 2813650; (b) number of index cases, 20; (c) period considered, March 1–31, 2017; (d) incubation rate (ε), 0.091; (e) recovery rate (γ), 0.143; (f) infectious mortality rate (δ), 0.00875; (g) transmission rate (β), 0.39; and (h) density of national population, 48.

2.2 COMSOL Multiphysics

The computational fluid dynamics (CFD) is a branch of physics that deals, through numerical simulation, with the study of different types of flow so as to allow for the study of dispersions [16]. The use of this approach, by the COMSOL Multiphysics® Modeling Software, is based on three steps. The software firstly divides the

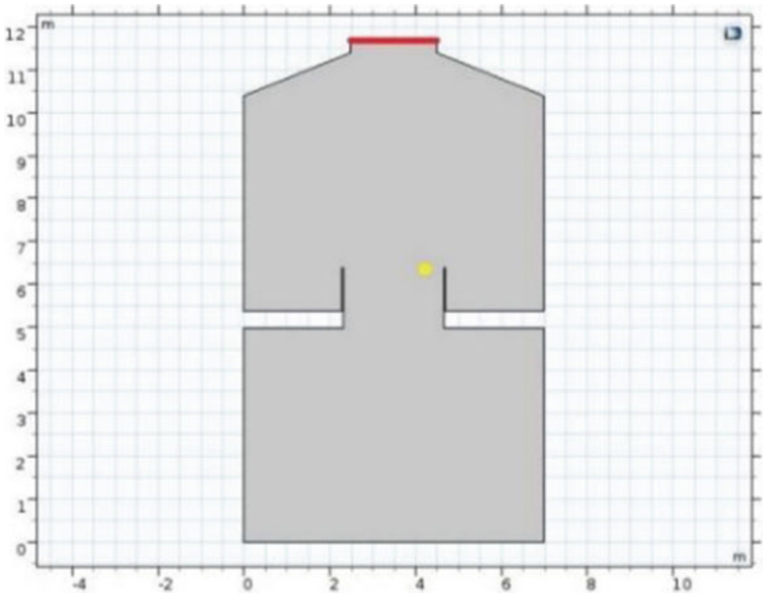

Fig. 1 Computational domain (dimensions are expressed in meters)

computational domain into sub-domains, called cells, useful for solving the equations of the chosen fluid model [16]. This virtual approach to experimentation lets you circumvent all the risks and costs of experiments.

A 2D simulation of the diffusion of anthrax powder in a confined space was carried out in this work. The geometry represents a section of a typical shopping mall, with two stairs. The clusters of anthrax spores are placed in a sphere (yellow star), and they are free to move (Fig. 1). The spore height is 6.4 m. There are no flows in the environment and the skylight at the top of the structure is the only exit path (Fig. 1, red line).

The data used for anthrax spores in the COMSOL simulation were (a) diameter (μm), 100; (b) density (kg/m^3), 1000; and (c) shape, sphere (3D).

The Eulero-Eulero turbulent multiphase model was chosen to carry out the flow simulation, which with its equations considers the interactions between dispersed particles and air. The same model has been used by Ciparisse et al. [16] to simulate anthrax releases.

Fig. 2 Results of STEM simulation of the measles' outbreak starting from the West Azerbaijan region in Iran. Map view of the geographical distribution of the infected; in the square the main information is reported, i.e., the name of the region considered, the area extension in km^2 and the coordinates of the region, the population numbers before the disease occurred, the population numbers after the period considered, and the end time of the period

3 Results

3.1 *Preliminary Study of the Diffusion of Measles*

Figure 2 represents the geographical distribution of those infected (I) by the disease, starting the simulation from the West Azerbaijan region in Iran. In particular, it is possible to see how the presence of infected people extends to neighboring regions: East Azerbaijan, Kurdistan, and the most affected Zanjan region. We can observe the presence of few infected persons even in regions not directly bordering the region of the epidemic origin, Hamadan and Markazi.

Figure 3 shows the progress of epidemiological data for the entire duration of the simulation. Contrariwise to the other curves, the infected line shows a peak of 20 individuals on the first day, according to the number of index case considered for the simulation. After this initial peak, it is possible to see as the number seems to decrease for about 10 days; this period corresponds to the incubation time of the disease. The graph does not show the S value as this value corresponds to the total number of the population, while it is possible to observe the curve of the D value representing the number of deaths due to the epidemic.

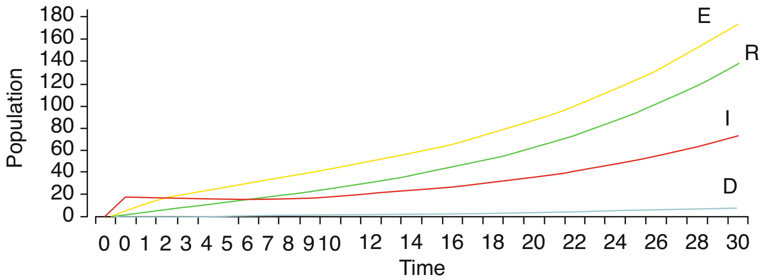

Fig. 3 The progress of epidemiological data for the entire duration of STEM simulation of the measles' outbreak starting from the West Azerbaijan region in Iran. (*D* is disease deaths, *I* is the infected people, *R* is recovered and removed people, and *E* is exposed people)

3.2 Preliminary Study of the Diffusion of Anthrax Spores After Intentional Release

Figure 4 shows the anthrax endospore volume fraction after 0.5, 1, and 1.4 s. The clusters drop due to gravity, and therefore aerodynamic drag occurs. Thus, solid particles begin to mix with the surrounding air, and the initial cloud of clusters gets flat due to the compressive action of drag and weight. Behind the falling powder, asymmetric vortices are generated, due to the asymmetry of the boundary conditions, as the initial cloud's center doesn't lie on the vertical symmetry axis of the structure. This causes an aerodynamic drag not directed only vertically, so the powder starts deviating horizontally toward the right. After less than 2 s, the majority of endospores are deposited on the ground. The low dispersion of endospores is mainly due to the large diameter. In fact, if we have smaller particles, the dispersion will be larger, since the drag force dominates the motion.

4 Discussion and Conclusions

Two innovative approaches were applied in this preliminary work in order to assess their appropriateness to describe a natural outbreak and an intentional release of emerging/re-emerging pathogens, measles and anthrax, respectively.

A natural outbreak of measles was modeled with the Spatiotemporal Epidemiological Modeler (STEM) software in a representative Iranian region belonging to the geo-cultural region of Kurdistan; the software output provides the information required for an in-depth analysis of the effects of an outbreak of measles.

The intentional release of anthrax spores was modeled using the computational fluid dynamics (CFD) COMSOL Multiphysics® Modeling Software. The simulation, carried out in a confined environment, was perfectly described by the computational approach; this tool will be used in order to analyze the diffusion in a more

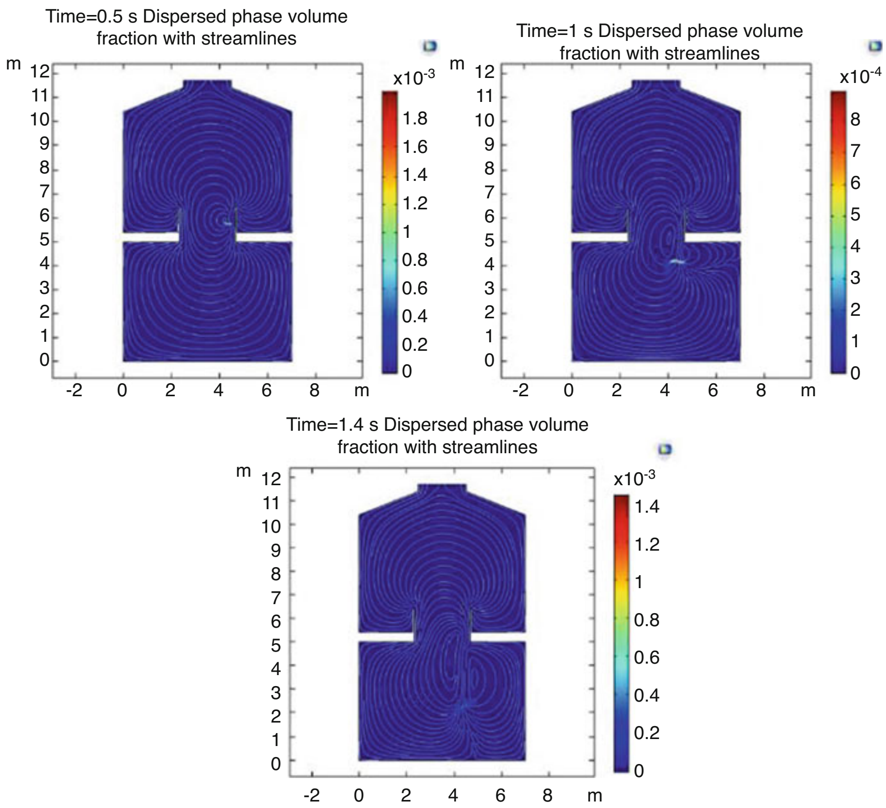

Fig. 4 Dispersed phase volume fraction with streamlines

complex environment taking into account the infrastructural barriers and the putative targets.

Both approaches have shown advantages and limits; the Spatiotemporal Epidemiological Modeler can properly describe the diffusion of an infectious disease among humans; the computational fluid dynamics COMSOL Multiphysics® Modeling Software can be used to model the dispersion of BAs without describing further spreads of the disease.

These two approaches will be applied in the development of a master's thesis in medical biotechnology. Merging medicine, biology, and engineering disciplines in the analysis of natural and intentional release of emerging and re-emerging pathogens is important to guarantee the proper proposal of mitigation measures and to understand the effects in the short, middle, and long period.

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Explosion Risks Inside Pharmaceutical, Agro-alimentary and Energetic Industries as a Consequence of Critical Dust Conditions: A Numerical Model to Prevent These Accidents

Riccardo Rossi, Jean-François Ciparisse, Pasquale Gaudio, and Andrea Malizia

1 Introduction

Dust explosions are critical safety issues in the industry field if we consider the number of deaths produced by these events [1–3]. Huge accidents caused by dust explosions are not uncommon; we remember the Benxihu Colliery explosion in China in 1942 [4], the Imperial Sugar explosion in the United States [5] and the most recent Formosa Fun Coast accident in Taiwan, an explosion caused by coloured starch powder during an outdoor music festival in Taiwan [6]. This phenomenon happens when a combustible dust is mixed in the air with a certain concentration and realizes an explosive mixture. The severity of dust explosions is function of many variables, such as concentration, type of dust, turbulence and moisture [7, 8]. The immediate damages caused by the explosion are usually the most severe and important. Anyway, we have to take into account the possible scenarios that dust explosion could cause. For example, we can consider the dispersion of toxic and dangerous chemicals because of pharmaceutical plant explosion. A worst case is the dispersion of radionuclides, such as a possible dust explosion of a nuclear plant because of loss of vacuum accidents (LOVAs) [9–11].

This work is born with the aim of showing how computational fluid dynamics (CFDs) may help in dust explosion prevention [11]. CFDs are algorithms able to replicate the fluid dynamics in a certain geometry. In this case, the idea is to simulate

It is an “Invited paper” and Dr. Malizia was an “Invited speaker” of the conference.

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the dispersion of dust in the environment, in order to calculate the explosibility risk. First, we have to describe how dust explosion occurs.

The dust explosion is the rapid combustion of fine particles suspended in air or, on a more general note, in oxidants. The conditions required to cause a dust explosion are resumed in a famous diagram known as the pentagon of dust explosion [8]. Infact, it is necessary the simultaneous presence of five conditions to cause a dust explosion: combustible dust, oxidant atmosphere, dust concentration within certain values, the "dust explosion range". This range is characterized by two limits, known as lower explosion limit (LEL) and upper explosion limit (UEL); ignition sources (sparks, heat sources, etc.) and enclosed environment (not always necessary). The combustible dust condition is easy to understand; if the dust can burn, the dust may explode. Several common dust are combustible, such as coal, sawdust, grain, flour, starch, coffee and sugar dust. Then, these phenomena interest many fields. The second condition, the oxidant presence, is usually achieved because of oxygen in the air. When possible, an inert atmosphere is used to prevent explosions. The concentration condition is maybe the hardest to reach, since the lower explosion limit is usually higher than the safety limit of dust in work environments. Several ignition sources may cause a dust explosion. Flames, friction, hot surfaces and static electricity are some of the most common ignition sources. The enclosed environment is not a strictly required condition, but it usually determines an aggravation of the accident.

The safety measures taken to face dust explosion are numerous and depend on the environment to protect [8, 12]. The first practice is the periodical elimination of dust deposits, which could explode because of dust resuspension or produce secondary explosions. An inert atmosphere, such as nitrogen and argon, can be used. Anyway, their usage is limited by the risk of asphyxiation of the workers [13]. In coal mining industries, coal dust is diluted with incombustible stone dust or sprayed with water [13]. These preventive actions decrease the probability of dust ignition and propagation. Furthermore, there are many control and suppression systems to avoid and mitigate the dust explosion accident, such as wetting, deflagration venting, etc. [8].

This work considers a filling silo as case study and analyses where and when the dust explosion could be a risk.

2 Materials and Methods

Evaluation of dust explosion risk inside a filling silo is considered as a case study. In this work, the evaluation of explosion risk is achieved bearing in mind only the dust concentration.

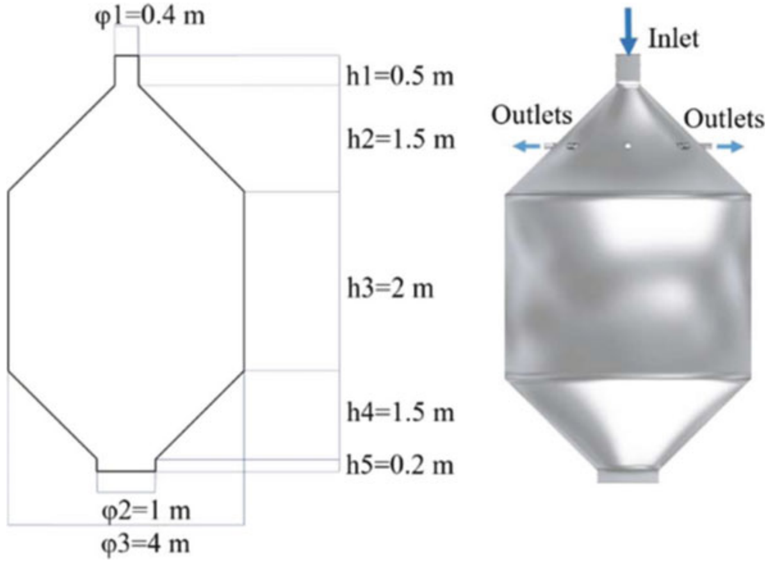

Fig. 1 Geometry of the silo, sizes and inlet and outlet

2.1 Geometry and Mesh

The silo considered in the case study is built following some guidelines in literature [14]. The geometry and the mesh of the silo are generated through gambit.

The total height of the silo is 5.7 m. The mean diameter of the silo is large (4 m). The inlet is positioned above the silos, with a diameter of 0.4 m. Vent valves are placed in the upper region of the silo. The vent valves are eight, and these allow to the air (and the dust) to flow outside. The region below is closed. Figure 1 shows the silo geometry.

The mesh is compounded by tetrahedral elements. Three kinds of mesh have been tried, and an analysis of convergence has been done. Medium, fine and extra fine are the three cases considered.

2.2 Mathematical Model

A multiphase CFD is needed to replicate the case study. The software used to perform the simulation is Ansys CFX. The Euler-Euler approach is used. We have two phases; the continuum phase, which is the air, and the dispersed phase, which is the dust. In the following equation, the subscript “c” indicates that the variable belongs to the continuum phase, while the subscript “d” to the dispersed phase. We consider an incompressible model. A deep analysis of the model is described in

Ansys documentation [15], while the book of Brennen defines well the theory of multiphase flows [16].

In multiphase models, the conservation equations changes in order to take into account the interactions between continuum phase and dispersed phase. Firstly, we consider the continuity equations:

$$\frac{\partial \varphi_{\mathrm{c}}}{\partial t} + \nabla \cdot \left(\varphi_{\mathrm{c}} \boldsymbol{u}_{\mathbf{c}} \right) = \dot{m}_{\mathrm{cd}}; \frac{\partial \varphi_{\mathrm{d}}}{\partial t} + \nabla \cdot \left(\varphi_{\mathrm{d}} \boldsymbol{u}_{\mathbf{d}} \right) = \dot{m}_{\mathrm{dc}}; \tag{1}$$

where φ is the volume fraction of the phase, u is the local velocity of the phase and $\dot{m}_{\mathrm{cd}}$ (and $\dot{m}_{\mathrm{dc}}$) represents the mass exchange between the phases. Then, we have to describe the momentum equations:

$$\begin{aligned} \frac{\partial (\varphi_{\mathrm{c}} \rho_{\mathrm{c}} \boldsymbol{u}_{\mathbf{c}})}{\partial t} + \nabla \cdot \left(\varphi_{\mathrm{c}} \rho_{\mathrm{c}} \boldsymbol{u}_{\mathbf{c}} \boldsymbol{u}_{\mathbf{c}} \right) = -\varphi_{\mathrm{c}} \nabla p + \nabla \cdot \boldsymbol{\tau}_{\mathbf{c}} + \varphi_{\mathrm{c}} \rho_{\mathrm{c}} \boldsymbol{g} + \boldsymbol{R}_{\mathrm{cd}} \\ + \dot{m}_{\mathrm{cd}} \boldsymbol{u}_{\mathbf{cd}} + \varphi_{\mathrm{c}} \rho_{\mathrm{c}} \left(\boldsymbol{F}_{\mathbf{c}} + \boldsymbol{F}_{\mathbf{lift,c}} + \boldsymbol{F}_{\mathbf{vm,c}} \right) \end{aligned} \tag{2}$$

where ρ_{c} is the density of the continuum phase, p is the pressure, $\boldsymbol{g}$ is the gravity acceleration and $\boldsymbol{\tau}_{\mathbf{c}}$ is the stress-strain tensor. $\boldsymbol{F}_{\mathbf{c}}$ is the external body force, which is zero in this case study, while $\boldsymbol{F}_{\mathbf{lift,c}}$ is the lift force. This force is usually very small and negligible if compared with the drag force. Its influence is not calculated. $\boldsymbol{F}_{\mathbf{vm,c}}$ is the virtual mass force, which is a force that arises when a phase accelerates inside another phase. $\boldsymbol{u}_{\mathbf{cd}}$ is the interphase velocity, which is equal to the velocity of the phase that is transferred to the other phase. Finally, $\boldsymbol{R}_{\mathrm{cd}}$ is the interaction force between phases. This force plays the most important role in the interaction between the two phases. This force can be computed in different ways. In this work, we consider the Gidaspow model. The energy equation is not computed since we assume an isothermal behaviour. Finally, a turbulence model is used to taking into account the eddies smaller of the elements. For the continuum phase, the model used is a RANS $k - \varepsilon$, while the turbulence of dispersed phase is modelled through a zero-equation model that is based in the geometric length scale and the mean solution velocity.

2.3 Boundary and Initial Conditions

The boundary conditions are important parameters to set in a CFD in order to replicate the phenomenon. In this case, we have three different boundary conditions: the walls, the inlet and the outlet. The walls are characterized by a no-slip condition; it means that the velocity of both phases must be zero. The model is isothermal, and then there is not the necessity to model a heat exchange through the wall. The outlets are the vent valves. The condition used is the pressure outlet. Both the phases are free to flow outside. The outlet pressure is the atmospheric pressure (101325 Pa). The inlet is the last boundary condition. In this case, we consider a normal velocity inlet condition, which indirectly involve a mass flow rate inlet. Two different inlet functions are considered. The first represent a slow filling of the silo, with a gradual increase of the inlet velocity and a slight decrease after a certain time. This inlet function is characterized by a transient function, described by the following equation:

$$u(t) = \frac{te^{-\frac{t}{40}}}{3,5} \tag{3}$$

where t represents the time variable. This case will be called case 1. The second inlet function represents a fast filling of the silos. At the beginning the inlet velocity is 5 m/s, and after a certain time (30 s) the velocity falls down to 0.1 m/s. This is the case 2.

Last, we have to set the initial conditions. The case study is a filling silo that is empty of dust at the beginning. Therefore, the initial dust volume fraction is zero as well as the mean velocity of both the phases. The pressure is one atmosphere (101325 Pa), while the temperature is 298.15 K (25 °C). Turbulence intensity is set as "medium", i.e. it is equal to 5%.

2.4 Risk Explosion Variable

As we declared previously, the aim of this work is to show how a CFD model could help in dust explosion prevention. The model description allows us to calculate at any time all the variables introduced, such as velocity, pressure and volume fractions. Anyway, we have to evaluate when and where dust explosion may occur. In this case, we use a simple model, a "risk" or "not risk" approach, based only on dust concentration. Anyway, we have to remember that dust explosion risk and severity are functions of many variables and the explosion may happen only when the conditions of the pentagon are reached. The model works taking into account the lower explosion limit and the upper explosion limit. If the concentration of dust is in the range, the explosion risk of the mesh element i is one, while if the concentration is out of range, the explosion risk is zero. Therefore, we have a map of risks at any time. Then, we can perform an average of the risk doing a weighted average where the weights are the element volumes. This variable gives information about the percentage of volume that has dangerous concentration. The explosive characteristics of dust are taken from the literature [16, 17].

3 Results and Discussion

The analysis of convergence has been made monitoring the explosion risk, which is the most important variable in this work. The difference between medium and fine mesh is too large (sometimes large than 15%) to accept the medium mesh. Contrariwise, the difference between fine and extra-fine mesh is not so large, with a medium value of 0.2% and a maximum of 1.1%. Therefore, the fine mesh is used to perform the silo analysis. Dust explosion became a risk when the concentration of dust is inside the explosion range. Then, we talk about explosion risk only when the concentration is inside this range, through the method described in "Risk Explosion Variable" section. The following results refer to case 1.

Figure 2a shows the concentration field of flour in the plane *xz* with $y = 0$ at the time $t = 2$ s. The field is represented in logarithm scale. As we can see, the larger values of concentration are reached in the inlet region. Then, the most part of dust falls down because of gravity with a portion of it that is mobilized inside the entire silo. Figure 2b shows the explosion risk map. There are two prevalent colours, blue that indicates no risk of explosion and red that indicates a possible risk. The intermediate colours are obtained because smoothing value between elements.

Figure 3a shows the trend of explosibility risk and average concentration in function of time inside the silo. The filling of the silo is characterized by a transient where the flour begins to flow inside the silo. The first seconds of the filling are the most critical, since the flour concentration arises from zero to the maximum value when it deposits. In the first instants, several regions of silo reach a concentration that is in the explosive range (about 78% of the silo is under risk at $t = 4$ s). Anyway, after 10 s, the explosion risk falls down to zero because the concentration reaches larger values of the upper explosion limit, and then silo dust explosion is a serious threat only at the beginning. Figure 3b shows the average map of explosion risk, obtained as the average of the explosion risk from $t = 2$ s to $t = 10$ s, that is, the interval time when the explosion risk is larger than zero. The map shows that the risk is possible to see that the risk is almost homogenous, excluding the region below and the inlet region. The inlet region does not have risk since this region reaches quickly

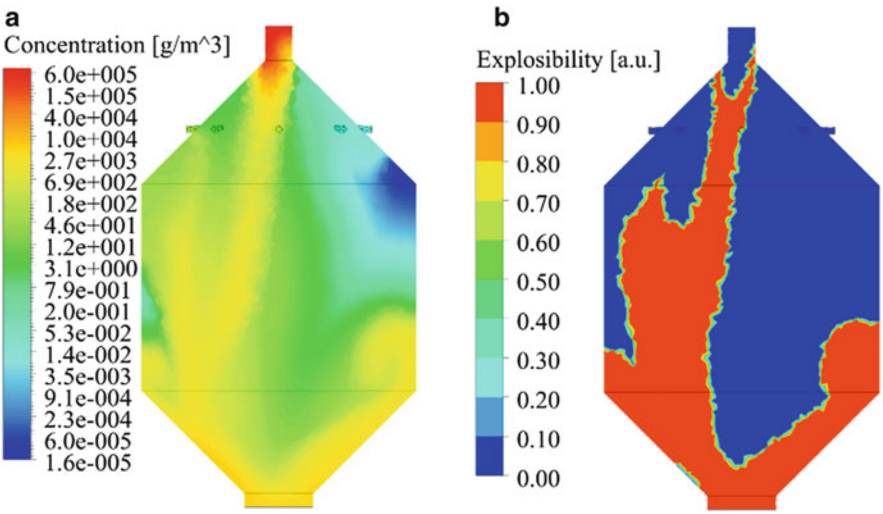

Fig. 2 Dust concentration at $t = 2$ s along the plane *x–z* (**a**) and the explosion risk at the same condition (**b**)

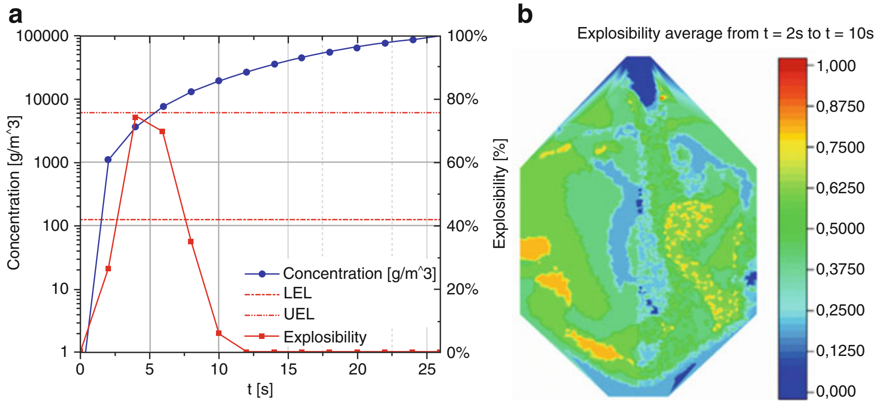

Fig. 3 Explosibility risk and concentration in function of time with LEL and UEL highlighted

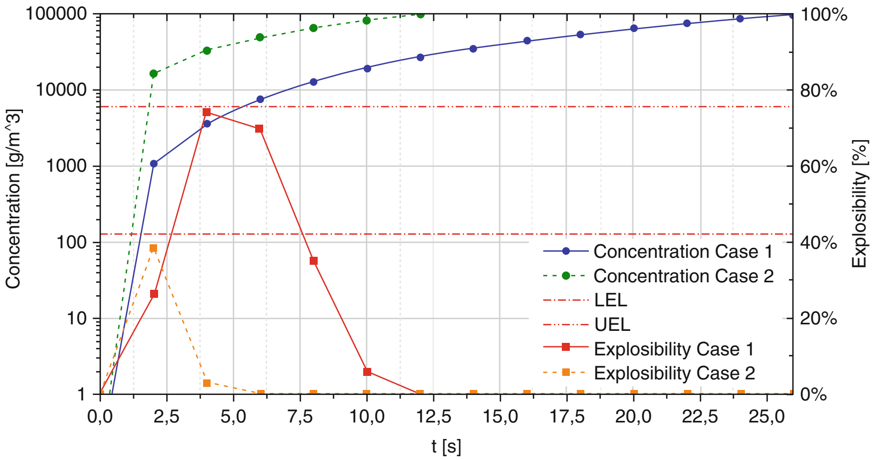

Fig. 4 Explosibility risk and concentration in function of time with LEL and UEL in the two cases. The case with larger filling velocity shows a shorter time of explosibility risk

a concentration higher than the upper explosion limit. The same phenomenon occurs in the region below because it is where the dust deposits quickly (Fig. 4).

From these results we should conclude that the faster is the filling of the silo, the lower is the risk. Anyway, this should be not true, since the explosibility risk has been calculated through a very simple model that does not take into account other important variables in dust explosion phenomenon. For example, faster velocities could improve larger friction and electrostatic charging of the dust, which may be the ignition source of the explosion. Then, it is clear the necessity to develop a mathematical model to evaluate the risk of dust explosion in a CFD. This model could improve the use of CFD in dust explosion prevention.

4 Conclusion

The dust explosion is a risk that threatens several industries and environments where combustible dust is present. These events usually involve large numbers of deaths and injuries directly from the explosion consequences. Furthermore, an additional threat should be considered: the explosion of enclosed environment which work with dangerous chemicals and radionuclides, such as a pharmaceutical industry or a nuclear power plant. This work wants to show CFD may help in dust explosion prevention. A filling silo of flour is considered as case study. The filling is replicated through a multiphase model, and the risk explosibility has been modelled through a simplified model that takes into account only the dust concentration. Mesh sensitivity has been performed using three different meshes. The authors show the obtainable results from this kind of tools, especially the evaluation of when and where the silo is subject to high explosion risk. Then, the work analysed how the explosibility risk changes when we modify how the dust flows inside the silo. The results show clearly that the inlet function modifies deeply the risk of dust explosion.

Anyway, the model used to evaluate the explosibility risk lacks entirety. In fact, a more complex model is needed in order to take into account all the variables that influences the dust explosion phenomenon. The presence of moisture, friction, high temperatures and turbulence are just some of the several variables that influence the explosion risk and severity. Then, the authors will investigate and try to develop a more realistic model, which can be used to improve dust explosion mitigation and prevention. Some occurred accidents will be replicated by this model in order to verify the functioning and the accuracy of it.

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IoT-Based eHealth Toward Decision Support System for CBRNE Events

Parag Chatterjee, Leandro J. Cymberknop, and Ricardo L. Armentano

1 Introduction

Internet of Things is a revolutionary technology which when clubbed with eHealth systems provides a comprehensive infrastructure toward efficient and advanced public healthcare. Data analytics in healthcare not only supports better treatment strategies but also helps in deciphering newer correlations between health parameters which give rise to better predictions of diseases and health risks [1]. Internet of Things (IoT) and data analytics play a big role in this field ranging from ubiquitous data collection to detailed analysis for deeper insights into the data, in addition to seamless resource sharing. In case of CBRNE incidents, one of the key necessities is a seamless connectivity and coordination between all the stakeholders for mutual sharing of data and information, and health data stands highly significant in this respect. An IoT-based healthcare system is potentially beneficial during a CBRNE emergency especially by providing a decision support system to facilitate fast treatment and emergency management. This work is focused on the aspects of remote monitoring of people's health based on IoT devices, storing the key health records, and finally devising a decision support system using data analytics to support the medical personnel in the event of an emergency, in addition to sharing these resources among different stakeholders for fast response and efficient treatment.

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2 IoT-Based Connected Decision Support System

A typical IoT-based eHealth system consists of multiple components to provide the complete healthcare platform (Fig. 1 and Table 1) [2].

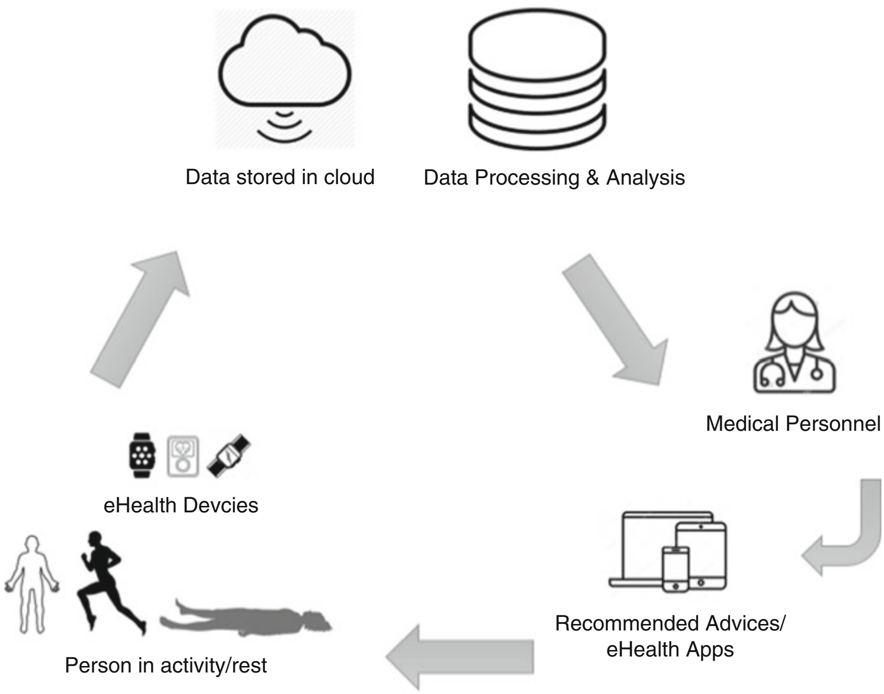

Fig. 1 Holistic view of the components and operation of a typical IoT-based eHealth system

Table 1 Components of a typical IoT-eHealth system

Components	Functionalities
eHealth devices	These devices are typically wearable, with built-in sensors which measure the physiological data of a person. These devices may have small storage capabilities as well
Data storage	Usually each user holds a uniquely identified personal profile, where all the health-related data is stored virtually
Data analytics and decision support system	Data analytics are an integral part of efficient eHealth systems. The stored data is analyzed in different ways to have better visualization of a person's health as well as the overall health conditions of the mass. Moreover, based on the analysis, a decision support system functions aiming to assist the medical personnel
Final advice	Based on the insights from the decision support system, the medical personnel prescribe the necessary actions

In the event of treating people after a CBRNE emergency, one of the major issues faced is the disruption of communication between different entities, followed by lack of organized personal health records. Other than treating the people hit by the CBRNE event, a decision support system based on the medical history of people would count significantly helpful toward the medical personnel in carrying out the treatment. But such a system needs a concrete foundation, involving collection, storage, and analysis of people's health records.

2.1 Electronic Health Records and IoT-Based Healthcare Devices

One of the fundamental aspects of IoT is data management. Medical and healthcare records constitute a huge share in this respect. However, there is a constant upgradation and shift to electronic health records. Less than a decade ago, nine out of ten doctors in the USA updated their patients' records by hand and stored them in color-coded files. By the end of 2017, approximately 90% of office-based physicians nationwide will be using electronic health records [3]. Medical data are inherently complicated because so many diverse components are important: quantitative test results; analog output such as electrocardiograms and electroencephalograms; pictorial output such as radiographs, computed tomography, magnetic resonance imaging, nuclear medicine scans, and ultrasound; as well as handwritten notes [4]. Clinical research databases can be used to provide rapid answers to queries such as possible drug interactions, risk factors, indicator thresholds, and disease signatures [5]. IoT contributes actively in this area by making the entire method of data collection, storing, and processing more efficient. The foundation of eHealth being data, it is crucial to manage health records well.

IoT-based healthcare devices facilitate this task of having electronic health records, in addition to minimizing the infrastructural costs involved and using automated in-home measurement techniques using IoT devices [6]. Several state-of-the-art IoT devices are capable of measuring physiological parameters like heart rate, blood pressure, activity, body temperature, weight, blood glucose, and cholesterol. Therefore, these IoT devices help collecting the health profile and store it virtually, linked to each person uniquely.

2.2 Data Analysis Toward Decision Support System

Once the health-related data is stored, the crucial task is to analyze the data carefully for deeper insights. Interestingly, analysis of the basic physiological parameters produces several conclusions which coincide with the medical decisions after supervision. Moreover, regular analysis of people's health-related data makes it

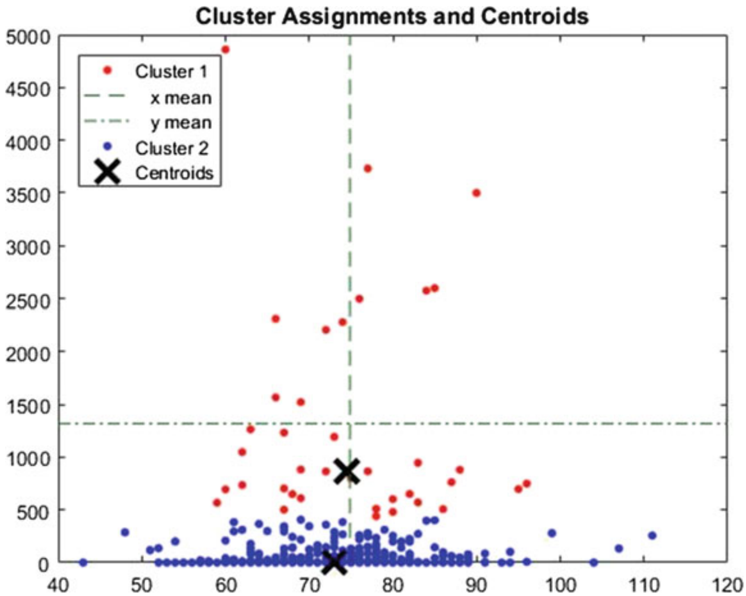

Fig. 2 Example of visualization of risk groups through clustering [2]

possible to ascertain several health risks well in advance, like risks toward cardiometabolic and chronic diseases. Moreover, it shows the holistic view to the overall health conditions of a group of people, facilitating the identification of high-risk groups. For example, performing a cluster analysis on the health data of a group of people identifies the most impactful health parameter and also separates the group of people into clusters, signifying their respective risks. This analysis constitutes one of the key components of the decision support system which aims to provide a comprehensive view to people's health (Fig. 2).

Another key component of the decision support system is the logic to support the treatment in case of a CBRNE emergency. It involves an extensive set of databases, followed by the medical logic to guide a CBRNE treatment. This conditional logic needs to be implemented centrally, so that it can be accessed from the distributed user locations.

2.3 Working of the System

In case of a CBRNE event, one of the major issues is the seamless information exchange between the stakeholders and medical personnel. The entire medical and healthcare profile being stored inside the common database makes it easier for the people involved in the treatment to easily access the summarized health profile of a person or of the whole group of people. Treating people after a CBRNE event could be twofold—personalized and generalized. Since people have their personal health profile stored against their unique identity using the IoT devices, accessing those data gets easy, which facilitates and helps taking decisions toward personalized treatment. On the other hand, data analytics show the holistic view of the entire health profile of a group of people, which facilitates mass treatment, supported by the decision support system. Based on the analysis and the instructions from the decision support system, treatment gets more structured and efficient. Moreover, a ubiquitous IoT-based platform enables different stakeholders to share the same information and update their insights and data into the system in a distributed manner. This implies multiple service access points to the IoT-based decision support system, which enables the treatment to be carried out in an extensive and distributed way, but still relying on the common platform of sharing.

3 Conclusion

IoT-based eHealth system has its application in multifarious fields. The primary focus being in personalized and efficient treatment, a comprehensive IoT-based healthcare system counts significant toward post-CBRNE emergencies. Primarily, people's health-related data being collected using IoT devices and stored at a common shared storage makes it possible for authorized entities to access and analyze it for efficient treatment. But on the other hand, analysis on this health-related data opens up newer dimensions and insights to the data, which in turn stands significant in case of a CBRNE event. Therefore, such an eHealth system opens newer possibilities to the CBRNE community to make use of the IoT platform and intelligent analytics to share health-related data between stakeholders and also to take advantage of the decision support system for efficient treatment strategies [7].

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Game Theory as Decision-Making Tool in Conventional and Nonconventional Events

Alba Iannotti, Riccardo Rossi, and Andrea Malizia

1 Introduction

The Chemical, Biological, Radiological, Nuclear and Explosive (CBRNe) defence is a complex system with the aim to protect the people and the environment from nonconventional accidents [1, 2]. This system needs an integration of several fields, such as scientific, communication, law, economics and politics. Between these fields, management is vital. In fact, the speed of interventions could be crucial in the determination of critical issues and damages involved by an accident. Other times, the decisions to make could be sensible to several aspects, such as public opinion, political and economic issues. These aspects make decision-making complex and critical. Therefore, software tools are usually used to help decision-makers [3–5].

This work introduces the game theory in CBRNe decision-making and wants to show its potential and critical properties. The game theory is a branch of mathematical models and born to study the conflicts and cooperation between intelligent and rational decision-makers [6, 7]. It means that the decision of one decision-maker, called in this algorithm "player", is optimised taking into account also the decision that any player could take. There are several kinds of game theory algorithms. Anyway, the greater distinction is about cooperative and non-cooperative game. In the cooperative game, the players can interact between themselves to reach the solution. Contrariwise, the non-cooperative algorithms do not allow the interaction

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between the players. Noam Nisan et al. [8] describe in detail the game theory algorithms. The prisoner's dilemma is a useful example to understand how the game theory works. We have two prisoners. Each prisoner has to take a decision between two possibilities: confess or neglect. If both confess, they have to pass 5 years in prison. If both neglect, the years are only one. If one confesses and the other neglects, the prisoner who neglects has to pass 20 years in prison, while the other is released. The number of years is called "payoffs" in the game theory. The two prisoners cannot talk between them. When there is no communication, the algorithm is "non-cooperative". The game theory algorithm is able to compute the most probable ending. A deep description of prisoner's dilemma and game theory is given by [9].

The transloading of chemical weapons from Syria to Gioia Tauro is considered as case study in this work. After the start of Syrian civil war (2011), the Syrian government used chemical weapon agents (CWA) against civilians, violating the Chemical Weapons Convention (CWC). Therefore, the OPCW, after several site examinations in Syria, decided to impose the CWA transloading and destruction. This case had involved the participation of many states. A deep description of the event can be found in the literature [10–14].

2 Materials and Methods

The problem has been simplified in order to make the case simpler to compute and understand. We consider only two players, the OPCW and the Syrian government, which are the main subjects of the crisis. The algorithm is non-cooperative.

2.1 Software Description and Prisoner's Dilemma Example

Gambit is the software used to solve the game theory algorithms and the Nash equilibrium. Players and payoffs are the variables that must be set in the software. As example, we consider the prisoner's dilemma.

Figure 1 shows the gambit interface in the prisoner's dilemma. Any colour characterises a player. The coloured points represent a choice point, while the black point is the arrival point. The numbers adjacent to the black point are the payoffs of each player. The segments are the possible paths. Even if there are consecutive segments, the choices are computed simultaneously.

Figure 2 shows the solution given by Gambit at the prisoner's dilemma. There is only a viable path, the confess-confess, which is the right solution of that problem. This path represents also the Nash equilibrium in this case.

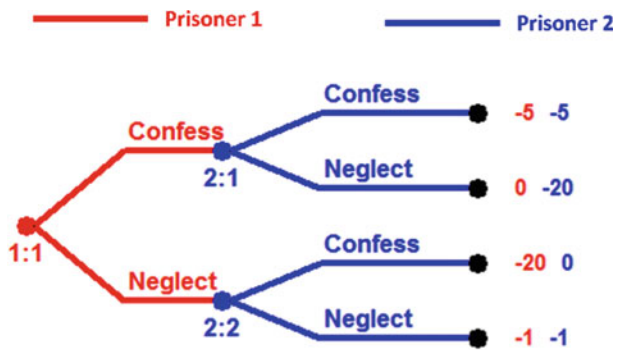

Fig. 1 Prisoner's dilemma tree

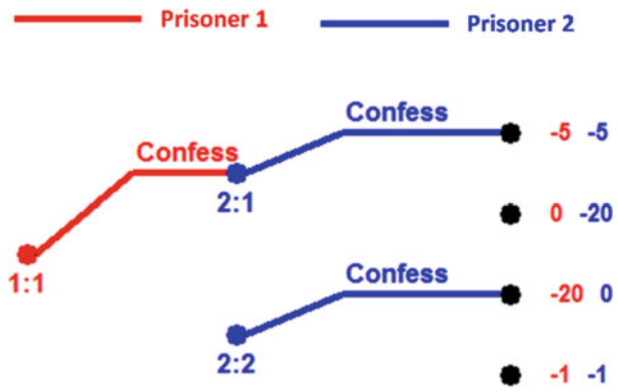

Fig. 2 Prisoner's dilemma tree—solution

2.2 *Case Study Payoffs*

The largest trouble in the use of game theory is the assignment of payoffs. In the case of prisoner's dilemma, it is not a problem since we can easily quantify the payoffs through the years. The problematic arises when the payoffs must be quantified from something that is not a number. In this work, the authors supposed payoffs following a law based on economics and political point of views.

The Syrian government is solicited to leave the chemical weapon agents to OPCW. At the same time, OPCW must decide if it wants to intervene and how to intervene. Therefore, both players have three possibilities: belligerent (B), cooperative (C) and give up (G). Nine possibilities arise:

1. OPCW: B, Syria: B—Both players take a belligerent way. In a political and economic point of view, this is not the best way to interact for OPCW: Strength use as first approach is usually frowned upon. Therefore, there are high costs. In case of Syria, the internal political view could be positive, since Syrian resistance

wants to be independent by external nations. Furthermore, chemical weapons are a strong weapon for the Syria. Then, the payoffs are 0 for OPCW and 5 for Syria (0, 5).

2. OPCW: B, Syria: C—In this case, OPCW political view decreases (since it uses a belligerent manner with a cooperative nation). Anyway, economic losses decrease. Syria loses internal political consensus. Furthermore, it is not prepared to belligerent resistance. The payoffs are −5 for OPCW and −5 for Syria (−5, −5).
3. OPCW: B, Syria: G—OPCW payoffs do not change respect to the previous case (B, C). Syria has the minimum payoff value since it loses chemical weapons and internal political consensus and it is not ready for belligerent resistances. The payoffs are (−5, −10).
4. OPCW: C, Syria: B—OPCW is cooperative: it is well thought by external political point of view. Anyway, it encounters belligerent resistances. Syrian internal political view is good, and it does not encounter strong resistances. The payoffs are 0 for OPCW and 5 for Syria (0, 5).
5. OPCW: C, Syria: C—OPCW has good political view and no belligerent resistances. Syria is frowned upon by internal politics. The payoffs are 10 for OPCW and 0 for Syria (10, 0).
6. OPCW: C, Syria: G—This is the best conclusion for OPCW. It has good political view and no resistances. Contrariwise, this is the worst case for Syria: it loses chemical weapons and internal political consensus. The payoffs are 10 for OPCW and −10 for Syria (10, −10).
7. OPCW: G, Syria: B—OPCW does not carry out its aim while Syria keeps chemical weapons. The payoffs are −10 for OPCW and 10 for Syria (−10, 10).
8. OPCW: G, Syria: C—OPCW does not carry out its aim. Syria keeps chemical weapons but cooperation is frowned upon by internal politics. The payoffs are −10 for OPCW and 5 for Syria (−10, 5).
9. OPCW: G, Syria: G—OPCW and Syria show lack of interest in chemical weapons. Anyway, Syria keeps the chemical weapons. The payoffs are −10 for OPCW and 10 for Syria (−10, 10).

3 Results

Computing the game theory algorithms, we can understand which are the accessible paths of choice and if the Nash equilibrium exists.

Table 1 shows the payoffs matrix. It resumes the payoffs of each player in function of each possible path of choices. At each colour corresponds a player.

The diagram at the left of Fig. 3 shows the tree of the Syria-OPCW case study. We can see the nine paths near the payoffs of each solution. Computing the game theory algorithm, we obtained the diagram at the right of the same figure. As we can see, we have two paths with the same probability. The possible paths are (B, B) and

Table 1 Payoffs matrix

		SYRIA					
		B		C		G	
OPCW	B	0	5	-5	-5	-5	-10
	C	0	5	10	0	10	-10
	G	-10	10	-10	5	-10	10

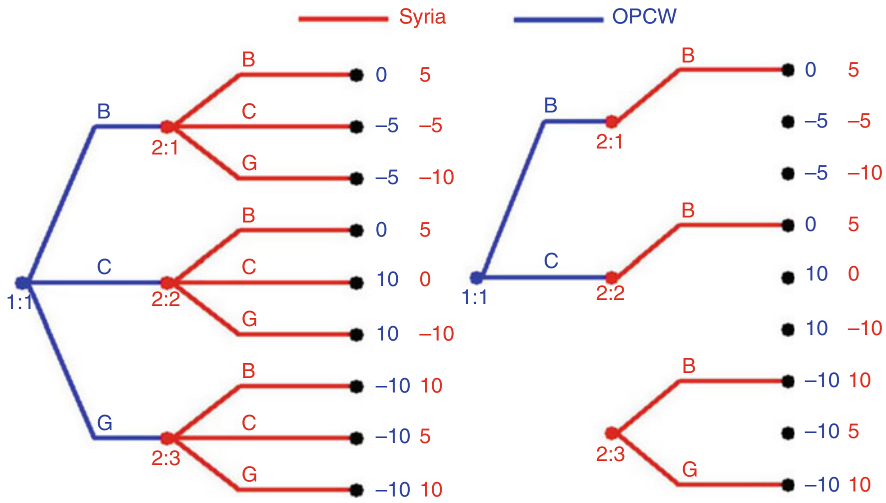

Fig. 3 Syria-OPCW case study tree

(C, B). It means that Syria best decision is to resist to OPCW request, while OPCW can decide if it goes "belligerent" or "cooperative".

At this point it is clear how game theory works. The next question is: How could it help decision-makers? The answer is: It depends. Let's suppose that OPCW wants to use the game theory. Through the solution, OPCW knows that Syria could take one decision: "belligerent". Therefore, OPCW is prepared to take the countermeasures. In the same ways, if Syria uses the game theory, it can exclude the "give-up" possibility of OPCW.

Anyway, we have to highlight the critical aspects of game theory. First, game theory supposes that each player reasons following a game theory approach. Then, the payoffs are very hard to set in situation where there are no quantifiable scores. For example, in the present case study, the payoffs are very hard to quantify. Social, political and economic aspects rule the payoffs. Therefore, the use of game theory in these aspects requires an important effort in payoff quantification. Furthermore, the game supposes that the playoffs are evaluated in the same ways by all the players. Moreover, only two players have been considered even if the actors of this case study and, more in general, CBRNe events are many more. Last but not least, we used a non-cooperative algorithm which implies no communication between the players. All these aspects should be considered through risk and statistic factors in order to understand the reliability of the results.

4 Conclusions

CBRNe defence requires a deep cohesion of several fields: economic, political, scientific and social. Decision-making is one of the most critical aspects in CBRNe. Sometimes, decisions could involve important consequences, and sometimes these decisions must be taken very quickly. Then, the use of software tool to help decision-makers can assume a relevant position in this field.

This work shows how it is possible to apply game theory to CBRNe decision-making. Game theory is a field of mathematical models able to compute the most solution when the problem is affected and governed by sentient "players", in our case humans. The most common example is the prisoner's dilemma, which is briefly described in this work.

The destruction of chemical weapon agents of Syria in 2011 is considered as case study. The problem has been deeply simplified and reduced to the conduct of two principal actors: OPCW and Syrian government. A non-cooperative algorithm has been used. Anyway, several aspects have been neglected, such as the participation of other players in the game as well as the interaction between them. The authors showed how to apply game theory to CBRNe cases. Anyway, they also highlighted the critical aspects, the limits and the efforts that this tool leads. In fact, the use of game theory requires many hypotheses that could be not always true and verifiable.

Future developments will be directed in the development of "ad hoc" game theory tool for CBRNe decision-making. This dedicated tool should simplify the game theory setup and enlarge and compute the reliability of the tool in any case.

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Provisioning for Sensory Data Using Enterprise Service Bus: A Middleware Epitome

Robin Singh Bhadoria and Narendra S. Chaudhari

1 Introduction

In today's era of computation, almost every data acquisition is offered by web services in every discipline of life. Many business enterprises deliver their services through the more sophisticated medium and channels that support a reliable framework for open and flexible architecture to multiple service integration. The ESB does this responsibility and act as middleware that mediates the task of service and its associated data handling. It is designed to provide the solutions for complex and heavily loaded service system [1]. It also enables the system to streamline the access and more sophisticated IDE for efficient service integration. ESB offers the interaction between multiple service components which is possible with the help of known service interaction patterns. It also offers loose coupling policy and helps in governing security rule stronger. Various service components could interact with each other via messaging, and message handling is best done in ESB [2]. The major application of such system could be possible in the area of data identification for biological life science.

The embedded devices in sensor networks create a lot of data which may be structured or semi-structured. This needs a federated solution to handle and monitor such sensory data over the web. This could be provided with means of an ESB which implements the system on distributed platform. Such platform not only resolves complexity among the data services but also provides easy integration between multiple service components [3]. An ESB also ensure the delivery of data with

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recognized routing algorithms. This also enables the message mechanism which could implement data service efficiently.

2 Related Work

The various experts have done enormous work in the field of sensory data over the web. This paper also extends the facts about the challenge and issue associated with ESB design and architecture. Yet, the researchers are still investigating various points related to the use of sensory data [4]. This is well depicted below in Table 1.

The solutions for acquisition of data especially from multiple sensors are focusing on the type of data and its associated system on which it is based. The ESB enables such solutions that handle sensory data [7]. This could also help in achieving the interaction between multiple services with the aid of messaging that is organized using predefined patterns. These interaction patterns are offered by the manufacturers of ESB as products and govern the services. Such service components actually engaged available set of resources through virtualization.

Table 1 Feature comparison for related work in sensory data handling

References	Design and architecture	Cross-service support	Data usage
Romero and Vernadat [1]	Discussed enterprise information systems	Integration pattern for various service interoperability	Product data management
Qiu et al. [3]	Presents architecture for IoT-enabled SHIP (Supply Hub in Industrial Park)	Real-time interaction with multiple services	XML-based data sharing
Chang et al. [5]	Used ESB to handle communication channel	Mobile cloud computing	Utilizing resources and entities data
Martínez-Carreras et al. [2]	Discussed enterprise integration solutions for web services frameworks	Business model language for web services in SOA	Utilized data generated in intelligent business environment (IBE)
Martínez-Carreras et al. [2]	Constrained Application Protocol (COAP) and Resource-Oriented Architecture (ROA)	Constrained sensory devices for handling composite services	Virtual event sources for data
Alena et al. [6]	Transducer Electronic Datasheets (TEDS)	Supports self-configuring architectures for fault tolerance	Used XML, JSON, paired-key value for data

3 Enterprise Service Bus for Sensory Data Acquisition

The data is always a crucial matter of concern in any sensor network for communication between multiple motes (nodes). The ESB plays an important role in providing the backbone to system architecture for accessing the service associated for sensory data handling across the networks. It also supports the guidelines to set up strong middleware for the combination of sensor network with service-oriented system (SoS). The communication aspect for such sensor data handling would be assured by different features of service-oriented systems which are mostly governed by ESB. It also facilitates the overall service accessibility through sophisticated developing environment for service accessibility and deployment (Fig. 1).

For best implementing data service in ESB for sensor networks, the following points must be adhered [2]:

- *Loose coupling in data service*: Implementing multiple service components isolates result for better execution of the business logic. By adopting loose coupling policy, the service interaction could be easier to implement the messaging mechanism. This ensures the delivery of sensory data. It also offers the data collection from multiple sensor devices and improves data quality like noise/error in the captured data [8].
- *Data accessibility*: The sensory data could be accessible through the interface which is dedicated to both client and the central computational unit. It should be isolated and reuse the agile business logic to reduce the complexity overhead during communication. It may comprise multiple tasks of compiling, storing, and querying for sensory data at global repository [9].
- *Data governance*: It offers the monitoring of sensory data that provides simple recognizable control with built-in logging facility for sensory data in specified formats. It also provides data audit and logging facility [10].

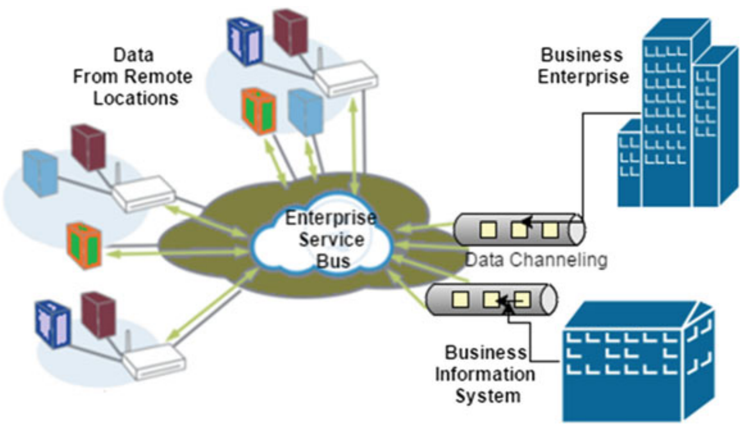

Fig. 1 Data flowing and channeling through enterprise service bus

- *Isolated management*: The developers need not to have special ability to manage data acquisition. ESB offers the well-defined framework to handle data control. It also enables the system with more reliable and secure environment for service accessibility [7].
- *Ease of development*: The isolated development environment provides ease to the developer for implementing sensory data services. It also supports Java Runtime Environment (JRE) to specify what sensory data need to be exposed through which service in ESB [3].
- *Path optimization*: The loose coupling with services offers an optimization and the shortest path for communication through dynamic routing path mechanism. It also supports the predefined set of interaction patterns for routing the data to its destination. The load balancing between multiple service components is also handled with this ESB. This reduces the overall system complexity and maintains the access latency. It is interesting to note that sometimes direct coupling with service components could improve the overall response time of particular data transactions [11].

In ESB-based solutions, the different business logics are implemented by services that provide the orchestration for multiple service components on common platform [12]. The key aspect of data acquisition could be summarized in the following two ESB deployment methodologies:

- Leveraging ESB benefits in service integration across multiple service components
  - Agile service component is responding to new business demands for sensory data (like biological life science service, banking access)
  - Service reusability among service components that helps in establishing interaction using message mechanism

- Leveraging data agility for sensory data acquisition
  - Centralized data handling
  - Rule-based data accessing
  - Enhancement in data quality
  - Agility in data format and structure
  - Recognition of known integration patterns
  - Unlocking key values from active business data

4 Evaluation Metric for Sensory Data Acquisition

In order to support the data quality for sensor-based application, the technical specification must be designed in such a manner that it defines the standard for data exchange and its processing. This paper experiments assessment of data received from different sensor nodes through effective middleware of ESB. This paper implements UtraESB [13, 14, 15] for handling sensory data. The received data may contain error/noise, and this needs to be stabilized before storing it to the global repository like cloud. Such data must be handled to reduce noise/error based on delay, type, value, and density [9].

4.1 Methodology

The object of this study is to stabilize the sensor metric value depending upon the last and first received metric count. This should immediately be done before and after the data lost. This could be achieved by adopting specified tolerance value. For particular time tolerance, one range (interval) of timings is fixed, and all the data are accepted within the time range. Any data that falls outside the specified range would be considered as invalid. But, every real field, some tolerances could be allowed [8]. Let $I = \{I_1, I_2, \ldots, I_n\}$ be a finite family of fuzzy intervals on the real line which represents time intervals and $\tau = \{\tau_1, \tau_2, \ldots, \tau_n\}$ be the corresponding fuzzy time tolerances. Now, the membership values ($\mu_{i,\,j}$) of intersections with time tolerance could be found in the following formula.

$$\mu_{i,j} = \begin{cases} 1 & \text{if } c(\tau_i \cap \tau_j) \geq \min\{c(\tau_i), c(\tau_j)\} \\ \dfrac{s(\tau_i \cap \tau_j) - \min\{s(\tau_i), s(\tau_j)\}}{s(\tau_i \cap \tau_j)} h(\tau_i \cap \tau_j) & \text{otherwise if } s(\tau_i \cap \tau_j) \geq \min\{s(\tau_i), s(\tau_j)\} \\ 0 & \text{otherwise} \end{cases}$$

This section also discussed the error which arises due to sudden hike/fluctuation from threshold value and need to be stabilized such data before storing it. The well-known relative error is defined as follows.

$$\text{Relative error} = \frac{\text{Absolute error}}{\text{True value}} \times 100$$

The true values are shown in the first column and filtered values in the second column in Table 2. If the received data is correct, then there must be an error. In the

Table 2 Relative error of filtered data

Actual value	Filtered value	Relative error (%)
20.6	21.1	2.4
20.1	21.1	4.9
33	32.0	3.03
31	32.0	3.22
50.0	22.6	**54.8**
50.1	22.7	**54.6**

third column, the errors have been shown. If the error is small, then the data could be accepted. Otherwise, the data filtration may be taken as invalid.

5 Conclusion

The purpose of this research article is to allow the service integration with sensory data. It also provides the prominent solution to how ESB could be useful in handling data from legacy application like wireless sensor networks. Here, ESB work as a depletion layer that implements the overall system to support data acquisition. This paper simulates the results for sensory data that is stabilized using time tolerance and threshold cuts. In Table 2, the last two rows show the relative error and reduce it up to 54%. Thus, such data might be stabilized and reduce its metric value to acceptable and valid limits.

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Part IV
International Legal and Economic Frameworks and Geopolitical Issues

Arms Control Law as the Common Legal Framework for CBRN Security

Eric Myjer and Jonathan Herbach

1 Introduction

On the occasion of the first scientific international conference on safety and security issues in the CBRNe field (chemical, biological, radiological, nuclear, and explosive), it is worth considering the fairly fundamental question of whether it is possible to place CBRN security in a single legal framework. Is there, in other words, a particular area of the law within which it can be said that all or most international arrangements relating to CBRN security logically hang together? Moreover, do these arrangements share certain common characteristics? In the view of the authors, it can be held that arms control law, as a branch of public international law, forms that logical common framework.

2 Security Council Resolution 1540

To give a concrete example of a key arms control instrument that ties all areas of CBRN security together, one can look at United Nations Security Council Resolution 1540 [1]. This resolution was adopted (unanimously) under Chapter VII of the UN Charter, meaning that it is legally binding on all UN member states.

All views presented are the author's own and do not necessarily reflect the views of the government of the Netherlands.

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In Resolution 1540, the Security Council affirmed that the proliferation of nuclear, chemical, and biological weapons and their means of delivery constitute a threat to international peace and security. Having made this finding [2], it then obligates all UN member states to take various actions to prevent the proliferation of nuclear, chemical, and biological weapons and their means of delivery to non-state actors. In addition to these nonproliferation-related measures [3], security measures are foreseen, such as establishing domestic controls over materials related to these weapons and their means of delivery. States will have to adopt and enforce appropriate and effective domestic legislation to give effect to these obligations, which gives Resolution 1540 its "legislative" character [4, 5].

The broad scope of this resolution encompasses various instruments—treaties, organizations, export control lists, and other arrangements. Among these instruments, classic arms control agreements are mentioned, like the NPT, the Chemical Weapons Convention [6] (CWC), and the Biological and Toxin Weapons Convention [7] (BWC), as well as the Organization for the Prohibition of Chemical Weapons (OPCW) and the International Atomic Energy Agency (IAEA), the two most important arms control supervisory organizations. At the same time, a couple of nuclear and radiological security-specific instruments—the Convention on the Physical Protection of Nuclear Materials [8] (CPPNM) and the IAEA Code of Conduct on the Safety and Security of Radioactive Sources [9, 10]—are mentioned. Given that security in this field is aimed at preventing non-state actors (i.e., terrorists) from obtaining and maliciously using these weapons correlated materials, a "third line of defense" is provided by the counterterrorism instruments, like the binding Security Council Resolutions 1267 [11] or 1373 [12], the latter being a comprehensive resolution aimed at prevention of terrorism, including its financing.

Furthermore Resolution 1540 tries to strike a balance between the prevention of proliferation of nuclear, chemical, and biological weapons and international cooperation in benefiting from the use of related materials and technologies for peaceful purposes. This dual-use issue is of course also the classic tension when states are asked to restrict their freedom in the military realm, for instance, in the case of nuclear weapons under the NPT.

As alluded to above, at the time of its adoption, Resolution 1540 was more or less a novelty in that it instructs in fact all states to adopt national legislation (all 193 member states of the UN). In that way, the SC in effect acts as a legislator, which was also the case with respect to Resolution 1373. This is remarkable for measures taken under Chapter VII UN Charter normally are for a defined period of time, whereas this legislation is for an indefinite period of time. A similar binding norm among states parties to enact domestic legislation is found in Article VII of the now almost universal Chemical Weapons Convention (an arms control convention), but in that case all states parties have agreed to such commitment.

What is also interesting is that Resolution 1540 establishes a kind of supervisory body, the 1540 Committee, which is a subsidiary organ of the Security Council. The 1540 Committee was established to oversee implementation of the resolution. A number of subsequent related resolutions have been adopted reaffirming the measures contained in 1540 and extending the mandate of the 1540 Committee [13].

We can therefore conclude that Resolution 1540 is a mixed resolution of a comprehensive nature which is not only a clear arms control resolution, prohibiting proliferation of weapons and means of delivery. It is also one that deals with CBRN security, recognizing the need to keep related materials that have peaceful applications but can also be used for producing weapons out of the hands of non-state actors.

3 Characteristics of Arms Control Law

In order to demonstrate that arms control law, as a branch of public international law, also forms the logical common legal framework for international arrangements relating to CBRN security, it is important to understand its scope and distinctive characteristics.

Arms control law [14–20] is a distinct branch of public international law (i.e., the general law between states and made by states), like human rights law or environmental law, that deals with a specific topic but still forms part of general public international law and answers to its general principles. Arms control law can be defined as that part of public international law that deals both with the restraints internationally exercised upon the use of military force (in general) and on the use, transfer, and/or the possession of armaments (in particular), including their component parts and related technologies, whether in respect of the level of armaments, their character, or deployment and with the applicable supervisory mechanisms.

This definition is quite broad and concerns a great number of treaties as diverse as the Intermediate-Range Nuclear Forces Treaty (INF Treaty) [21], the Treaty on Conventional Armed Forces in Europe (CFE) [22], the strategic arms reduction treaties [23], the NPT, or the CWC. These are all treaties between states and therefore binding (so-called hard law). Also relevant binding decisions by the Security Council (Under Chapter VII of the Charter) dealing with arms and related materials, like Resolution 1540, fall into that category. Arms control law however also includes soft law arrangements agreed on by states, which can range from politically binding arrangements to recommendations and guidelines, memoranda of understanding, and codes of conduct to non-binding resolutions by international organizations (viz., General Assembly resolutions).

A few of the most striking common characteristics of arms control arrangements are:

- Control on use, transfer, and/or possession of in particular armaments, component parts, and related technology (the arms or weaponization element)
- The element of security
- Verification via supervision of compliance
- Important role for confidence-building measures

First, arms control law is of course about controlling arms, armaments, etc., in the sense of the definition. This may range from a specific concrete disarmament to the nonproliferation of weapons and related technologies, to other limitations on the numbers or deployment of forces, to prohibitions on weapons testing, and to freezes on weapons production [24]. All of these are forms of arms control. In general, the aim of arms control has been to lower the risk that certain weapons are used in case an armed conflict breaks out. In that sense states may agree among themselves to get rid of a certain number of arms, for instance, with respect to number of troops, or tanks, or nuclear weapons (like in the SALT and Start agreements), or to get rid of a complete category of weapons (e.g., chemical or biological weapons), or to restrict the proliferation of certain weapons, like under the NPT. States have also agreed on various export controls to prevent the spread of certain materials and technologies for weapons purposes. These are all approaches that have been taken under arms control law.

A special category of arms control is if states not only want to prevent other states (including rogue states) from obtaining certain weapons (the main category) but also agree among themselves to take steps to prevent non-state actors from acquiring them. In the CWC we find such a commitment. But, in addition, the UNSC has decided to address this issue, which is the purpose of Resolution 1540. This quite specific category under arms control law relates to CBRN security, as will be discussed later.

Secondly, states will only agree on binding arrangements that will increase their security, or at least not diminish their security. In order to be certain that parties comply with their commitments reliable verification is central. That means that a system that allows for verification should be agreed upon. For that reason, where direct action is required, it will normally take place under some form of supervision. Examples are the monitoring system under the CWC, carried out by the OPCW with both initial and routine inspections, but most importantly also with the possibility of challenge inspection [25, 26]. With regard to non-diversion of nuclear material to non-peaceful uses, such supervision is done by the inspectorate of the International Atomic Energy Agency (IAEA) on the basis of safeguards agreements between the International Atomic Energy Agency and nonnuclear weapons states parties to the NPT.

In the absence of verification mechanisms, security can further be enhanced by confidence-building measures, demonstrating credibility of and adherence to commitments. Such measures can be codified in a treaty, be part of final declarations of conferences (i.e., the Helsinki Final Act of 1975), or even be unilateral, bilateral, or multilateral voluntary measures.

Of course, there are more features specific to arms control law (viz., no customary law), but that is beyond the scope of this paper.

4 How Does CBRN Security Fit in

CBRN security is primarily about preventing non-state actors from obtaining/developing/using/illicitly trafficking weapons of mass destruction (WMD) or related materials/technologies that may be used for hostile purposes. Like other instruments of arms control law, CBRN security arrangements also deal fundamentally with the control of arms and related technology. Different from the main category under arms control, it is not about controlling weapons and military capabilities of states, but about preventing non-state actors from obtaining them either from states or from natural or legal persons. CBRN security therefore primarily is about realizing security via prevention (contrary for instance to control via disarmament). This predominantly preventive nature is a distinctive feature of CBRN security.

Again here, states are only willing to agree on binding commitments to increase, or at least not diminish, their security. In order to be certain that all parties fulfill their commitments, therefore, there should ideally also be the possibility for verification pursuant to CBRN security arrangements or at least means and methods of confidence-building and enhancing transparency (while accounting for confidentiality). For when it comes to security, states will want to be certain that others are also complying with what they have agreed on and not secretly circumventing their commitments. Weaknesses with respect to CBRN security can be exploited that lead to harm in other states.

Agreeing on a treaty with binding commitments in combination with effective supervision is difficult to achieve and may lead to lengthy and acrimonious negotiations when it comes to most if not all arms control arrangements. But CBRN security instruments have the added obstacle of states not willing to share information concerning what they feel falls purely under national security (specifics of the threat, intelligence gathering, law enforcement). Not surprisingly, therefore, states may then prefer non-binding commitments, like adhering to a code of conduct, or a voluntary export control system, which grants flexibility, can provide additional technical detail and can always be stopped or adapted relatively easier in light of changing circumstances.

Next to that of course, as with Resolution 1540, the Security Council may always decide on (additional) binding rules by adopting a resolution under Chapter VII (when there is a threat to the peace, breach of the peace, or an act of aggression). This, however, is difficult for all the P5 (permanent members of the SC) will have to agree.

Besides these arrangements that deal directly with WMD's and related materials/technology, there is another set/category of arrangements aimed, inter alia, at establishing criminal offenses related to terrorist acts, setting rules for exercising jurisdiction, and providing for mutual legal assistance among parties. This is the general category of counterterrorism conventions, which can range from the financing of acts of terrorism to preventing terrorist bombings, instruments that have a criminal justice character. Since this category of arrangements does not concern arms as such and is less CBRN specific, though some do make direct reference to offenses involving CBRN materials, but addresses acts of terrorism more generally, it does not belong in this branch of arms control law. Rather, it should be dealt with either under general public international law, or international criminal law as a special branch.

5 The Element of Security: What Does It Mean in General and the Preventive Nature of CBRN Security

Since the concept of security is so central to arms control law in general and CBRN security in particular, in order to get a better understanding of it, it is useful to consider for a moment what is meant by security.

In general when referring to security, it is necessary to make a distinction between internal security and international security. The classical internal function of a state is to guarantee the security of its citizens within the state, whereby the state has the monopoly on the use of force, criminalizes certain behavior, and organizes its police function to protect its citizens from interference with their rights and to protect them from criminal behavior.

On the international level, the nation state has a similar role to play, albeit slightly different. Here, its role is to protect the integrity of the nation state, and thereby of its citizens against a military attack by another state. Under international law, it is allowed to do so by use of military force in self-defense (as in the UN Charter, Art.51), thereby realizing military security.

There may, however, be other interferences with a state's security, when its vital interests are being threatened. A state may want to withstand any foreign pressure on its vital interests (sometimes even by military means.). This can be called interest security. Different forms thereof could be distinguished, like wanting to preserve a state's economic security in case, for instance, its soil sources (are threatened to be) cut off, or a state may want to realize security against terrorist interference (terrorist security), which can pertain to internal or international security. CBRN security represents a concrete form of this, when a state might want to protect against interference by CBRN means, the classical WMD's, but coming not from another nation state but from non-state actors. This, then, could be called CBRN security.

On the face of it, rather diverse areas like chemical, biological, radiological, and nuclear substances are all tied together in the concept of CBRN security. The concept as such is about being secure from the consequences of the malicious use of the respective materials, as well as related technologies. But CBRN security as a term of art interestingly is in a way more limited than it might at first appear, for unlike the classical case of security between states, it primarily is about the actions of non-state actors, namely, terrorists and terrorist organizations. Because we are talking about WMD materials, use, regardless of who carries it out, may lead to casualties on a wide and unimaginable scale.

Protection against actions by non-state actors is a difficult category, for by definition it is not an entity with which it is possible to conclude a treaty. That is only possible between states or between states and international organizations. Furthermore, a non-state actor is an unknown entity, made up of one or more individuals, of which the nationality is not necessarily known, and thereby it is not known whether there is an applicable national criminal law if they were to be caught.

But perhaps more importantly, in the case of CBRN security, it is not about rules to either militarily or criminally sanction acts (that have taken place) with CBRN means, but it is about realizing security against the very application of such means. When criminal sanctions are in order, it is already too late. What concerns us primarily, therefore, is developing a set of rules of a preventive nature. This leads us to the finding that CBRN security is characterized by its preventive nature.

Of course, prevention could also be realized because of the deterrent effect of possible criminal sanctions. However, that applies less in the case of terrorists, willing to carry out suicide attacks (such as the September 11, 2001, attacks in the USA). The most important measure is to prevent such non-state actors from obtaining the materials, or gaining access to the technologies or related facilities, that are involved in weapons of mass destruction.

6 Conclusion

The central element of security, the importance for national security of knowing that other states are adhering to obligations and commitments (whether through verification mechanisms or other forms of confidence-building), and the fundamental aspect of controlling armaments or weaponization of dual-use materials place CBRN security in the broader framework of arms control law. As a specific category within arms control law, CBRN security arrangements are predominantly preventive in nature, perhaps more so than traditional arms control arrangements. In the case of CBRN security, it is not about restraining military power of a potential adversary, but rather about cooperative efforts to deny non-state actors, namely, terrorists, from obtaining WMD capabilities.

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“One Single Official Voice or Multiple Voices?” Ensuring Regulatory Compliance in Communicating (CBRN) Emergency or Crises

Matteo E. Bonfanti

1 Crisis and Emergency Communication Management with Regard to CBRN Threats and Beyond

The adoption and implementation of communication solutions and strategies are key elements for managing different types of emergencies or crises.[1] They are fundamental components of the array of tools that public authorities and rescue agencies can deploy for dealing with situations that are characterised by intrinsic uncertainty, insecurity, and growing need for information.[2] Communication complements and supports the execution of the activities and actions taken to face crises and emergencies. Often, the lack of communication solutions and strategies hinders significantly the effectiveness of designed preparedness, prevention, response, and recovery measures.

Together with “command” and “control”, “communication” is crucial. Command and control cannot be accomplished without the existence of two-way communications. Commands could not be passed from the commander to subordinates; control would be impossible unless feedback in some form could take place. Basic to any command and control system is the incorporation of an efficient communications network/infrastructure that should bring timely, reliable, and “consumable” information to targeted individuals or groups that are part of the network. From this point

[1]For the purpose of this section, “crisis and emergency communication” refers mainly to the actions taken by an organisation or agency in order to inform and alert the public about an emergency or critical event. The terms “the public” or “the audiences” are used in this section only as a shortcut; obviously, there are different groups of audiences with distinctive needs.

[2]The main objective of the crisis and emergency communication is the reduction of the uncertainty. On crises and emergency communication, see [1–8].

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of view, the correct functioning of the network is paramount to the provision of information that may be consumed by decision-makers for detecting or foreseeing potential hazard, as well as managing them. It is also essential for the monitoring of an ongoing crisis or emergency and its evolution, as well as for assessing the effectiveness of the response measures that are adopted.

However, the importance of communication is not limited to the flow of information among members of the organisations who are in charge of managing a critical event or emergency. In other words, it does not exclusively concern the way relevant agencies share and examine information that are useful for decision-making. Communication in crises and emergency management refers also to the way authorities, first responders, and other relevant actors inform, advise, and impart instructions to the population that is/may be directly or indirectly affected by a dangerous event. As one commentator noted: "Life-threatening crises, such as natural and environmental disasters, terror attacks and epidemics are among those rare moments when communication with the public may become an issue of life and death. Under these circumstances, effective communication with the public can save the life of many civilians".[3]

It goes without saying that communicating in crises or emergencies is different from communicating in "normal" situations [12]. During a critical situation or emergency, all affected people are likely to take in and process information differently. They will also act diversely on information ([7], 64). Therefore, there is a need for effective and accurate communication mechanisms to target and reach the affected people, provide them with relevant and understandable information, and invite/persuade them to follow clearly given instructions within a narrow time constraint. In other words, communicators should inform and persuade the public in the hope that they will plan for, and respond appropriately, to risks and actual threats. They should build a relationship of trust with their audiences. Achieving this overarching goal is not easy since there are many variables at stake. Among these variables, there are the content, form, media, and timing of the communication [13]. The nature and type of the "communicator"—i.e. the actor/organisation providing for the information—are relevant too.

Generally, the practitioners' and experts' discussions concerning the mentioned variables are framed within the broader debate on the so-called single voice principle and its application during emergencies and crises.[4] What is this principle about? Where is it stated? How is it formulated, and what does its adoption/application entail? Is it an "absolute" principle, or can it be derogated and applied flexibly? These are few core questions the present chapter aims at answering to. In particular, it aims at investigating the adoption of the single "official" voice principle (SOVP) across selected European emergency and crisis communication mechanisms—as

[3]The fact of communication playing a central role in emergency and disaster management is reflected by the institutional framework/setting that is adopted by several states to deal with this type of situation. See [9, 10]. Cf. also [11].

[4]See infra par. 2.

they are defined by relevant legal and policy frameworks. The concerned frameworks are those established in France, Spain, Italy, the United Kingdom, Finland, and Switzerland.[5] Starting from the study of the content and reach of the single official voice principle—and its different declinations—the chapter addresses if and how the principle is endorsed by the above selected European countries' crisis and emergency communication frameworks. Then, it examines whether these frameworks leave a room for adopting a "multiple voices" approach to communicating crisis and emergencies and if this creates opportunities for a more effective engagement with the population. Regardless of the formal adoption and implementation of the "single voice" or "multiple voices" principles, the chapter concludes that the key challenge for successful crisis communication is achieving high and consistent coordination among the different actors that contribute in disseminating alerts and information during crisis.

2 The "Single Voice Principle" in Crises and Emergencies

It is often said that in time of crisis or emergency, leaders, experts, officials, institutions, and agencies should "speak with one voice" in their communication with the public. It is the so-called single voice principle (SVP)—also known as "speak-with-one-voice" principle—that demands centralisation and high coordination of the communication in disaster/emergency/crisis management [14]. There is actually no agreed definition of the principle and several meanings coexist. Sometimes, SVP refers to the need to identify a single speaker, e.g. an authority who is officially and solely responsible for providing information during a disaster/emergency/crisis or for coordinating public announcement.[6] In the latter case, the principle is better named as "single *official* voice" (SOVP) to stress that the information is provided by an entity who is appointed or authorised to act in a designated official capacity [16]. Occasionally, SVP concerns the message itself or the medium that carries the message. For the principle to work, conceptually, there must be a single message whose meaning must be unambiguously shared and understood between the speaker and its audience.

There are several arguments supporting the application of the SVP in time of crisis and emergency, CBRN events included. It is said that by speaking with one voice—or one official voice—public authorities, rescue organisations, and other

[5]The selection of the national frameworks was based on the opportunity to have access to relevant documental sources as well as further knowledge provided by nine national experts across the concerned countries. These experts were asked to answer a questionnaire which investigated the topic.

[6]The "hard" application version of the principle demands total centralisation of the public communication role; everyone is told to refer all inquiries to a single source who is the only one entitled to provide information. Versions that are more moderate suggest generating a set of key messages that everyone is supposed to stick to [15].

relevant stakeholders can effectively “ally public fears and quell panic, unify messages and improve coordination, and reduce conflicts between them and with the public” ([14], 162–164). In some cases, the application of the SVP is instrumental to exercising a strategic control over other stakeholders (Ibid., 164. See also [15]). In general, the SVP aims at avoiding confusing or contradictory statements, which could increase public panic, anxiety, and undermine trust.[7] “The idea is that rhetorical consistency diminishes the likelihood of public confusion and over-reaction. If government agencies or experts disagree on the science, its interpretation, or the information to be transmitted, they may convey different messages about the same topic. Many policy makers decry this practice, call for interagency coordination, and urge government to ‘speak with one voice’ as the remedy for the problem”.[8]

It should be noted that there is no universal consensus among practitioner organisations and scholars with regard to the recommendation to apply the single voice principle *always* and in *every* critical situation and emergency. Indeed, the *erga omnes* validity of the principle is challenged. As pointed out by some experts and commentators, the length and complexity of many crises make it unrealistic to expect that only one person, or voice, can represent an organisation or many of them [15]. Furthermore, communication is inherently a social process in which “diverse” publics are the target of communicative efforts ([14], 166). Warnings, instructions, and other information about potential risks and threats that are delivered before, during, or after a crisis are filtered through social contacts, the media, and other mechanisms and are interpreted differently by the public based on the influences they are exposed to. Information are most believable if they come from a mixed set of persons because people have different views about who is credible and who is not. People are keener on believing to information provided by family members, friends, and other trusted individuals than “not-familiar” organisations. Furthermore, the information receivers’ subculture, language, gender, social class, and ethnicity do influence the way they understand a certain message. In other words, different groups can hear different things from the same words, depending on the cultural frames and political interests they use to make sense of those words (Ibid.). Rhetorically, SVP “obliterates possibilities of multiple meanings, neglecting variations in culture and social context that are known to shape the meaning of messages” [15]. As it is generally conceived and implemented, the principle further assumes the audience is a passive receiver of a message whose meaning is clear to all. “Following a command-and-control vision of how the world works, SVP lends an image of a single, all-knowing speaker with the requisite authority and expertise to tell a single, indisputable truth. However, in most controversial situations that involve technology, science, and therefore experts there is no single, indisputable truth to be told” (Ibid.).

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[7] [1], 54: “Ensure that all credible sources share the same facts. Speak with one voice. Inconsistent messages will increase anxiety, quickly undermining expert advice and credibility”; and “Consistent messages are vital, especially when asking people to take actions or steps that are unfamiliar”.

[8] Ibid., 161.

In light of the above, it seems that speaking with one voice can be a misguided prescription for how to communicate during a crisis or an emergency. Of course, this does not mean that the application of the principle proves to be always ineffective and counterproductive. Its valuable and valid component is the inherent prescription of communicating a consistent and not-misleading message. Such a prescription sounds logic and enduring (see [16], 28). However, the application of the principle should be examined contextually. In some cases, it could be better to speak with many voices meaning that not only one message should be disseminated by one official authority, but several messages with different wording need to be sent out through many different channels in order to reach targeted groups within the public.[9]

3 "Single Official Voice", "Multiple Voices", and Warnings: International and National Standards

In reviewing the contexts and situations in which the SVP and, in particular, the single official voice principle should be adopted and implemented, discussions arise with regard to the application of the principle when the issuing of "warnings" to the population and "pre-alerting" them of any danger/hazard are at stake. Usually, these discussions concern warnings about medium or highly impact weather events; however, the dispute surrounding the application of the principle regards also other types of warning, CBRN-related alerts included (e.g. flu).

On the one side, there stand several experts and institutions who stress the importance of establishing an official recognised authority—or more authorities each of them to be responsible for specific hazards (earthquakes, meteorological events, fires, floods; chemical, biological, radiological, and nuclear)—who represents the single authoritative voice on warnings within one country, region, or similar (see [16], 28). In other words, these experts and institutions support the single *official* voice principle and underline its centrality to any warning system which aims at being effective. For example, the 2012 World Meteorological Organization's (WMO) publication on *Institutional Partnerships in Multi-hazard Early Warning Systems* recommends the establishment of early warning systems capable of issuing messages that are "(iii) issued from a single (or unified), recognised and 'authoritative' source" ([17], 226). A similar position is taken by the UNIDSR. In its checklist for developing early warning systems, UNISDR notes that communication and warning sources at different levels (regional, national, and local) must be pre-identified and appropriate authoritative voices established ([18], 2). However, it also suggests to use multiple communication channels in order "to ensure as many people as possible are warned, to avoid failure of any one channel, and to reinforce

[9]See references in Ibid.

the warning message".[10] In the UNISDR's perspective, it is therefore important to predefine authoritative voices that are the ones solely in charge of issuing official alerts; these alerts can be then reissued or disseminated also by other non-official actors through different media. The best way of ensuring the SOVP to be applied is providing a concerned entity with a clear legal mandate. Depending on the national requirements and arrangements, the form and the content of the legal instrument providing for the mandate can vary greatly.[11]

The implementation of the SOVP is challenged by those acknowledging that there are also other actors—even *non-official* ones—who can play a significant role in issuing and, above all, disseminating warnings. For example, the *International Federation of the Red Cross's (IFRC) guiding principles on Community Early Warning Systems (CEWS)* questions the ideas that "single source is the best" and that information should be as succinct as possible. The IFRC's guidelines suggest that "individuals and communities at risk will seek out information from a variety of sources. Multiple sources help people triangulate and confirm warnings leading to stronger belief in their credibility". They emphasise that "[i]n a free and information-rich society, people are used to processing information. They often assume someone is trying to hide information if it is not available" ([19], 17). In line with this approach, the IFRC Guiding Principle 11 requires "redundancy in warning communication" (Ibid., 43).

With regard to national settings, it seems that the adoption of the single official voice principle is anyhow preferred over the multiple voices approach. At least, this emerges from the review of the relevant standards governing crisis and emergency communication that are established in France, Spain, Italy, the United Kingdom, Finland, and Switzerland.[12]

In France, the Law 2004-811 on the modernisation of civil security establishes the mayors' duty to put in place Local Protection Plans (*Plan Communal de Sauvegarde*, PCS) for the municipalities exposed to major risks ([20], Art. 13). The PCS shall include information on means to distribute official warnings to the population as well as on the measures to follow during an emergency. On similar lines, at the departmental and zonal levels, the French crisis management system is based on the so-called ORSEC plans (*dispositif ORSEC*, *Organisation de la Response de la*

[10] Authoritative voice means that a specific type of information is provided by recognised authorities empowered to disseminate warning messages (e.g. health authorities to provide health warnings). See Ibid, 7. Furthermore, UNIDSR recommends establishing a two-way communication system "to allow for verification that the warnings have been received" and to tailor warning messages to "the specific needs of those at risk (e.g. for diverse cultural, social, gender, linguistic and educational backgrounds)". Ibid., 7.

[11] In practice, however, even when a legal mandate is in place, issues can arise with other providers of "non-official warnings" to the public that are styled as "warnings". See https://www.wmo.int/pages/prog/dra/eguides/index.php/en/5-functions/5-5-warnings-systems

[12] A detailed analysis of the countries' civil protection systems falls beyond the scope of this chapter; the focus is instead on the legal basis for keeping the population informed and engaged during crises and emergencies as well as for distributing official warnings.

SecuritèCivile, created in 1952, modified in 1987 and more recently revised by Law 2004-811), which include details on crisis management arrangements, including warnings and information to the population during a crisis.[13] With specific reference to crisis communication, an ORSEC guide published in 2013 notes the difference between warning (*alerte*) and information during a crisis (*information*) ([21], Sect. 1). While the former is defined as the distribution of official alerts by public authorities in case of an emergency, through a signal (audio, visual, or a text), the latter refers to distribution of more detailed information on the event before, during, and after the emergency phase.[14] Distributing official warnings is the responsibility of the mayor or the prefect for local emergencies and the Prime Minister or of the Ministry of the Interior for more serious national emergencies. As per the means of warning, the ORSEC Guide mentions not only the more traditional means like sirens or mobile loudspeakers; it refers also to mobile phones or the Internet and classifies these means according to their capacity to alert, and provide information to, the population and target different audiences which may have different information needs. The Guide also notes that it is not possible to identify just one mean as flawless and perfect for every situation; it rather suggests combining different means.[15]

In Spain, the Law 17/2015 establishes the National Alert System (*Red de Alerta Nacional de Protección Civil,* RAN), managed by the Ministry of Interior's Centre for Emergencies management and coordination (*Centro Nacional de Seguimiento y Coordinación de Emergencias de Protección Civil*).[16] This is the voice officially entitled to issue alerts at the national level. At the regional and local level, alerts are provided by pre-identified authorities as established by the emergency plans which usually include a section devoted to warnings and communication with the public during an emergency. For example, the Flood Management Plan of the Cataluña region foresees different communication phases, such as prewarning, warning, and information provided during a crisis ([23], 124). In Cataluña, the Operation Coordination Centre (*Centre de Coordinació Operativa de Catalunya*, CECAT) is responsible for transmitting alerts to local authorities, who will immediately activate the contingency plans. Information and advice to the population is distributed by the

[13]In relation to the most serious emergencies, the Direction for Civil Security and Crisis Management under the Ministry of the Interior prepares and implements emergency measures covering the national level. https://www.interieur.gouv.fr/Le-ministere/Securite-civile/Documentation-technique/Planification-et-exercices-de-Securite-civile

[14]The latter are complementary to the former.

[15]The ORSEC Guide considers Internet of particular importance for serious emergencies; however, it mentions the problem of verifying information that is shared at a very rapid pace especially through social media. Ibid., 53.

[16]Ley 17/2015, Art. 12 [22]. According to the Spanish Civil Protection's website, competent authorities for the management of the RAN are currently working on the elaboration of a more comprehensive plan for distribution of official warnings and communication standards. http://www.proteccioncivil.es/que-hacemos/ran/presentacion

Centre's Information Centre (*Gabinetd'Informació*) and shall be precise and clear and targeted to the seriousness of the situation.[17]

In Italy, each municipality and, for more serious emergencies, each region have the responsibility to guarantee the immediate activation of the local civil protection system, to alert the population, and to maintain the communication with the public during the emergency. In cases of national emergencies, the operational responsibility rests with the Department of Civil Protection under the authority of the Prime Minister, who assumes the overall political responsibility. In case of crises, it is the Ministry of Interior—again under the authority of the Prime Minister—through its local prefects which takes the lead of alerts and communications.[18]

In the United Kingdom, responder agencies are required to maintain arrangements to warn the public if an emergency is likely to occur or has occurred. In addition to warnings, they must also have arrangements to provide information and advice to the public if an emergency is likely to occur or has occurred ([24], 2(1)(g)). Responders are required to cooperate for the purpose of identifying which organisation will take lead responsibility for maintaining arrangements to warn in regard to that particular emergency ([25], 6). According to the UK Emergency Preparedness Guidance, the arrangements to warn are usually planned and tested through the Local Resilience Forums, i.e. committees involving—as a minimum—responders at the territorial level.[19] Importantly, the Guidance clarifies that "[r]esponders should alert the members of a community whose immediate safety is at risk by all appropriate means, and be mindful of using a variety of available channels and existing community resilience networks to reach community groups and vulnerable people" ([25], Chapter VII, 16). "A mix of techniques should be utilised to maximise the chance of receipt, comprehension and effective response from the public" (Ibid., 37). In this respect, the Guidance notes that "[t]he media landscape is continuing to develop" and that "some of the biggest growth has been in online news services". In addition, it emphasises the potential for private citizens to actively share information on crisis, by noting that "[m]obile phones with cameras and other similar devices mean that the public are able to publish their own content" (Ibid., 55). With particular reference to social media, the guide underlines both positive aspects and associated risks to their usage (Ibid., 57–59). It suggests Local Resilience Forums to consider the benefits of agreeing a multi-agency social media protocol to ensure usage is consistent with both individual and multi-organisational policy.

In Finland, a general principle is that the authorities responsible for running the operations and investigations are also responsible for communications and for informing other authorities and stakeholders ([26], 9 ff). Other authorities provide

[17]Ibid, 125. The regional government has recently set up a twitter account (@emergenciescat) through which official warnings may also be distributed.

[18]Reference to national legislation in [9].

[19]For further details on Local Resilience Forums, see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/62277/The_role_of_Local_Resilience_Forums-_A_reference_document_v2_July_2013.pdf

support. Municipalities, local authorities, and joint municipal authority bodies, such as hospital districts and regional rescue departments, bear the main responsibility for local communications. With regard to emergency warnings, these may be issues by pre-identified authorities only (Ibid., 30). When the severity of the situation so requires, the government may set up a cooperation group for coordinating communications among various authorities. In such events, the Prime Minister’s Office is responsible for the coordination of communications among the different branches of government. In practice, the responsibility rests with the Government Communications Department. All relevant branches of government are involved in the cooperation group. The group steers and coordinates the authorities’ nationwide communications in accordance with the government’s policy outlines and separate decisions (Ibid., 35).

In Switzerland, the Law 520.1 on Civil Protection adopted in 2002 sets out the local authorities’ duty to alert the population in case of danger and to inform them about the conduct to adopt ([27], Art. 4.b). The Alert and Warning Ordinance adopted in 2010 establishes that, depending on the authority in charge of crisis management (i.e. whether the crisis is managed by the Federation or by each administrative district), the warning shall be provided by the National Alarm Centre (*Centralenationaled’alarme*, *CENAL*, in case of national emergencies) or by competent authorities at the local level ([28], Art. 9). According to the Ordinance, the alert shall be transmitted through sirens or by means of a telephone call, in case of isolated buildings, and shall be accompanied by advice on emergency measures to adopt through radio and television channels, which are required to transmit this information (Ibid., Art. 4). In a factsheet developed by the Office for the Protection of the Population (*Office fédéral de la protection de la population*, OFPP), the single official voice principle (*voix unique*) is meant as per the following: emergency information has to be clear and comprehensive and has to be identified as unambiguously emanating from the competent authority [29]. The Swiss Federation, in collaboration with the administrative districts, is currently working on an instant alert app to alert and inform the population of an emergency.[20]

4 Making Room for “Multiple Voices” Approach

In all the surveyed countries, the issuing of warnings is the sole responsibility and task of local, regional, and national authorities—depending on the seriousness of the situation. They have the remit to alert the population in case of an imminent or occurring emergency and to immediately activate and coordinate the response system, which includes keeping the population informed during a crisis. From this point of view, the examined standards adopt the SOVP. As per the communication media, these can be diverse, both official and unofficial. Once the alert is officially

[20] https://alertswiss.ch/fr/

issued, other entities like private organisations or individual citizens are allowed to contribute in disseminating it. In this perspective, there can be multiple voices which propagate authorities' delivered messages and information. Actually, their support can prove to be quite useful because—especially before but also during a crisis or emergency—there is an increasing number of actors that demands access to timely multi-hazard warnings and information in order to better inform their own decision-making. This demand of information can be served by non-official or *quasi-official* organisations too. However, considering the above discussed standards, it seems that organisations should anyhow be formally "co-opted" as partner in crisis or emergency management/communication; their activities should be harmonised with those carried out by authorised official bodies. The goal is avoiding public confusion and uncertainty on the source of information to be trusted ([16], 28). It is therefore important to establish—also through the adoption of soft-law instruments or nonbinding guidelines or set of principles—a better framework governing cooperation between official authorities in charge of crisis communication and other para-official entities who can contribute to it. With regard to the contribution offered by individual citizens in communicating alerts and other crisis-related information, this is increasingly provided by them through the employment of social media or other online channels (website, blogs, etc.). Given the risks of spreading ambiguous messages for decision-makers and/or generating confusion and panic among the whole population, it is important that individuals who want to contribute to crisis communication follow predetermine protocols or guidelines.[21] These guidelines should suggest how private individuals can contribute to the official authorities' efforts to solve the crisis by sharing relevant and validated(!) information and news. They should contain some basic principles "governing" the provision of information especially online (e.g. through blogs or in social networks) or through new ICT (e.g. smart phones). More broadly, individuals and organisations to be involved in crisis communication should be educated or trained on how reporting alerts and avoid alarming the population unnecessarily or provide incorrect or conflicting messages. Acknowledging that there are other actors in charge of public communication during emergencies or crises is a very sensitive issue. Among other things, it is strictly linked with the determination of the ultimate responsibility (and liability) for issuing the warning and for the quality of the provided information.

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[21] See, for example, the recent case of a false report on the spreading of the Ebola virus in Spain, http://portaley.com/2016/03/enviar-falsos-sobres-infectados-virus-delito-desorden-publico/

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The Erosion of the International Ban on Chemical Weapons: The Khan Shaykhun Attack Case—Challenges and Perspectives for the Chemical Weapons Convention

Maurizio Martellini and Ralf Trapp

1 Introduction

On 4 April 2017, a Sarin gas attack against the Syrian city of Khan Shaykhun in the Idlib province killed more than 80 people [1]. This chemical weapons (CW) attack in Syria was the most serious among the about 100 alleged CW events that occurred in the aftermath of the 21 August 2013 "inception" nerve agent attack in the neighborhood of Damascus (Ghouta).

The purpose of this "reflection paper" is not to deal with the serious problem of the "attribution" of a CW attack within an instable region or a region in chronic conflict, but rather to point out some critical aspects that an event like Idlib implies.

2 Implications of the Attack on Khan Shaykhun

An asymmetric warfare scenario like the Syria one, as well as scenarios in other critical geographic areas in which some of the actors (whether state or non-state actors) are ready to use weapons of mass destruction (WMD)—in this case a chemical weapon—in a substantially politically irrational context, thereby causing a limited number of causalities, makes it possible that multiple actors may cross "red

It is an "Invited paper" and Prof. Martellini was an "Invited speaker" of the conference.

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lines" between conventional and nonconventional warfare multiple times. For the international community to respond to such scenarios in order to protect the integrity of the norm against the use of such weapons, and to find effective means of preventing repeated violations of international norms, investigations of what actually happened are important. But while national intelligence assessments of such incidents may be made public relatively quickly, they cannot as a rule be independently verified and are usually seen as biased by those who are involved in the conflict (directly or as sponsors). As in the Syria case, this may involve big powers and lead to political impasse. International, independent investigations, on the other hand, face certain problems (see, e.g., the OPCW's Fact-Finding Mission (FFM) report on the Khan Shaykhun attack [2], or the seventh report of the OPCW-UN Joint Investigative Mechanism (JIM) [3]).

Especially:

(a) The number of victims is limited, and while the analysis of biomedical samples allows to show that a nerve agent (in this case Sarin) had been used, it provides little further information to determine which use scenario was likely.
(b) The limited number of the craters due to the delivery system used (rocket or bomb or improvised explosive device (IED) disseminating a toxic agent) and difficulties to access the attacked locations to assess context, to analyze weapon remnants, and to collect environmental samples make it difficult to convincingly reconstruct the use scenario.
(c) The limited amount of agent involved and number of environmental samples available, while they may allow to undertake comparative analysis with known agent stocks or synthesis processes, make it difficult to demonstrate beyond any doubt the provenance of the nerve agent used, as well as its operational properties.

As a consequence, statements and conclusions about who might have been able to manufacture, weaponize, and use the CW can be, and are being, challenged. Such challenges do not just put in question the findings of the investigations but often also the integrity and impartiality of the investigation mechanism (see the example of the JIM [4]).

At the same time, independent international investigations such as the OPCW's FFM or the JIM face problems with regard to timely access on-site and procedural manoeuvers which can be used to delay them further or undermine their credibility.

But the crude fact is that in the twenty-first century, we are seeing the re-emergence of the use of chemical weapons in Syria but also in Iraq—weapons which should be banned forever by the Chemical Weapons Convention (CWC). Under the UN Charter, Chapter VII, the international community could, in principle, adopt economic and military sanctions, but against who giving the problem of legal attribution? This is both a question of technical challenges to make attributions at a level of conclusiveness where they cannot be challenged easily on scientific grounds and of a lack of judicial process at the international level that is agreed to be applied to these cases—none of the investigation mechanisms applied in Syria [the OPCW's FFM and its Declaration Assessment Team (DAT), the JIM, the Commission of

Inquiry on Syria of the UN Human Rights Council, and most recently the International, Impartial and Independent Mechanism to Assist in the Investigation and Prosecution of Those Responsible for the Most Serious Crimes under International Law Committed in the Syrian Arab Republic since March 2011 (IIIM)] link to any judicial mechanism such as an international tribunal or the International Criminal Court (ICC), as a result of which conclusions and decisions are based as much on political preferences and power constellations as they are on factual evidence, if not in fact more so.

A well-designed nonconventional CBRN attack calibrated to achieve the intended psychological and political impact but limited enough to avoid generating the amount of evidence that would allow undeniable attribution might become a "modus operandi" for the asymmetric warfare scenarios of this century, at least in the instable or chronic-conflict geographic regions of the world. Therefore, some international CBRN agreements and arrangements should be enforced to assure the global security of the CBRN materials, equipment, and technologies of concern, and some innovative ideas should be developed to assure compliance with the norms underpinning such an international CBRN mechanism.

Returning to the Khan Shaykhun attack, the chemical analysis carried out by France, the United Kingdom, and the OPCW showed that the samples of the CW contained a solid and liquid mix of Sarin with a high degree of potency (toxicity), a specific secondary product (diisopropylmethylphosphonate or DIMP) formed as a by-product during the synthesis of Sarin and an acid scavenger as stabilizer (hexamine, which is solid at room temperature). The JIM in its seventh report included results from a comparative analysis of environmental samples from Khan Shaykhun and five DF samples previously collected from the Syrian chemical weapons stockpile, in an attempt to identify markers for the origin of the Sarin used. It reported the presence of phosphorous hexafluoride, isopropyl phosphate, and isopropyl phosphoroflouridates which it interpreted as indicators that the agent used in Khan Shaykhun originated from the Syrian DF stockpile [3]. Russia subsequently contested this interpretation [5].

Irrespective of these differences, the presence of these substances denotes a "binary route to Sarin." In order to manufacture such a Sarin rocket or IED, a very rooted operative expertise is needed, which is not credible for a non-state actor unless this actor has the ability to access or recruit experts from a state program with the requisite expertise and access to essential material and equipment. The OPCW FFM provided testimonial and physical evidence that limited the choice of possible scenarios, and the JIM collated additional evidence in an attempt to determine who was responsible for the Idlib chemical attack. But neither was able to generate consensus in the international community that would lead to common action to prevent future such CW incidents.

What we would like to point out here is that today, after Syria's accession to the CWC in October 2013, (1) there nevertheless remain CW-usable neurotoxic agents and/or components for binary systems to manufacture them on demand in Syria, (2) there is the problem of how to address the potential incompleteness of Syria's CW declaration to the OPCW in a multilateral context, and (3) even if the specific case of Khan Shaykhun was resolved (something that at least at this moment cannot be expected), there remains the problem of the so-called CW latent knowledge, which cannot be "disinvented," and hence the concrete possibility of a potential CW knowledge and expertise proliferation in the region and worldwide.

3 Possible Actions

The "problem of compliance" within an arms control regime, in this case the Chemical Weapons Convention (CWC), is always a painful and time-consuming process in the international policy and law framework. Furthermore, although the CWC does contain provisions on "sanctions," these are not at the same level as sanctions under Chapter VII of the UN Charter; and if compliance issues are of a serious nature, the CWC foresees that the issue be transferred to the UN (where in the Security Council, any decision on sanctions can be vetoed by any of the five permanent members (P5), while in the General Assembly, no such binding resolutions can be passed). This is needed in order to discourage unilateral and arbitrary military sanctions outside the framework of Chapter VII of the UN Charter.

Neither the voluntary multilateral export control regimes (such as the Wassenaar Agreement, Australia Group, the Missile Technology Control Regime (MTCR), etc.) nor UN sanction mechanisms are able to halt promptly continuous violations of the "WMD taboo"—in this case chemical weapons—if these incidents are low intensity in terms of causalities and timing, if they are pursued in regions under very tense conflicts (or with external actors involved at opposing ends of the range of belligerents), and if the attribution of the guilty actor is difficult or controversial under the international legal framework. However, there exists always the possibility to raise the political costs associated with the pariah status of a state member of an international treaty, in this case the CWC, in pursuing continuous violations of its provisions and commitments.

In the case of violations committed by a state, the rationale to raise soft measures and/or innovative restrain mechanisms is to push it to exercise restraints in pursuing its course of (non-compliant) actions.

In the case of the repeated CWs attacks in Syria, between January 2016 and November 2017, Syria submitted 6 allegations to the OPCW for investigation and referred to 9 other incidents in other communications with the OPCW, and the OPCW information cell recorded 121 incidents of alleged chemical weapons use from open sources [6]—a line of action to induce restraint in nonconventional CW attacks against the Syrian civil population, in line with the humanitarian international law, could be a sort of "catch-all regime" that could build on a partnership of responsible governments, industry, nongovernmental organizations, and any other relevant player. Catch-all clauses, of course, exist already in the export control regimes, but it is not clear how effective they are in this situation and how easily alternative supply channels can be found involving alternative suppliers or black markets. At the same time, the chemical industry has shown that it can roll out selfcontrols and other compliance measures on a global basis, an example being its "Responsible Care®" program. Other examples exist in other industries that have set up voluntary procedures for customer screening to prevent misuse of their products, for example, the bio-industry. Such an approach would imply a more enhanced cooperative approach among governments and dual-use manufacturing companies in strengthening WMD norms/taboos. It may be worthwhile organizing an informal discourse between government experts (security, arms control, export control) and experts from industry and certain competent academic/nongovernmental organizations, to discuss what types of "soft restraint" measures might be acceptable and could actually work.

The risk of not taking action against continued violations of the CW norm/taboo is that these might spread to the other categories of WMD, namely, biological and radiological/nuclear, and might also cause the erosion of the whole international arms control regime, thus weakening the mission and credibility of the agencies involved in the verification and monitoring process.

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A Human Rights Perspective on CBRN Security: Derogations, Limitations of Rights and Positive Obligations in Risk and Crisis Management

Silvia Venier

1 Introduction

The two communities of experts in Chemical, Biological, Radiological and Nuclear (CBRN) security and human rights law (HRL) have rarely considered the overlapping issues of their respective fields [1]. These include, for instance, the incompatibility of the right to life with the use of nuclear weapons, the drain of resources resulting from the existence of nuclear arsenals on the realisation of resource-demanding rights or the fact that the fear engendered by CBRN terrorism is used by governments as an allegedly stronger justification for curtailing or suspending rights. This article aims at providing a broad HRL perspective on CBRN security[1] by looking at two types of obligations imposed by HRL on states, namely, negative obligations (NO) and positive obligations (PO).[2]

When the human rights (HR) project was born after the atrocities of the Second World War, the state was considered as potentially the main oppressor of individual's freedoms and dignity. Civil and political rights, such as those enshrined in the European Convention on Human Rights (ECHR),[3] served exactly the aim of obliging the state to refrain from intruding upon individuals' life in a disproportionate and unnecessary manner. However, as Fredman suggests, "[w]hile the state needs to be restrained from abusing its powers, only the State can supply what is needed from an

[1]In this paper, CBRN security encompasses events of both accidental and intentional origin.

[2]This article adopts the NO/PO dichotomy since it mainly looks at obligations deriving from civil and political rights. In relation to economic, social and cultural rights, the different types of obligations are often referred to as pertaining to the "tripartite typology", i.e. duties to respect, to protect and to fulfil rights.

[3]1950 Convention for the Protection of Human Rights and Fundamental Freedoms (ECHR).

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individual to fully enjoy her rights" ([2], 3). The role of the state is thus evolving from being considered as the chief oppressor of HR whose actions need to be restricted to being more comprehensively identified as the main responsible for HR protection. In other words, under HRL it is now widely acknowledged that duties of restraint (NO, "traditional" obligations to refrain from violating rights) and duties to take action (PO) are complementary and mutually reinforcing.

In this article, it is first argued that CBRN security may have a specific impact on NO by offering allegedly stronger justifications for the admissibility of derogations and limitations of HR (Sect. 2). It is then suggested that more attention must be also devoted to PO, as duties to take action to actively protect rights, including by preventing, preparing and responding to emergencies. After a brief overview on the development of PO under the ECHR (Sect. 3), PO related to risk and crisis management are presented, among those recently identified by the European Court of Human Rights (ECtHR) in cases involving natural and man-made disasters as well as counter-terrorism operations (Sect. 4).

2 Derogation and Limitation Clauses in HRL

According to Hein van Kempen, HRL "fails to provide a comprehensive, balanced view of what security means from a human rights perspective" ([3], 1), since it offers different concepts of security that are not mutually reinforcing and may even undermine each other. These concepts include international security, security as justification to derogate from and limit human rights, negative individual security against the state and positive obligations to offer security against other individuals (Ibid.).[4] The second concept mentioned above is mainly based on NO, i.e. duties not to impact on HR in a disproportionate or unnecessary manner when implementing security measures. This section looks at derogations from and limitations of HR with the aim to explore whether security measures adopted particularly to counter CBRN risks have specific implications on HRL.

The existence of derogation clauses in HR treaties[5] represents not simply a concession to the inevitability of exceptional measures in particularly serious circumstances but also a way to control situations that pose the greatest challenge for HR protection. Fitzpatrick identifies six key requirements in the derogation regime [4], including (1) the identification of a threshold of severity, (2) an official proclamation, (3) compliance with other obligations under international law, (4) necessity and proportionality of the measures adopted, (5) non-discrimination in applying

[4]As this article will show, however, PO to provide security are broader than simply securing individuals against threats posed by other individuals.

[5]As included in the 1966 International Covenant on Civil and Political Rights (ICCPR), Article 4, and ECHR, Article 15.

those measures and (6) respect of non-derogable rights.[6] The hearth of the derogation regime is constituted by points (1) and (4) above: the situation has to constitute a "public emergency threatening the life of a nation", and the measures adopted have to be "strictly required by the exigencies of the situation".

The ECtHR found that a "public emergency" indicates "an exceptional situation of crisis or emergency which affects the whole population and constitutes a threat to the organized life of the community of which the State is composed".[7] A wide margin of appreciation is granted to national authorities in their determination of whether these conditions are met. As noted by Gross and Ni Aolain, the margin of appreciation has been "extended and expanded in these cases, increasingly eating away the Court's ability to exercise meaningful and effective supervision over the actions and measures undertaken by state parties in circumstances of alleged public emergencies" ([5], 632). This is particularly problematic if one considers situations in which "the state of emergency under review [. . .] is rather an entrenched emergency, i.e. a de facto, permanent, complex or institutionalized state of emergency" (Ibid., 645).

Sheeran suggests that "[t]errorism can become a form of entrenched public emergency that breaks down the theoretical distinction between the normal and the exception or even stretches the exceptional to become the norm" ([6], 545). Indeed terrorism poses a significant challenge to avoid the abuse of states of emergencies since "[t]he point at which the threat of terrorism reaches the threshold necessary to satisfy a public emergency that requires derogation of human rights obligations is unclear" (Ibid., 542). Interestingly, this point has been often identified as being terrorism deploying weapons of mass destruction (WMD) or more precisely as the situation in which "a state uncovers compelling evidence that a terrorist organization has obtained or will soon obtain a weapon of mass destruction capable of paralyzing essential public institutions" ([7], 62).[8] In contemporary times, invoking a derogation from HRL in similar circumstances is not simply a theoretical possibility: after the November 2015 terrorist attacks in Paris, Prime Minister Manuel Valls stated that the risk of chemical and biological terrorism could not be ruled out, while he was asking the French Parliament to extend the country's state of emergency.[9] In the

[6] Article 15 (2) ECHR allows no derogation from Article 2 (the right to life), except in respect of deaths resulting from lawful acts of war, Article 3 (the prohibition of torture and other forms of ill-treatment), Article 4 (the prohibition of slavery or servitude) and Article 7 (no punishment without law).

[7] ECHR, *Case of Lawless v. Ireland*, Judgement, 14 November 1960, para 28. This definition has been further refined by successive case law.

[8] This scenario represent some similarities to the so-called ticking-bomb scenario, when it is argued that torture may be allowed in order to prevent WMD terrorism. See ([8], 250). Among the many critics of the ticking-bomb scenario, Luban suggests that it is a "remarkably effective propaganda device" as it "rests on a number of assumptions, each of which is improbable, and which taken together are vanishing unlikely". See [9].

[9] See http://www.politico.eu/article/manuel-valls-france-rule-out-chemical-threat-paris-terror-attack/

aftermath of these attacks, France submitted a notice of derogation from the ECHR,[10] currently extended until July 2017, which has been criticised as being vague and not addressing what are the measures taken that are "strictly required by the exigencies of the situation" [10].

In addition to derogation clauses, HRL allows states to restrict certain civil and political rights in the interest of national security, public safety or public health or to protect the rights and freedoms of others. While many of the same principles, such as necessity, proportionality and non-discrimination, are applicable to both derogations and ordinary limitations of rights, there are also important differences. If inherent in the idea of derogation is the need to deal with an emergency situation until normal conditions are restored, ordinary limitations of rights usually occur in situations of normalcy and can have a permanent character. While states of emergency are usually said to be one of the most serious challenges for HR protection, ordinary limitations are the normal outcome of the balancing exercise between individual and community interests or between individual interests themselves. Similarly to derogations, however, the possibility of abuse cannot be ruled out, particularly since there are some inherent difficulties in balancing HR with collective goals which are not easily defined by law ([6], 499). The post 9/11 world is experiencing impressive interferences on HR in the name of national security, including the adoption of mass surveillance measures with a disproportionate impact on the right to privacy and freedom of expression, or the infringements of due process rules for individuals suspected to pertain to terrorist groups.

It has been suggested that the measures adopted to specifically counter CBRN terrorism are not having a HR different impact than counter-terrorism measures ([11], 161). However, for the specific character of CBRN material such as its dual-use potential, it may be argued that additional implications are likely to emerge, for instance, in relation to academic freedom. This was the case in the H5N1 research controversy, which involved the publication of two papers reporting the results of research on genetically engineered strains of the avian influenza virus.[11] The US National Science Advisory Board for Biosecurity (NSABB) initially recommended that neither paper should be published in full, justifying this decision by stating that they could be used to make a bioweapon or that attempts by scientists to replicate their results could lead to accidental release of the pathogen. This controversy may offer an example on CBRN security measures impacting on other freedoms and rights in addition to the ones usually impacted by counter-terrorism measures more in general, such as privacy, freedom of expression and due process.

[10] Declaration contained in a Note verbale from the Permanent Representation of France, dated 24 November 2015, registered at the Secretariat General on 24 November 2015.

[11] The two research teams that authored the papers were led by Yoshihiro Kawaoka, who conducted his research at the University of Tokyo and the University of Wisconsin-Madison, and Ron Fouchier, who conducted his research at Erasmus Medical Center in the Netherlands. The papers were submitted to Nature and Science, respectively. For an account of this controversy, see [12].

3 Positive Obligations Under the ECHR

A complete understanding of HR implications in crisis situations needs to consider also PO, which put emphasis on the fact that the state's failure to act can limit freedom and endanger dignity as much as its disproportionate action. The development of PO, which according to Alexy has become "a European project" ([13], 3), determines an expansion of obligations incumbent upon the state. Since when the notion of PO under the ECHR first appeared in the late 1960s, the ECtHR has broadened this category of obligations to the point that all provisions "have now a dual aspect in terms of their requirements, one negative and one positive" ([14], 6). The main elements of PO identified by the Strasbourg Court include the duty to adopt laws or to amend legislation in order to ensure effective protection of rights, to take concrete ad hoc measures to implement legislative and administrative frameworks, to conduct effective investigations in cases of alleged violations and to keep the population informed of any life- or health-threatening risks.

Because of their potential open-ended scope, there may be difficulties in determining their exact scope and content. Besson suggests that a related challenge is the problem of justiciability, i.e. the fact that courts are expected to exercise considerable self-restraint in adjudicating over potentially resource-demanding rights [15]. It is therefore important to clarify their legal basis and to clearly specify the scope and content of such duties. The ECtHR affirms that PO are based either on a specific provision (e.g. Article 2 establishes that "[e]veryone's right to life shall be protected by law") or on the combination of the different provisions and Article 1, which refers to the obligation to "secure", and not merely respect, rights. The imposition of PO is inextricably linked with the effective application of the Convention, which "is intended to guarantee not rights that are theoretical or illusory but rights that are practical and effective".[12] Furthermore, PO are constantly refined in light of the interpretation of the ECHR as a "living instrument".

The development of PO under the ECHR is still subject to limited academic attention. In 1995, Sudre explored the potential arbitrariness in choosing to frame a case in negative or positive terms [16], a discussion more recently and comprehensively developed by Lavrysen [17]. Other authors identified common elements in PO development [18, 19], discussed their potentially open-ended scope [20] and their applicability to other institutions, such as the European Union [21]. Looking at PO through the lenses of international law of state responsibility, Pisillo-Mazzeschi distinguishes between PO of immediate result (i.e. establishing a legal and administrative framework to protect rights), of due diligence (i.e. implementing the framework in the best possible way) and of progressive realisation (particularly relevant to economic and social rights) [22]. Interestingly, the author notes that this categorisation may be subject to change: obligations of second and third type may assume more legal strength over time ([22], 495).

[12]ECHR, *Case of Airey v Ireland*, 9 October 1979, para. 24.

4 Positive Obligations in Risk and Crisis Management

The ECtHR jurisprudence is of particular relevance to identify the content of PO in relation to prevention and response of major emergencies, including disasters caused by natural or man-made hazards, as well as counter-terrorism operations. In these cases, PO are mainly related to protection of the rights to life (Article 2) and to private and family life (Article 8) and can be identified in all the phases of the crisis management cycle, from prevention to response and recovery.

The first PO incumbent upon the state is to assess and mitigate the risk of disasters through the adoption of adequate normative and regulatory frameworks. In *Oneryildiz*,[13] the court held that a primary duty is "to put in place a legislative and administrative framework designed to provide effective deterrence against threats to the right to life".[14] In the context of dangerous industrial activities, regulations must be geared to the special features of the activity in question. Domestic regulations must govern "the licensing, setting up, operation, security and supervision of the activity and must make it compulsory for all those concerned to take practical measures to ensure the effective protection of citizens whose lives might be endangered by the inherent risks".[15] Ad hoc measures to ensure that these frameworks are implemented in practice include the duty to take technical and precautionary measures and to establish procedures for emergency management. Xenos suggests that these practical measures have to be in line with "the minimum pan-European standards of safety" ([23], 246). Furthermore, it is expected that "early studies and reports must be prepared by the state's agents that control the industrial activity from the very beginning" ([23], 245).

States are responsible for monitoring and mitigating the risk deriving also from natural hazards. In *Budayeva*, the court affirmed that a greater margin may be afforded "in the sphere of emergency relief in relation to a meteorological event, which is as such beyond human control",[16] but it nevertheless stated that the exact scope of the obligation depends on the extent to which the hazard can be foreseen. In any case, a PO is to have in place a system "to adequately inform the public about any life-threatening emergency".[17] The court held that in this case "the authorities' omission in ensuring the functioning of the early warning system was not justified"[18] and found that there was a "causal link between the serious administrative flaws [. . .] and the death of and injuries to the applicants".[19] The existence of PO in situations of

[13]ECHR, *Case of Öneryildiz v. Turkey*, Judgment, 30 November 2004. Öneryildiz involved the death of 39 people caused by a methane explosion at a municipal rubbish tip close to a slum area of Istanbul.

[14]Ibid., para 89.

[15]Ibid., para 90.

[16]ECHR, *Case of Budayeva and others v. Russia*, Judgement, 29 September 2008, para 135.

[17]Ibid. para 133.

[18]Ibid. para 155.

[19]Ibid. para 158.

natural hazards is confirmed by more recent case law, namely, in the *Kolyadenko* and *Ozel* cases.[20]

Another PO refers to the duty to adequately plan and conduct a rescue operation. In two recent dramatic cases related to counter-terrorism operations, the court offered some clarification on what is required to avoid threats to the right to life during such operations. The case of *Finogenov*[21] concerned the use of an anaesthetic gas[22] by Russian authorities in October 2002, when storming a theatre in Moscow where hundreds of civilians had been taken hostage by Chechen terrorists. Russian authorities killed all terrorists and rescued hundreds of hostages, but approximately 130 hostages died due to the adverse reactions to the incapacitating chemical agent used. The court considered that it was "not in a position to indicate to member States the best policy in dealing with a crisis of this kind [. . .]"[23] and therefore established that the decision to resolve the crisis by using the "non-lethal" gas was not in breach of Article 2. However, this conclusion did not "preclude the Court from examining whether the ensuing rescue operation was planned and implemented in compliance with the authorities' positive obligations [. . .], namely whether the authorities took all necessary precautions to minimise the effects of the gas on the hostages, to evacuate them quickly and to provide them with necessary medical assistance".[24] Interestingly, the court justified its competence by stating that "the planning and conduct of the rescue operation, in particular the organisation of the medical aid to the victims and their evacuation, can be subjected to a more thorough scrutiny than the political and military aspects of the operation".[25] The outcome of the court's assessment was that Russian authorities seemed to have been completely unprepared to deal with persons affected by the gas, due to the limited on-site coordination between various services and the inadequate information exchange on the type of gas used which resulted in the lack of appropriate medical treatment.

A more recent judgement offered further details on how to assess the lawfulness of a large-scale antiterrorism operation. The case concerned a dramatic hostage taking in a school of the town of Beslan, which lasted 3 days and involved at least 1100 persons including more than 700 children, and ended with the death of more

[20]ECHR, *Case of Kolyadenko and others v. Russia*, Judgement, 28 February 2012, and ECHR, *Case of Ozel v Turkey*, Judgement, 17 November 2015.

[21]ECHR, *Case of Finogenov and others v Russia*, Judgement, 20 December 2011.

[22]Believed to be a derivative of the opiate fentanyl, an incapacitating chemical agent not scheduled in the Chemical Weapons Convention. The Moscow theatre crisis produced an intense debate on whether non-lethal chemicals (NLCs) are banned under the Chemical Weapons Convention. On one side, NLCs' advocates emphasised that the combination of NLCs with conventional forces had contributed to ending the crisis sooner than what would be expected without the use NLCs. On the other side, NLCs' sceptics pointed out that the death rate of the fentanyl was 16%, more than twice "lethal" chemicals' fatality rate in WWI. The Moscow crisis had demonstrated that incapacitating chemicals may result in being "lethal" if used without strict control of dosage.

[23]Ibid., para 223.

[24]Ibid., para 237.

[25]Ibid. para 243.

than 300 persons. In *Tagayeva*,[26] the court found a violation of Article 2 of the Convention because of the authorities' failure to try to prevent an event which had been planned days before and about which they had precise knowledge. The inadequate planning of the response operation offered further justifications to find a HR violation.

The last PO refers to the duty to conduct an adequate investigation to ascertain the facts that caused the death of individuals. States have the obligation to investigate any errors of those responsible of implementing regulatory frameworks and to grant reparation for violations. The court has clarified that sanctions, which may be criminal sanctions in particular circumstances, "must be adequate to reflect the gravity of the consequences involved and have the requisite of deterring effect against negligence on the part of public officials in charge of industrial control" ([23], 250). Sanctions may also function to deter negligence from public authorities and private entrepreneurs: in *Budayeva*, the court held that "negligence was an aggravating factor contributing to the damage caused by natural forces".[27]

5 Conclusive Remarks

This article has aimed at providing a HRL perspective on CBRN security. It has first argued that CBRN security measures may have a specific impact on our understanding of NO, by discussing the implications for derogations and limitation clauses. It has then suggested that it is becoming increasingly clear that PO are extremely relevant to HR protection and play a crucial role even in situations when wide margins of appreciation are granted to public authorities, such as in the prevention and response to major emergencies. The identification of specific duties in these circumstances are among the main outcomes of the development of PO under the ECHR. The scope of PO depends on the extent to which the risk is foreseeable and susceptible to mitigation. States have considerable flexibility with regard to the operational choices they must make in terms of priorities and resources devoted to prevention and preparedness strategies. However, the ECtHR puts particular emphasis on the potentially affected population's right to be informed and alerted of specific risks. Finally, states have the duty to identify any shortcomings or errors committed by those responsible to implement regulatory frameworks and, if applicable, to guarantee the victims' right to reparation.

[26]ECHR, *Case of Tagayeva And Others V. Russia*, Judgement, 13 April 2017.

[27]Budayeva, para 182.

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The EU Response to the CBRN Terrorism Threat: A Critical Overview of the Current Policy and Legal Framework

Francesca Capone

1 Introduction

Recently, the European Union (EU) has been called to face a significant surge of terrorist threats and has been affected by deadly terrorist attacks. Terrorism has been high on the EU agenda since 2001 as several EU Member States have been directly involved in the US 'war on terror', triggered by the 9/11 attacks. In the following years, the tragic events that occurred in Madrid and London have urged the EU to design a comprehensive counter-terrorism strategy, which is based on four pillars, i.e. prevention, protection, pursuit and response.[1] The unprecedented wave of terrorist attacks carried out on the EU soil since January 2015 and claimed by the Islamic State of Iraq and the Levant (ISIL) has marked the beginning of a new era in the struggle against terrorism and has prompted the reinforcement of the exiting framework. The self-proclaimed 'caliphate', which is still spanning over portions of Syrian and Iraqi territories, has captured global attention by using various types of exemplary violence and relying on technological means and social networks to disseminate its message and recruit new adepts [4]. ISIL's approach definitely departs from that of many other terrorist organisations, e.g. whereas Al-Qaida has built its strategy on the goal of 'defeating the others' [5], ISIL focuses mainly on providing a concrete alternative to the models set up by Western and 'apostate' countries. ISIL unique features, thus, encompass the ability to attract foreigners and lure them to participate in the armed conflicts currently taking place in the Middle East,[2] as well as the fascination exercised over people indoctrinated from afar and ready to plan attacks in their own countries (the so-called sleeper cells or human time

[1] On the EU antiterrorism framework, see [1]. See also [2, 3].

[2] On the Foreign Fighters phenomenon [6].

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bombs, awaiting a signal to act). Recent allegations that ISIL is seeking nuclear material for a dirty bomb have exacerbated fears that the group could carry out a weapon of mass destruction (WMD) attack outside of the Middle East.[3]

Although some experts doubt that ISIL and its followers will ever acquire the technical expertise to pose a real WMD threat,[4] which refers to any mine, bomb or device that releases chemical, biological, radiological and nuclear (CBRN) material,[5] it is clear that the risk itself is frightening and shall not be underplayed. It was reported that on 14 November 2015, the day after the terrorist attacks in Paris, the French Government authorised the use of atropine sulphate, which can be used as an antidote in the event of chemical attacks, and that such antidote has been, indeed, distributed to emergency medical services and firefighting teams.[6] A few days later, the Belgian police retrieved a worrisome video while searching the home of a man with ties to ISIL.[7] The video showed that members of the terrorist group were spying on a senior researcher working for a Belgian nuclear centre that produces a significant portion of the world's supply of radioisotopes. Radioisotopes are used by hospitals and factories around the globe as diagnostic tools, but they are also capable of causing radiation poisoning and sickness ([7], 26; see also [8]), making them a potential target for terrorists seeking to build a so-called dirty bomb. The authorities have since speculated that the group was trying to figure out a way to collect such materials from the nuclear centre, perhaps by kidnapping the researcher. Furthermore, it has been noted that radioisotopes are too plentiful to count precisely, but roughly estimate they are contained in more than 70,000 devices, located in at least 13,000 buildings all over the world, which in many cases lack special security safeguards (Ibid.).

Besides sporadic episodes that suggest an interest in the acquisition of CBRN materials and the report that ISIL fighters stole nearly 90 pounds (40 kg) of low

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[3]Warrick and L. Morris, "How ISIS nearly Stumbled on the Ingredients for a 'Dirty Bomb', The Washington Post, 22 July 2017, https://www.washingtonpost.com/world/national-security/how-isis-nearly-stumbled-on-the-ingredients-for-a-dirty-bomb/2017/07/22/6a966746-6e31-11e7-b9e22056e768a7e5_story.html?utm_term=.0a6caf49f49e (last accessed 2 August 2017).

[4]European Parliament, "CBRN Terrorism: Threats and the EU Response", Briefing, January 2015, available at http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/545724/EPRS_BRI(2015)545724_REV1_EN.pdf (last accessed 15 May 2017), (EP Briefing I).

[5]In sum, it is the substance released, rather than the scale of the effect, that is important. However, high-grade WMD could kill thousands of people and cause long-lasting contamination of vast areas. Ibid., 2.

[6]European Parliament, "ISIL/Da'esh and Non-Conventional Weapons of Terror", Briefing, December 2015, available at http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/572806/EPRS_BRI(2015)572806_EN.pdf (last accessed 18 May 2017), (EP Briefing II).

[7]Mr Mohamed Bakkali, who rented the home where the films were seized in a raid, was captured on 26 November 2015 and has been charged with engaging in terrorist activity and murder, stemming from his alleged involvement in the 13 November attacks in Paris that killed 130 people and wounded hundreds more.

enriched uranium from scientific institutions at the Mosul University in Iraq,[8] so far there has been no public, concrete evidence that ISIL is aggressively pursuing the radioactive building blocks of a dirty bomb or any other WMD.[9]

The mere possibility that this will happen, however, triggers the question of whether the current EU antiterrorism framework is sufficiently developed to effectively prevent and respond to such a challenge.

After presenting the EU antiterrorism strategy and the latest layer added in the aftermath of the attacks occurred in France at the beginning of 2015, this chapter will provide an overview of the legislation adopted at the EU level to tackle the issues at stake, and, finally, it will discuss whether the existing policies and the EU's legal framework are, in principle, capable of addressing the challenges posed by a CBRN threat. In fact, if we assume that outside the war-torn Middle East ISIL is not operating in a black spot—in other words, that at least at the EU level we can count on a stable and sound political and legal authority—the question of the impact of the current strategies and norms on potential WMD's seekers can be addressed only by providing a critical assessment of the present framework.

2 The EU Antiterrorism Strategy

The events that occurred in Europe since the beginning of 2015, in particular the attacks in Paris and the subsequent episodes in Belgium and Denmark, have fuelled a crucial debate within the EU on the urge to strengthening its counter-terrorism strategy and adapting it to the current threats. On 12 February 2015, EU Heads of State and Government have discussed new initiatives that aim, among other goals, at preventing potential European foreign fighters from going to fight alongside terrorist groups in the Middle East and carrying out attacks in Europe upon their return [9]. Prior to start the analysis of the existing policy and legal framework it is important to stress that the EU role in counter-terrorism is 'complementary'[10]; meaning that the EU strategy in this field is dominated by Member States' governments *that are assisted* by EU executive institutions and offices, such as the European Commission and the EU Counter-Terrorism Coordinator.

As mentioned above, the origins of the EU counter-terrorism agenda can be traced back to the conclusions of the extraordinary EU Justice and Home Affairs Council (JHA) convened on 20 September 2001 in the aftermath of the 9/11 attacks [1].

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[8]D. Oliver, "Growing ISIL CBRN Threat", CBRNe Portal, 25 January 2016, available at http://www.cbrneportal.com/growing-isil-cbrn-threat/ (last accessed 16 May 2017).

[9]More pessimistic is the view expressed by NATO, according to which 'we might soon enter a stage of CBRN terrorism', W. Rudischhauser, "Could ISIL Go Nuclear?", NATO Review, 2015, available at http://www.nato.int/docu/review/2015/ISIL/ISIL-Nuclear-Chemical-Threat-Iraq-Syria/EN/index.htm (last accessed 15 May 2017).

[10]Consolidated version of the Treaty on the Functioning of the European Union, 26 October 2012, OJ L. 326/47-326/390.

These conclusions called for concerted action in 33 specific areas, with a further eight measures relating to cooperation with the USA.[11] Three years later, the terrorist attacks in Madrid, which occurred on 11 March 2004, galvanised the EU into further and renewed action. On 25 March 2004, the European Council adopted a new declaration on combatting terrorism, containing 57 specific measures, many of which were new.[12] In 2005, following the '7/7' bombings in London, the EU counter-terrorism programme was renewed again with the adoption of the EU Counter-Terrorism Strategy, covering, as mentioned above, four strands of work, i.e. 'prevent, protect, pursue, respond'.[13] Consistently with this pattern, a new layer has been added to the EU counter-terrorism framework in February 2015, when the EU leaders have endorsed an ambitious approach based on a comprehensive strategic vision based on three pillars: (1) ensuring the security of citizens, (2) preventing radicalisation and safeguarding values and (3) cooperating with the EU's international partners.[14] Furthermore, in line with the directions pointed by the European Council, on 28 April 2015, the European Commission has adopted the European Agenda for Security, which includes counter-terrorism as a top priority and supports the approach previously identified by the EU Heads of State or Government.[15] Notably, whereas the EU Counter-Terrorism Strategy and the Statement by the members of the European Council contain no reference to WMD or CBRN threat; the European Agenda on Security makes and explicit reference to CBRN, stressing that:

> One way to disrupt the activities of terrorist networks *is to make it more difficult to attack targets and to access and deploy dangerous substances, such as Chemical, Biological, Radiological and Nuclear materials and explosives precursors*. Protecting critical infrastructures, such as transport infrastructure, and soft targets, for instance at mass public events, present real challenges for law enforcement, public health authorities and civil protection authorities.[16]

The European Agenda on Security provides an overarching strategic focus for the EU and its Member States to take action in the area of security.[17] Nonetheless, given

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[11]Extraordinary Council meeting, Justice, Home Affairs and Civil Protection, the Fight against Terrorism Conclusions 4, 20 September 2001.

[12]Declaration on Combatting Terrorism, 25 March 2004 (see Section 5.1.1).

[13]The European Union Counter-Terrorism Strategy, 14469/4/05 REV 4, 30 November 2005, 6.

[14]Informal meeting of the Heads of State or Government Brussels, 12 February 2015, Statement by the members of the European Council, available at http://www.consilium.europa.eu/en/press/press-releases/2015/02/150212-european-council-statement-fight-against-terrorism/, (hereinafter 'Statement by the members of the European Council'). See also [10], 305.

[15]Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, The European Agenda on Security, COM (2015) 185, 24 April 2015 (hereinafter "The European Agenda on Security").

[16]Ibid., 14.

[17]See the Communication from the Commission to the European Parliament and the Council Implementing the European Agenda on Security: EU action plan against illicit trafficking in and use of firearms and explosives, COM(2015) 624 final.

its broad scope, although the Agenda does mention the issue of CBRN threats, it cannot be said that it tackles it in detail. This menace is better addressed in other documents, e.g. the 'Council Conclusions and new lines for action by the European Union in combating the proliferation of weapons of mass destruction and their delivery systems',[18] which builds on the 2003 EU strategy against proliferation of weapons of mass destruction[19]; the so-called EU CBRN Action Plan adopted in 2009,[20] which is based on an all-hazard approach and focuses on three key set of actions, i.e. prevention, detection and preparedness and response; and the Global Strategy for the European Union's Foreign and Security Policy launched in June 2016.[21] Furthermore, in May 2014, the European Commission adopted a Communication setting out a new approach to mitigating CBRN-e risks, thus officially merging policy on CBRN materials with that concerning explosives. The focus of the new approach is on stepping up capabilities to detect CBRN-e risks and putting in place measures to mitigate such threats. Finally, the Annual Progress Report on the Implementation of the European Union Strategy against the Proliferation of Weapons of Mass Destruction,[22] which covers the activities carried out in 2016, has showed the strong EU commitment against the proliferation of WMD. In particular, the EU strategy in this field remains informed by four guiding principles, i.e. (1) effective multilateralism by promoting the universality of international treaties, conventions and other instruments and their implementation, (2) close cooperation with countries to strengthen the international non-proliferation regime, (3) addressing non-proliferation issues in the EU's bilateral political and non-proliferation and disarmament dialogue meetings and in more informal contacts and (4) the effective and complementary use of all available instruments and financial resources in order to maximise the impact of the EU activities in pursuit

[18]Council conclusions and new lines for action by the European Union in combating the proliferation of weapons of mass destruction and their delivery systems, Council of the European Union, 17172/08.

[19]The Strategy recognises that non-proliferation, disarmament and arms control policy can make an essential contribution in the global fight against terrorism by reducing the risk of non-state actors gaining access to weapons of mass destruction, radioactive materials and means of delivery.

[20]Communication from the Commission to the European Parliament and the Council on Strengthening Chemical, Biological, Radiological and Nuclear Security in the European Union—an EU CBRN Action Plan, COM(2009) 273 final.

[21]The Global Strategy for the European Union's Foreign and Security Policy recognises that proliferation of weapons of mass destruction and their delivery systems remains a growing threat to Europe and the wider world and restates EU support for the expanding membership, universalisation, full implementation and enforcement of multilateral disarmament, non-proliferation and arms control treaties and regimes. See Shared Vision, Common Action: A Stronger Europe: A Global Strategy for the European Union's Foreign and Security Policy, June 2016, available at http://eeas.europa.eu/archives/docs/top_stories/pdf/eugs_review_web.pdf (last accessed 17 May 2017).

[22]Annual Progress Report on the Implementation of the European Union Strategy against the Proliferation of Weapons of Mass Destruction, EEAS(2017) 3.

of its foreign policy objectives.[23] Hence, the current EU policy framework dealing with WMD encompasses a wide range of initiatives and actions, which must be read in combination with the existing legal framework, presented in the following paragraph.

3 An Overview of the EU Antiterrorism Legal Framework

Before diving into the exiting EU antiterrorism legal framework, it is important to stress that the EU has never been shy in voicing its support for the full, complete and effective implementation of the relevant universal non-proliferation treaties, i.e. the Biological and Toxin Weapons Convention (BTWC),[24] the Chemical Weapons Convention (CWC)[25] and the Treaty on the Non-Proliferation of Nuclear Weapons (NPT).[26] In addition to those treaties, whose main scope is to ultimately outlaw several classes of WMD, the EU uses every opportunity to advocate for the Comprehensive Nuclear Test-Ban Treaty (CTBT) ratification in international *fora* and meetings and continues to use diplomatic means to promote the entry into force of the CTBT.[27] The EU has also adopted a regulation that sets out a uniform system to control the export, transfer, transit and brokering of dual-use items, i.e. goods and technology for civilian but also military use, including items that may assist in any way in the manufacturing of nuclear weapons or other nuclear devices.[28] The EU dual-use export controls stem from international obligations (in particular UN Security Council Resolution 1540, the CWC and the BTWC) and are in line with commitments agreed upon in multilateral export control regimes.

It is also worth mentioning that the EU actively participated in the review process of UN Security Council Resolution 1540(2004),[29] which continues to be a central pillar of the international non-proliferation architecture as it represents the first international instrument that deals in an integrated and comprehensive manner with WMD, their means of delivery and related materials. More in detail, the Resolution requires all Member States to adopt the necessary legislation barring non-state actors from getting nuclear, chemical or biological weapons and to establish appropriate domestic controls for related materials to prevent their illicit

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[23] Ibid., 2.

[24] Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction, 1015 UNTS 163.

[25] Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction, 1974 UNTS 45. Notably, the CWC established the Organization of the Prohibition of Chemical weapons (OPCW) as its implementing body.

[26] Treaty on the Non-Proliferation of Nuclear Weapons, 729 UNTS 161.

[27] Comprehensive Nuclear Test-Ban Treaty, 35 ILM 1439 (1996).

[28] Council Regulation (EC) No 428/2009 of 5 May 2009 setting up a Community regime for the control of exports, transfer, brokering and transit of dual-use items

[29] S/RES/1540(2004).

trafficking.[30] In 2016, the 1540 Committee carried out a comprehensive review on the status of implementation of Resolution 1540(2004). In this exercise the Committee interacted with the UN membership, international organisations, academics, industry and parliamentarians. In particular the EU set out its activities in support of UNSCR 1540 in a report addressed to the 1540 Committee and formulated a series of recommendations for the future development of the Resolution.

Many of these recommendations were included in the report on the comprehensive review that the 1540 Committee submitted to the UNSC and in the subsequent UNSC Resolution 2325(2016) adopted on 15 December 2016 and cosponsored by all 28 EU Member States.[31] Significantly, Resolution 1540 and the subsequent ones dealing with the issue on non-proliferation of WMD do not contain a definition of terrorism, thus referring to 'terrorism threat', 'terrorist acts' and 'terrorist purposes', without explaining the breadth and scope of these terms. This shortcoming stems from the lack of a universally accepted definition of terrorism, which certainly represents one of the most debated challenges concerning the existing international legal framework.[32]

Notably, at the EU level, the attempts made to outline the legal contours of terrorism have been more fruitful than at the international level. The 2002 EU Framework Decision, whose scope is to uniform Member States' criminal laws on the prosecution of persons who committed terrorist acts, was adopted in the aftermath of the 9/11 attacks and serves the purpose to uniform Member States' domestic criminal laws providing a definition of terrorist activities[33] and terrorist groups.[34] The Framework Decision has been revised in 2008, and the amendments have introduced three new offences linked to terrorism, i.e. 'public provocation to commit a terrorist offence', 'recruitment to terrorism' and 'training for terrorism'.[35] Due to the growing threat posed by the foreign terrorist fighters phenomenon and the consequent adoption of UN Security Council Resolution 2178(2014),[36] the Framework Decision is going to be replaced by a new Directive on combating terrorism, whose text has been adopted by the EU Parliament on 17 February 2017 and by the Council on 7 March 2017.[37] The Directive criminalises the conducts enshrined in the operative part of Resolution 2178, *inter alia* travelling within, outside or to the EU for terrorist purposes; the organisation and facilitation of such travel; training and

[30] Ibid., para. 3.

[31] S/RES/2325 (2016).

[32] On the lack of a universal definition of terrorism, see, inter alia, [11, 12].

[33] Art. 1, Council Framework Decision of 13 June 2002 on combating terrorism (2002/475/JHA), OJ L 164, 22.6.2002, 3–7.

[34] Ibid., Art. 2.

[35] Council Framework Decision 2008/919/JHA of 28 November 2008 amending Framework Decision 2002/475/JHA on combating terrorism, OJ L 330, 9.12.2008, 21–23.

[36] S/RES/2178 (2014).

[37] Directive of the European Parliament and of the Council on combating terrorism and replacing Council Framework Decision 2002/475/JHA and amending Council Decision 2005/671/JHA.

being trained for terrorist purposes; providing or collecting funds with the intention or the knowledge that they are to be used to commit terrorist offences and offences related to terrorist groups or terrorist activities. Notably, neither the Framework Decision nor the Directive pay particular attention to the issue of CBRN threats, besides including in the list of terrorist offences the 'manufacture, possession, acquisition, transport, supply or use of explosives or weapons, including chemical, biological, radiological or nuclear weapons, as well as research into, and development of, chemical, biological, radiological or nuclear weapons'.[38]

Despite what can be defined as a detailed and sound legal framework on 'combating terrorism', which is constantly developing to face new challenges, there are still a number of significant shortcomings that hamper its effective application, for example, the significant criminal enforcement gaps among the Member States' domestic legislations.

4 Conclusive Remarks

Even though most experts agree that the probability of a CBRN terrorist attack remains much smaller than that of a comparably damaging attack with conventional arms, especially since the latter are much easier to acquire, the EU and its Member States still need to implement effective measures to mitigate this risk. Up until now the weapons of choice of ISIL have been explosive devices, including car bombs and suicide belts, and automatic weapons, but the group constantly vows that its future strikes will be more lethal and even more shocking. Thus, the possibility that ISIL could start using chemical, biological, radiological or even nuclear materials in the context of future attacks on European targets cannot be quickly dismissed, and in any case, it cannot be overlooked.

There are a plethora of documents and norms that in principle govern the EU's policies and legal framework in this delicate field; however there is no EU's legislation specifically targeting or seeking to control chemical, biological, radiological and nuclear substances that could be used as ingredients of weapons of mass destruction.[39] Furthermore, the most pressing goals identified so far are to ensure that unauthorised access to CBRN materials is difficult everywhere across Europe, that Member States have the capacity to detect CBRN materials in order to prevent CBRN incidents and that they have in place tools and mechanisms to respond to incidents involving CBRN materials and recover from them as quickly as possible. However, as the primary responsibility to protect the population against CBRN

[38] See, respectively, Art, 1(1)(f) of the Council Framework Decision of 13 June 2002 on combating terrorism and Art. 3(1)(f) of the Directive on combating terrorism.

[39] See Regulation (EU) No 98/2013 on the marketing and use of explosives precursors, which is based on Article 114 of the Treaty on the Functioning of the European Union (TFEU) and has been amended in 2016 in order to add magnesium nitrate hexahydrate to the list of explosives precursors in Annex II. C/2016/7650, OJ L 34, 9.2.2017, 3–4.

incidents, including terrorist attacks, is borne by Member States, the EU's role in this sphere will always be essential, *but* limited. This means that the implementation of the relevant legal provisions, action plans and strategies is still dependent on the political will and economic means of each and every Member State and, thus, it risks to remain utterly uneven.

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Chemical and Biological Weapons Conventions: Orienting to Emerging Challenges Through a Cooperative Approach

Naeem Haider

1 Introduction

The Chemical Weapons Convention (CWC) and Biological Weapons Convention (BWC) are leading international legal instruments for guarding against the proliferation and misuse of chemical and biological (chem-bio) agents [1] in the context of CBRN. For meaningful utilization this international legal framework requires prioritizing risks and adjusting resources and efforts. These regimes have weaknesses, which needs to be addressed at priority. This has become essential due to rapid scientific and technological (S&T) developments and evolving international security environment. National capacity building mainly requires enhancement of knowledge, human resource development and new scientific knowledge and technology. The cooperative relations amongst states and international organizations can contribute to national capacity building, strengthen international regimes and prevent the misuse of chemistry and biology and would also bolster their peaceful uses. CWC and BWC obligate states to provide fullest possible cooperation that could advance economic and technological development within states [2]. Thus, assistance and cooperation is an international obligation that merits renewed attention by states and relevant international organizations. International regimes remain relevant when they are non-discriminatory and contribute to economic and security needs of all states, rather than a select few. Such a balanced approach strengthens regimes and contributes to willing participation and cooperation amongst states. Facilitation of states through international cooperation based on non-discriminatory criteria would also incentivize states for investing in national implementation measures and taking voluntary measures.

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The disarmament of declared chemical weapons (CW) is a huge but a straightforward mission. The verified elimination of declared CW stockpiles may be completed by 2023, [3] but new states may join the Convention as CW possessor states [4]. Moreover, another priority issue is to prevent the re-emergence of chemical or biological weapons and their likely misuse by non-state actors, criminals and even states. This necessitates a more cooperative approach by all stakeholders and especially international community [5]. Since, the security aspects from chem-bio weapons is multifaceted, therefore, scientific cooperation amongst states would also contribute to legitimate national protective programmes, and scientific and economic developments.

2 Augment National Authorities

Scientific and technological developments are taking place at an accelerated pace. Therefore, national authorities must have qualified and experienced technical staff. This staff must be imparted requisite training in new technologies for chemical production and processes, which would help in national and international verification activities. There is also a need for holistic and quantitative assessment of national implementation measures, for which they must have better analytical and interpretative tools and capacities for evaluation of declaration data and reliable public information that covers full spectrum of chemical industry and toxic chemicals. This approach and capability would significantly contribute to national and international implementation of CWC.

3 OPCW: Global Fight Against Terrorism

The operating environment of the OPCW will gradually change. To stay relevant, the focus of the organization's activities will progressively have to be shifted from disarmament of CWs to preventing their re-emergence [6]. This will require new investments in a wide range of activities. The security aspects of the Convention are multifaceted, and the use of CW is no longer confined to states. Therefore, the OPCW has an important role in contributing to the global fight against terrorism. To effectively perform this role, the OPCW, relevant international organizations and initiatives, and states must develop good cooperation amongst themselves.

4 New Approach to Arms Control

The rapid developments and interdependence in the life-sciences research present new challenges to arms control and disarmament. In the prevailing international environment, the traditional models of arms control and nonproliferation may not deliver effectively. Similarly, for regulatory perspective, the governmental authorities of states alone may prove insufficient. Therefore, this warrants good cooperation amongst various stakeholders at state level [7]. For example, industry can monitor its products and carry out customer vetting; NGOs can educate masses regarding their responsibilities and provide useful information to law enforcement agencies, etc.

5 International Assistance and Protection Under CWC

Chemical weapons inflict enormous sufferings on a mass scale. Therefore, states cannot protect their entire population. CWC provides positive security assurance to its states parties [8] in the form of international support and assistance [9]. This assurance and associated mechanism is a very important aspect of international cooperation. Moreover, CWC provides a mechanism for investigation of alleged use and the provision of challenge inspection in case a state is suspected of violating its obligations under the Convention. After 9/11, the OPCW confirmed that the provisions of 'assistance and protection' can be invoked in case toxic chemicals are used or released by terrorists. In this regard, OPCW regularly conducts exercises and table-top exercises, which are attended by states parties, regional and international organizations, NGOs, etc. These exercises mostly depict terrorists using improvised chemical weapons or release of toxic chemicals from industry [10]. Coordinating an international response is an extremely complex and complicated process as amply explained in the *United Nations Counter-Terrorism Implementation Task Force* (CTITF) [11]. Such exercises must be conducted regularly for streamlining responsibilities and standing operating procedures of various international organizations and states parties. International response is very important, but developing national response capacity is the most important factor. In this context, regional response mechanism will prove very effective against hostile acts such as release of toxic gases. Therefore, states must develop and standardize procedures and protocols for sharing information and launching coordinated response [12].

6 Misuse of Biological Agents

The Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction, commonly known as the Biological Weapons Convention (BWC), opened for signature in 1972 and entered into force in 1975. This important pillar of international security architecture requires further strengthening. The term Biological Weapon is defined by the BWC as 'microbial or other biological agents, or toxins whatever their origin or method of production, of types and in quantities that have no justification for prophylactic, protective or other peaceful purposes' [13]. Infectious diseases are a serious threat to public health, economy and security [14]. The outbreak of diseases can threaten the stability of nations and even regions, particularly for developing states [15]. In the recent past, terrorists have used biological agents to cause deaths and disruptions, such as Anthrax attack in the USA in November 2001. Moreover, due to immense developments and diffusion in the field of science and technology, the deliberate misuse of biological agent is becoming more possible [16].

7 Facilitating Environment for Infectious Diseases

The world is witnessing immense developments in the field of communication, transportation and scientific and technological developments. Moreover, migrations are uncontrolled due to many unregulated and open borders. Climate change is another serious threat to global public health and is enhancing the range of vector-borne diseases such as Zika, dengue, etc. [17]. These developments are helpful in natural spread of diseases [18] and the deliberate misuse of biological agents [19]. To counter this threat, the BWC is an important instrument, but it lacks verification mechanism for effectively monitoring national compliance measures [20].

8 Augment WHO

Effective international governance of diseases is the need of the time. Former US President Barak Obama said during the Global Health Security Agenda Summit in 2014, "We have to change our mindsets and start thinking about biological threats as the security threats that they are... we have to bring the same level of commitment and focus to these challenges as we do when meeting around more traditional security issues" [21]. In fact, disease and security have strong linkage [22]. WHO responds to major infectious diseases, but it lacks requisite resources [23]. Moreover, the working relationship of WHO and the level of international cooperation amongst states require improvement [24]. The International Health Regulations (IHR) of 2005 provides a useful framework for international cooperation for launching an effective multilateral response to the outbreak of infectious diseases. The IHR basically obligates states to develop core capacities for detection and responding to infectious diseases [25]. Unfortunately, almost 70% of states have not developed their core capacities, and the level of cooperation is inadequate. It is because of such inadequacies that WHO could not launch effective response to the Ebola Outbreak [26] in West Africa in 2013. Therefore, WHO must be augmented for the betterment of international community.

9 Gaps in BWC

The BWC specifies strict national obligations, but it has serious gaps, such as universality gap, i.e. 18 states are still not BWC parties; implementation gap, i.e. lots of work is required in national implementation measures; response gap, i.e. BWC does not have institutionalized mechanism for the provision of assistance to any state in case of an accident or incident; and institutional gap, i.e. BWC is a 'skeleton operation' compared with NPT and CWC. The BWC Implementation Support Unit (ISU) has only three persons [27]. The international community must exhibit political will and commitment to address these gaps and make BWC an effective multilateral legal security regime.

10 International Cooperation Under BWC

Article X of the BWC deals with international cooperation. Multilateral and non-discriminatory mechanism for 'full, effective and non-discriminatory implementation' of Article X will significantly contribute to effective implementation of BWC and building national and regional capacities for responding to public health emergencies. To develop trust and cooperation, the BWC ought to have effective verification mechanism, [28] which actually serves as a CBM (confidence-building measures) amongst states.

11 Provision of Assistance to States

The aspect of provision of assistance in case of disease outbreak is crucial. However, the procedures and methodologies are not quite clear for timely emergency assistance. Moreover, it cannot be easily ascertained that whether the disease has occurred naturally or is the result of malicious act. The provisions of Article VII of the BWC become applicable when the United Nations Security Council establishes the fact that BWC has been violated. Then states would provide assistance. In this context, a database established by the BWC Implementation Support Unit (ISU) under Article VII may prove valuable tool. This database would help ISU in matching specific requests for assistance and thus coordinating and then providing assistance [29]. Presently, the ISU has few generic offers of assistance. It may be noted that setting up this database would not duplicate existing national or regional health emergency assistance mechanism. Rather, these cooperative measures may be synchronized in a manner that they complement each other.

12 Enhance Cooperation and Improve National Implementation

The advanced states ought to help developing states in developing more efficient and low-cost vaccines and drugs. Undue restrictions would have implications on developing the public health capacities of developing states. The cooperative approach would contribute improved multilateral cooperative emergency assistance mechanism. The concerns of dual-use are real, but this pretext may not be used for denying cooperative research in biotechnology with developing states. Rather, the national capacities of developing states may be enhanced in a systematic way, which would serve as the first line of defence against global public health emergencies.

13 Significance of Developing States

Developing states can play very useful role in contributing to international peace and security. To give the example of Pakistan, it has taken comprehensive national measures under both CWC and BWC to effectively and comprehensively enact and enforce international obligations. Pakistan provides all kinds of assistance to the OPCW such as provision of protective equipment, experts, training, etc. It regularly annually conducts advanced international courses for states parties of CWC and has established Regional Assistance and Protection Centre against the use of chemical weapons. Pakistani experts have played key role in important OPCW and BWC missions and conferences and remain ready and committed to contribute to strengthening international regimes and organizations. Such measures and approach prove that developing countries are useful partners for improving international peace. Hence, they need capacity development and trust as partners.

14 Conclusion

The dual-use nature of emerging technologies in both chemical and biological fields should not be the cause for restricting or proscribing their availability to developing countries for peaceful purposes. Nothing should hinder permitted activities under CWC and BWC such as vaccine and drug developments, which are essential for meeting the legitimate and permitted medical, pharmaceutical, industrial and defensive needs of developing states. Therefore, developed countries should remove unnecessary restrictions on the exchange of scientific information, materials and equipment for peaceful purposes. Both developed and developing states should develop procedures and mechanisms for non-discriminatory and effective implementation of international cooperation and export control provisions of CWC and

BWC. The said mechanism may also cater for dispute settlement amongst states that may arise during international cooperation.

To address the nonproliferation concerns, states must establish effective export control mechanisms as stipulated under BWC and UNSCR 1540 [30, 31]. States must remain committed to nonproliferation of WMDs and their delivery systems and regularly update their National Control Lists with other export control regimes/ arrangements such as Australia Group, etc. Moreover, states must develop capacity of health and customs officials and keep industries and laboratories in both private and public sector under governmental controls. In brief, the legitimate security and nonproliferation concerns may be addressed through better coordination and cooperation amongst states and relevant international and regional organizations, which is the main objective of both the regimes.

Disclaimer The views contained in this paper belongs to the author, and does not in any way reflects organizational position.

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The International Maritime Security Legislation and Future Perspectives for Italian Ports

Amalia Alberico

1 Introduction

Maritime sector is one of the most relevant elements of a national framework because of its impact on the maritime industry and its impact on society and internal economy. On a first stage, the international legal framework on maritime field was mainly focused on safety, but today, since 11 September 2001, particular emphasis has been placed on security in all its aspects.[1]

The Italian administration aims to promote the improvement and application inside national boundaries of international legislation on maritime security.

New procedures and new techniques have been implemented in order to improve maritime security in Italy, such as exercises and drills in all maritime contexts, specific training and new security figures, and many new aspects will be introduced and renewed.

In the next future, Italy will face up new challenges to prevent and combat threats to maritime security, but the further and renewed efforts will have to combine the need for higher security levels with economic sustainability, minimizing negative impacts of maritime security regime to shipping industry, seafarers, fishers, private individuals and environment.

[1]Though the two words *safety* and *security* may be used together, there is a distinction between the terms maritime safety and maritime security, especially when these expressions are used in terms of threats to the safety and security of navigation or, in general, of maritime sector. The difference between the two words, especially because some languages do not distinguish between these terms, is quite debatable and can be highlighted when intended as protection against mishaps that are unintentional, such as accidents (*safety*), or as protection against deliberate accidents, such as attacks from pirates or terrorists (*security*).

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In this paper is briefly analysed the actual context of the maritime security, giving an overview of the maritime security legal instruments that Italy put in place to construe the impact that the international legal framework and the newborn strategies are having on the future of maritime security and modern society.

2 The Actual Context for Maritime Security

The current geopolitical situation increases the feelings of fear and uncertainty that directly affects our life style while threatening maritime peace and security. Nowadays a number of criminal acts such as trafficking in narcotics, arms and persons, terrorism, piracy and armed robbery threaten human life and safety, both at sea and on land, maritime trade as well as the social and economic fabrics of both coastal and landlocked states. To address these menaces, the international community adopted several conventions to raise common standards of countermeasures. It is evident that a whole legislation approach, national and international, is needed for an effective protection of the maritime field. The Italian Coast Guard is the national authority in charge of defending national boundaries at sea, looking for new solutions against the evolving threats.

In modern history, the world has experienced some tragic events that brought a massive change in the world making clear the need to rethink the perception of security. We can remember the tragedies of ETA's planned bomb attack against Spanish car ferry, the attack on USS Cole that happened on 12 October 2000, the well-known 11 September 2001 attack on the Pentagon and the World Trade Center and the 6 October 2002 attack on Limburg.

The last two events have deeply affected the public opinion, making the entire world begin to talk about security. The last mentioned event, in particular, had a strong impact on media, not only for the high number of life losses but also because it pointed out the weakness of the maritime transportation system (MTS).

The maritime transportation system (MTS) generates worldwide a big amount of money and handles about 80% of all international trades in terms of volumes and more than 70% in terms of value.[2] In a direct or indirect way, the nation's economic and military security is linked closely to the health and functionality of the MTS. It is fundamental to prevent each damage that could destroy critical infrastructures and key assets in the maritime domain and disrupt the MTS.

So which are the potential threats we have to defend national ports from? Of course, the oldest one is piracy, and then we have terrorism, smuggling, stowaways, thefts and collateral damages. But, we may also list threats such as maritime interstate disputes; trafficking of narcotics, people and illicit goods; arms proliferation; illegal fishing; environmental crimes; or maritime accidents and disasters.

[2]United Nations Conference on Trade and Development (2015).

Probably the actual main fear is terrorism considered as the eventuality that a ship might be used as a weapon.

In the absence of a commonly accepted definition of maritime terrorism, it is quite hard to distinguish between piracy, terrorism and other acts of maritime depredation; even if combining the motivations, methods and targets of terrorists and pirates operating at sea, it will be possible to underline differences and common points.

Merging the UNCLOS[3] definition of piracy[4] and other definitions of terrorism[5] and maritime security,[6] without any pretention of giving an ultimate definition, the maritime terrorism could be identified as *all the actions made by a single person or an organized group, outward any state jurisdiction, that, for political motivations, plan or execute an attack to provoke panic or damages, against a ship, port facility or offshore facility, in order to gain international visibility for their political cause.*

According to the previous sentences, it is possible thinking to the maritime security, as the international legal framework and all the activities that international community put in place with the aim of fighting against maritime terrorism.

Major actors in maritime policy, ocean governance and international security have, in the past decade, started to include maritime security in their mandate or reframed their work in such terms. As we said before, the concept of "maritime security" gained initial salience after the terrorist attacks of 11 September and the associated fears over the spread of maritime terrorism. The goals of a terrorist in attacking the maritime sector could be multiples, such as to provoke fear and panic, gain attention both politically and spiritually, promote worldwide their religious beliefs, rid the world of opposing beliefs or gain recognition for their cause.

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[3] Acronyms of "United Nations Convention on the Law of the Sea". The United Nations Convention on the Law of the Sea (UNCLOS), also called the Law of the Sea Convention or the Law of the Sea treaty, is the international agreement that resulted from the third United Nations Conference on the Law of the Sea (UNCLOS III), which took place between 1973 and 1982. The Law of the Sea Convention defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for the businesses, the environment and the management of marine natural resources.

[4] UNCLOS United Nations "Convention on the Law of the Sea" in 1982 defines piracy as "any illegal act of violence or detention, or any act of depredation, committed for private ends by the crew or the passengers of a private ship, a private aircraft and directed to:

- in the high seas, against another ship or aircraft, or against persons or property on board such ship or aircraft;
- against a ship, aircraft, persons or property in a place outside the jurisdiction of any State".

[5] The Council for Security Cooperation in the Asia Pacific (CSCAP) Working Group has offered an extensive definition for maritime terrorism as the undertaking of terrorist acts and activities within the maritime environment, using or against vessels or fixed platforms at sea or in port or against any one of their passengers or personnel against coastal facilities or settlements, including tourist resorts, port areas and port towns or cities. http://www.maritimeterrorism.com//definitions.

[6] Eric Shea Nelson: "Maritime terrorism and Piracy: Existing and potential threats". Global Security Studies, Winter 2012, volume 3, Issue 1. Nelson puts in correlation ". . .maritime terrorism and piracy are terms used to describe violent acts carried out by malevolent actors operating at sea".

Despite the international attention on maritime terrorism, it has to be pointed out that the statistical data says that the events of voluntary accident in maritime field are quite uncommon (less than the 2%[7] of the total events in the last 30 years); for several reasons, many of that are practical and logistic, explained by the fact that most terrorists are tactically conservative or have little experience of the maritime environment, so they prefer other fixed land targets offering higher visibility and greater ease of access.

If maritime terrorism has largely remained a virtual threat, the breakthrough for maritime security came with the rise of piracy off the coast of Somalia between 2008 and 2011.[8] Moreover, the inter-state tensions in regions, such as the Arctic, the South China Sea, or the East China.[9]

3 The International Legal Framework on Maritime Security

Even if national governments have the primary responsibility for internal security, it soon became evident that international legal instruments on maritime security were needed, mainly in consideration of the transboundary nature of maritime security risks that could threaten the international maritime commerce. On requests of several countries in 1948, an international conference in Genève adopted a convention establishing a permanent international body: the International Maritime Organization (IMO).[10] IMO's first task was to adopt a new version of the International Convention for the Safety of Life at Sea (SOLAS), the most important of all treaties dealing with maritime safety. In 2000, it has been put a subsequent focus on maritime security, with the entry into force in July 2004 of a new, comprehensive security regime for international shipping, including the International Ship and Port Facility Security (ISPS) Code,[11] made mandatory under amendments to SOLAS adopted in 2002.

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[7]Martin N. Murphy: "Contemporary Piracy and Maritime Terrorism: the threat of international security". Adelphi 2007.

[8]IMO: Annual report on piracy and armed robbery against ships in 2016—ICC International Maritime Bureau.

[9]Bloomberg, Reuters: article "Waves of tension in East China Sea"—The Strait Time—10 June 2016.

[10]International Maritime Organization (IMO) is a specialized agency of the United Nations, entered into force in 1958, that currently has 172 member states and 3 associated members. IMO is the global standard-setting authority for the safety, security and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented.

[11]The ISPS Code has been adopted in Europe through the Regulation 725/2004 for port facilities and ships and the Directive 2005/65 for ports European community planned with the Regulation

Any action of law enforcement in maritime field is much more complicated, because these crimes often occur at sea which are carved into zones that dictate, and often limit, the extent to which any one state may act. Therefore, the opportunity for perpetrators to cross-jurisdictional lines after the commission of an offence makes their interdiction and punishment difficult and subject to surrounding circumstances that made maritime offences not be dealt with effectively by any single state. The international character of these crimes has consequently warranted a concerted reaction by the international community to maritime crimes.

On November 1986, the IMO Legal Committee started working on the preparation of the Convention for Suppression of Unlawful Acts of Violence Against Safety of Maritime Navigation (SUA). SUA and its protocol were finally adopted during Rome Conference of 1988. The SUA Convention received ratification by the various states and entered into force in 1992. The main purpose of SUA Convention was to ensure that people committing unlawful acts against ships are not sheltered in any country but that they are prosecuted or extradited where they will receive a trial. UNCLOS as the currently prevailing law of the sea is binding completely, so it can be enforced broadly. Illicit acts covered by the Convention include the taking of vessels by force, violent acts against people abroad and on-board device that may destroy or damage the ship.

UNCLOS itself is considered often as a framework convention; it sets up institutions and balances the rights and interests of states with the interests of the international community. UNCLOS provides specific regimes, which are fundamental to maritime security, namely, the regime of consecutive maritime zones and the jurisdictional trinity of flag, coastal and port state control.

The adoption of UNCLOS Convention by international community has spurred states parties to implement domestic measures enabling them to take the prescribed law enforcement action.

4 Italian Perspectives

The Italian legislation framework is based on the Inter-ministerial Committee (CISM),[12] which adopted the National Maritime Security Program,[13] establishing all the details on how to issue security documents for ships, ports and port facilities. Moreover, it gives all the specific details about controls and preventive measures to

324/2008, a complex monitoring system for managing and organizing a revised procedure for conducting commission inspections in the field of maritime security.

[12]CISM has been created by the Italian Transport Ministry Decree, on 29 November 2002.

[13]The National Maritime Security Program (NMSP) has been approved by CISM on 26 April 1997. It defines coordinated application of maritime security regulations and procedures; staff roles; single duties of each authorities, police forces and operators; and implementation of security measures.

implement each one of the three levels of MARSEC Security.[14] Each security level under ISPS Code describes the current scenario related to the security threat to the country and its coastal region, including the ships visiting that country. The security levels are established by the cooperation of ship and port authority keeping the current condition of national and international security. The local government sets the security level and ensures to inform port state and ship prior to entering the port or when berthed in the port.

Subsequently with a 2004 ministerial decree, the Italian Coast Guard has been invested of all the maritime security functions. The Italian Coast Guard Headquarters has been identified as competent authority for implementation of security measures and as focal point for maritime security, while the Harbour Masters of Local Coast Guard Offices have been appointed as port security authorities for ports falling under their territorial jurisdiction and, in the main time, as designated authorities for port facilities[15].

The Italian Coast Guard is in charge of various tasks that can be classified into three main areas: governance, safety and, of course, security.

The Italian Coast Guard contributes in securing our 8000-km-long nation's maritime borders; it ensures the safe and the efficient transportation of people and goods. Moreover, it protects marine environment and natural resources. It is its duty, of course, to defend our country at home and abroad, alongside the other armed forces and police services. Moreover, it performs tasks of search and rescue at sea.

A great part of these tasks and activities arises, mainly, from specific obligations assumed by Italy within international agreements.

The activities in maritime security are carried out within the three core areas of applications: the ship, the port facility and the port. The Italian Coast Guard is in charge of managing 88 ports, 351 port facilities and 577 ships under ISPS Code,[16] quite a huge amount of ports, port facilities and ships, without considering about 1000 of minor ports and private marinas.

The Italian Coast Guard Headquarters is appointed to check the copy of all the security documents related to ships, ports and port facilities, which makes possible monitoring and cataloguing data.

For the above, it is easy to understand the holistic approach of Italian Coast Guard to the mentioned field, having the responsibilities of all the processes involved in maritime security in the broadest meaning. To give an idea, the Italian Coast Guard is responsible even for releasing clearances to ships for embarking privately

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[14]The MARSEC (maritime security) is a three-tiered system employed by US Coast Guard for maritime security purposes. The three MARSEC levels are set to reflect the prevailing threat environment to the marine elements of the national transportation system, including ports, vessels, facilities and critical assets and infrastructure located on or adjacent to waters subject to the jurisdiction.

[15]Italian Ministry of Transportation dated 18 June 2004.

[16]Italian Coast Guard Headquarters—Monthly Report—May 2017.

contracted armed security personnel (PCASP) with anti-piracy duties[17] or for testing private security guards that need a specific authorization to work in ports.[18]

The Italian Coast Guard performs other security services, such as harbour patrolling with patrol vessels and escorting cruise ships during their staying in the proximities of port infrastructures. All these activities are related to reduce the eventuality of maritime risks, as there is no way to eliminate them.

Analysing the best approach to fight against maritime security threats, Admiral Thomas Fargo[19] said: "no nation is so big as to be able to go it alone, and no nation is too small to contribute". If maritime security is a global problem, it needs a global solution. Therefore, it represents a global challenge inside our nation that involves public sector, as well as the private one, but also an international target that needs a global cooperation.

The challenge includes keeping focused for governments, remaining vigilant and prepared for industry and sustaining interest and awareness for public and customers even if the menace does not realize today.

To address effectively menaces is important to reduce vulnerabilities, because vulnerabilities potentially amplify terrorist capabilities and therefore increase the chance of a negative event. Moreover, vulnerabilities must be prioritized, through an understanding of the local security context, to focus and ensure proportional targeting of risk mitigation strategies.

5 The Future of Maritime Security

The future for maritime security is oriented primarily on raising of security awareness that can be enhanced through cooperation, at national level and on European base too. The Italian Coast Guard is an active part of AQUAPOL, a European association of maritime polices that promotes active collaboration to fight any type of criminal activities that may impact on or use the marine environment. The continuing collaboration promotes an improving of relationships and a proficient exchange of experiences and of inquiring methodologies, leading to creation of a common language that in a virtuous loop enhances the collaboration as well.

In the framework of maritime security measures, governments have the responsibility of the effectiveness of measures and procedures to be applied for their port, port facilities, shipping companies, vessels and recognized organization, authorized to act on their behalf. Italian authority has built a tripartite approach to manage the monitoring activities. From this point, an effective national future framework can be developed.

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[17]Italian Coast Guard Headquarter Decree no. 307 of 2015.

[18]Decree no. 269 of the Italian Ministry of Interior, 1 December 2010.

[19]Admiral Thomas B. Fargo commander of US Pacific Command 2002–2005, during the Pacific Command Chiefs of Defence Conference of 2004.

At headquarter level, the control system is divided into three moments. First, we have the collating of data related to approval of security documents of ships, port facilities and ports. In a second time, we have continuous reporting of monitoring activities performed at the previous step, in order to avoid any future non-conformities of the entire system. On the last step, we have on-site audits. All these activities are aimed to verify control activities carried out by the Local Coast Guard Offices, without substituting to them. Also in this stage, methodologies used for audit reflect the standards required by UNI EN ISO 9001 on quality system management but customized on our specific needs. Otherwise, this activity is still ongoing, the feedback and the results followed are positives, and it can be considered as a good opportunity for continuous improvement of our maritime security system.

Another aspect that could be underlined and improved is enhancing awareness. All the people working in or going through a port shall collaborate, even if in an indirect way, with the security of the place. Moreover, the maritime security needs to invest on training and development of personnel. The Italian Ministry of the Interior pointed out that the security personnel involved in security activities inside of Italian ports have to be specifically trained and skilled, through a personal licence each of them has to obtain after a specific training course, practical and theoretical, and a public exam.[20] That will ensure higher quality of personnel with security duties in the maritime field. An analogue training course has been planned for PCASP[21] embarking in protection of Italian merchant vessels in the high-risk areas,[22] which the international community considered at a higher risk of piracy and within which self-protective measures are most likely to be required.

A more effective control system has to be dedicated to monitoring of security incidents, where each single event must be deeply analysed and categorized both for statistical studies and for investigations. On security incident, a specific procedure shall be included in the security plans of ports, ships and port facilities. All investigation activities need to find its final issue in a continuous process of identification and resolution of suspicious events. After that process, a specific training in "Detection of suspicious behaviours" has to be addressed to Italian Coast Guard personnel and private guards authorized for working in ports. To achieve a ready reaction to both incidents and emergencies, a complex and continuous scheduling of drills and exercises is mandatory for ships, ports and ports facilities, and the output, in the case of emerging evidences, is transmitted to Italian Coast Guard Headquarters for further investigations.

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[20]Decree no. 154 of the Italian Ministry of Interior, 20 November 2009 related to the regulation about security services for private security guards in charge of subsidiary services in ports, airports, railway stations, bus stations and metro stations.

[21]Head of Italian Police Circular no. 557/PAS/U/3004/12982.D (22)5 and Disciplinary on Training of Private Authorized Guards engaged in subsidiary security services—2015.

[22]In 2015, the International Chamber of Shipping (ICS) has advised that the cosponsor of Best Maritime Practices 4 (BMP4) has agreed to a revised definition of the high-risk area. The actual boundaries are Red Sea lat. 15° N, Gulf of Oman lat. 22° N, eastern limit long. 065° E and southern limits lat. 5° S. In Italy see Decree of Ministry of Defence dated 24 September 2015.

Promoting a better-trained security personnel is only the first step in the maritime security improvement process held by Italian administration. Other activities have been in process, such as strengthening of internal inspections, monitoring of audit's output and a more effective data control. All these activities need more investments in staff training. A new directive has recently been issued[23] to give coherent answers and protections that are more effective to privates and to port facility users. A new figure of security (maritime security inspector), an expert with specific technical skills, a dedicated training process both theoretical and practical and a process of continuous training have been created with this new regulation. This new inspector is going to be officially recognized by government as actually is for duly authorized officers, but with specific responsibilities on maritime security. Of course, the introduction of this new element will require a complex structure for national coordination that is not implemented yet.

Inside national boundaries, Italian Coast Guard Office has recently renewed totally its legal instruments for local controls. The issue of a new circular on port facility monitoring[24] states that all port facilities must be subjected to, at least, two annual inspections, in order to verify that security measures described into the security plan (PFSP) are properly applied.

Therefore, we will have an ISPS audit planned and one unscheduled inspection. The inspection activities are carried out by duly authorized personnel in accordance with directive mentioned above, and the results of the activities must be collected, classified, analysed and regularly forwarded to Coast Guard Headquarters.

The audits planned are carried out at least once during the calendar year and are aimed at verifying proper application of measures and security procedures approved with the PFSP.

Audits unplanned or additional are also performed in the event of a breach of security or security incidents, on initiative of the local or the national competent authority.

A further action is to plan in the next future the possibility to have an armed service on our national vessels. Actually, it is possible to embark privately contracted armed security personnel on national flag vessel only in high-risk area, but for the near future, it is on study the possibility of a permanent armed service on board of passenger vessels of European flags.

Of course having armed personnel on board could cause problems concerned to the safety on board and risks of collateral damages that have to be solved before we may have such legal issues.

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[23] Italian Coast Guard Headquarters Circular Security no. 33—MARSEC Directive, Formative training for Officers and Petty Officers engaged in the specialization of maritime security, February 2017.

[24] Italian Coast Guard Headquarters—Circular no. 24, var. 2nd of 1 March 2017—Port security, Inspection Activity of Port Facilities—Procedures and frequency.

6 Conclusions

A number of different threats currently characterize the maritime security scenario. These menaces have important consequences for the internal and international organization of MTS and, consequently, both for world economy and global social structure.

The most recent government assets are further expanding the capability of reaction against these menaces. One of the crucial factors is the need for increased interaction between the different national bodies working in coast guard and border police duties, to promote common security standards and homogeneous actions.

Today we can experience more efficient monitoring and preventive actions that will be able to counteract any risk in a more effective way. This propitious attitude will create, for the near future, a positive loop uprating the way daily levels of security and expansion possibilities related to MTS are perceived.

The element that could contribute to this positive trend is the human factor. This kind of "human factor" is related to the aspects—external and internal—that affect human performance: equipment, procedures, supervision, training, culture as well as aspects of human nature, such as our capabilities and limitations. Factors affecting humans tend to include both aspects of personal instruction and background and structural organization.

It is even and even more evident the need to invest resources in training and instruction of all the ones that are involved in maritime security tasks, at every level. The goal to be achieved is an organization set up of persons with specific competencies and effective capabilities of risk countermeasures. To reach these targets will require heavy and concerted efforts to all international communities.

Maritime security will not increase without costs. Talking about costs is not referred to the money that each government needs to invest to increase security. Rather, it is related to the trade-off between security measures and economic efficiency in the shipment of goods and the trade-off between securities in the form of, for example, background checks and security identification cards and individual liberty of those who work at or pass through ports. While maritime security is an essential part of the safe, secure and competitive operation of the maritime transportation system, too much security can damper trade and lead to a loss of a sense of freedom and to feelings of insecurity.

That is why the MTS is an essential component of the National Strategy for Maritime Security. Improving security of the MTS while maintaining its functionality will not be an easy task.

The Increasing Risk of Space Debris Impact on Earth: Case Studies, Potential Damages, International Liability Framework and Management Systems

Elisabetta Bergamini, Francesca Jacobone, Donato Morea, and Giacomo Primo Sciortino

1 Introduction

The words "space debris" refer to the uncontrolled and unwanted fall onto Earth of no longer functional space vehicles or parts of any size (no asteroids involved whose trajectories and their potential dangers are considered uninsurable acts of God). This definition[1] excludes whatever is generated at launch areas, which are conceived to encompass this risk. Since the beginning of human activities in space, the number of variously defined objects in orbit around the Earth has increased exponentially, and the trend is up now more than ever with the new wave of the so-called small satellites. NASA (US National Aeronautics and Space Administration) and ESA (European Space Agency) estimate in their webpages that there are over 150 million "objects" orbiting between the LEO (low Earth orbit)—up to 10,000 km from Earth's surface—and GEO (geostationary Earth orbit), above this mark, for a total weight of more than 5000 tons. This definition applies to objects ranging from submillimetric (propellant dust, paint flakes, etc.) to "baseball" sizes (ca. 20,000 objects) and more. Figure 1 offers, based on the same aforementioned sources, a

[1]See ESA definition on www.esa.it Our Activities/Operations/Space Debris, 2017.

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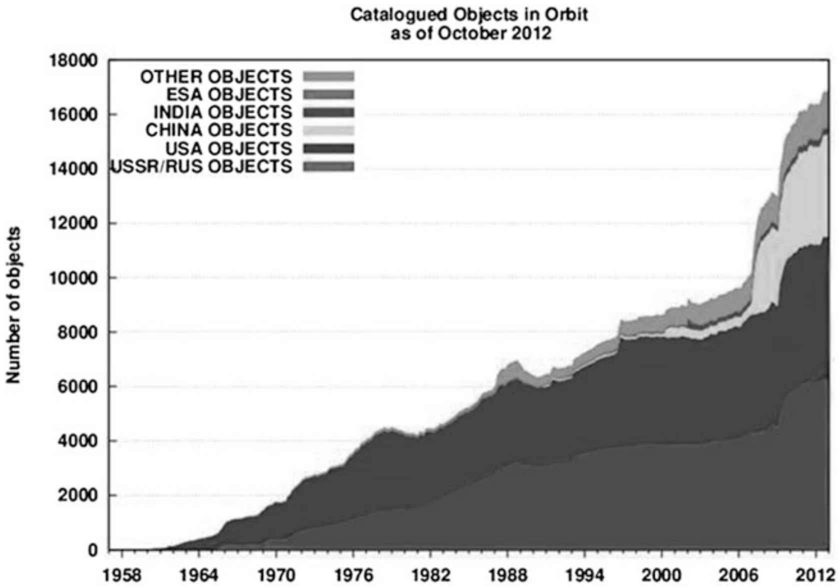

Fig. 1 Space debris: how dangerous is it to people on Earth (Source: Globalnews.ca—Nicole Mortillaro [1])

dynamic ownership's graph of these objects, divided by the launching State's property. The sharp rise of newcomers like China appears very clearly.

We reasonably estimate that by the end of the decade, the overall quantity will at least triple for the combined effect of the big increase of small satellite cheap launches (Google—Planet Labs, OneWeb, SpaceX, etc.), space and suborbital tourism finally becoming popular in the more dangerous LEOs. What could amplify these fears is mostly the so-called Kessler syndrome [2], which is the massive propagation of debris ensuing collisions in space. As an evidence of this, ESA reports that 65% of the ca. 20,000 notable orbiting objects result from 250 breakups and from just 10 collisions [1]. As an example, consider that the Chinese Feng Yun SO1C antisatellite test, in 2007, created 3300 pieces of sizeable debris, and in February 2009, 2200 more fragments were created by the crash between the US Iridium 33 and the Russian Kosmos 2251 satellites. Consider in fact that at an average speed of 30,000 km/h in LEO, where gravity is stronger [3], even 1-cm-large (there are approximately 300,000 of them) items can destroy a satellite, while risk mitigating techniques, such as vehicle route monitoring and adjustments, debris cleaning, onboard protections, etc., are still shy of being effective. Although 75% of objects launched into space are recorded as they re-entered into the atmosphere in a controlled way (by saving fuel for the end-of-life assisted deorbiting and demise) and the atmosphere itself, should these manoeuvers fail, is a natural "firewall" that destroys anything re-entering at that speed, the risk of impacts on Earth is surging, and its magnitude might be soon perceivable, on persons, land and properties. An elaboration on NASA-NORAD's archive of catalogued space debris shows that the actual rate of one reported uncontrolled impact a day (>10 wide objects) [4] could increase from three to ten times by the end of the decade, including large items. Our work examines case studies and various levels of debate on the impact of space debris on Earth (legal, liability, surveillance and tracking, debris cleaning techniques, insurance) to identify possible risk management solutions to be developed in the future.

2 Case Studies

In Table 1, we have collected some of the most notable cases of space debris impacts onto Earth. So far no damage to property has been reported but only to the environment, mostly of lesser value (in Canada, Australia, South-East Asia (see Fig. 2), etc.) and minor injuries to people (Japan in 1969 and Oklahoma, USA, in 1997).

3 Risk Management

3.1 Legal International Framework and Considerations from the Point of View of CBRNE Events

The international Outer Space Treaty (1967) prohibits mass destruction (but not conventional) weapons, declares the principle of mankind property of space resources and defines responsibilities of Governments (Art. 7 on Responsibilities and following Liability Convention of 1972) for third-party damages resulting from space activities (related to their own assets or caused to other States). Of these main principles, it is the latter which has by far the strongest influence on the context of space debris damages on Earth, because it establishes a clear overarching governmental responsibility, no matter how the Governments, who still are the most frequent "operators" of space activities, might have endorsed, by national acts, this responsibility to private operators. The above Treaty is signed by 105 States, but only few detain an open archive and perform monitoring of their own flying objects or debris, so that quite often these cannot be identified. To make the Outer Space Treaty norms on responsibility more stringent, NASA (and DoD) issued in 1995 the "Debris Mitigation Standard Practices" or a national enforcement for mandatory controlled deorbiting of space vehicles at the end of their useful operations. Likewise, the COPUOS and the IADC (the UN Space Organ on Debris) adopted similar "guidelines" for voluntary subscription [5]. So far only the USA, Russia, France,

Table 1 A history of the most notable cases of damages by falling space debris for the purpose of this study

Date and place of impact	Identified objects	Damages	Liability and insurance
1978—Northern Canada	One nuclear-powered ocean surveillance Russian satellite Kosmos 954	Actual coolant release and risk of puncture and more release rated 8% over 50 years	**Russian Government** liable pays 3 million euros settlement to Canadian Government
1979—South of Perth in Australia/ error due to quick burning	Space litter with large pieces of the deorbited US Skylab	Minor environmental damage (it was due to crash in S. Africa)	**US Government** rescues fallen parts and pays Shire a fine of $400
1991—Argentina/route error by several 1000 km	Deorbiting Russian Salyut7 manned—40 tons	Space littering of wide area in Argentina	**Russia**—not known
April 2000—Township outside Cape Town (S. Africa)	Three large pieces of USAIR Delta II launcher rockets for GPS sat	Minor damages to cause by white hot large objects	**USA**—not known but likely settlement for private owners
June 2000—Pacific Ocean	US Gamma Ray Observatory	1500 debris spray after controlled crash	**USA**—none
Jan 2001—Saudi Arabia desert (Riyadh)	Engine assist and GPS satellite large parts + part of Delta II launcher	None	**USA**—none
March 2001—in dead sea zone South Pacific2500 km east of NZ	**MIR—130 tons Russian human laboratory deorbiting and controlled sea crash**	**None**	**Russia subscribed insurance policy before deorbiting up to 200 million euros settlement for damage/ casualties**
2003—Texas and Louisiana (USA)	Over 2000 debris items of Columbia shuttle destroyed during re-entry from Hubble mission	One of single large space debris incidents in history	**USA**—none
Sept 2004—Utah desert (USA)	Genesis USA spacecraft solar mission capsule	Parachute failed to deploy—no damages	**USA NASA**—none
2007—Western Australia	Russian Breeze booster explodes while orbiting Arabsat satellite	More than 1000 debris scattered	**Russia**—not known if settlement is paid
Nov 2015—Spain	Unlisted parts of spy satellites—fuel tanks	None	Undefined
Nov 2015—Sri Lanka (Indian Ocean)	**WT1190F classified objects coming from Moon's orbit (may be Apollo)**	**None—destroyed by atmosphere. Intercepted and tracked via algorithms**	**None—mitigation technique carried out by dedicated aircraft US, Germany, and Emirates crew**

(continued)

Table 1 (continued)

Date and place of impact	Identified objects	Damages	Liability and insurance
Jan 2016—Vietnam	Metallic spheres of air tanks for Russian Zenith launcher	None, landed by a river in the countryside	**Russia**
Nov 2016—Myanmar	Long March 11 (PRC) booster and litter thereby	Crashes into jade mine field	Not acknowledged yet

Source: Authors' elaboration

Fig. 2 On 11 November 2016 at a jade mine in Hpakant (North Myanmar), a booster of the Long March 11 Chinese launcher, departed from Jiuqing base 1600 km to the North, slams onto Earth with a blast, and one small piece pierces the metal roof of a nearby shack (Source: The Guardian: Large metal cylinder crashes to earth in Myanmar—UK, 2016)

Italy, Japan and the UK have adhered [6]. It must be also mentioned that after China antisatellite test (2007), the Outer Space Treaty prohibits "intentional" destruction. Lastly, a "cleaning tax"—as a fee to pay for each orbital launch licence—is being studied, but it is difficult to apply, as the property framework of space is by definition "nonrivalrous" and "nonexcludable". This is why the situation is defined in macro-economics as "Tragedy of Commons" [7] with extremely negative externalities.

Space debris impacts on Earth should be surely classified, by their nature, under the explosive heading of the CBRNE acronym, or in some cases where nuclear engines and propellants are involved, they could also encompass this additional aspect. From the introduction and the cases described in the previous paragraphs, we can say that a CBRNE approach toward this area (prevention of occurrence, management of incidents) is still scarcely considered. Minor environmental littering in fact seems to be the most sizable damage record, so far. No doubt, on the other hand, this new awareness is growing, for the threat posed by the Kessler effect (see par. 1) and a further series of reasons: the alarmingly growing congestion of low orbits resulting from the new small satellite constellations, the increase of stratospherical activities at 20–30 km asl (unmanned aircraft for military purposes, blimps, balloons for TLC and near-space experimentation) and the planned start of space tourism at these altitudes [8].

These risks, moreover, involve aviation. In fact, seen from space, this is a "terrestrial" activity, and the space debris phenomenon has already been clearly perceived. Passenger planes have been already hit by small debris, as their travel speed and altitude expose them to lethal collision risks much higher than for any static subject on Earth [9]. Having all these in mind, we try hereon to desume, from the heated current general debate on space debris awareness and management, what are the updated CBRNE considerations, which will appear at various levels: risk mitigation approach by debris cleaning techniques and onboard equipment and national space surveillance and tracking, to finish with some insurance solutions.

3.2 CBRNE-Like Considerations on Space Debris Incidents in Terms of Risk Mitigation (Prevention, Management) and Insurance

The main risk mitigation countermeasure is currently the SST (Space Tracking and Surveillance) systems, being implemented worldwide with new dedicated infrastructures, such as ground and space telescopes, radars, radio radars and tracking softwares and algorithms, or the reconfiguration of existing ones, like aeronautical static and bistatic radars. According to NASA-DoD mapping algorithms, there are 20,000 tracked hazardous (ca >10 cm) orbiting items of this kind (Fig. 3). ESA SST integrated programme—and Italy's relative segment along with the other 14 subscribing States—is worth about 50 million euros of a 3-year investment started in 2012, including space weather and asteroid protection programmes within the wider SSA project [10].

Another strong aspect of risk mitigation relies on onboard and flying techniques and equipment [11]. Here are some solutions already in use: the ISS (International Space Station) has been equipped with "Whipple shield" capable of disintegrating small debris [12], and a debris avoidance emergency manoeuver has been enforced with the crew, stronger space vehicle structures are designed to resist small-sized impacts (<1 cm), inflatable shields and impact-sensing electronics are increasing

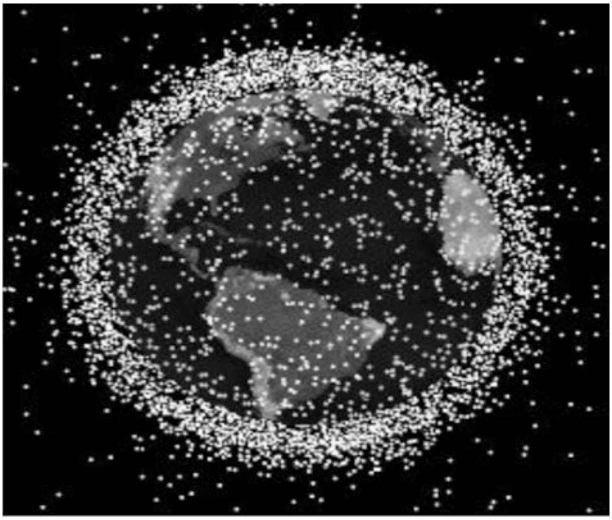

Fig. 3 NASA radar image of trackable space orbiting items. 95% items. 95% is debris. 60% is concentrated in LEO with higher congestion over the poles; >200,000 potentially harmful items of smaller size (>1 cm) remain untrackable but have no direct significance as CBRNE events (Source: NASA www.orbitaldebris.jsc.nasa.gov, October 2012)

too, and "cleaning" satellite systems are under consideration that will be capable of locating the hazardous debris and engaging and "treating" it accordingly (capture and exploit precious materials in space, destroy it). These satellites will be equipped with nets, destructive lasers, rescue arms and stowage bays. Let's in fact consider the high value of flying rescued scrap, which is useful for space reparations and refueling: 1000 tons of available aluminium can save up to 10 billion euros in launching cost [13]!

Concluding with insurance, the space debris risks are at by now only a smallest fraction of the worldwide space insurance business estimated in 2015 at about 700 million euros in premiums and 650 million euros in claims [14] and concentrated on failures and misfunctionings of the big commercial TLC satellites. Some examples—see the case of Russian MIR deorbiting in 2001 in Table 1—refer to tailor-made coverages of particular situations. However, there is a potential for insurance coverage, but only if a legal international framework will finally offer guarantees for the business. And especially active risk generation is connected to third-party liability along the UN Protocols. So, the otherwise scarce insurance cases will become customary, when a tracking and mitigation system will finally integrate into a highly performing control procedure of operations and responsibilities and extend firstly, business-like, to the area of aviation [15].

3.3 Specific Risk Mitigation and Management Solutions for Small Satellites

The current commercial rush to launch constellations of small satellites,[2] now that construction and launch costs have been greatly cut by technology, is really making space debris risks a strong concern for the Governments. In the last 2 years, Planet Labs only has launched into LEO (1000 km ca.) some 200,000 nanosatellites, the "doves", weighing less than 5 kilos each (and an average price of 0.5 million euros per unit), to provide medium optical resolution Earth imagery with a considerable refresh rate to various commercial users in the sectors of agriculture, tourism, estate management, security and environmental monitoring. This programme has obtained cheap "multipayload" launch tariffs from various providers worldwide (ISRO, India; Cygnus and SpaceX, USA; Vega, UAE). The full deployment of this constellation is planned for 600 satellites in 2020, and their number will be kept thereon with turnover replacements. OneWeb too will implement within 2019 its first-phase constellation of 600 Airbus-made minisatellites (120 kg each), to grant 50 Mbps Internet band to all digital divide areas worldwide. This venture is using Ariane (and Europeanized Soyuz under this logo) launchers due to the higher weights and altitudes, as well as Virgin Galactic's LauncherOne airborne platform. Its project financing structure (SoftBank has a seizable share), moreover, makes it more adaptable to strong increases in the fleet mass according to business response. To conclude this overview, there are also SpaceX and Samsung TLC constellation, with a minimum 1000 units planned in orbit by 2020, and other minor competitors like Dauria Aerospace and Elecnor Deimos in Europe, in both fields of Earth observation and TLC. These numbers clearly support the growing concern on space debris by the end of the decade, as they amplify all the considerations contained in this study. Risk mitigation and management should therefore be firstly and seriously considered from the side of the "active" operator (the satellites' owner). This indeed is partly happening as it is recommended and imposed by the respective Governments, who according to the Space Treaty (see Sect. 3.1 above) are the ultimate liable subjects of damages resulting from their citizens' space activities. Anyway, there's a series of positive and negative considerations which are summarized in Table 2.

Finally, seeing risk mitigation and management from the side of the "passive" subject, that is, the person or asset (terrestrial or aerial) that could suffer the damage, the small satellites themselves, for technical and economical reasons, cannot sustain sophisticated devices, even if, for their "heavier" classes, integrated orbit removal systems, instead of deorbiting procedures, are studied (performed by dedicated cleaner satellites). This happens because of the economic advantage in reusing materials already in space for repair and maintenance of the constellation, thus saving on launch costs. Insurance schemes are also by now being considered for

[2] By international standards, small satellites are in turn divided into ranges according to their weight: minisatellites $<$ 1000 kg, microsatellites $<$ 100, nanosatellites $<$ 10, picosatellites $<$ 1, and femto-satellites.

Table 2 Positive and negative elements in the risk mitigation and management practices of space debris impact risks connected to small satellite constellations

Positive elements	Negative elements
Construction characteristics	
Small satellites (especially from class nano down) have almost total chances of being destroyed by the atmosphere in re-entering, unlike weightier satellites. They can to some extent compensate their non-manoeuver ability by visual detection through ground radars implementing their own "scatter" enhanced radio image	They are not continuously position—assisted and routed as big satellites are because they cannot embark complicated flight units. They are only spot position—located periodically and driven until life end by radio assistance impulse as they can only manoeuver their thruster power and direction
Flight and route monitoring	
Countries applying the IADC and COPUOS Orbital Mitigation Guidelines (USA, UE, Russia, Japan—see Sect. 3.1 above) impose their citizens to register flying objects and set up permanent monitoring by algorithms and radar, mostly for a fee at dedicated SST centres, so constant monitoring is ensured until the programmed end of life, and any error can generate a suitable warning. Dedicated routes and altitude layers are assigned to ensure safe re-entry or destruction by atmosphere	Although the said Guidelines are a recommendation for all, some countries (see China, India) do not yet subscribe to the strict requirements of registration and monitoring, because it implies the openness of archives to international inspection and collaboration
Legal and insurance framework	
Ultimate responsibility of space debris damages resides with the owner's State. Some insurances are studied for minimum mandatory coverage of the owner in case of third-party involvements and relative claims	Both the ultimate State's liability principle and even more any insurance scheme to cover private subject are very hard to implement where there's no strict regulation or control as by COPUOS Guidelines, together with a critical, breakeven mass of flying satellites, capable of basing the insurance business affordable process

Source: Authors elaboration

airline companies, as the events of planes being dangerously hit by small particles are not so rare anymore.

4 Conclusions and Outlook for the Future

Apart from the monitoring of potential evolutions in the various areas of mitigation and insurance, along with the level of awareness and alarm that the space debris issue will generate, there should be more attention for the effects of space debris on the regular operations of the same satellites which are providing space services (Earth observation, positioning, TLC) which have become crucial in prevention, detection and management of most CBRNE events. One example is the recent misfunctioning (as of August 2016) of ESA's Copernicus Earth observation satellite A1 and several avoidance manoeuvers already performed by the ISS, to conclude with the already mentioned destruction of the Iridium communication satellite in 2009. The paramount importance of aviation, in the potential development of more robust mitigation and insurance systems, is witnessed also by the commitment of the SESAR (Single European Sky ATM Research) EU's ADMIRE initiative (Aviation—Debris and Meteorites Integrated Risk Evaluation) at the international level, involving terrestrial protection from destructive impacts and littering [16]. Finally, what it is currently absent but desirable is to define an analysis in terms of benefit-costs that allows to assess public and private investments aiming at containing or removing the costs resulting from the occurrence of these CBRNE events following to the start of specific preventive actions of the events. This is left to further studies.

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Application of Economic Analysis to the Selection of Security Measures Against Environmental Accidents in a Chemical Installation

Valeria Villa, Genserik Reniers, and Valerio Cozzani

1 Introduction

1.1 Security-Based Events in Chemical Installations

Chemical installations are nowadays recognized as attractive targets for potential intentional malevolent acts, named also security-based accidents, such as terroristic attacks and sabotage [1]. Indeed, chemical plants are generally characterized by a high inventory of hazardous materials, often stored and processed in critical operating conditions; such substances may range in nature and effect, and a comprehensive definition may be provided by the CBRNE (i.e., chemical, biological, radiological, nuclear, and explosive) acronym [2]. The presence of hazardous substances may lead to dreadful consequences of security-based events, including environmental, economic, social, and human damages, with possibility of supply chain disruption and cascading effects [3].

For instance, in 2015, two security-related accidents, possibly terroristic attacks, took place in France, raising public opinion awareness toward the topic. These two security-based accidents are just the latest ones of a long series; as reported by the ARIA governmental agency, only in France, 850 malicious acts have been

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committed, with various scopes, ranging from theft and vandalism to sabotage and terrorism, within industrial facilities, mainly chemical installations, in the period 1992–2015 [4]. ARIA survey results highlight that 46% of security-based accidents resulted in severe environmental consequences (e.g., due to the release of hazardous substances), often overlapped with significant economic damages, which were sustained in 84% of the accidents.

1.2 The Role of Security Measures

Security measures have a crucial role in preventing malevolent acts in chemical installations. Therefore, the evaluation of possible risk-reducing security measures, according to economic criteria, becomes a priority topic, requiring novel models and approaches. All the security measures present on site form the physical protection system (i.e., indicated with acronym PPS) that can include people, procedures, and equipment for protection against security threats, ranging from terrorism to sabotage. The classification of PPS is generally carried out in three main categories accordingly to the function they serve: detection, delay, and response [5].

Economic analyses, such as cost-benefit and cost-effectiveness analyses, may offer rational criteria for the selection and allocation of security measures, within chemical domain [6], but economic analyses models tackling the specific features of security-based accidents are limited [7–9] and require further validation by means of applications, in purpose to become a sound decision-making support tool.

In the present study, the fundamentals of economic analysis within chemical-industry-related security framework have been discussed, and later an application to an illustrative case study, freely inspired by a real event, has been presented.

2 Economic Analysis in the Chemical Security Context

2.1 General Layout

The general layout of economic analysis within chemical industry security domain is reported in Fig. 1. The economic model [8, 9] includes six main terms: (1) definition of the likelihood of the attack, (2) effectiveness assessment, (3) cost assessment, (4) benefit assessment, (5) cost-benefit analysis (i.e., indicated with acronym CBA), and (6) cost-effectiveness analysis (i.e., indicated with acronym CEA).

The model, starting from the analysis of the baseline PPS, allows proposing security upgrades and accounting both the performance improvement and the costs derived from their implementation. Inputs to economic analyses also include the evaluation of benefits that are either averted or sustained damages from the accident, expressed in monetary values. Therefore, economic analysis application enables the comparison among different single security upgrades and guides the selection of

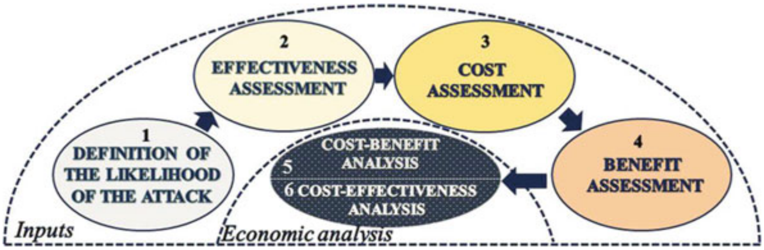

Fig. 1 Layout of economic analysis for the chemical security domain

those that are economically feasible, according to CBA. Moreover, economic analysis application allows defining the ranking of security measures combinations respecting budget constraints, according to CEA. The ultimate aim of the analysis is providing a comprehensive security decision-making tool that assists the selection of security measures and the allocation of the budget, within the context of chemical installations.

2.2 *Economic Analysis Inputs*

Definition of the Likelihood of the Attack

The likelihood of the attack $P(T)_{ij}$ expresses the attractiveness of a chemical installation toward possible malevolent acts committed according to different scopes (e.g., theft, sabotage, terrorism). The quantification of this term, varying from 0 to 1, may be carried out by means of statistical data treatment, as well as on available intelligence, law enforcement, and open-source information. In the present study, a semiquantitative model for the estimation of the likelihood of the attack was applied [10]: it requires site-specific information regarding sociopolitical conditions, inventory, and location of hazardous materials.

Effectiveness Assessment

Effectiveness assessment is aimed at evaluating the baseline PPS performance by site-specific analysis, proposing security upgrades, and determining the performance improvement due to each additional measure. The principal indicator for the performance of a PPS is its effectiveness, varying from 0 to 1, which expresses the conditional probability of an attacker's sequence of actions being stopped. Effectiveness improvement due to the introduction of one generic security measure i in the existing PPS can be expressed as:

$$\Delta R_i = \eta_{\text{PPS, new } i} - \eta_{\text{PPS, old}} \tag{1}$$

where $\eta_{\text{PPS,new } i}$ indicates the upgraded PPS effectiveness after the introduction of a security upgrade i among the possible n security measures and $\eta_{\text{PPS,old}}$ represents the baseline PPS effectiveness. Both the terms can be determined by means of a pertinent path-level effectiveness model. EASI model (i.e., Estimate of Adversary Sequence Interruption) [5] has been applied in the present study.

Cost Assessment

Cost assessment is aimed at evaluating direct and indirect costs due to the implementation of each security upgrade i ($C_{\text{Security},i}$). The overall annual costs due to the implementation of one generic security measure can be computed as the sum of six contributions [8]:

$$C_{\text{Security},i} = (C_{\text{INITIAL}} + C_{\text{INSTALL}} + C_{\text{OPERATION}} + C_{\text{MIS}} + C_{\text{OR}} + C_{\text{SPEC}})_i \forall i \in \{1, \ldots, n\}, n \in Z \tag{2}$$

where C_{INITIAL} overall initial costs; C_{INSTALL} installation costs; $C_{\text{OPERATION}}$ operating costs; C_{MIS} maintenance, inspection, and sustainability costs; C_{OR} other running costs; and C_{SPEC} specific costs. In turn, each cost category is calculated as the sum of several subcategories; information can be retrieved from a previous study [8].

Benefit Assessment

Benefit assessment consists on the definition of the losses ($C_{\text{Loss},j}$) of an either prospective or retrospective accident scenario j among m possible ones. Indeed, losses quantification depends on scenario selection. For instance, in case of a retrospective analysis, the actual losses may be accounted. The overall benefits derived from a generic accidental scenario can be computed as follows, for each scenario j considered in the analysis [8]:

$$C_{\text{Loss},j} = (B_{\text{SUPC}} + B_{\text{DMG}} + B_{\text{LGL\&INS}} + B_{\text{H}} + B_{\text{ENV}} + B_{\text{REPT}} + B_{\text{SPEC}})_j \forall j \in \{1, \ldots, m\}, m \in Z \tag{3}$$

where B_{SUPC} supply chain benefits, B_{DMG} damage benefits, $B_{\text{LGL\&INS}}$ legal and insurance benefits, B_{H} human benefits, B_{ENV} environmental benefits, B_{REPT} reputation benefits, and B_{SPEC} specific benefits. In turn, each cost category is calculated as the sum of several subcategories; additional information can be retrieved from a previous study [8].

2.3 Economic Analysis

Cost-Benefit Analysis

Before starting an economic analysis, it is necessary to introduce a discount rate to convert all cash flows to present values of annuities, by means of appropriate discount rates [11]. Cost-benefit analysis is aimed at defining the single security measures that are economically feasible with reference to all the m scenarios, according to the following formula:

$$\begin{cases} \text{Net Benefit}_{ij} = P(T)_{ij} \cdot C_{\text{Loss},j} \cdot \Delta R_i - C_{\text{Security},i} \\ \forall i \in \{1,\ldots,n\}, n \in Z, \quad \forall j \in \{1,\ldots,m\}, m \in Z \end{cases} \tag{4}$$

where Net Benefit$_{ij}$ indicates the net benefit (i.e., net present value) obtained by applying a security measure i, among n possibilities, with reference to a specific scenario j, among m scenarios. The implementation of a single security measure i is acceptable, with reference to all the m scenarios if the following constraint is satisfied:

$$\text{Net Benefit}_{ij} \geq 0, \forall j \in \{1,\ldots,m\}, m \in Z \tag{5}$$

Else, it should be rejected.

Cost-Effectiveness Analysis

Cost-effectiveness analysis is aimed at defining the most profitable combination of security measures (i.e., the one with the maximum net benefit) among all possible combinations v, within budget constraints ($C_{\text{Budget},j}$), for each scenario j:

$$\begin{cases} \max \left(\text{NetBenefit}_{vj} \cdot x_v\right) \\ C_v \cdot x_v \leq C_{\text{Budget},\ j} \forall j \in \{1,\ldots,m\}, m \in Z \\ x_v \epsilon \{0,1\}, x_v \in Z, v \epsilon \{1,\ldots,w\}, w \in Z \end{cases} \tag{6}$$

Moreover, cost-effectiveness analysis allows defining the ranking of security measures and combinations of them (i.e., whose overall cost is expressed by C_v), respecting the budget, in decreasing order of profitability for each scenario j. Therefore, the outputs of cost-benefit and cost-effectiveness analyses are economic indicators for security decision-making support.

3 Application of Economic Analysis to a Case Study

3.1 Definition of the Case Study

Economic analysis was applied to an illustrative case study, freely inspired by a real accident that took place in 2010 in Villasanta (Italy), consisting in the sequential sabotage of an oil depot that led to a major spill of hydrocarbon liquids (i.e., 2,600,000 kg).

The released substances flowed into the nearby river, causing pollution of river water and sides downstream for about 100 km and requiring massive emergency intervention [12]. The attacker was supposed to carry out the sabotage by foot, starting from the facility boundaries, running to critical area, performing a series of actions in correspondence of each target, leading to the spill of the entire contents of four tanks. The identification of key protection elements and key distances is necessary to calculate the baseline PPS effectiveness. The likelihood of the attack was estimated at 0.42, considering a medium-sized chemical installation located in Italy.

3.2 Effectiveness and Cost Calculations

The baseline PPS performance has been evaluated according to EASI model, and the results highlighted a rather low value of baseline PPS effectiveness (i.e., 0.0912). Therefore, five security upgrades have been proposed, according to the functions of detection, delay, and response [5]; effectiveness improvement values (i.e., ΔR_i) have been calculated for each of the proposed security measures (Table 1). Cost calculations have been realized for each of the five PPS upgrades, according to the categories displayed in Sect. 2.2, retrieving realistic information from vendors' websites. Cost calculations results, reported in Table 1, showed that the order of

Table 1 Effectiveness, cost calculations, and cost-benefit analysis results for five security upgrades

Upgrade ID	Description	Effectiveness improvement	Overall costs (€, 2017)	Prevailing cost category %	Net benefit (€, 2017)
U1	Detection sensors at perimeter	0.5223	1.12E + 04	Installation costs; 37.3%	1.19E + 07
U2	Detection elements at sabotage targets	0.4828	3.39E + 04	Installation costs; 55.8%	1.10E + 07
U3	Delay elements at sabotage targets	0.0595	3.60E + 04	Installation costs; 86.6%	1.35E + 06
U4	Alarms and cages at targets	0.6121	2.10E + 04	Installation costs; 37.5%	1.40E + 07
U5	Reduction of response force time	0.6489	2.60E + 05	Operating costs; 65.5%	1.48E + 07

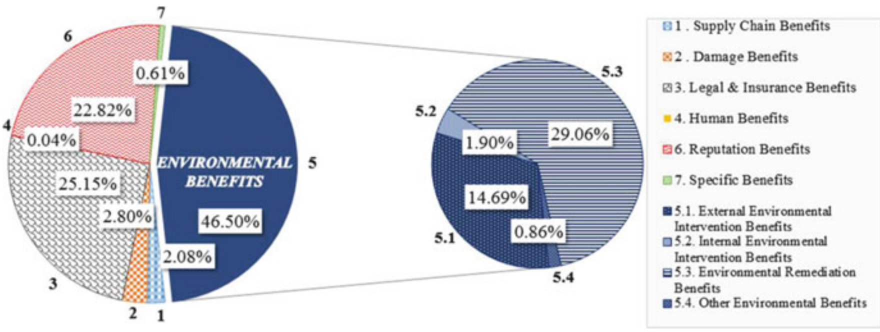

Fig. 2 Percentage composition of overall benefits derived from the actual scenario of a security-based environmental accident

magnitude of the overall costs is the same one for detection and delay measures. Nevertheless, despite costs distributions are slightly different, according to the security function, installation costs are the prevailing ones for both detection and delay upgrades.

3.3 Benefits Calculations

The actual losses derived from the accident were estimated of 8.17×10^7 €, confirming the definition of the accident as an "ecological disaster" [12]. As visible from Fig. 2, environmental benefits are strongly prevailing (i.e., about 47% of overall benefits), with relevance of environmental remediation benefits subcategory. Indeed, reputational benefits and legal and insurance benefits are relevant (i.e., about 23% and 25% of overall benefits, respectively).

4 Results and Discussion

The results of the case study consist of cost-benefit and cost-effectiveness analysis results, which are the values of actualized net benefits, for five PPS upgrades and the profitability ranking for combinations respecting budget, with reference to the actual scenario.

Overall costs for each security measure and overall benefits have been made comparable by applying appropriate discount rates (i.e., 3.5% and 1.5%, respectively) over 10 operational years [11]. The values of net benefit have been calculated for each of the five PPS upgrades, according to Eq. (4) (Table 1). According to the acceptability criteria provided by Eq. (5), all the single security upgrades are feasible because costs of security measures are several orders of magnitude inferior to overall losses. Therefore, CBA application does not provide screening criteria for the

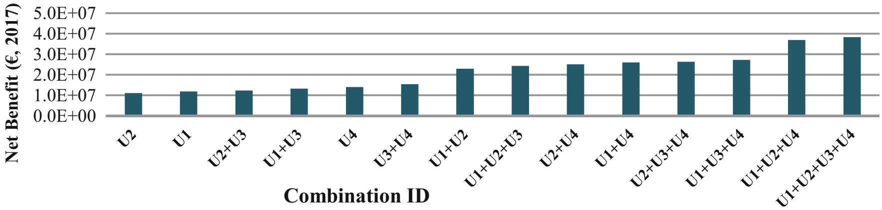

Fig. 3 Cost-effectiveness analysis results: upgrades respecting budget constraint are reported in increasing profitability order from the left to the right

selection of security upgrades in the present case study. On the other hand, CEA results, reported in Fig. 3, provide useful indications on the most profitable combinations of security measures, under budget constraint (i.e., 7.14×10^4 €). The top four combinations include at least three measures, offering an integration of different security functions (i.e., detection and delay) and a more complete security protection. It should be noted that none of the combinations reported in Fig. 3 include the security upgrade U5, because its overall cost exceeds the security budget, even if its effectiveness improvement is the highest one.

5 Conclusions

The current contribution has been aimed at presenting the specificities of economic analysis within the framework of chemical industry security. An application to an illustrative case study, regarding a sabotage to an oil depot, leading to severe environmental losses, was presented. The results of the case study made clear that the application of economic analysis provides to security managers site-specific answers on the most profitable single security upgrades and combinations of them needed to prevent security-based accident scenarios. Therefore, economic analysis outputs, consisting in a set of economic indicators, provide a significant support to managers and regulators in the decision-making process, and its application may eventually foster the reduction of chemical installations vulnerability toward malevolent acts.

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Economic Impact of Biological Incidents: A Literature Review

Donato Morea, Luigi Antonio Poggi, and Valeria Tranquilli

1 Introduction

According to the European Union's (UE) point of view, no public authority can afford to ignore chemical, biological, radiological, and nuclear (CBRN) threat due to its potentially very significant consequences in terms of human life and economic effect; indeed, "There is also a consensus amongst experts that the case of a somewhat limited attack needs to be carefully considered because the psychological, health and economic effects on the population of even a small scale attack using such materials would be significant" [1].

In particular, EU focused its attention on the relevance of critical infrastructures, meant as the infrastructure located in one of the member states whose destruction or malfunction would have a significant impact in at least two member states of the European Union. In fact, CBRNe incidents may cause behavioral, cognitive, and physical damages to persons that in addition to cascading effects for failures of potential critical infrastructures and assets may increase the number of victims. So, EU has identified the process of the impacts that EU member states should assess, according to Article 3 of the Council Directive 2008/114/EC ("the identification and designation of European critical infrastructures 1 and the assessment of the need to improve their protection") [2]:

- *casualties criterion (assessed in terms of the potential number of fatalities or injuries);*
- *economic effects criterion (assessed in terms of the significance of economic loss and/or degradation of products or services; including potential environmental effects);*

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- *public effects criterion (assessed in terms of the impact on public confidence, physical suffering and disruption of daily life; including the loss of essential services).*

EU regulation context brings to characterize any CBRNe incidents in three types of large-scale effects:

- Casualties (effects in terms of persons):
  - Injuries
  - Fatalities
- Social impact (effects in terms of persons, assets, and infrastructures):
  - Changes in social confidence
  - Changes in quality of life
  - Movement of communities with personal/cultural losses
  - Effects of unemployment, etc.
- Economic impact (effects mainly in terms of assets and infrastructures):
  - Damages to productive infrastructures
  - Costs for rebuilding
  - Costs for decontamination (including environment losses, costs for improved health assistance), etc.

Moreover, EU carried out investigation activities aiming to the implementation of biological actions like the adoption of risk management standards, the codes of conduct in bio issues for laboratories, and the funding of research projects on biosecurity activities.

Since CBRNe events and particularly biological events can be profiled through methodological approaches, this paper has the purpose to investigate the main, included in literature, production on that field.

Our work wants to seek the limits and the possible future scenarios of the research, aiming to refine the impact profiling of the biological events and study the related economic costs.

2 Methodological Approaches

Structural effects and related economic effects of biological incident can be assessed differently according to selected methodologies and to the adopted indicators.

Kaufmann et al. [3] modeled economic analyses of a theoretical biological postattack caused by *Bacillus anthracis*, *Brucella melitensis*, and *Francisella tularensis* (agents of biologic war) released as aerosols in the suburb of a major city with an exposed population amounting to 100,000 persons. The economic impact measured for each agent was related to the parameter of the cost of hospitalization and outpatient visits. The research considered that only persons with symptoms would use medical facilities. The remainder of the exposed and potentially exposed population would receive postexposure prophylaxis. They stressed the time-dependent effectiveness factor of the response: “The speed with which a post-attack intervention program can be effectively implemented is critical to its success.”

The RAND Corporation [4] analyzed the possible insured losses related to two different types of anthrax attacks: one inside a single large building and the other in a widely dispersed outdoor. In this case the chosen parameters were relative to the geographical extension, property damage insured, and workers’ compensation, while time-dependent ones were not weighed.

Enders and Sandler [5] reviewed some works related to potential consequence scenarios for CBRNe attacks. In the biological case, assessment of the consequences ranges from 26.2 billion dollars for an aerosol spray of anthrax spores with 100,000 people exposed to 254 billion dollars for 10 kg of anthrax slurry in a large city. Another large part of the literature related to the assessment of the effects of large-scale critical events relies on the evaluation of consequences on assets and unavailability of infrastructure network disregarding causes. Any effect is the target of investigation; one of the main difficulties in its assessment to be considered is the definition of the incident key elements. From the social point of view, CBRNe incidents may cause behavioral, cognitive, and physical damages to persons that, together with economic costs due to cascading effects for failures of potential critical infrastructures and assets, may increase the number of victims.

Ramseger et al. [6] considered that in case of CBRN events, there should be investigated three economic-related effects:

- The economic impact of the past disasters
- The probable financial impact of possible incident scenarios
- The financial efforts to prevent chemical, biological, or radiological attacks or to minimize their consequences

He also hypothesized two step methodologies to assess the economic impact of the CBRN events, the first one based on the identification of the substances of the incident and the second one on the related categories of costs.

Concerning on the first step, he identified four types of substances: poison, viruses, bacteria, and plagues. About the second step, he defined four cost categories: first response measures; recovery, reconstruction, and restoration; indirect damage; and macroeconomic loss (Table 1).

For Ramseger et al. [6], other crucial parameters for the profiling could be the economic loss, due to casualties, but:

> it is important to distinguish clearly between the economic value assumed for a lost life and compensation demands for a lost life.(. . .) According to a representative from an international insurance company (i.e. American International Group), insurance companies have experienced that legal claims in respect of loss of human life are settled quite differently in different regions of the world. Publicly available loss statistics indicate that typically, settlements of fatality claims in the USA are often in the order of some million euros. The costs for the lifelong support of a young invalid are much higher than the economic loss caused by his death. The average economic values given represent a rough approach and can only be used to approximately estimate the economic impact of a biological event.

Table 1 Breakdown of the CBRN incidents cost

Type of cost	Chemical/biological/radiological/nuclear incidents: potential economic effects
First response measures	• Rescue of injured and threatened people • Evacuation • Registration of contamination • Blocking the spread of dangerous CBRN materials • Immediate decontamination • Measures to cordon off the contaminated area
Recovery, reconstruction, restoration	• Health care for injured people • Costs for the deceased (medical forensics, funerals, life insurances) • Pensions, etc. for disabled people • Cleaning up measures and thorough decontamination • Reconstruction of buildings • Resettlement and relocation • Restoration of infrastructure: transport system, public services (water supply, electricity, telephone network) • Gathering of infected animals • Clearance of contaminated cadavers and plants (CBRN waste management substances)
Indirect damage cost	• Loss of earnings caused by loss of consumer confidence • Loss of earnings caused by (preventive) culling • Loss of earnings caused by decline in tourism • Loss of earnings resulting from injuries/sicknesses or death of employees • Loss of earnings because of state of emergency (regional and international) • Economic impact of temporary infrastructure breakdown: transportation system, public services (water supply, electricity, telephone network).
Macroeconomic loss	• Consequential costs from loss of income (multiplier effects) • Loss of investor confidence/propensity to save

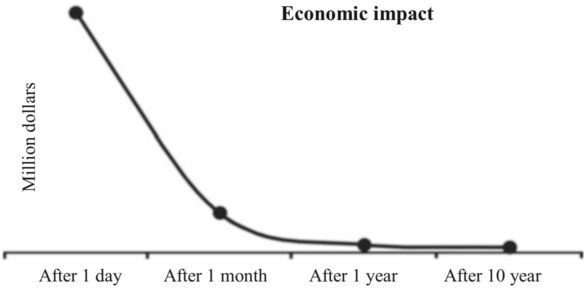
Source: Ramseger et al. [6]

In their study, Cavallini et al. [7] proposed an approach based on the "type of large-scale economic effect" and on the "persistence of the effects."

In attempting to profile impacts in terms of economic damages, they proposed as the indicator the severity of the direct (i.e., first response measures, recovery, reconstruction, restoration) and indirect (i.e., indirect damage cost, macroeconomic loss) effects in the area of reference.

In terms of economic effects, economic values of damages of biological incidents should be reported in absolute terms. The main obstacles to provide reliable values are two: lack of information/data on specific cost elements with the risk of underestimation of the overall economic losses and differences in the assessment approaches used to define the cost elements with the risk of bias estimation of the overall economic losses.

Immediate effects of a biological incident are highly severe in terms of victims, probably less than a comparable CBRNe incidents.



Preventive costs	2 million USD (€1.78 million) to get information on the perpetrator(s)
Costs for decontamination	90.3 million USD (€ 80.46 million)
People killed	5
People injured	22

Fig. 1 Economic impact profiling of a biological incident (source: Cavallini et al. [7])

The main goal of this paper is to provide an information base to make first responders' prompt actions and policymakers' strategic decisions immediately after the occurrence of the events more effective and efficient.

Cavallini et al. [7] examined a case study attack with bacteria anthrax on 18 September 2001 in the USA which gave no opportunity with the collected information to define a detailed profiling of the economic impact of such incident. In any case the adapted "Ramseger approach" applied to the antrax attack allows to create a general curve of the economic impact for biological events (Fig. 1).

They examined the economic costs by event during the attack with bacteria anthrax on 18 September 2001 in the USA (Table 2).

3 Conclusions and Future Researches

According to European Union point of view, no public authority can afford to ignore chemical, biological, radiological, nuclear, and explosive (CBRNe) threat given its potentially very significant consequences in terms of human life and economic effect.

Examining the literature in the field of the CBRNe events, in particular the BIO one, it comes out that theoretical and realistic case studies have been analyzed with the purpose to extract the related costs and then, as Cavallini et al. made, profile the economic impact of a biological incident.

What has been recognized is that besides the lack of certain data to establish the effective postattack costs, the quantification of the economic losses is heterogeneous depending on specific cases. Moreover, what is currently absent but desirable is to

Table 2 Economic costs, attack with bacteria *B. anthracis* on 18 September 2001, USA

Attack date	Event	Economic cost	Potential economic effects (adapted by the "Ramseger approach")
15 January 2002	US postal and law enforcement officials announce that the reward for information on the perpetrator (s) of the anthrax attacks will be increased to 2 million USD	2 million USD	• Security measures
22 January 2002	Official announcement of the increase in the reward for information: in addition, postal and law enforcement officials announce that they will send out 500,000 flyers targeting central New Jersey and Bucks County (PA) in a search of additional information. The Hart Office Building officially reopens after 96 days of quarantine and decontamination. The Environmental Protection Agency estimates that it has spent 13.3 million USD on cleanup operations, and expects the total cost to rise to 20 million USD	13.3–20 million USD	• Registration of contamination • Immediate decontamination
26 March 2002	Postal officials estimate that it will cost 35 million USD to clean both the Brentwood and Hamilton (NJ) postal facilities	35 million USD	• Cleaning up measures and thorough decontamination • Resettlement and relocation • Restoration of infrastructure: transport system, public services (water supply, electricity)
26 July 2002	Postal service officials hold a press conference to announce that a test of decontamination techniques at the Brentwood facility will be conducted on 29 July. Postal officials also estimate that it will cost approximately 22 million USD to decontaminate the facility	22 million USD	• Cleaning up measures and thorough decontamination • Resettlement and relocation • Restoration of infrastructure: transport system, public services (water supply, electricity)
30 July 2002	Postal service officials in New Jersey announce that the Trenton Processing and Distribution Center in Hamilton will be reopened in the spring following a 20 million USD decontamination and renovation process	20 million USD	• Cleaning up measures and thorough decontamination • Resettlement and relocation • Restoration of infrastructure: transport system, public services (water supply, electricity)

Source: Cavallini et al. [7]

define an analysis in terms of benefit costs that allows to assess public and private investments aiming to contain or remove the costs resulting from the occurrence of CBRNe events following the start of specific preventive actions of the events. This is left to further studies.

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The Risk Management and the Transfer to the Insurance Market

Antonio Coviello and Giovanni Di Trapani

1 Introduction

The risk management within an organization should be an integral part of both technology and management. In this context "the challenge of risk management is to learn to live with uncertainty, so that the risk can be an acceptable stimulus rather than an unacceptable threat" [1].

Really, the role of risk management in the company is to help individuals and businesses to live with uncertainty in a productive and careful way. Hence, the recent theorization of a new science called "chindinica" (from the Greek *kindunos*, danger), or the science of the danger, whose purpose is to explain human behavior in dangerous situations through the emergence of a number of regularities appearing when the danger occurs [2]. So risk management is concerned with the knowledge, understanding, and representation of different aspects of the danger [3].

Obviously, as confirmed by several experts in the field, the management of a risk cannot be limited to its identification and measurement, but also to its treatment. Instead, the risk manager will control the strategic and operational management of pure risks and all related activities to support the other business functions in relation to more general business risks. In fact, the lack of synergy between the managers of other corporate functions would cause negative effects such as the lack of an overall risk strategy—which is essential to ensure the organization's security in case of adverse events [2].

Any operating system targeting future outcomes is, by definition, in a situation of uncertainty, even if different situations are characterized by different levels of risk and uncertainty. Risk and uncertainty are part of the human condition, and rationality

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lies in controlling and reducing them to acceptable and manageable levels in specific situations, rather than in avoiding risk and eliminating it.

2 Crisis Management and Risk "Insurability"

The highly systemic nature of modern economy and the increasing technological development levels of complexity require an even deeper economic knowledge and control of the growing vulnerability of these systems. Paradoxically, vulnerability increases with the improving performances of modern technology and quality; in fact, management errors and accidents happen to a lesser extent (as numerically reduced thanks to improving technology), but their effects will have more expensive systemic consequences in this context.

From the point of view of risk management, (also in order to well clarify the function of the state and its direct intervention about some types of risk), it seems appropriate to refer to the concept of insurability [4]. This expression essentially translates the ability to rationally manage the risk of pure type. Insurability, therefore, is connected with the fact that the peculiar characteristics of risk (frequency and gravity) will be forming so that that risk can be predictable and economically manageable within a reasonable level of probabilistic confidence [5].

Natural events, (such as earthquakes, floods, fires, etc.), together with man-made crises, whether accidental or intentional, when occurring, can seriously jeopardize the company assets, even causing its failure (Fig. 1).

In order to analyze these phenomena, the crisis of the management [6] technique is increasingly spreading; it is a branch of the wider field of corporate security and aims to provide methodologies and techniques whose purpose is reducing adverse events quickly, effectively, and with the least amount of damage [7, 8].

In this sense, the definition of crisis is related to strong elements of subjectivity: if a particular phenomenon has the typical characteristics (identified by Hermann) of threat (considered as a phenomenon that can hamper the corporate mission), of time (the decisions to be taken to face the situation will have to be quick, failing which a total loss of control), and surprise (the effect produced by the event will cause a feeling of loss of management), we will be able to talk about crisis management [8].

As a consequence, some essential operations are needed, such as the identification of crisis occurrence trends, the isolation of the causal mechanism characterizing a particular situation, and the indication of the means leading to the best solution. It follows, then, that corporate security includes a whole series of activities planned to prevent, face, and restore the goods subjected to harmful events (in this case, respectively, we will be talking about anticipatory activity and contextual and subsequent operations) in the shortest time possible. Through the proper use of human and financial resources organizing and implementing preventive actions, the activity of enterprise security and its related area, risk management tries to anticipate the harmful event; obviously, the vastness of the threats to which the enterprise is subjected does not allow a complete elimination of the risks on it, as it is economically burdensome. Instead, the right mix of combinations available to the

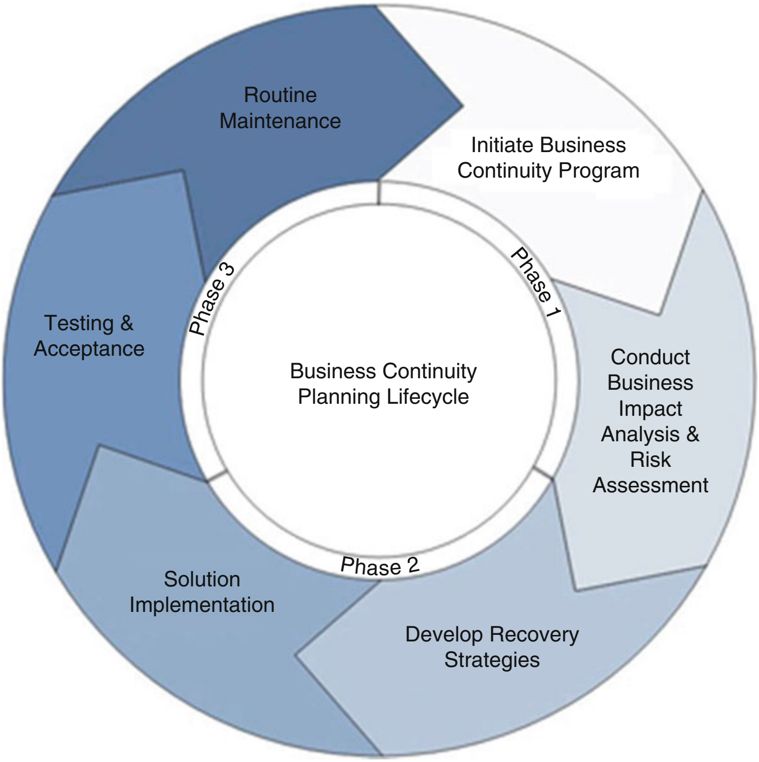

Fig. 1 Business continuity planning (BCP) life cycle (Source: Societal Security—ISO 22301, Societal Security—Business Continuity Management Systems)

management, ranging from the elimination of risk to its general taking, allows intermediate choices, including the transfer to third parties, the reduction of its size, and finally the use of insurance coverage, more and more required by businesses as a result of the increasing risks faced by companies. As a consequence, today, risk carrying is hard for ensuring companies.

The insurance market should be organized not only to face risk management but to also stand up to the innovations that are being introduced into community legislation (in terms of preparation of financial statements, regulation of financial conglomerates, insurance brokerage, solvency) you need to individuate and implement risk-integrated management models.

3 Risk Prevention and Protection Measures

We are increasingly seeing cases where dramatic events strike suddenly and unexpectedly companies, inevitably producing not only huge economic losses but also effects on companies' public image. Today, in fact, it is no longer possible to speak

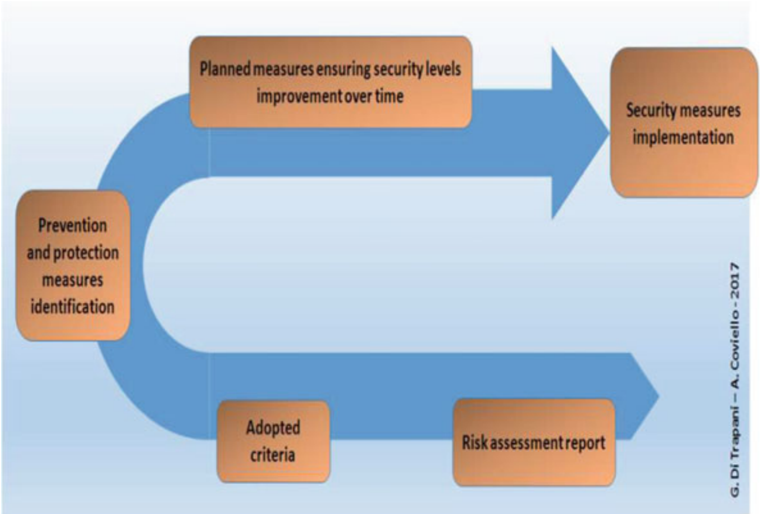

Fig. 2 Construction process of preventive actions

simplistically of unavoidable circumstances. If you think about the events that can cause damage to businesses, it is noted that these latter show distinct connotations that deserve deepening to permit their effective prevention. The knowledge of risk allows us to understand what behaviors should be avoided, what behaviors should be followed, and the one taking place in the action: all that are the key factors of success or failure. The next aspect of approaching risk is not only influenced by different behaviors but also by environmental factors, by "values" at stake and by inclination to sustain asset losses (whether our own or others') that we could be forced to pay due to our not particularly careful behavior. What seems like a great opportunity worth the risk in favorable conditions can then quickly turn into a disaster (Fig. 2).

Then, a key factor in growth is the increasing importance of the strategic management, which involves, besides the need to ensure the shareholders, an adequate monitoring of risks and their coverage, hence the finding of the growing importance of risk management for the companies, which inevitably leads to a parallel use of internal structures and external expertise. Undoubtedly, the temptation of outsourcing this function is very strong for companies, and their offer, in particular by large global insurance brokerage companies, is increasingly aggressive and qualified. However, there are activities such as the policy administration or the management of repetitive claims that can be outsourced; but other ones, such as the decision about what risks should be transferred to the insurance market, to what extent, and in what forms, certainly cannot be entrusted to third parties if not handled in the company by highly qualified professionals.

Even prevention policies and their subsequent management should be included in the company's internal business functions: no third party could think of suitable solutions without valid interlocutors in the company. Ultimately, an appropriate mix

Fig. 3 Emergency management cycle

of internal strategic management and support by outside operators could definitely be the recommended way for a company focusing on the problems of risk management (Fig. 3).

To better understand the phenomenon so far reported, it is possible to make a distinction between protection activities and those of prevention.

Prevention indicates all the works and actions to prevent or limit the occurrence of events[1] and related claims.[2] The harmful event originates from an unfruitful relationship between the parties, and it transforms into a conflict: voluntarily, common interests and purposes between the parties[3] are no longer present (risk of resonance lack); the parties, on their own will, misbehave (risk of ethics lack). Therefore, prevention substantially refers to an internal consulting activity, to the necessary time to influence the relational behaviors of the enterprise, in order to avoid not appropriate behaviors (own or by the counterpart, probability of resonance lack) or misconducts (own or by the counterpart, risk of ethics lack); the damage to the company emerges as a result of the negative outcome of the report.

[1]The event means all that happened or could happen, for example, in a factory producing ethyl alcohol.

[2]The accident is the damage connected with the event and is detectable in terms of losses, material injury, and nonmaterial harm by the subject.

[3]Misconduct can also concern only one of the parties toward the other one.

Protection means all the activities taking place through concrete action to protect the business from the damaging effects that originate from the occurrence of specific predictable events (to which a chance of occurrence can be associated) or unforeseen (not considering their predictability); the company is not able to influence in its attempt to avoid the emergence of the damage in the harmful event. Substantially, we are talking about the risks linked to the occurrence of phenomena happening in a more or less knowable but not influenceable environment. Such projects are also considered as the series of works and actions aiming to restrict the harmful event extent. As a matter of fact, these actions can be applied when the event cannot be avoided. The occurrence does not originate from an unfruitful relationship, but from something outside its own field of action and thus of influence.

Generally, protection measures are divided into two large families: passive protection works and active protection works. Active protection includes all those activities that can work through a specific action, normally using electricity (e.g., as to protective firefighting works, this category includes fire-extinguishing systems, scavenging systems through actuators, etc.). Instead, passive protection includes all those works already present on the spot and not requiring any further intervention (in referring to protective firefighting systems, for example, let's consider smoke-resistant structures, the separation of heavy-burden fires areas, etc.). The choice of a specific "family" means a particular behavior toward the idea of protection.[4] Active protection (which, if working properly, considerably reduces the harmful event extent compared to passive protection) requires an appropriate planning along with an efficient monitoring and preventive maintenance work; otherwise, performances could not be valid [9].

4 The Risk Control Activity

The risk control, together with the related phase of their evaluation, is the most relevant phase of the whole process. For a better understanding of this stage, let us consider the previously reported example, referring to the possibility of fire of in a factory [9].

In this case the control of risks consists of three different phases:

- Before the occurrence of the event
- During the occurrence of the event
- After the event occurs

The risk control measures prior to the event can be divided into two broad categories: the works of prevention, which—as you recall—represent the set of operations, and actions to prevent or limit the occurrence of events. Among the preventive works, the "rules of conduct" acquire a special importance; they provide

[4]Generally, for example, within passive security measures, firemen will have to intervene anywhere and anytime, as they know that they can unconditionally trust on such works.

for an appropriate behavior by those performing some specific functions in the enterprise.

An important category of control actions prior to the occurrence of the harmful event refers to the protection works, which represents the set of actions aiming to limit the loss extent (and not the event, which cannot be avoided).

Conversely, the risk control activity during the occurrence of the event is represented by the so-called emergency plans, which are made up of the set of actions that must be carried out when the accident takes place in order to rescue first people and then the company assets. These plans must be prepared upstream and not during the event; in fact, an earlier detection of proper actions to be carried out in case of fire can drastically reduce the direct damage and, especially, the time required to restore the conditions existing before the accident. The emergency plan must be written and indicate the operation to be carried out in case of need, as well as the name of the person in charge of each operation and the possible substitutes.

Finally, the risk control actions after the occurrence are represented by the so-called recovery plans, that is, the set of actions to restore the production capacity existing before the accident. Some authors believe the creation of an emergency team, made up of people who will have a deep knowledge of all the issues related to information and management supply, is more effective. These professionals will be specially trained to find the best solutions to manage crisis.

5 Conclusions

The crisis management was created with the aim to provide methodologies and techniques to face and reduce the economic impact of adverse events. The assessment and measurement of risks entity is an essential step to make correct decisions about countermeasures. The risk control, together with the relating phase of their evaluation, are the most defining phases of the whole process. The role of risk management in the company is therefore to help individuals and businesses to live with uncertainty in a fruitful and careful way. Then, the insurance market needs to be equipped not only with risk management but to stand up to the innovations that are also being introduced into community legislation (in terms of preparation of financial statements, regulation of financial conglomerates, insurance brokerage, solvency) and must detect and implement management models.

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Part V
An Overview on Different Emergency Management Aspects

EU CBRN Centres of Excellence Effective Solutions to Reduce CBRNE Risks

Margarida Goulart, Mariana Goncalves, Ivana Oceano, and Said Abousahl

1 The EU CBRN Centres of Excellence Model

1.1 Concept and Development of the Network of Partners for CBRN Risk Mitigation

In the early 1990s, following the breakdown of the former Soviet Union, the European Commission (EC) initiated a technical assistance to the Commonwealth of Independent States (CIS). This was named the TACIS support programme, which ran from 1994 to 2006, and included projects related to nuclear safeguards, enhancing border monitoring, improving measures to combat illicit trafficking and upgrading of nuclear forensic capabilities. The significant experience that the European Commission's Joint Research Centre (JRC) built up in measuring and controlling nuclear material through its involvement in the nuclear safeguards has been made available and transferred to CIS countries through dedicated projects carried out in the framework of the TACIS. The follow-up programmes went on taking into account new international threats while sustaining past initiatives within an enlarged international cooperation. These cooperative projects were launched in 2005 with initial funding from TACIS and continued under two instruments: the Instrument for Stability (IfS) [1] launched in 2006 and the newly named Instrument contributing to Stability and Peace (IcSP) [2], launched in 2014.

The security threat being of a global, multidimensional and cross-border nature, it was understood that chemical, biological, radiological and nuclear risks cannot be dealt with in isolation. The shift in the nature of risks and threats calls for a comprehensive approach to CBRN risk mitigation to ensure an adequate response.

It is an "Invited paper" and Dr. Goulart was an "Invited speaker" of the conference.

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In order to address these challenges, the EU CBRN Centres of Excellence initiative was launched in 2010 under the IfS, with the aim of strengthening the institutional and technical capacity of countries outside the European Union's borders to mitigate CBRN risks by implementing a comprehensive strategy for reducing national and international vulnerability to CBRN threats.

The EU CBRN CoE initiative is implemented jointly by the JRC and the United Nations Interregional Crime and Justice Research Institute (UNICRI) and is under the aegis of European Commission's Directorate General for Development and Cooperation (DG DEVCO) and the European External Action Service (EEAS). The EU CBRN CoE is developed with the technical support of relevant international/regional organisations, the EU member states and other stakeholders, through coherent and effective cooperation at national, regional and international level. The initiative provides a platform for voluntary regional cooperation on all CBRN-related hazard issues, be it of criminal (trafficking, terrorism), natural (pandemics, volcanic eruptions) or accidental (e.g. Fukushima) origin [3].

Under the ICSP, the EU CBRN CoE has grown to a network of 58 partner countries across the globe, organised around 8 CoE regional secretariats (RS), grouping all partner countries belonging to the same geopolitical area [4].

– African Atlantic Façade (AAF), RS in Rabat, Morocco
– North Africa and Sahel (NAS). RS in Algiers, Algeria
– Eastern and Central Africa (ECA), RS planned in Nairobi, Kenya
– Middle East (MIE), RS in Amman, Jordan
– Gulf Cooperation Council Countries (GCC), RS in Abu Dhabi, UAE
– South East and Eastern Europe (SEEE), RS in Tbilisi, Georgia
– Central Asia (CEA), RS in Tashkent, Uzbekistan
– South East Asia (SEA), RS in Manila, The Philippines

The CoE follows an "all hazards" approach and has a twofold aim [5]: to prevent CBRN incidents and to build partners' capacities for emergency responses to such incidents. Areas of concern for the EU and its partner countries include communicable diseases surveillance, waste management, emergency planning, early warning, civil protection, export controls on dual use goods and the cross-border trafficking of CBRN materials.

Moreover, the initiative is characterised by a "bottom-up" approach, where participating countries identify risks, assess gaps and needs, draw up national CBRN action plans and collectively agree on activities or projects to be taken forward at regional level. Regional secretariats (RS), national focal points (NFP) and CBRN national teams (NT), representing most of the relevant governmental stakeholders, work towards enhancing this cooperation. As of today, the initiative has funded 66 projects of which 25 are currently ongoing.

Finally, the initiative responds to the need to reinforce existing links between the EU's internal and external policies on CBRN. The CoE activities are, in fact, conceived to mirror the EU CBRN action plan [6] established within EU borders to enhance the fight against illicit trafficking and terrorism.

The EU CBRN CoE RS play a major role in developing a high level of cooperation and coordination between countries in the region and within the overall CBRN CoE network. They contribute to local ownership and improved sustainability of the CBRN CoE network. Examples of the activities conducted in the secretariats can be found in the CoE newsletters available on the CoE public website (http://www.cbrn-coe.eu).

1.2 The CoE Tools for Needs Assessment and Establishment of CBRN National Action Plans

Needs Assessment Questionnaire (NAQ) The NAQ was developed to facilitate the assessment of the national CBRN risk mitigation capacities and related needs of the CoE partner countries and is intended to be used on a voluntary basis by national authorities and their representatives to collect and review the elements of the national CBRN risk mitigation strategy, to review and evaluate the national infrastructure in place for CBRN risk mitigation and to identify gaps in CBRN risk mitigation capacity and prioritise the needs.

It consists of around 300 closed questions and is structured according to international practice which should lead the national CBRN representatives through all main elements of the national CBRN-related infrastructure and risk mitigation measures. Answering the questions included in the questionnaire will require a review and an evaluation of the current status of the national CBRN risk mitigation strategy and related infrastructure. The questionnaire has nine sections: legislation and regulation for CBRN material, facilities and activities, CBRN managing authorities, risk-mitigating strategy, CBRN prevention measures, detection of CBRN material, preparedness for potential CBRN incidents and response, CBRN recovery measures, sustainability and strategic trade control.

Designed for self-assessment of the CoE partner countries, the needs assessment should be a national effort, and therefore it should involve participation of national institutions and bodies with responsibilities related to CBRN, including those not represented in the NT. Bringing all the relevant stakeholders together (the NT and other relevant national CBRN stakeholders under the supervision of the NFP) triggers a valuable discussion and increases the quality of the assessment results, ensuring that all aspects of the questions are considered (e.g. risks of natural/accidental/intentional origin as well as C, B and RN dimensions) and that there is a full understanding of the answers given.

The NAQ can be further used as a basis for development of CBRN National Action Plan (NAP) and will enable monitoring of the progress made.

National Action Plan (NAP) The CBRN NAP is an essential tool for national authorities to articulate priorities and coordinate the implementation of a comprehensive safety and security national strategy against CBRN risks. Its purpose is to provide the policy framework to guide the creation and maintenance of sustainable capabilities and common standards in CBRN policies, programmes, equipment and training.

Built upon the outcome of the NAQ exercise previously performed at national level, the NAP includes adequate and realistic actions, specific tasks, objectives and leading agencies. The inter-ministerial and interdisciplinary approach, the harmonisation of definitions and procedures and the sustainability of the planned measures are ensured by the involvement of the relevant CBRN stakeholders and national authorities at all levels of the NAP development. The development of the NAP is in line with existing international instruments and activities in the CBRN field. Furthermore, each partner country shall take into account actions and recommendations provided by other strategic documents in order to avoid discrepancies and contradictions between those and the CBRN NAP.

On a confidential basis and upon request from the partner countries, the EC may continue providing its scientific and technical support for the formulation and drafting of the CBRN NAP. The EC will be able to assist the partner country in obtaining a comprehensive overview of the countries' capabilities and needs related to CBRN risk mitigation, highlighting main hazards and threats and possible gaps identified during the NAQ exercise previously performed by each partner country.

Finally, the CBRN NAP can also provide a basis for developing future projects to strengthen CBRN risk mitigation.

1.3 CoE Projects: From Proposals to Implementation

A series of projects are developed and supported within the framework of the EU CBRN CoE initiative. They would target comprehensive tailored training and institutional capacity building, meeting specific needs identified regarding CBRN risk mitigation. This includes matters such as export control, illicit trafficking, border monitoring, biosafety and bio-security. So far, the EU has invested in the implementation of around 60 projects, covering many aspects of CBRN risk mitigation. The projects emphasise and support regional cooperation.

Development of Project Proposals Based on the priorities identified by the NT and during the needs assessment questionnaire exercises, each country is welcomed to put forward needs to be addressed and to draft specific tailored project proposals. The possible topics are intensely discussed at the regional round table meeting. Priorities, both at national and at regional levels, drive the drafting of robust and coherent proposals by the NT coordinated by the NFP. This work is done with the scientific and technical support of the JRC.

Implementation of Projects The implementation of the projects is done by EU consortia selected by the EC through negotiated procedures. Due to the sensitivity of the domain, typically EU member state's governmental bodies lead the consortia. International organisations, local or regional bodies as well as the private sector can be part of the consortia. As the EU CBRN CoE initiative is also a platform open to other EU instruments (e.g. Instrument for Nuclear Safety Cooperation—INSC) and to other donors, co-funding of activities is looked for.

The RS, together with the CBRN NT, follow the implementation of projects led by the consortia. The RS will also provide logistical support when necessary. In view of its scope and the limited funds available, the EU CBRN CoE will only be able to support some projects, and others could possibly find a better place in alternative programmes for CBRN international cooperation.

Review and Quality Control The European Commission (DG DEVCO and JRC) together with the RS, and the CBRN NT, is responsible for the monitoring and evaluation of the project implementation, including quality control, review and impact assessment. The analysis of the review and feedback will provide the ground for improving the CBRN guidelines, the technical support and the management of the network.

2 The EU CBRN Centres of Excellence Achievements

2.1 Success Stories

Thanks to its multidimensional, multi-hazard and multilateral approach, the CoE initiative plays a crucial role in countering today's complex, interconnected cross-border and cross-sectorial threats, including by preventing incidents involving CBRN materials and CBRN agents misuse by criminal and terrorist organisations. In more than 7 years since its launch, it has contributed to creating a CBRN international community.

The CoE network has now reached a point of maturity and is ready to gradually expand its range of activities in terms of expertise, training and tabletop and field exercises in order to enhance its usefulness as an operational tool. Several achievements can be highlighted in each CoE region:

For the African Atlantic Façade (AAF), the development of a new and more country-specific needs assessment methodology was a key achievement of the CoE initiative. The numerous training workshops held in the region to reinforce partner countries' capabilities have led to the proposal to establish a regional CBRN training centre, which may contribute to enhance the sustainability of the initiative.

In North Africa and Sahel (NAS), CoE-related activities count seven regional ongoing projects. In addition, the regional secretariat is currently organising the "*Journées de formation et sensibilisation sur les menaces CBRN*", gathering representatives from Algerian civil protection, police, health and environment services, and announced that the same programme will be repeated in each partner country.

The Eastern and Central Africa (ECA) enjoys a broad membership with 11 countries, including Ethiopia that joined in 2017. Several countries completed their NAQs while some have also finalised their NAPs. A CoE award was granted to Zambia in 2016 for its amendment of the antiterrorism bill to include clear reference to CBRN-related terrorism. The amended bill paves the way for the national team to become a government subcommittee and guarantees the sustainability of funding for CBRN antiterrorism activities.

The Middle East (MIE) region is experiencing an increased use of the CoE network and structures by members of the international community, such as the Governments of the United States, Canada and Denmark, and international organisations, including the International Atomic Energy Agency (IAEA).

The countries represented in the Gulf Cooperation Council (GCC) region have also undertaken positive steps towards the establishment of national teams. Moreover, the first inter-Arab nuclear detection and response exercise "Falcon" organised in 2016 in cooperation with the MIE regional secretariat proved very successful, and a Falcon II field exercise is currently under preparation for 2019.

In South East and Eastern Europe (SEEE) major achievements have been made possible by the CoE, namely, the institutionalisation of national focal points in most of the countries, the adoption of NAPs and their endorsement by public authorities, the development of a regional strategy and the mapping of training institutes and expertise in the region. In 2016, a CoE award was granted to the region for its efforts to promote the CoE initiative and its bottom-up approach and methodology.

Central Asia (CEA) region has recently launched a new project on "Strengthening the National Legal Framework and Provision of Specialized Training on Biosafety and Biosecurity in Central Asian Countries", involving all partners in the region. Moreover, CoE impacts on Afghanistan's institutions enabled the country to establish coordination and communication among relevant ministries and agencies.

For the South East Asia (SEA) region, a recent success story is represented by the cooperation that Laos and Vietnam have developed in the framework of the activities related to CoE project 46. With the support of the Vietnamese Nuclear Regulatory Agency, Laos is establishing its nuclear regulator. The Philippines, which presented the priorities identified through the NAP exercise during the last G7 Global Partnership Biological Working Group meeting, will receive support from the US Defense Threat Reduction Agency (DTRA). Malaysia was selected among the six SEA applicant countries in the Biological Weapons Convention Implementation Support Unit (BWC-ISU) call for proposals.

2.2 Capacity Building Activities

The EU CBRN CoE initiative follows a regional bottom-up and voluntary approach, supporting partner countries in various activities such as creating CBRN NT, assessing CBRN national needs, drafting CBRN National Action Plans (NAPs), developing new project proposals and organising tabletop and real-time live exercises based on agreed scenarios. Several CBRN real-life simulation exercises and scenario-based tabletop discussions have been conducted or are under planning: Falcon Vision (February 2016), Sunkar (June 2017), Lionshield (2018) and Falcon II (2019).

2.3 Coordination with International and National Institutions and Initiatives

Structured CBRN risk mitigation cooperation is ongoing with relevant international organisations, such as the IAEA, Interpol, the International Science and Technology Centre (ISTC), the Science and Technology Centre (STCU), the Organisation for Security and Cooperation in Europe (OSCE), the World Health Organization (WHO), the World Customs Organisation (WCO), the Organisation for the Prohibition of Chemical Weapons (OPCW) and other fora such as the UN 1540 Committee, the Global Health Security Initiative (GHSI) and the Association of South-East Asian Nations (ASEAN) Regional Forum (ARF), as examples.

In the context of the UN 2017 General Assembly, the CBRN Group of Friends led by Georgia, Morocco and the Philippines proposed a resolution acknowledging the role of EU CBRN CoE NAPs in the implementation of UNSCR 1540 resolution; during the G7 Global Partnership Against the Spread of Weapons and Materials of Mass Destruction, the crucial contribution of the CoE NAPs was acknowledged.

The EU supports the implementation of the BWC with specific financial resources, but the link with the EU CBRN CoE was strong since the beginning. There is complementarity and synergy potential between the BWC implementation and the NAP implementation and EU CBRN CoE partner countries' visibility and support in BWC capacity building projects.

The OPCW recognises the high added value of the EU CBRN CoE, and especially of the NFP, NT and NAPs, to the organisation's goals and has reaffirmed that OPCW is ready to work with and for the EU CBRN CoE in a mutually beneficial fashion. In particular, if countries are able to identify common needs and gaps on a regional level through the NAQ, the OPCW stands ready to support them through training, capacity building and funding, especially in the field of response to chemical incidents.

With the IAEA, and through the liaison of the JRC, there is regular exchange of non-sensitive information regarding the status of the implementation of the EU CBRN CoE and the nuclear security support centres of the IAEA.

There is proven collaboration with Interpol on matters such as illicit trafficking, identification of traffickers and tracing of materials in SEEE region, under the CoE.

3 Sustainability and Future Perspectives

The EU CBRN CoE initiative increases partner countries and EU citizens' protection against events that may have large and severe transnational consequences. The Centres of Excellence promote development and emphasise multilateral cooperation; ultimately, the Centres of Excellence enhance peace, security and prosperity. More specifically, partner countries benefit from the activities of the EU CBRN CoE to develop sustainable national and regional capacities and resources which will remain after the EU investment is completed. Examples of such advantages include:

– Reinforcement of National CBRN policies: the development or improvement of National CBRN policy enables countries, with the support of the EU CBRN Centres of Excellence, to better respond to their needs in the area of CBRN risk mitigation and to enhance their institutional capacity.
– Maximisation of existing capacities in the region by linking them together. Cooperation between all national authorities and among partner countries increases common knowledge and best practices transfer, avoiding duplication of efforts.
– Enhancement of coordination and integration through the establishment of NT, tasked to assess needs and support national strategies in the area of CBRN risk mitigation. The NT consists of experts from all relevant national bodies and thus promotes mutual coordination and integration of national and regional strategy.
– Membership of an international network of CBRN experts: the EU CBRN CoE includes a network of highly qualified experts in the CBRN fields. Experts come from all participating countries, regional and international organisations as well as EU member states.
– Needs addressed through specific projects: based on needs assessment at national and regional levels, specific projects are developed and implemented in close coordination with other international initiatives. Partner countries benefit from tools/resources such as an e-learning platform, training and expertise, guidelines, procedures and equipment.

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1 Introduction

Readers will be familiar with insurance in which a policyholder pays a sum of money (a premium) to an insurer in order to be compensated should the policyholder suffer specified losses. CBRNE terrorism insurance is not available for households in the UK but is provided for businesses to ensure their confidence to invest. Large losses associated with, for example, extreme weather events, earthquakes and terrorism have spurred the development of reinsurance [1], which may be thought of as insurance for the insurer. In Sect. 2 we further describe reinsurance and how the pool system for terrorism reinsurance was developed in the UK following the 1993 Bishopsgate bombing, leading to the formation of Pool Re [2]. Pool Re is now funding the development of the interdisciplinary Cranfield University Counterterrorism Centre of Excellence as described in Sect. 3. Preliminary work on blast loading from explosive events is presented in Sects. 4 and 5 outlines how such loading will be used in insurance loss estimation.

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2 Reinsurance and Terrorism Reinsurance

An insurer seeks a reinsurer in order to share the risk associated with a policy or set of policies when potential losses would bankrupt, or severely deplete the reserves of, the insurer. For a premium, the reinsurer contracts to cover losses on the primary insurer's policy that are in excess of a lower limit (the retention) and up to a specified loss limit [1]. Reinsurance is available in the UK for many risks, but we consider the building and business continuity risks associated with large-scale terror attacks.

2.1 Pool Re: Pool Reinsurance for UK Terrorism

Following the 1993 Bishopsgate bombing, which resulted in 1 dead, 44 injured and £0.35 billion (bn) in damage, reinsurers stopped providing terrorism cover causing businesses to question their future viability in the UK. The UK government intervened and set up a pool system named Pool Re [2] to own the risk from large terrorism losses.

The Pool Re scheme provides reinsurance for terrorism losses beyond a market retention limit. Initially, only cover for explosive and fire risk was provided. CBRN cover was added in 2003, and presently provision of cyberterrorism cover is being considered. Following Pool Re's success, ten or more similar schemes have been created worldwide [3].

The members (insurers) of the Pool Re scheme cede premium to Pool Re in respect of the cover they provide. As of December 2016, these premiums have accrued to give Pool Re funds of £6.3 bn. The market retention limit for members is £0.15 bn. Losses beyond this are successively covered by the following:

1. £0.5 bn of Pool Re funds
2. £2 bn from international reinsurers (known as *retrocessional reinsurance*), negotiated by Guy Carpenter on behalf of Pool Re
3. A further £5.8 bn of Pool Re funds

This amounts to £8.45 bn of scheme resilience. Annually Pool Re pays premium to UK's Her Majesty's Treasury, which is recallable should losses exceed Pool Re's funds. If losses exhaust its reserves, Pool Re would draw further funds from the UK government to meet its obligations.

Pool Re is seeking ways to reduce and mitigate terrorism risk: events are held to inform reinsurers of changes in risk; research is funded at Cambridge Judge Business School on cybersecurity and at Cranfield University on CBRNE models (e.g. see Sect. 4); and Pool Re and Cranfield University are creating a Counterterrorism Centre of Excellence as now described.

3 Cranfield University Counterterrorism Centre of Excellence

Cranfield University is a wholly postgraduate university, providing world-leading expertise in the security and defence sector to industry, security services, military and governments around the world. Its counterterrorism capabilities include surveillance and intelligence, forensics, CBRNE, counterterrorism studies, leadership and management, explosives, ballistics, cybersecurity and national infrastructure protection.

Under Pool Re funding, Cranfield will develop an interdisciplinary Counterterrorism Centre of Excellence to provide thought leadership for catastrophic and unconventional terrorism loss assessment and to improve UK economic resilience to terrorist action. By combining Cranfield's facilities and the capabilities of current staff with new appointments and external collaboration, the centre will provide sufficient critical mass to allow enhanced research, education, skills and understanding in the UK counterterrorism stakeholder community.

The aims of the Centre of Excellence are:

- Encourage, co-ordinate, procure and conduct academic research to aid in understanding the risk of UK terrorism and propose resilience measures.
- In conjunction with Pool Re, provide an appropriate forum for improved dialogue between the UK government, the insurance industry and other stakeholders.
- Conduct research into current and future terrorist attack vectors and methods, and assess relevance to the insurance industry
- Agree common terms of reference, and improve understanding between industry sectors to aid more consistent assessment of the threats and risks.
- Collate and share data to allow for more realistic modelling. Employ this data to develop a common perception of risk between key stakeholders.
- Publish a code of conduct for use by vendors, providing advice to the insurance industry, and manage a register of experts.
- Propose insurance industry mechanisms to encourage behaviours likely to reduce the probability and consequences of a terrorist event in the UK.
- Commission independent and joint government research on pre- and post-loss mechanisms that mitigate the effect of an act of terrorism.
- Work with international academic and governmental institutions on joint initiatives to improve the understanding and evolution of the terrorist.
- Act as a conduit for information on the terrorism threat and mitigating strategies from the UK government.

The Centre will be led by the newly appointed Professor of Counterterrorism from the end of January 2018. The Professor will, amongst other things:

- Forge a research programme, aligned with Pool Re's and Cranfield's research strategy leading to high-quality, academic publications.
- Lead bids for research funding to various bodies, not just Pool Re.

- Lead the development and delivery of education in resilience and counterterrorism including professional development and masters courses.

Preliminary work on both CBRN and explosive blast loss (see Sect. 4) has been performed from late 2016 through 2017.

4 Damage and Loss Assessment for Explosive Events

Present insurance sector blast damage estimation tools simplify explosive blast physics and either ignore the effects of buildings on the blast wave or assume a straight path for the blast wave, limiting damage to buildings with a line of sight to the charge location [4]. Such approaches have doubtful validity in built-up areas due to blast waves being channelled along streets, reflected off buildings and diffracted around corners [5].

In Sect. 4.1 we describe our approach to the estimation of blast loads on city centre buildings, and in Sect. 4.2 we present some preliminary results.

4.1 Methodology

We employ our computational fluid dynamics tool, ProSAir [6], which simulates the effects of the detonation of a high explosive charge, using a high-resolution, finite volume scheme. The geometry is provided as a geometric *shapefile* [7] augmented with building height. The shapefile data type describes the buildings' components as vertically extruded polygons, as shown in the example of Fig. 1. A preprocessor was

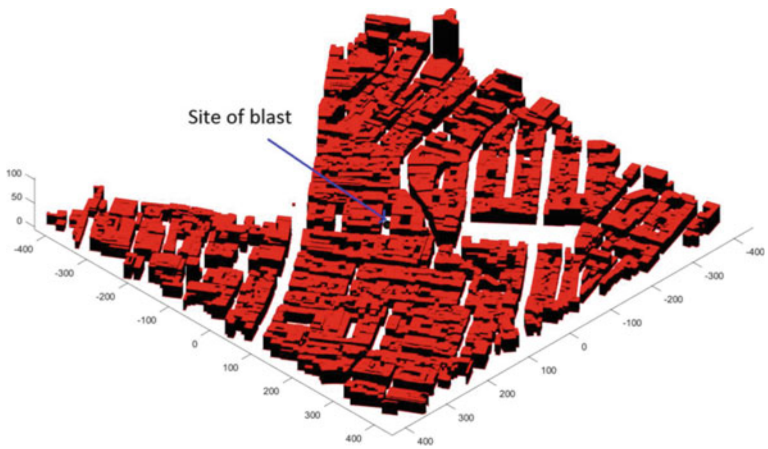

Fig. 1 Shapefile description of a complex city area with 3675 shapes over 800 m × 800 m

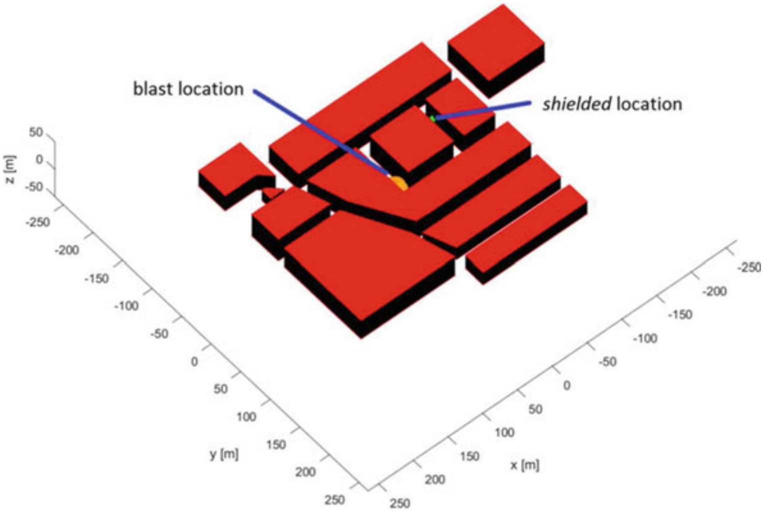

Fig. 2 Configuration of generic city centre location. The shielded location is not visible from the blast location and would be assumed to be unaffected by the blast according to direct line of sight

written using MATLAB's Mapping Toolbox [8] to convert the shapefile to ProSAir input.

ProSAir was used to simulate the blast waves arising from the detonation of the explosive charge. For commercial reasons, we are unable to share the results for the scenario of Fig. 1. However we have developed a generic city centre configuration to demonstrate the challenges associated with such work. The generic configuration is shown in Fig. 2. The blast was taken to be from 10 tonnes of TNT detonated 2 m above the ground.

4.2 *Preliminary Results*

A simulation of the generic scenario was run using a cell size of 1.5 m and a domain of 500 m × 500 m × 100 m, centred on the blast. Data collection points were evenly spaced across the ground of the domain; on buildings, they were spaced with at least one every 5 m and one per building surface. The simulated overpressure at various times after the blast is shown in Fig. 3 and clearly shows that, due to shock diffraction around street corners and over buildings, the blast wave impacts areas without a line of sight from the blast location.

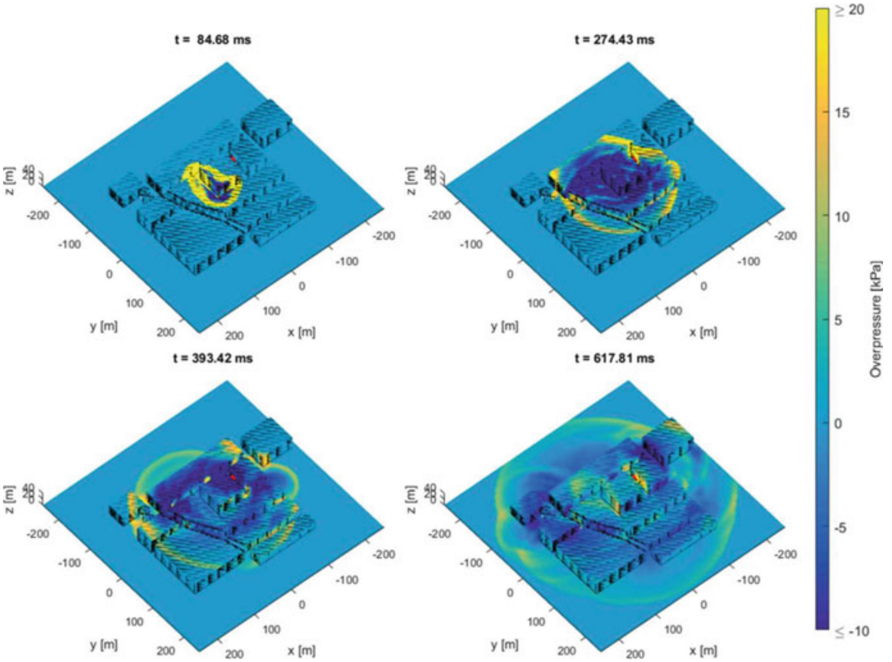

Fig. 3 Overpressure at various times after blast for generic city centre configuration. Note the data exceeds the −10 to +20 range of the scale. The location shown in Fig. 2 (shown in red here) experiences significant pressure loads despite being *hidden* from the blast site

5 Conclusions and Further Work

As described in Sect. 2, reinsurance allows the insurance risk arising from CBRNE terrorism to be spread between insurers and reinsurers; pool reinsurance enables private sector insurance for catastrophically large events. The remit and financial structuring of the world's first terrorist loss reinsurer Pool Re was given in Sect. 2.1.

Pool Re is now commissioning research to aid understanding of UK terrorism risk and suggested resilience measures. It is facilitating the formation of the interdisciplinary Cranfield University Counterterrorism Centre of Excellence led by the Professor of Resilience and Counterterrorism. The centre will facilitate research, education, skill development and understanding within the UK's counterterrorism community, as described in Sect. 3.

In Sect. 4, and as an example of the future work typical of the centre, we have demonstrated the feasibility of simulating terrorist bombings in complex city centres to estimate blast loading on buildings. Such simulations highlight the need to model shock diffraction and reflection to get accurate estimates of blast loading and building damage. Collaborators at Guy Carpenter Ltd are using the simulated blast loads within the FACEDAP [9, 10] building damage methodology to provide insurance loss estimates, which will be validated against historic data. Such estimates will then be used to stress-test Pool Re's reinsurance structure.

We are presently working to further improve the accuracy and efficiency of the ProSAir solver. This will allow us to model the effects of uncertainty in the blast site location, charge size, atmospheric conditions, etc. At present, our modelling assumes buildings are perfectly rigid and do not fail. In the future, we wish to study how building failure close to the blast centre affects blast loading on more distant buildings.

As a result of increasing our understanding of these features of the blast loading, we will be well-placed to develop improved physics-based estimates of terrorism reinsurance losses to more accurately price premiums and guide premium reductions for resilience measures, e.g. blast-resistant glazing.

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Crisis Managers' Workload Assessment During a Simulated Crisis Situation

Clément Judek, Frédéric Verhaegen, Joan Belo, and Thierry Verdel

1 Introduction

Crisis situations are recognized to be complex situations [1] to handle by an organisation. In addition to its complex nature, there is a critical requirement for crisis managers to efficiently cope with the situation in order to recover and retrieve normal operating condition [2]. For an unprepared organization, the management of certain incidents can lead to a crisis-like reaction of managers. The term crisis may then be used to define the situation.

Characteristics of crisis situation as well as characteristics of the managers' reaction who cope with it influence psychological characteristics (e.g., mental load) and consequently the effectiveness. The concept of mental workload is defined as the difference between an individual's available cognitive resources and a cognitive task demand [3]. The collective workload is defined as an index of the ratio of the team available resource regarding cognitive task demands [4]. Research often highlighted that a high level of workload has negative effects [5]. Thus, to better our understanding, there is an issue in assessing how does the individual and collective perceived workload behave during the steering process of a crisis situation at a strategic level.

Simulations mimic a real-world process or system over time [6]. Crisis simulation is therefore a solution to recreate a crisis situation as accurately as possible allowing participants to cope with a virtual but realistic crisis situation.

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2 Material

2.1 Presentation of iCrisis Simulation Approach

iCrisis [7] is an organisational and technical system developed from crisis simulation experimentations that have been carried out with students and professionals since 2003. As a system enabling message exchange, iCrisis is a web application that supports the conduction of full-scale virtual simulations. The information that is transferred though the web application remains virtual, but each participant in the simulation is a real person playing under conditions that are supposed to resemble crisis-like. Therefore, the objective of an iCrisis simulation is to allow managers at a strategic level experience the characteristics of the crisis.

The iCrisis approach is being scientifically validated as an approach that recreates the characteristics of the crisis situation as well as of the reaction it provokes among crisis managers (see Table 1).

An iCrisis simulation implicates one to several physically kept-apart crisis units (see Fig. 1), an animation team and a media office. As an example, the crisis units generally consist of a Regional Command Post, a Municipality Command Post, and a Company Command Post, which are connected by the Internet, messaging through the iCrisis app. However, any configuration at a strategic level can be applied. Groups can exchange messages (see full line arrows in Fig. 1); the animation team can exchange messages with all groups and also receives copies of all messages exchanged (see dashed arrows in Fig. 1) through the iCrisis application, to know exactly what is occurring for the participants. Journalists take part as free agents and can come by the different crisis units to collect information. Their role is essential since their interactions with the participants and their interpretation of the material they gather can originate disturbances. These interconnections and the presence of observers (see solid blue arrows in Fig. 1) enable the animation team to adjust the storyline based on the participants' reactions.

The simulations carried out with iCrisis run an open scenario; that is, only the context of the scenario remains set. The story of the scenario is willingly left flexible in order to be congruent with the behaviour of the participants, which is not predictable. A debriefing that lasts for approximately 2 hours comes after each simulation. During

Table 1 Characteristics of the crisis identified based on literature review

Crisis situation	Reaction to a crisis
Chaos	Astonishment
Unexpectedness	Time pressure
Important consequences	Anxiety
Uncertainty	Changes in relationship
Evolving nature of the problem	Relative nature of the crisis
Irregular rhythm	
Numerous stakeholders	
Information management issues	
Media involvement	

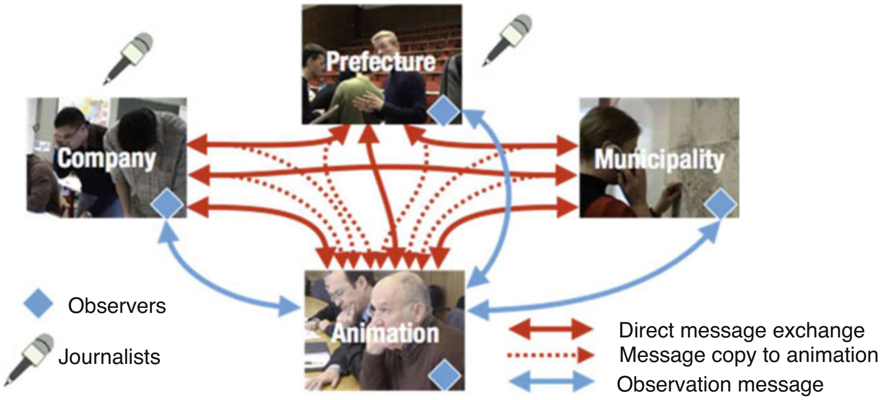

Fig. 1 iCrisis simulation general overview of the organization

the debriefing, participants from each crisis unit relate their experiences which gives to the facilitators the opportunity to talk about the pitfalls that can be encountered in dealing with the crisis situation and increase participants' awareness.

2.2 Individual and Collective Mental Load Assessment

The Nasa Task Load Index, developed in 1988 [8], is a short questionnaire that subjectively measures the individual workload (IWL). This tool has been widely used in a large variety of domain such as aviation or surgery for examples [9]. Participants have to score on a scale from 0 to 100 their perceived feeling regarding six items. The admitted assumption is that the combination of these dimensions is apt to correspond to the workload perceived by individuals [8]. A limitation of the NASA-TLX is its interpretation since no threshold values exist regarding the scores. Nevertheless, it can still be a relevant tool to use to make comparison.

The Team Workload Questionnaire (TWLQ), developed in 2014 [4], is a tool that allows measuring the collective workload (CWL). It has been designed based on the six-dimensional structure of the NASA-TLX. As well as for the NASA-TLX, the mean of the six-dimensional scores gives the collective mental load score. The fact that both tools propose a scale on the same scale is interesting to make comparisons afterwards.

3 Method

Seventy-five (42 women, 33 men) students from the "Institut Régional d'Administration de Metz" participated in the study by being involved in an iCrisis simulation. This simulation was part of their training class. Their average age was

31.7 (SD = 8.2) years, with age ranging from 23 to 55 years. Divided into six crisis units, representing department prefectures (regional level), the participants have managed, during a 3-hours simulation, a winter storm striking Northeastern France. The crisis simulation was carried out following the iCrisis approach in order to recreate as accurately as possible the characteristics of the crisis. A control group has also been surveyed; there were 27 students of the "Ecole des Mines de Nancy" (7 women, 20 men) with age ranging from 20 to 34 years old ($M = 22.3$; SD = 2.7). It has been decided to select different people to control because we have observed that the context of the simulation influenced the psychology of the group of participants, even before starting.

The individual workload of participants has been investigated *off* the context of crisis with the control group of students in the framework of regular training class and then *in* the context of crisis during the simulation with the group of participants (± 2 hours after the start of the simulation). Regarding the collective mental load, it has only been investigated *in* the context of crisis during the simulation (± 2 hours after the start of the simulation). It was only relevant to assess the collective workload individually while they were performing a group task. The filled questionnaires have been gathered and processed one by one to calculate the scores.

4 Results and Discussion

Heat maps show a data matrix where colouring gives an overview of the numeric differences and the sorting relies on correlation calculations. This statistical tool was used to identify groups of individuals. Indeed, since the crisis is relative to anyone, individuals do not experience the situation by sharing the same feelings.

The IWL heat map (see Fig. 2) shows that the population can be divided into three groups regarding the perception of the IWL with groups 1 and 2 ($n = 52$) scoring around 50 and more (respectively, $M = 47.2$ and $M = 63.6$). However, individuals of group 3 ($n = 23$) perceived a low IWL ($M = 26.9$).

Within group 3, scores for "Frustration" are for some individuals very high (>80) although the other items have been scored very low reflecting the fact that these individuals did not accept the crisis nature of the situation which is by definition unmanageable, and it resulted in making them perceive a high frustration. Still within group 3, another subgroup can be defined due to very low scores (<20) except for performance for which scores increased (>60). This fact is interesting because it means that, for these individuals, they found the situation as being a manageable situation since they perceived their performance as being good. Eventually, within group 3, a third subgroup can be identified as a group of individuals that perceived very low IWL (<20). This last subgroup is an illustration of the fact that in crisis units, some people give up.

Regarding the items of IWL, they indicate that both items "Effort" ($M = 45.7$) and "Mental Demand" ($M = 54$) are correlated (Pearson product-moment correlation, $r = 0.8$), and what is more they are the most important items perceived during a

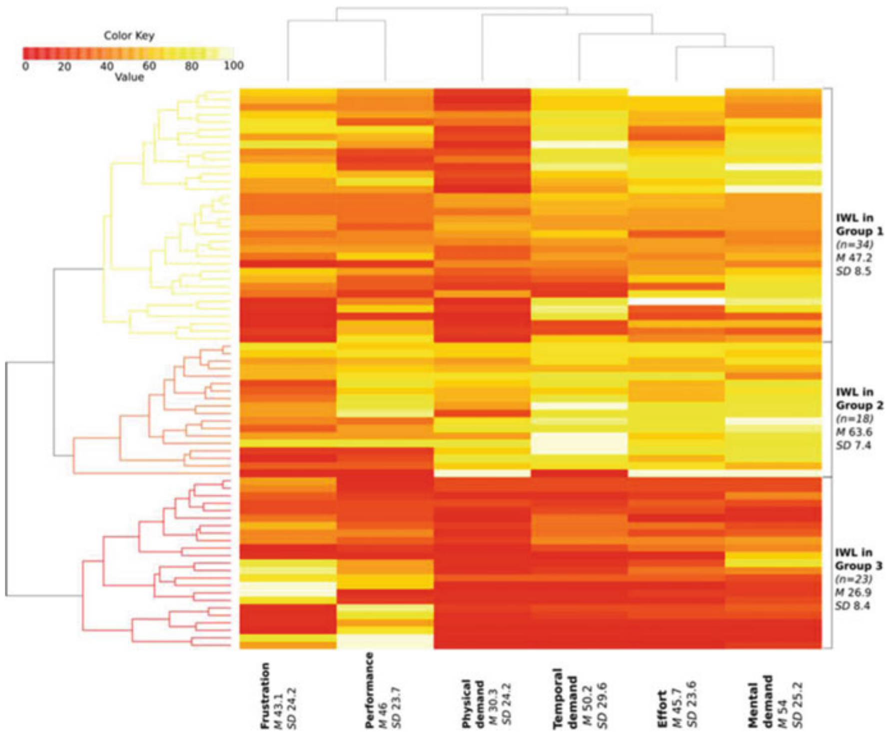

Fig. 2 Heat map of IWL (individual workload) in context of crisis

crisis situation. The high scores as well as the correlation between them show that, during the crisis situation, the mental demand is such that the perception of making an effort is important for individuals.

Off context of crisis, the obtained results ($M = 26.2$; $SD = 15.2$) show that the IML is lower in comparison with *in* context (p-value <0.001) highlighting the fact that the crisis situation asks for more psychological resources. When going into the details of each item (see Fig. 3), this difference is clear for most of them; only the performance is perceived to be psychologically demanding as well in both contexts (p-value >0.5).

The CWL representation of the scores (see Fig. 4) highlights that a majority of individuals (groups 4, 5, and 6; $n = 66$) perceived a strong CWL (≥ 50) in the context of crisis, whereas the members of group 7 ($n = 9$) perceived a low CWL ($M = 25.3$). The six items of the CWL are divided into two classes regarding their mean scores. Actually, "Coordination" ($M = 63$) and "Communication" ($M = 67.9$) are considered as very high compared to "Team emotion demand" ($M = 41.7$), "Team support" ($M = 45.1$), "Team performance monitoring demand" ($M = 47.3$), and "Time share demand" ($M = 52.8$). This reveals that in crisis situation, coordination and communication aspects are found by the members of the groups to be an issue that affects considerably their collective workload. With regard to group 7, in addition to the fact

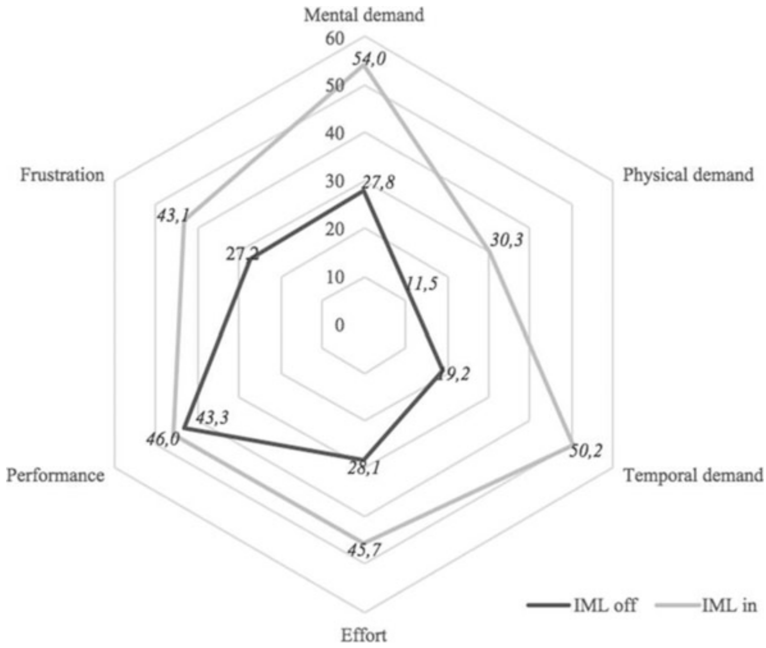

Fig. 3 Individual mental load in and off context of crisis

that the scores are very low, no differences can be observed between items highlighting a low involvement.

In the context of crisis (see Table 2), CWL is higher than IWL (p-value <0.001) showing that collective effort is perceived to be more important than individual. Whether groups given by CWL heat map distribution (see Fig. 4) are considered, this increase is put into evidence (p-value <0.05) for groups 4 and 5, whereas for group 6, this increase is not significant. In opposition, members of group 7 perceived an as low CWL as IWL. For groups given by IWL heat map distribution (see Fig. 2), groups 1 and 3 show a higher CWL, whereas for group 2, the scores for both parameters are high and almost of the same intensity. Beyond the fact that most of the results show high scores, analysing the CWL of group 3 and group 7 allows to distinguish them even though their IWL scores are very low (<30). Indeed, while group 7 scores indicate a low IWL and a low CWL, members of group 3 perceived a low IWL, whereas their perception of CWL was higher.

Observations made emphasize that the perception of the CWL is superior to the perception of the IWL except two cases:

– When IWL is very high, then the CWL is very high (group 2) showing that the task demand on individuals is too important to perceive a "group effect."
– When both IWL and CWL perception are very low (group 7) showing a lack of involvement of the individuals.

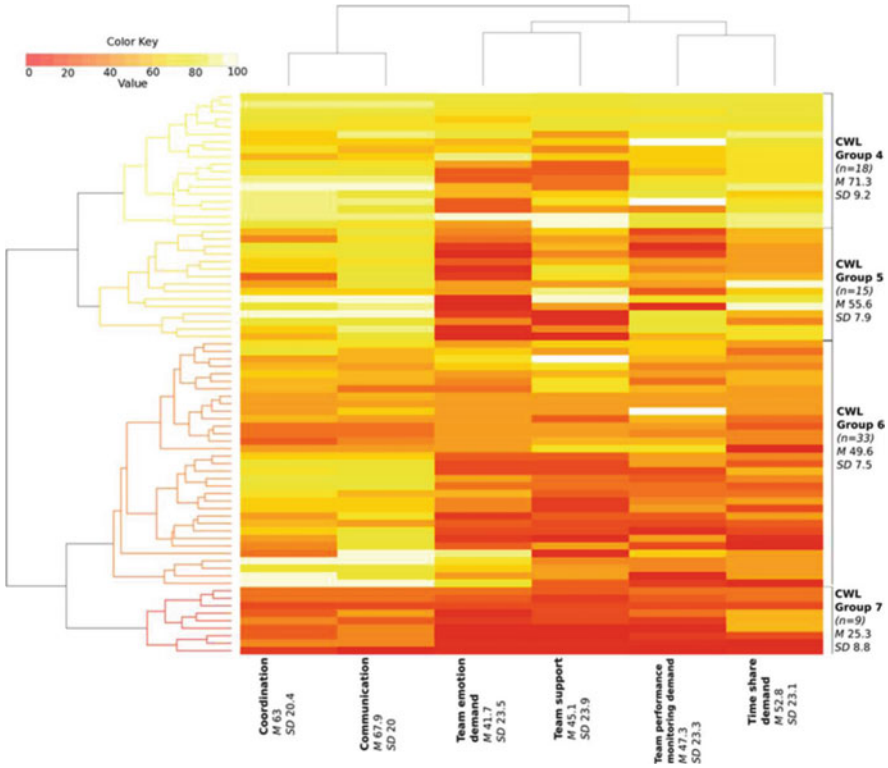

Fig. 4 Heat map of CWL (collective workload) in context of crisis

Table 2 Comparison between CWL and IWL in context of crisis based on statistical groups

		Gr. 1	Gr. 2	Gr. 3	Gr. 4	Gr. 5	Gr. 6	Gr. 7
IWL	M	47.2	63.6	26.9	55.9	47.8	48.8	29.7
	SD	8.6	7.4	8.4	15.6	13.3	15	11.2
CWL	M	54.5	62.8	43.4	71.3	55.7	49.6	25.3
	SD	11.2	13.9	17.6	9.2	7.9	7.4	8.8

5 Conclusion and Perspective

This study emphasizes that the crisis situation and the perception during a crisis influence the cognitive performances of the persons as individuals or as members of a group. More precisely, we highlighted differences between groups of individuals which therefore indicate that feelings are relative to anyone due to experience and involvement, for instance.

We emphasized that the CWL is higher than the IWL. This finding should be studied further more into details because of the multifactorial nature of both tests as well as the fact that they do not consider the same items. However, this comparison brings insight on the fact that crises are steered out by crisis units which are groups. Thus, studying the psychological parameters at the scale of the group becomes relevant since until now, the individual dimension has been privileged.

Beyond the fact that we observed that the IWL is higher *in* context of crisis, this study allowed to emphasize that during a crisis situation, some workload items were more important than the others. Regarding the IWL, the most perceived items are Temporal demand, Effort and Mental demand during a crisis situation. It has been highlighted that there is a correlation between the Effort produced by an individual and the perception of the Mental demand. For groups of individuals perceiving very low IWL, the focus on both items, Frustration and Performance, allowed to put into evidence that some individuals could find the situation easy to deal with, by scoring a level of Performance, or unmanageable by perceiving a high level of Frustration. Regarding the CWL, it was shown as an evidence that Coordination and Communication were items that participants perceived as the most important *in* context of crisis situation.

Highlighting the fact that individuals do not behave equally and the fact that some parameters are more important than others while coping with a crisis situation is an interesting result for professionals. This type of findings aims to aware the professionals to the issues that can be encountered while managing at a strategic level a crisis situation.

As a perspective, the use of specific tools that assess more precisely the items could be used to carry out more detailed studies like on performance or anxiety. Moreover, the analysis of the workload enables us to make a study (under conduction) on the relation between workload, anxiety, and performance during a crisis situation.

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Increasing Forensic Awareness of CBRNE Responders and CBRNE Awareness of Forensic Experts: A Pan-European Challenge

Bart Nys, Natalie Kummer, Peter de Bruyn, and Jan Blok

1 Introduction

In recent years, the possibility that forensic experts will be confronted with CBRNE-type hazards in the field has increased. Increasing terrorist activities in Europe's cities mean that the risk of encountering a CBRNE-related crime scene has increased. Likewise, the work in and around an ever larger number of clandestine drug labs is a safety concern for first responders who are often badly trained in the handling of these still-active chemical production facilities. At the Belgian NICC, as in many other forensic institutes, experts from the drug lab have teamed up with first responder units of the police and fire brigades to train for these eventualities and face these situations together.

A general forensic dimension in the approach towards such CBRNE situations is, however, lacking in many countries' emergency response procedures for CBRNE incidents. This is in large part due to the fact that in many nations, the CBRNE threat response lies in the realm of the security and military forces. Unfortunately, they generally have no experience in handling the specific forensic requirements of crime scene situations. As a result, although forensically interesting contaminated items may be packed and their CBRN contamination characterized, they are usually not submitted for decontamination and forensic analysis. The police and the justice

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system are therefore bereft of the necessary skills to effectively and efficiently pursue those responsible for the attacks or incidents. Fortunately, the use of CBRN materials in civil crime has until now been limited. However, events in war zones in Syria and elsewhere have shown that the CBRNE threat is very real. Dangerous materials and knowledge of their use are probably already available to terrorists who have demonstrated their willingness and ability to strike in innovative ways, including in the heart of European cities. Only time will tell if CBRN attacks will eventually be attempted.

Recently, a number of research projects have come up with a possible solution for police and forensic experts that will allow them to address these hazardous situations. The *Generic Integrated Forensic Toolbox* for CBRN incidents (GIFT-CBRN) project[1] proposes a number of solutions that can enable forensic analysis of contaminated items, at the crime scene, in specific CBRN facilities hosting forensic investigation capabilities and in specialized CBRN-capable forensic institutes to be undertaken.

The need for continued education and training of forensic experts—both working at the crime scene and in the forensics lab—is also recognized by the *European Network of Forensic Science Institutes* (ENFSI), a network of European forensics labs working together to set the standard for forensic science and so assist the police and judiciary with the prosecution of criminals. ENFSI is engaging in the development of a training and education initiative for all forensic officers involved in dealing with CBRNE situations. ENFSI does this together with other specialized institutes within the field of CBRNE. A first noticeable deliverable of this initiative was the organization of a conference dedicated to the CBRNE-Forensic Awareness Issue, co-organized by the GIFT project and the R&D Standing Committee of ENFSI in Brussels in October 2017.

2 The Forensic Dimension of CBRNE Incidents

When dealing with CBRNE incidents, most attention is paid to the evacuation of the victims, the treatment of the wounded and the safety of the surroundings. Hence, the scene is, in the first instance, dominated by 'blue light' first responders and officers of the civil protection and possibly military services. When dealing with real criminal or terrorist CBRNE incidents, however, the police and forensic CSI technicians will also need to enter the scene in order to document the situation and secure the items that are of interest to the forensic and police investigation. Indeed if, for example, a cell phone could be recovered from the scene, it might be possible to extract vital information stored on the device that may lead to the identity of the culprits and possibly prevent future attacks. Examining the forensic DNA and fingerprint clues on the device may also be of vital importance in the police

[1]The GIFT project is sponsored by the EU FP7 programme under grant agreement number 608100.

investigation. The use of standard forensic procedures for these investigations is, however, almost impossible due to possible hazardous contamination issues.

Similar factors enter into play in a typical police raid on an illicit drug production lab. These installations—although often abandoned by the time police arrive—may still be operating and therefore pose a grave threat of explosion and/or chemical contamination to bystanders. Specialized forensic personnel assist in these cases to quickly determine the type of chemicals present and the processes that are still running in the lab in order to reliably estimate the risks and defuse the hazardous situation. Furthermore, forensic investigations are to be undertaken in response to the specific judicial demands. For example, the determination of the type and quantity of illicit drugs manufactured, as well as the identification of possible suspects involved in running the lab.

Finally, it should be noted that the classification of a crime scene as a CBRNE incident is also an issue of scale. Indeed, while a domestic arson case will be treated in a routine way by forensic specialists, an industrial fire or large chemical spill at a large sea port, a chemical plant or a nuclear installation may pose problems that require the same type of response as a CBRNE incident.

All these examples illustrate that, although CBRNE may not form an issue in the daily routine and training of a forensic scientist, nor are forensic requirements the first priority of a CBRNE specialist, there are circumstances where there is a great need for both of these specialists to be aware of each other's needs and capabilities in order to be able to optimally respond to the call at hand.

3 The GIFT-CBRN Project

To assist the forensic specialists in their mission of handling and analysing contaminated items of evidence, the GIFT-CBRN project was developed in 2014. The GIFT-CBRN project was an EC-sponsored FP7 project that united 21 international partners in the development of solutions to forensic problems that are experienced both at the crime scene and in the lab environment.

Forensic problems at the crime scene itself comprise of:

- Recognizing threats and risks arising from the fact that forensically interesting items were contaminated by CBRN materials
- Recovering items from a crime scene in a judicially correct way, without compromising the safety of the personnel at the crime scene or in the forensics lab
- Decontaminating items in such a way that renders them safe to handle, while at the same time preserving the forensic traces for subsequent analysis

The deliverables of the GIFT project in this context will be briefly described. For further detailed information, we refer readers to the GIFT project's own dissemination channels [1].

3.1 Detecting Contaminated Items in the Hot Zone

Developments were made in the means to detect chemical weapon components on the surfaces of objects, the presence of chemical and radiological contaminants in the atmosphere and liquids using portable equipment for imaging gamma and alfa radiation emitted by objects in the hot zone.

Furthermore, a number of procedures were developed for use in a conventional forensics lab, as well as inside a *forensic glovebox* (a sealed workbench in which a contaminated item may be placed for forensic investigation).

3.2 Recovery of Contaminated Items

The recovery of items from the hot zone not only means that the items need to be packaged, transported and stored in a safe way but also that the seizure of these objects needs to be performed by qualified personnel, i.e. police personnel. The seizure needs to be properly documented from the start in order to ensure a lawful transfer of the items from one person or service to the next. This documentation is commonly referred to as the *chain of custody* (CoC) and is of vital importance in ensuring that the evidence will later be admissible in court.

An indispensable ICT tool to document the CoC—the *Toolbox*—was developed within the GIFT project. The Toolbox is a networked computer knowledge base, linking actors at the crime scene with forensic scientists in the labs. The Toolbox software furthermore not only contains knowledge pertaining to historic CBRNE incidents, forensic procedures, contact information of experts and specialized facilities but also the measurement data on the items recovered from the crime scene.

3.3 Decontamination of Items

One of the possible pathways to the analysis of items from a CBRN crime scene is to decontaminate them in a way that preserves the forensic traces. The forensic analysis can then be performed in a conventional forensics laboratory using standard forensic procedures. During the GIFT project, a number of procedures were developed to decontaminate items from C, B and RN incidents without disturbing the following important forensic traces:

- Fingerprints
- Human DNA traces
- Digital information stored on electronic devices such as cell phones

3.4 Investigation of Items in a Forensic Glove Box

Apart from the analysis of decontaminated items in a conventional lab facility, it may be necessary to perform a forensic examination of the seized objects while they are still (partially) contaminated. This means that this analysis needs to be carried out in specialized facilities, often while items are contained within so-called ‘glove box’ workbenches. For this kind of situation, a number of procedures have also been developed within the GIFT project.

4 The European Network of Forensic Science Institutes

The European Network of Forensic Science Institutes was established in 1994 by the directors of a small group of forensics labs, who recognized the need to exchange experiences about managing their service facilities in order to set a high-quality standard for forensic investigations within Europe. From these humble beginnings, a network of partners has grown which now comprises more than 70 labs, spread out over more than 30 European countries [2]. The network is active in many forensic domains, covering most fields of forensic science. Seventeen technical working groups of experts meet on a regular basis to discuss problems of a technical, managerial, educational or quality assurance nature and to collaborate in scientific projects. A total of more than 1000 forensic experts are active in this network, thus comprising the vast majority of scientists working in the forensic field in Europe. Furthermore, a Quality and Competence Committee (QCC) and a Research and Development Standing Committee (RDSC) assure the quality of the expertise delivered and ensure that the knowledge and experience of the experts are maintained at a high level.

The focus of the RDSC’s involvement in the forensic CBRNE arena lies in the context of new developments and in the training and education of experts. As forensic experts and CBRNE specialists are not very well informed about the current possibilities and requirements of each other’s work, their collaboration during a potential CBRNE incident is less than optimal. Moreover, in most cases, the national CBRNE emergency procedures currently do not take the forensic requirements into account. This makes it necessary to build awareness among both groups of specialists and adapt these procedures as soon as possible.

5 Building Forensic Awareness After CBRN Incidents

As a first step, a seminar, tailored to promote awareness of each other’s needs and possibilities, was organized. This *One Day One Topic Seminar* took place following the final conference of the GIFT-CBRN project, as an integral part of its dissemination activities. During the conference, presentations were given by forensic and CBRN specialists from the aforementioned partners. A number of GIFT deliverables were presented by the developing partners. Both this seminar and the GIFT conference were attended by over 100 international specialists coming from Europe, Asia and America.

In the immediate future, a number of the parties that are already active in the area of training CBRNE specialists and forensic experts will be contacted by ENFSI to extend their partnerships, either within the existing curricula or in the form of new EU projects. These initiatives will be developed together with the Standing Committees of ENFSI. Examples of such potential partners are the EU Joint Research Centre [3], the NATO SPS program [4], Hot Zone Solutions [5], ICI [6] and SCK•CEN [7]. Furthermore, a number of academic institutions already offer formal education programmes in the area of CBRN. Examples of existing CBRN specialist training courses can be found in the curricula of CEPOL [8], the University of Rome Tor Vergata [9] and Cranfield University [10].

6 Formalization of ENFSI Education and Training Solutions

In the mid- to long-term future, we envisage a well-established curriculum for mixed groups of CBRNE and forensics specialists, offering combined education and training from a consortium of international partners. Education and training will be adapted to the technical level and role of each actor in the context of a CBRN-Forensics investigation. In this respect, the GIFT project has already provided conceptual tools such as a 'criticality matrix' for training. This matrix describes the criticality of specific knowledge and skills that an actor, who assumes a specific role in the investigation, should master.

Although we are, at present, far from fully realizing this potential in expertise and awareness level, concrete work is firmly under way to develop the necessary infrastructure and professional networks, thus providing these important facilities for all European specialists that are active in the forensics and CBRNE fields.

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Community Awareness in Disaster and Emergency Settings: A Case Study of the United Arab Emirates

Ibrahim Almarzouqi

1 Introduction

The UAE is located in the southeastern region of the Arabian Peninsula in southwest Asia. Today the UAE is made up of seven emirates: Abu Dhabi (the capital), Dubai, Sharjah, Ajman, Umm al-Quwain, Ras al-Khaimah, and Fujairah. The UAE has a federal political system, which includes all of the emirate governments [1]. This study looks at emirates as a case study.

Some features:

– The UAE has a large coastline of some 1300 km.
– Approximately 85% of the population and over 90% of the infrastructure of the UAE are located within several meters of sea level in low-lying coastal areas.
– Since 1975, the population of the UAE has grown approximately tenfold. However, the main source of population growth has been non-national workers.
– The UAE is a federal political structure of seven emirates.

Aspinall [2], Dougherty [3], Ministry of Energy Report [1], El Raey [4].

This research focuses on three main areas. They are hazards, vulnerability, and disaster management in disaster risk reduction. The research is focused on the UAE as little has been done on the natural hazards in both the UAE and the wider Arab world.

2 Hazard Profile in the UAE

The natural and artificial hazards in UAE are resumed in Table 1.

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Table 1 Natural and artificial hazards in the UAE

Natural hazards	Artificial hazards
Seismic activity in the UAE	Transport
Flooding	Car accidents
Dust and sand storms (DSS)	Nuclear technology
Climate change	

3 Methodology

– *The aims and objectives of the study*. The main objectives of the study are to analyze hazards and vulnerability within the UAE and to identify measures to reduce the vulnerability of different groups of people.
– *The methodology and methods of information gathering*. Mixed-method approach was used to gather data on awareness and an overview of the UAE approach to disaster management such as key informant interviews, community members' interviews, and focus group. The study found that in general levels of awareness were low and that the UAE was more focused on building institutional capacity for disaster management as opposed to building community resilience.
– *Analysis of data*. It is evident that there is level of knowledge of hazards. Many of the interviewees recognized that new hazards and vulnerabilities had been introduced by the rapid development of the UAE, recently. One interview was clearly concerned about climate change. It is clear from studies that have been conducted that climate change provides a range of short- and long-term threats. It is a crucial element that the UAE government set the key factors of vulnerability. This process allows the authorities to implement adequate intervention such as prioritizing vulnerabilities based on their characteristics and level of exposure [5, 6]. Particularly the UAE has experienced a rapid change since its independence in all country domains.
– *Ethical consideration.* The researcher considered the ethical principles to conduct this sort of study as the following: informed consent, expected duration, interviewees' privacy, the confidentiality of data, and the considerations of religious matters. There also was no conflict of interest.

4 Pressure and Release PAR Model: UAE Case Study

"The PAR model provides an explanation of the relationship between processes that give rise to 'unsafe conditions' (e.g. exposure) and their intersection with some type of hazard event thus creating a form of social vulnerability. The focus is clearly on the dynamic pressures and underlying driving forces that give rise to vulnerability in the first place" (Weichselgartner [7]:89) (Fig. 1).

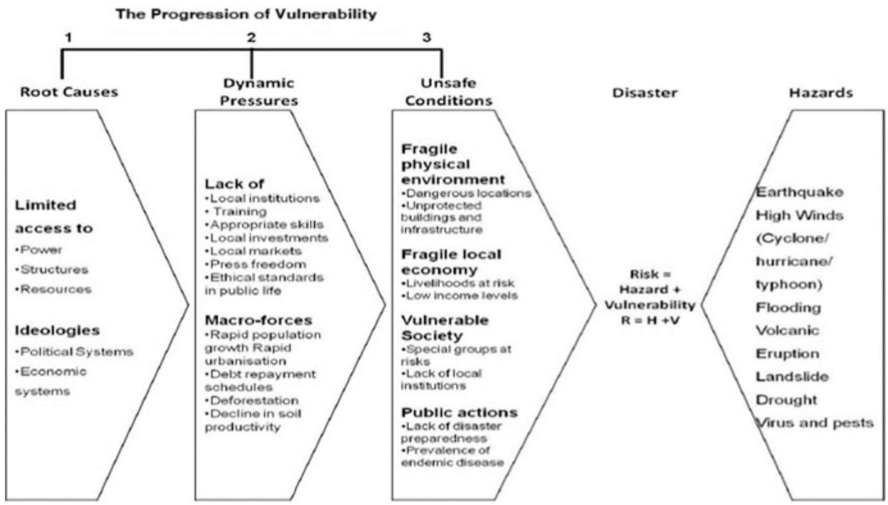

Fig. 1 Pressure and release model [5]

4.1 Social Factors

The UAE is a multinational country which comprises of various religions, perceptions, cultures, and traditions. Therefore, the level of exposure could increase due to these factors. As a result, the pressure will be higher on the responsible authorities to deal with this social variety especially that there is internal migration from rural to urban areas in the UAE and international migration particularly the labors [2, 8, 9]. Hence, it is an important point that the government focuses on identifying the root causes of vulnerability rather than focusing on having an adequate response to disasters [5, 7, 10].

4.2 Political Factors

With regard to the political factors of vulnerability creation in the UAE, the country is located in the Middle East which is unstable politically. As consequences, the potential of any political threat is high such as terrorist attacks. Therefore, it is crucial for the UAE government to identify those hazards in order to be tackled prior to their occurrence as a proactive approach [11].

4.3 Economic Factors

With regard to the UAE economic situation, the country deploys various strategies to reduce dependence on the oil sector as a way of sustainable economy. Another issue is that the UAE is a trading and a business center in the Asian continent. The UAE developed and urbanized rapidly in the last few decades [4].

5 Disaster Management Challenges in the UAE

The education level is also one of the challenges for the UAE government particularly that the study findings showed that this could affect the actions that have been taken in case of disasters.

Demographics: this is according to the variety of cultural backgrounds and traditions in the UAE. It is a challenge for the UAE's authorities to deal with various demographic groups in terms of their various beliefs and cultures.

Rapid development in the UAE is also a challenge particularly for emergency services providers with unfamiliar sort of risks that could emerge such as high-rise building fires.

The media is one becoming an increasingly important factor in disaster management and plays a vital role in dealing with disasters specifically for communication in disasters [12, 13].

These challenges could vary from an emirate to another due to the preparation standards especially that the UAE has a federal political system.

6 Community Resilience

It was through the Hyogo Framework of Action that resilience building became an important of disaster management. It identified that pre-disaster planning along with a culture of prevention input and resilience are important components of risk reduction. Actions are framed around governance, risk identification and reduction, and preparedness [11].

Building community resilience requires people to be involved in all disaster management cycles as a key stakeholder to ensure an overall resilience building. Public engagement in disaster management legislation, policies, and rules and also in emergency training and exercises is an important way of ensuring knowledge exchange and opportunities for the public to contribute in DRR. Based on this, it seems that the UAE is a vital contributor in DRR; however, disaster management implementation can be better.

In order to ensure that the UAE government is better prepared, there is a need to focus more on community resilience. Members of the community are considered as the first responders, and hence a greater focus on them is needed [14].

7 Analysis and Discussion

The results illustrated that there is a gap between the government and the public in terms of disaster management aspects. In addition, there are some communication gaps between the local and national authorities and between public and private sectors in terms of public awareness and disaster management. The media role in disaster management is limited as some communities do not use it; particularly there are different speaking languages. Furthermore, there is a limited knowledge about disaster management according to the high number of expatriates in the UAE. What is more, most of the research's sample has no idea about the existing risks particularly climate change impacts and disaster management policies. There is more concentration on institutional preparedness and resilience than public resilience.

In addition, different sorts of hazards have been emerged such as tall building fires as a result of urbanization. Urban projects are also a source of new sort of risks and threats.

From the interviews with the research's sample in Kalba City (Sharjah Emirate), it emerged that the victims acted firstly based on their experience and claimed that they have not been consulted prior to the recent construction projects in the area which led to flash flooding. In addition, there is a lack of data about some vital domains such as the population and the infrastructure.

8 Conclusion

UAE citizens moving from a seminomadic life to living in an apartment block in an area with a number of resident expatriates are likely to have had a difficult period of adjustment to the new lifestyle. This is a challenge from a disaster management prospective as they need to be given the adequate knowledge about the potential hazards which they are unfamiliar with.

Blaikie et al. [5], Lewis [15], and Pelling [16] claimed that in order to ensure vulnerability reduction, the root causes should be emphasized and enhanced to ensure better mitigation as Fig. 1 demonstrated.

The vulnerability of the public and individuals are influenced by a number of factors, such as transport, income, residential area, and culture. Therefore, the accessibility of infrastructure is a significant element in reducing disaster vulnerability. Currently, there is a little knowledge of vulnerability in the UAE because of the pace of change, but there is a significant knowledge of hazards.

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On the Reconstruction of a Radiological Incident and Its Possible Implications for an R-Type Terror Attack

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1 Introduction

There are many ways by which bad actors could make use of radiological material to harm innocent civilians, creating uncertainties, panic, confusion, and an increasingly escalating situation from the crisis management viewpoint. These scenarios are often referred to in the literature as overt and covert attacks. A typical example of the former is the well-known radiological dispersal device (RDD), also known as dirty bomb, and another one to some extent less dramatic example as there are no explosions involved is the radiological exposure device (RED), by which an unsealed high-strength radioactive source is hidden in a public place with intention to irradiate those passing by. If one is to learn from the possible consequences of this type of radiological attack and by doing so provide crisis managers with a consequence assessment, it is beneficial to learn from past radiological accidents, such as the one that took place in Cochabamba, Bolivia [1].

In the framework of the European Commission's Seventh Framework Program for security research, the CATO project [2] (CBRN crisis management, architecture, technologies, and operational procedures) was to develop guidelines for first responders as well as assess and evaluate a prototype decision support system for CBRN preparedness and resilience. For this purpose, the CATO project organized several "field experiments," which were to perform and impact assessment of an RDD (the results are classified) and another set of experiments inspired on the

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Cochabamba radiological incident. The CATO project drew its conclusions from theses and extracted some learnings to dealing with RED type of scenarios. The following sections elaborate in more detail on this second scenario.

2 Materials and Methods

The RED-type incident was carried out at the premises of the Austrian Armed Forces military camp *Schwarzenbergkaserne* (Salzburg Province), the largest military camp in Austria. A commercially available and standardized vehicle was used for these experiments as shown in Figs. 1 and 2. In each seat, a water container resembling the composition and density of the human body was equipped with a suite of monitoring devices, such as thermoluminescent and electronic personal dosimeters, TLDs and EPDs, respectively. In addition, two anthropogammametric phantoms were used in order to assess and evaluate the internal organ dose.

Radiation protection measures were carried out jointly between the Government Radiological Measurement Laboratory Salzburg (RMLS) and the Paris Lodron University of Salzburg (PLUS), comprising of (1) personal dosimetry for all persons involved in the field test, (2) gamma spectrometry survey in the area adjacent to the bus containing the radiation source, (3) surrounding the bus with an earth wall (height: approximately 6 m) on three sides, (4) strictly enforced access control to the test area, and (5) continuous monitoring of the environmental gamma dose rate in the near-zone to the bus with a dedicated monitor. All radiation exposure-pertinent records were mapped by PLUS staff and archived at the RMLS.

These experiments were also designed to assess and evaluate the performance of incidental dosimeters, not specifically designed for the purpose, such as cellphones and credit/identification (ID) card chips for retrospective dosimetry as compared to standard dosimetry methods such as TLDs and dicentric analysis in blood samples.

Fig. 1 Standard vehicle used in the simulation of a radiological exposure device type of attack

Fig. 2 Thermoluminescent dosimeters (TLDs) and electronic personal dosimeters (EPDs) (upper left corner), water canisters equipped with TLDs and EPDs (center), and an anthropogammametric phantom used to assess the organ doses (right)

Fig. 3 One of the configurations tested consisted of an unshielded source inside a suitcase and deployed in the cargo bay of the bus

Iridium-192 sources provided by Seibersdorf Laboratories, Division of Radiation Safety and Applications (Seibersdorf, Austria), of activities ranging from 650 GBq to 1.5 TBq, were used, and the exposure times varied from 30 minutes to 8 hours, each time the source was deployed underneath the passenger area into the cargo compartment of the bus.

3 Results and Discussion

Figure 3 shows one of the configurations tested, which assumes that an unshielded source is placed inside a suitcase and deployed in the cargo bay. The measured dose rates outside the bus are shown in Fig. 4.

Fig. 4 These are the EPD dose rates measured outside the bus. The driver seats are on the right-hand side of the figure, and the engine block is on the left. The yellow X marks the place where the source was located

The EPD used for dose rates monitoring outside the bus was measured for the configuration shown in Fig. 3. As expected, distance plays an important role in the attenuation of the irradiation, and the engine block provides additional shielding if a person were to stand behind the bus. These results correspond to a total exposure time of 30 min. For comparison purposes, a standard abdomen computer tomography (CT) scan delivers a dose of 10 mSv.

TLD dosimetry yielded comparable results, and for an 8-hours irradiation, doses ranged between 1 and 3 Sv for those seats right above the source. It is well known [3] that deterministic health effects will start appearing for exposures in the range of 2–5 Sv. Most of the passengers on the bus would likely suffer from stochastic health effects, i.e., increased probability of developing some form of cancer.

The International Atomic Energy Agency performed an intercomparison of EPD measurements for two consecutive irradiations in order to determine whether the EPD dosimeters would yield similar results for both Hp(10) and Hp(0.07), which correspond to the dose equivalent in the human body 10 mm below a specified point of the body and the shallow dose equivalent, also referred to as skin dose equivalent or surface dose equivalent, respectively. These results are shown in Table 1.

These results indicate that the measurements are consistent and that they also provide an estimate of the dose ranges to be expected. The values correspond to different seats on the bus.

4 Concluding Remarks

An RED type of attack is covert in nature and therefore of low profile, i.e., it does not require an explosion nor heightened media attention as it could pass undetected for several days, weeks, and even months. If this type of scenario is executed in a busy location, it would be very difficult to trace down the cause of people's illness as they could pass by and return to their homes in different cities or even countries. On the other hand, their exposure would have to be prolonged in order to become apparent,

Table 1 Equivalent and skin dose (see text) results for two irradiations

	Hp(10) (mSv)			Hp(0.07) (mSv)		
Unit label	Irradiation 1	Irradiation 2	Total	Irradiation 1	Irradiation 2	Total
CATO01	0.78	0.84	1.62	0.82	0.77	1.60
CATO02	1.25	1.28	2.53	1.22	1.24	2.47
CATO03	4.19	5.25	9.44	4.08	4.86	8.94
CATO04	25.88	26.42	52.33	25.20	30.93	56.13
CATO05	2.93	4.37	7.30	3.10	4.31	7.42
CATO06	23.79	23.10	46.907	23.94	22.99	46.94
CATO07	0.13	0.13	0.26	0.12	0.13	0.26
CATO08	75.13	73.90	149.037	73.59	71.57	145.16
CATO09	33.71	57.63	91.350	30.57	49.22	79.79
CATO10	380.30	555.92	936.232	397.37	489.44	886.82
CATO11	13.87	14.83	28.716	13.39	13.91	27.31
CATO12	2.75	2.84	5.68	2.70	2.88	5.59
CATO13	7.18	7.08	14.272	6.88	6.76	13.64
CATO14	16.10	16.90	33.011	20.32	20.81	41.14
CATO15	18.33	17.18	35.514	16.62	15.67	32.30
CATO16	4.09	5.20	9.29	3.92	4.80	8.72
CATO17	6.78	4.13	10.918	8.06	2.56	10.63
CATO18	11.74	9.51	21.260	12.04	9.74	21.79
CATO19	3.22	2.97	6.19	3.97	3.34	7.32
CATO20	0.759	0.789	1.548	0.671	0.781	1.452

for example, for commuters using the same means of transport every day. It is highly likely that at least one person will report to a hospital showing signs and symptoms of acute exposure to ionizing radiation. This in turn would lead to authorities sounding an alarm should there be no reports of radiological incidents being followed by the national competent authority.

The dose ranges observed indicate that at least some people on board the bus would likely show stochastic health effects as reported by the World Health Organization [3].

Acknowledgments We are grateful to the European Commission for providing funding through grant 261693 and to Mr. Rodolfo Cruz-Suarez of the IAEA for his valuable assistance with the dosimetric study.

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CBRN Events and Mass Evacuation Planning

Stefano Marsella and Nicolò Sciarretta

1 Introduction

There are dangerous threats to crowds or large communities whose damages can be limited by the timely evacuation of the affected populations. In particular, the effects of some natural events (hurricanes, volcanic eruptions, wildfires, tsunamis, and flashfloods) and of a number of man-made disasters, such as wars, terrorist attacks, and industrial or nuclear plant accidents, can be limited through adequate planning. Independently by their origin, the most effective way to limit casualties generated by hazards of natural or anthropic origin is to adequately manage the emergency response. Thus, planning the evacuation from a location exposed to risk to another location considered adequately safe is pivotal in many cases. Such action, which is meaningful mostly in case of fast-approaching threats, must be feasible and adequate to the evolution of the threat itself. In order to better define the areas of improvement in planning a mass evacuation, it is necessary to ask the question: "how do we establish parameters for mass?" The answer is basic to the planning process, but there isn't a shared definition of the term "mass," which is essential to understand the object of the evacuation. The National Fire Protection Association 1616 Standard on

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"Mass Evacuation and Sheltering Program" [1] provides the definition of two separate terms:

> 3.3.12 Evacuation. The act or process of evacuating. To leave a dangerous place or remove someone from a dangerous place. To withdraw from a site and/or building in an organised way especially for protection. Organised, phased, and supervised withdrawal, dispersal, or removal of civilians from dangerous or potentially dangerous areas, and their reception and care in safe areas.
>
> 3.3.21 Mass. A quantity or aggregate of matter, usually of considerable size; a large body of persons in a group (a mass of spectators); a large quantity, amount, or number.

However, in its definition section, the Mend Guide [2], funded by the UN and the EU, relates to mass evacuation as:

> For the purpose of this Guide, mass evacuation implies the evacuation of whole communities, neighborhoods or geographical areas. The scale and complexity of such evacuations creates the potential for emergency response capacity in a given jurisdiction or country to be overwhelmed and the necessity for coordination across one or more jurisdictions to effect the evacuation and sheltering of evacuees.

The same guide, on the other hand, quotes also an alternative definition of mass evacuation, adapted from the Los Angeles Operational Area Alliance [3]: "The potential for emergency response mechanisms to be overwhelmed due to an inability amongst local authorities to effect evacuation and sheltering solely within their own jurisdiction and using their own resources, thereby requiring coordination with one or more other jurisdictions."

The differences between the above definitions show that effectuating a mass evacuation may involve either a small, densely populated area or a large but not densely populated territory. Such specification raises a problem of relativity: a mass evacuation is not defined by the number of people involved but by its possibility of being controlled by the authorities. In any case, the correct assessment of a mass evacuation needs appropriate planning and management tools, different from the ones normally used to assess buildings' safety, even if extremely complex. Every aspect is more complicated: the coordination of different agencies, the difficulty in issuing an alarm capable of reaching all exposed people, the problem of estimating the travel speed on long routes, and the interference between pedestrian and vehicular flows. In any case, the complexity of a mass evacuation needs appropriate planning and management tools that are more complex than the ones normally used even in the most complex buildings.

The list of Table 1, showing the arguments to be considered in drafting an emergency plan, gives an idea of the complexity of planning a mass evacuation. The NFPA 1616 standard quoted in the table adopts the current approach in managing risks which, for the purposes of this paper, can be summarized in three main steps:

1. Identification of the risks and hazard assessment
2. Planning of the evacuation from the areas exposed to risk to the designated safe areas
3. Establishing procedures to manage the evacuation

Items 2 and 3 show clearly that the capabilities of simulating a mass movement are needed to ensure that mass movement is estimated in a reasonable way. Since the

Table 1 Table of contents of NFPA 1616 "Standard on Mass Evacuation, Sheltering, and Reentry" redrawn from [1]

Chapter 1 Administration 1.1 Scope 1.2 Purpose 1.3 Application *Chapter 2 Referenced publications* 2.1 General 2.2 NFPA publications 2.3 Other publications 2.4 References for extracts in mandatory sections *Chapter 3 Definitions* 3.1 General 3.2 NFPA official definitions 3.3 General definitions *Chapter 4 Evacuation, sheltering, and reentry program management* 4.1 Leadership and commitment 4.2 Program coordinator 4.3 Program working group 4.4 Program administration 4.5 Performance objectives 4.6 Records management 4.7 Laws and authorities 4.8 Finance and administration *Chapter 5 Planning* 5.1 Plan requirements 5.2 Plan assumptions 5.3 Plan format 5.4 Planning process	5.5 Threat, hazard identification, and risk assessment 5.6 Requirements analysis 5.7 Resource needs assessment 5.8 Communications and public information 5.9 Warning, notifications, and communications 5.10 Operational procedure planning *Chapter 6 Implementation* 6.1 Incident recognition 6.2 Situational assessments 6.3 Notifications and activation 6.4 Mobilization 6.5 Evacuation operations 6.6 Sheltering operations 6.7 Transition to re-entry *Chapter 7 Training and Education*	7.1 Curriculum 7.2 Goals of the curriculum 7.3 Scope and frequency of instruction 7.4 Record keeping 7.5 Regulatory and program requirements 7.6 Public education *Chapter 8 Exercises* 8.1 Program evaluation 8.2 Exercise methodology 8.3 Design of exercises 8.4 Exercise evaluation 1 8.5 Frequency *Chapter 9 Program maintenance and improvement* 9.1 Program reviews 9.2 Corrective actions 9.3 Continuous improvement Annex A Explanatory material Annex B Self-assessment for conformity with NFPA 1616 Annex C Evacuation risk matrix Annex D Evacuation requirements analysis Annex E Mass sheltering requirements analysis Annex F People with access and functional needs Annex G Service animals and pets Annex H Informational resources

majority of threats have a time-related manner of posing their risks to people, phases and times of an evacuation need to be assessed quantitatively, from the time needed to issue the alarm to the moment a safe place is reached. An improved approach to the assessment of the time history of the evacuation is expected. The main expected improvements concern the availability of simulation tools and the possibility to quantitatively assess the time needed to alert people.

The approach adopted in structural fire protection can help in the first area. Assessing how safe a building is and to what extent an evacuation can match the safety goals is an already defined method, based on the comparison between the evolution of the threat and the egress from the building capabilities. According to the authors, the same approach should be applied to mass evacuation. The capabilities of simulating the spread of large-scale threats (tsunami waves, forest fires, flashfloods) have reached the same level of reliability of fire spread in buildings. Similarly, the egress behavior on an urban or territorial scale can be simulated with tools similar to the ones used for the emergency egress from buildings.

The problem of quantitatively assessing the time needed to alert people doesn't seem to have been studied, either in the past, when sirens, radio, or TV broadcast could be used, or in recent years, as the widening use of social media and cellular communications has changed the scenario of emergency communication from authorities to citizens.

2 CBRN Events and Mass Evacuation: The Fukushima Case

On 11 March 2011, the Great East Japan Earthquake caused a massive earthquake with a magnitude of 9.0 and a tsunami which struck a wide area of coastal Japan, with several waves that reached heights of tens of meters [4]. The earthquake and tsunami killed more than 15,000 people, injured more than 6000 people, and resulted in around 2500 people missing. The Fukushima Daiichi nuclear power plant suffered severe damages to the operational and safety infrastructure (Fig. 1).

The effects of the tsunami led to the loss of electrical power, with the consequential result of the loss of the cooling function at the three operating reactor units and at the spent fuel pools. After a few days, radionuclides were released into the atmosphere and were deposited on land, affecting people who lived around the plant. The consequent flow of events can be considered an important case study for any community involved in integrating evacuation planning in the management of nuclear emergency.

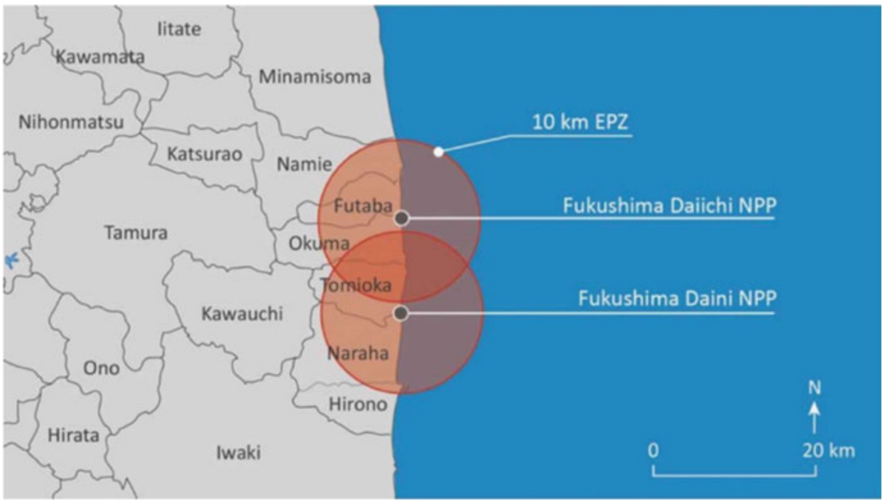

Fig. 1 Emergency planning zones for the Fukushima Daiichi NPPs established prior to the accident. The evacuation area has a 20 km diameter [5]

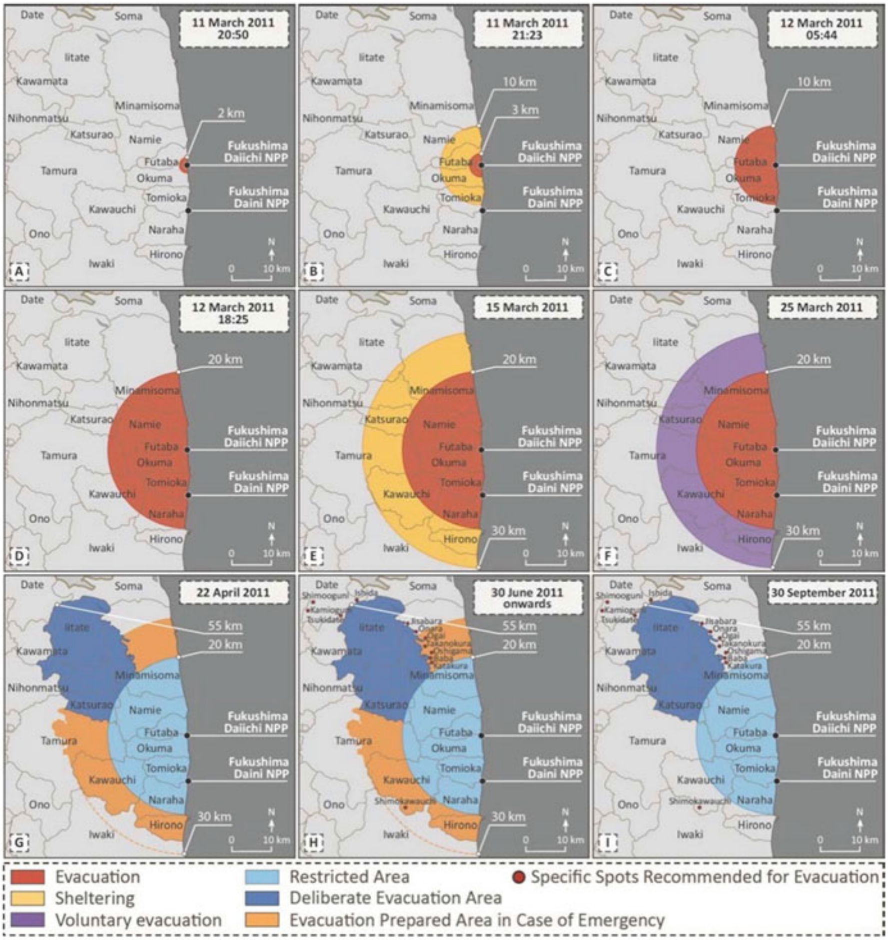

Fig. 2 Areas and location where protective actions were ordered or recommended until 2011. The areas have diameters up to 55 km [4, 5]

On 11 April 2011, the national government announced that the criterion selected to assess the relative safety of an area would have determined areas beyond the 20 km evacuation zone from which people would have been relocated. On 22 April 2011, a "Deliberate Evacuation Area" was established beyond the 20 km evacuation zone to include areas where this projected dose criterion of 20 mSv might be exceeded. Thus, the national government issued an order that relocation of people from this area should be implemented in approximately 1 month. In addition to the "Deliberate Evacuation Area," an "Evacuation Prepared Area in Case of Emergency" was also established on 22 April 2011. Residents of the "Evacuation Prepared Area in Case of Emergency" were advised to shelter or evacuate by their own means in the event of possible renewed concerns regarding the Fukushima Daiichi plant (Fig. 2).

The designation of the "Evacuation Prepared Area" was lifted on 30 September 2011. As a result of the monitoring conducted beyond the "Restricted Area" (i.e., the 20 km evacuation zone) and the "Deliberate Evacuation Area," specific locations were identified with projected doses to residents above 20 mSv within 1 year after the occurrence of the accident. On 16 June, the national government announced a guideline which specified that these locations should be designated as "Specific Spots Recommended for Evacuation." Beginning on 30 June, the national government began to designate these locations to be relocated (Fig. 3).

The description of the events above, mentioned in very few words, is intended to highlight that during the emergency phases: (1) emergency plans were not adequate to the needs of the situation and (2) relocations of people previously evacuated have been necessary.

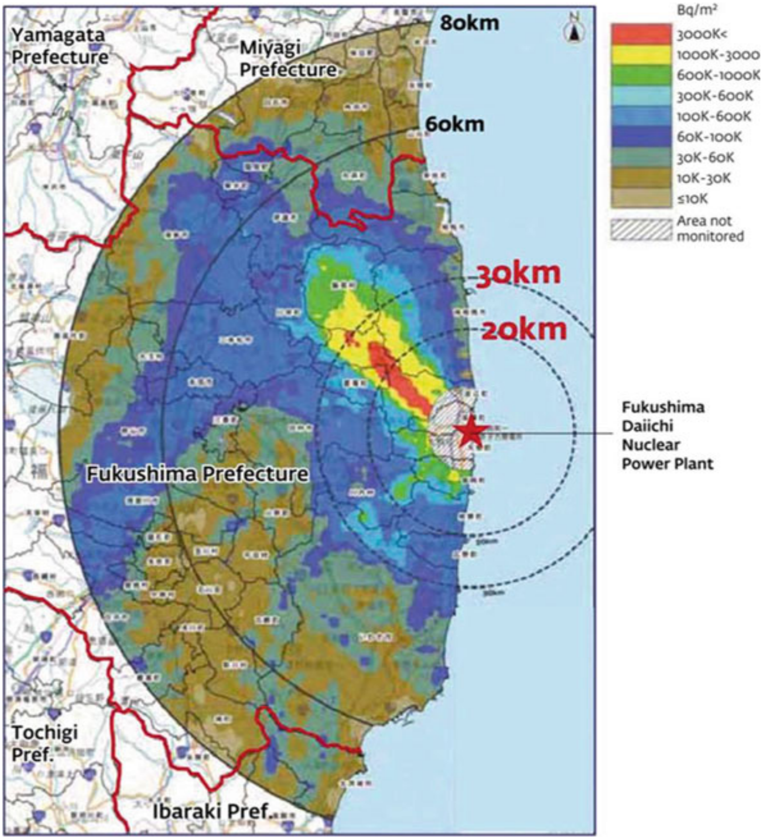

Fig. 3 Map showing accumulated cesium-137. The diameter of the area is 80 km [6]

3 Buildings vs. Urban Scale Evacuation: Similarities and Differences

In order to appreciate the differences existing between evacuation from a building and evacuation on an urban scale (or territorial scale), it can be useful to describe the criteria underlying structural fire protection. In particular, the common application of the fire safety criteria to buildings accepts the coexistence of two different approaches: (1) the prescriptive-based approach (based on the compliance of the project with prescriptions concerning the distribution of means of egress and the characteristics of systems and materials) and (2) a performance-based approach [7] (based on the application of fire science concepts to the assessment of the compliance of the performances of the building against the requested life safety performance). Environmental (paths, obstacles, number of people) and behavioral aspects (limitations in perceiving the alarm, in understanding the threat, communicating, or moving) are critical in both approaches, but in the prescriptive-based approach, the risk assessment is intrinsically developed when the code is drafted. On the contrary, in the performance-based approach, the fire safety engineer is asked to assess risk in any scenario. Therefore he or she will identify the risks, assess the hazards, and simulate the spread of fire effects. Finally, he or she will judge if the sum of the intervals needed to detect the fire, to raise the alarm, and to move people to a safe place is compatible with the time the fire effluents allow before a closed environment is incompatible with the presence of people.

One more aspect that deserves to be described concerns the time interval between the alarm and the initiation of movement. The extensive studies developed in structural safety [9] have suggested the consideration of adding an additional time to the bare movement time. Such studies show that the assumption is not true that, when an alarm rings, everybody that hears it will start immediately to move. So, it is also important in the case of mass evacuation to take into account that such a delay is related to the fact that the entire population cannot be reached by a single medium. Studies about issuing the alarm in an extensive and effective way are subject to rapid evolution, since the communication technologies are continuously adding new capabilities in such a specific field [10].

4 Why a Mass Evacuation Plan Could Benefit from a Performance-Based Approach

Planning a mass evacuation with a performance-based approach means attributing numbers to aspects that, until now, have not been considered or, when considered, have been evaluated with a rule-of-the-thumb method. On the contrary, questions like “how long does it take to inform people about an incumbent menace?” or “will social or age difference require different communication channels?” or “how much time will be needed to evacuate civilians to a safe place, whether a pedestrian

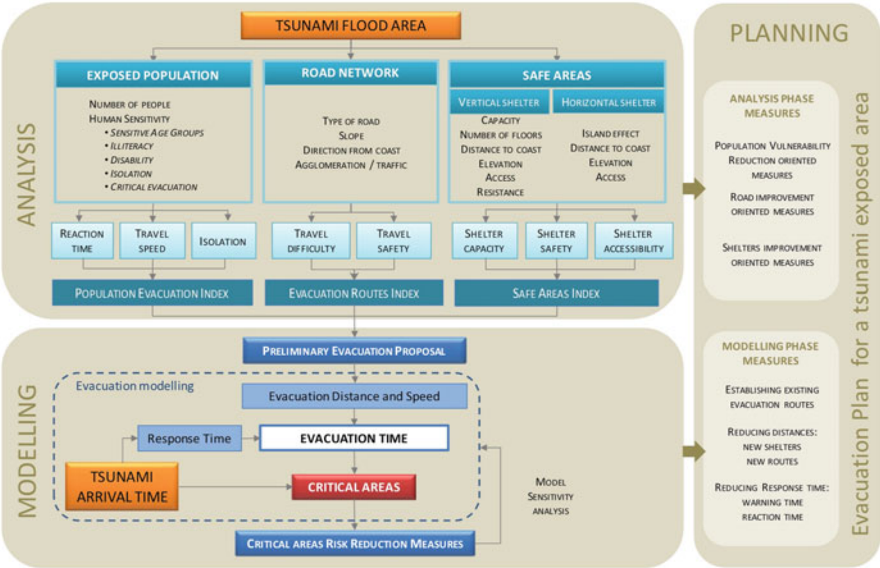

Fig. 4 The schema of the emergency planning in case of tsunami. Assessing quantitatively the evacuation time is part of the process [8]

evacuation, a vehicular evacuation, or both modes at the same time?" need to have an acceptable answer. Figure 4 [8] shows in graphic form the position and importance of modelling simulation in the planning of tsunami evacuation. Consequently, a number of areas of emergency management can take advantage of the possibility of a quantitative approach. Deciding if a "defend-in-place" strategy is better than a mass evacuation will be much easier when the assessment will be based on numbers. A plan will much more probably fit the needs if its main assumptions are based on numbers rather than on qualitative assessments.

5 Modelling a Mass Evacuation

Some studies about modelling tools have been published to help managers improve mass evacuation planning [11, 12], but more reviews on such tools are needed, in order to clarify if applications can simulate the emergency movement of a large group of persons which can be defined as a mass on an urban or territorial scale. From the authors' point of view, the lack of even one of such requirements weakens the results of a simulation. Moreover, the difficulty of testing the results of the simulation against the real situations makes it difficult to assess the reliability of the tool.

One more complexity issue is added by the existence of a vehicular evacuation, especially when it interferes with pedestrian evacuation. In this case, the authors have not found in the specific literature any reference to pertinent studies or research developed [13].

6 Engineering the Process: Putting Tools Together

As described, a real mass evacuation planning can be drawn with a quantitative-based approach, since it cannot be considered plausible to entrust the lives of hundreds or thousands of people to judgments that are not based on an objective assessment.

The quantitative assessment of a mass evacuation needs to be able to estimate (1) the time history of the threat, (2) the time needed to raise the alarm and let people understand which actions they have to do, and (3) the time needed to move people from their location to a safe place. Such temporal intervals must be considered in order to organize a consistent alarm/evacuation plan. Once such data are available, the engineering process can be defined, and the overall evacuation process can be assessed under its time evolution consistency.

Another general aspect that the above considerations bring to the attention of the community committed to improving people's safety is the specific interest of managing the entire process during the emergency through models and algorithms. In this case the interest does not lie only in improving the planning capacity but also in allowing control centers to improve their capacity of giving the operators the possibility to adopt choices that, based on data and simulations, will be the most appropriate. The same models used to plan the emergency, in fact, can be integrated within the situation awareness solutions (software, hardware sensor networks, etc.) that are currently used in the most evolved control rooms.

7 Existing Gaps

When it comes to warning thousands (or tens of thousands) of people, which media should be used to promptly reach everyone promptly with the most efficient communication? Information and communication technologies are subject to continuous improvements in aspects critical to the specific matter, as the availability of affordable mobile devices, of appropriate band width, and of land cover. Some non-technological questions are equally critical: for example, are the existing differences of media use by people due to their different age, cultural and social conditions, and the resulting response to the alarm relevant? Defining the time needed to inform people, for example, obliges emergency planners to be aware of the time-related curve in delivering messages and different response times. There are not yet published data concerning delay times, which allow a quantitative assessment useful to assess the overall information and evacuation process. While the matter has been defined under a theoretical point of view, emergency managers cannot yet use numbers to support their planning.

8 Conclusions

The analysis of the mass evacuation after the Fukushima earthquake shows the need for improving the capability of planning a mass evacuation and managing it with the support of quantitative assessments. In structural fire protection, the development of specific assessment tools has introduced the performance-based approach into national and international rules. The use of such an approach in building safety design and in emergency planning is made possible by the availability of appropriate computer programs that calculate the two most important parameters needed to assess fire safety in buildings: how long it takes for the fire effluents to make the conditions inside a closed environment untenable for people and how long it takes for people to reach the designated safe place.

In the case of a mass evacuation, assessment tools that allow the attainment of the same goals of fire safety for built environments are available as well. As a consequence, it is no longer justifiable to assess planning evacuation of a large scale on a purely qualitative basis.

In order to define the missing assessment tools, some specific issue still need to be addressed. In particular, the key role played by the time needed to inform people needs to be addressed by social sciences and ICT industry and should define how to use media and to take into account the time needed to reach all people exposed to an incumbent threat and let them understand the actions to be taken.

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The Impact of Climate Change on Radiological Emergencies in Italy: A Case Study in a Nuclear Medicine Department

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1 Introduction

According to the last IPCC report of 2013 [1], warming of the climate system seems unequivocal, and, due to the strong sensitivity to climate change (CC), specifically the Mediterranean region has been identified as a primary hot spot with higher climatic risk [2].

CC, whether driven by natural or human forcing, can lead to changes in the frequency, intensity, spatial extent, duration and timing of weather and climate extremes such as extreme precipitation events. An extreme event is generally defined as the occurrence of a value of a weather or climate variable exceeding (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable [3]. Increases in precipitation extremes, for example, are actually consistent with a warmer climate [1].

In the latter half of the twentieth century, and up to 2100 according to studies of projected changes, an increasing trend has been found for some extremes. In particular, since 1951 there have been statistically significant (e.g. above the 95th percentile) increases in the number of heavy precipitation events (more consistent trends in winter than in summer in Europe), and in the projections heavy precipitation events' frequency is very likely to increase over many areas of the globe [1]. Moreover, projected precipitation and temperature changes imply possible changes in floods.

It is an "Invited paper" and Dr. D'Arienzo was an "Invited speaker" of the conference.

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Then CC can result in unprecedented extremes, which, even if not out of proportion in a statistical sense, can still lead to extreme conditions or impacts, also because the severity of the impact depends on the vulnerability and the exposure of the system. To date, most of the climate change research has focused on the health of general population, but CC can affect negatively also workers' health and safety [4]. In this paper, the consequences of events such as tornadoes and floods are analysed in hospitals where radioactive substances are held and employed, suggesting that risk assessment methods should be adapted to fully address these extreme events.

2 Incidents in a Nuclear Medicine Department

The core of a system of protection and safety in workplaces is to identify the hazards and assess the risks to safety and health of workers and population. To this scope, the risk assessment has to include a systematic critical review of possible events leading to accidental exposures [5], in order to prevent them and, in a nuclear medicine (NM) department, to implement suitable measures to respond to a potential radiological emergency.

In particular, the current Italian legislation for radiation safety [6] requires a pre-assessment of the spatial and temporal distribution of dispersed or released radioactive materials as well as of potential exposure of workers and reference groups of population in case of a radiological emergency. This kind of assessment involves the identification of maximum-credible accident scenarios.

To this regard, due to the presence of unsealed radioactive materials for the preparation of radiopharmaceuticals in high-density population areas, NM departments show a high degree of vulnerability and exposure to extreme weather events (EWEs) [7].

However, in order to identify plausible scenarios, a good starting point for the safety assessment is collecting information about accidents that have already occurred.

Apart from misadministrations and dose irregularities to the patients, which are outside the topic of this paper, typical incidents in NM departments are [5, 8]:

- Radioactive spill (radiopharmaceutical, radioactive urine, radioactive vomit)
- External radiation exposure to sealed source or radioactive patient
- Contamination with unsealed source
- Evaporation of radioactive source
- Damage to portable generator (^{68}Ge/^{68}Ga, ^{99m}Mo/^{99m}Tc, etc.)
- Damage to a package containing radioactive material
- Loss of source
- Breaking of a radioactive target inside the cyclotron bunker
- Flood
- Fire

Usually, the risk assessment considers the case of fire as maximum-credible accident scenario.

However, it should be considered that in areas where radioactive substances are used and/or stored, the probability of a fire is very low because nonflammable construction materials are used and highly flammable or highly reactive materials cannot be held in order to keep the fire loading to a minimum [9]. In addition, firefighting equipment must be provided, and these areas must be subdivided from the point of view of fire prevention, so as to be protected from fires from the outside and to contain an internal fire until it is completely extinguished.

For the above-mentioned reasons, fire can be regarded as a low-probability risk. On the other hand, because of the increased frequency of EWEs, nowadays flooding has a non-negligible probability. In Italy, in the last years, various accidents have occurred in NM departments because of the consequences of extreme precipitations. For example, in March 2011, heavy rains flooded the NM unit of the hospital Santa Maria Goretti of Latina, which is placed in a basement. In September 2012, heavy rains lashed Pescara, and water infiltration caused ceiling collapse with subsequent flooding of the NM department.

This article analyses the consequences of two potential cases of accident due to flooding or heavy rain in the NM department of an Italian hospital (H). Effective doses to emergency personnel are also evaluated due to inhalation of the evaporated contaminant, to submersion in the contaminated air and to irradiation from the contaminated water on the floor.

In the first scenario, the area used for the storage of liquid radioactive waste is flooded, and the entire ^{131}I content of one tank containing waste produced by excreta of patients after administration of radiopharmaceuticals for therapeutic procedures is poured in the room.

In the second scenario, the area where radioactive sources are used for the preparation of radiopharmaceuticals is flooded, and all the unsealed sources are dispersed in the room.

3 Flooding of the Area for the Storage of Radioactive Waste Produced by Excreta of Patients

In many hospitals the areas for the storage of liquid radioactive waste from diagnostic and therapeutic NM departments are often in detached underground areas, extremely vulnerable to incoming water in case of flooding.

In the hospital H, the area for the storage of radioactive waste produced by excreta of patients has a total surface 26 m^2; 4 m^2 are at ground level and 22 m^2 are 0.9 m under floor plan (Fig. 1).

The height of the ceiling is 2 m above the ground level; hence the ceiling over the 22 m^2 under floor plan is 2.90 m high.

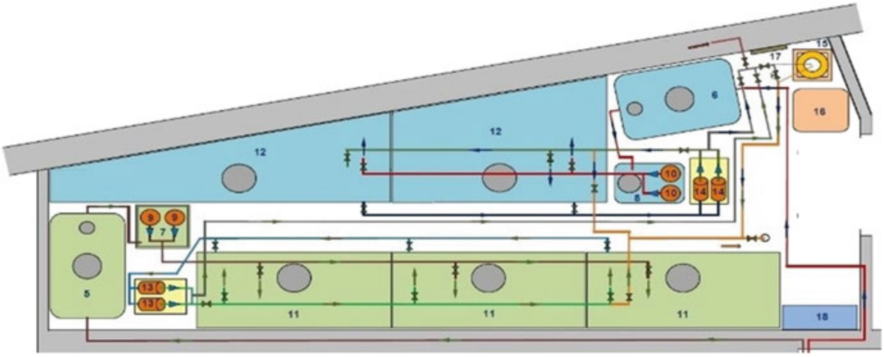

Fig. 1 Map of the area for the storage of radioactive waste produced by excreta of patients. Description: 5. Imhoff purification therapy unit, 6. Imhoff purification diagnostic unit, 7. discharge and lifting unit, 8. discharge and lifting unit, 9. pneumatic supply unit, 10. pneumatic supply unit, 11. therapy decay tanks, 12. diagnostic decay tanks, 13. pneumatic supply unit, 14. pneumatic supply unit, 15. sample collecting unit, 16. rack, 17. air discharge, 18. power supply unit

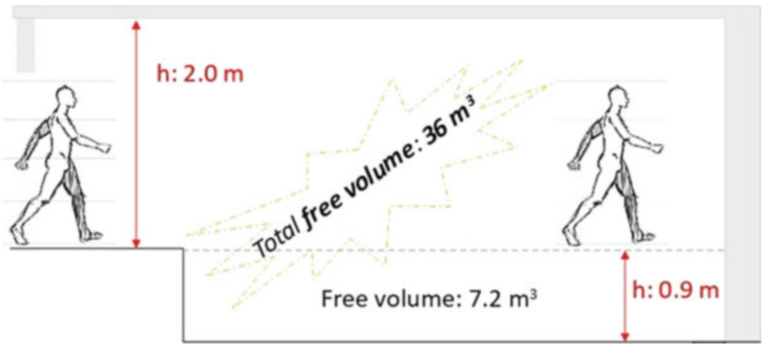

Fig. 2 Side view of the area for the storage of radioactive waste

The total volume is then 72 m^3, of which about 20 m^3 under floor plan. Part of this volume is occupied: 30 m^3 by the tanks for the excreta (three tanks of 4.5 m^3 each for excreta produced by patients subjected to therapeutic treatments, and two for excreta produced by patients subjected to diagnostic exams), 5 m^3 by the Imhoff tanks and 1 m^3 by various objects. Then the total free volume is 36 m^3.

Under the floor level, there are 20 m^3, 7.2 of which are free and then could be filled by water in case of flood. In particular, the floor of the underground area has a surface of 22 m^2, of which 14 are occupied by the tanks and 8 are free (see Fig. 2).

The roof of the building consists of a 13 cm laminated slab, half of which is covered with 3 mm of lead over the Imhoff tank loaded with excreta produced by patients subjected to therapeutic treatments.

In the maximum-credible accident scenario, it is assumed that, due to an EWE like a tornado, the roof has been torn away or has sunk under the weight of broken branches of the trees nearby and debris carried by the wind.

If there is heavy rain entering the room with a precipitation rate of 100 mm/h (not unusual for Italian extreme precipitation events), the rebounding cockpit fills up first, triggering the alarm. If this happens during the weekend (worst-case scenario), the radiation protection expert (RPE) is not present in the hospital, and it takes about 2 hours to her/him to be on site and take remedial actions. Due to the heavy precipitations (100 mm/h), after 2 hours in the room, there will be 1.6 m^3 of rain water.

It is then assumed that, due to the EWE, the pipe connecting two tanks of the therapeutic department is broken when one of the tanks is full, so that its content (4.5 m^3) is completely discharged into the room, pushed under its own weight. In the maximum-credible accident scenario, the tank is supposed to contain 30 GBq of ^{131}I, i.e. 1/3 of the maximum possible content of the three tanks.

Since 4.5 m^3 of water are spilled from the tank and, after 2 hours, 1.6 m^3 of rain water have been accumulated, upon arrival of the RPE, there are about 6 m^3 of contaminated water in the room, leaving 30 m^3 of free volume.

The available volume in the underground area is 7.2 m^3, and then even in the maximum-credible accident scenario, the contaminated water does not overflow from the room.

The concentration of ^{131}I in the contaminated water inside the room is then 30 GBq/6 m^3 = 5 kBq/g.

In order to evaluate the evaporation of water containing radioactive material, it is presumed, under cautionary conditions, that the incident takes place at a temperature of 27 °C and a relative humidity of 70%—very conservative assumption since the incident occurs during extreme precipitations (100 mm/h). In the psychrometric chart, at these temperature and relative humidity, there are 23 g of water vapour per kg of moist air.

In theory, evaporation can continue to saturation, even though actually the rate of the process is slowed down by the high amount of water already present in air. It is then estimated from the psychrometric chart that, under these assumptions, the concentration of water cannot exceed 10 g per kg of air, for a total of 300 g of contaminated water evaporated from the ground in the 30 m^3 of free volume inside the room.

Then on the arrival of the RPE, it is likely that an activity of 1.5 MBq of ^{131}I is dispersed in air (calculated as 5 kBq/g × 300 g), with a concentration of 1.5 MBq/30 m^3 = 50 kBq/m^3.

Under these environmental conditions and after about 20 minutes (necessary to assess the situation and to implement the intervention actions), the effective committed dose to the emergency personnel (e.g. the RPE) would be:

$$\left(1.1 \times 10^{-5}\mathrm{mSv/Bq}\right) \times \left(1.2\mathrm{m}^3/\mathrm{h}\right) \times \left(3.3 \times 10^{-1}\mathrm{h}\right) \times \left(5 \times 10^4\mathrm{Bq/m}^3\right) = \mathbf{0.22mSv}$$

where:

- 1.1×10^{-5} mSv/Bq is the committed effective dose inhalation conversion factor.
- 1.2 m^3/h is the inhalation rate for workers.

- 3.3×10^{-1} h is the time spent by emergency personnel in the contaminated area.
- 5×10^4 Bq/m^3 is concentration of ^{131}I in air.

This dose is approximately the committed equivalent dose from inhalation to the thyroid, which can be calculated using $w_T = 0.05$ and the IAEA thyroid conversion factor, equal to 0.23 (mSv/h)/(kBq/m^3) for ^{131}I [10]:

$$0.23(\mathrm{mSv/h})/\left(\mathrm{kBq/m^3}\right) \times 0.33\,\mathrm{h} \times \left(50\,\mathrm{kBq/m^3}\right) \times 0.05 = 0.19\,\mathrm{mSv}.$$

Using the IAEA conversion factor for external γ exposure due to immersion in contaminated air, equal to 8.1×10^{-5} (mSv/h)/(kBq/m^3) for ^{131}I [10], it is then possible to evaluate the effective dose from external exposure:

$$8.1 \times 10^{-5}(\mathrm{mSv/h})/\left(\mathrm{kBq/m^3}\right) \times 0.33\,\mathrm{h} \times \left(50\,\mathrm{kBq/m^3}\right) = \mathbf{1{\times}10^{-3}mSv}.$$

Regarding the effective dose due to the external irradiation from the contaminated water, in the room there are 8 m^2 of flooded area and 6 m^3 of water. This configuration can be simulated with the Microshield® software (Grove Software—4925 Boonsboro Rd, #257 Lynchburg, VA 24503 USA) as a parallelepiped of contaminated water with an area of the base equal to (2.83 × 2.83) m^2 and a height of 0.75 m, in which 30 GBq of ^{131}I are diluted.

The effective dose to the personnel is evaluated at a height of 2.4 m, because the flooded area is 0.9 m under the floor plan.

After 20 minutes spent in the room, the effective dose to the emergency personnel in the worst-case scenario (anteroposterior geometry) is equal to **0.08 mSv**.

Then the total effective dose due to inhalation, immersion in contaminated air and external irradiation is about **0.3 mSv**.

4 Flooding of the Hot Laboratory

In worst-case accident scenario of flooding of the hot laboratory of the hospital H, it is assumed that all the unsealed sources present at any given time (Table 1) are completely dispersed in the room flooded with 20 cm of water. Then the radionuclides are diluted in 2 m^3 of water, as the surface of the laboratory is 10 m^2.

Table 1 Unsealed sources present in the hot cell and maximum quantities held in 1 year

Radionuclide	^{51}Cr	^{67}Ga	^{90}Y	^{99}Mo	^{99m}Tc	^{111}In	^{123}I	^{131}I	^{153}Sm	^{177}Lu	^{186}Re	^{201}Tl
Maximum activity held in 1 year (GBq)	0.4	20	500	1400	5600	5	30	600	25	600	30	20
Maximum activity present at any given time (GBq)	0.07	2	40	30	25	0.5	0.5	11	4	25	6	2

Table 2 PET radionuclides present in the hot cell

Radionuclide	^{11}C	^{13}N	^{15}O	^{18}F
Maximum activity present at any given time (GBq)	74	19	19	37

Following the same approach as before, up to saturation 300 g of contaminated water evaporate in 30 m^3 of free air in the room. Then the effective dose to the first responders due to inhalation of each radionuclide in Table 1, after 20 minutes spent in the room, is equal to **0.2 mSv** (using the committed effective dose inhalation conversion factor for each radionuclide [6]).

The simulation with the Microshield® software allows to evaluate an effective dose of **0.2 mSv** due to external irradiation from the 2 m^3 of contaminated water (at the height of 1.5 m from the floor and in the worst-case anteroposterior geometry).

The total effective dose (due to inhalation and irradiation) to first responders is then about **0.4 mSv**.

If in the laboratory there are also PET radioisotopes (Table 2), which have an emission of 511 keV γ-rays, in the worst-case scenario of flooding, the effective dose due to inhalation is **0.23 mSv**, and the effective dose due to external irradiation at the height of 1.5 m is **2.14 mSv** (worst-case anteroposterior geometry). Then in this case, the total effective dose (due to inhalation and irradiation after 20 minutes) to first responders would be **2.37 mSv**.

As before, the effective dose from external exposure due to immersion in contaminated air is negligible compared to the other contributions, varying from a few μSv to a few dozen of μSv, depending on the presence or absence of PET radioisotopes [11].

5 Discussion

In this paper maximum-credible accident scenarios of flooding are discussed in the NM department of the hospital H, and effective doses to first responders are evaluated after 20 minutes spent in the flooded area.

On one hand, the assessment shows that the consequences of flooding generally lead to effective doses below 1 mSv to personnel (e.g. the RPE, the fire brigade, etc.) that should be classified as category A workers. However, in the case of a hot laboratory where PET radioisotopes are present, the effective dose to emergency personnel can exceed 2 mSv, if the radionuclides are completely poured on the floor. It should be noted that the activities of PET radioisotopes present in the laboratory of various Italian hospitals can be even twice or three times higher than the ones considered in this study. In such cases the effective doses could reach several mSv.

On the other hand, in NM departments radioactive sources are actually contained in sealed vials, which are placed in lead containers stored in the hot cells, and remain outside the cell only for the time of preparation and administration. Therefore, in case of flooding, the sources would remain confined to the hot cells or in the premises. Moreover, regarding PET radioisotopes, which have proven to be the greatest concern, only daily scheduled activities are present, because the daily amounts that are used are not the maximum amounts that are stored and the radiopharmaceuticals present in the NM department are only those that need to be injected on that particular day. Then the probability that there is a significant amount of any radionuclide in the event of an accident is low, and actual effective doses to first responders generally should be lower than those of the scenarios presented here.

However, all these considerations apply also in the case of fire, which is usually the accident scenario considered as worst case. As a matter of fact, the risk associated with these two events can nowadays be comparable due to the increased frequency of extreme precipitations and floods.

Actually, the risk can be parameterized according to the approach presented in [7]:

$$R = P \times V \times G$$

where R is the risk, P is the probability of occurrence of the type of accident, V is the vulnerability of the system, i.e. the tendency of the system to be damaged by the accident, and G is the severity of the consequences.

As shown in this article, P and V (regarding NM departments) are higher for accidents related to flood than to fire. On the contrary, G is higher in the case of fire, as the fire release fraction is of the order of 10^{-2} [10], versus 10^{-4} in the case of flooding, as it can be extrapolated from the above calculations. As a consequence, the product R of the three factors P, V and G may be comparable in the two cases, depending on the circumstances.

In addition, the perception of the risk is higher in the presence of fire than in the case of flooding, and in event of fire personnel have to use immediately protective masks and stay away from the blaze. On the other hand, when entering a flooded room, respiratory protective equipment is not usually worn, and the first responders have to walk into the water for rescue actions, thus receiving a higher external exposure. This could be parameterized by a factor multiplying the gravity G of the accident: in the case of fire, this factor could lower the gravity with respect to the case of flooding.

6 Conclusions

The results discussed in this paper point out that flooding is an event to be considered in the design of NM departments as maximum-credible accident, just like the case of fire, which is usually considered the worst-case scenario. As a matter of fact, the increased probability of EWEs could make the risk associated with these two types of accident comparable. Moreover, the procedures to face the two types of accidents are such that in case of fire, protective equipment has to be worn independently from the presence of a radiological threat. In other words perception of risk could be lower in front of a mass of water, which does not appear per se as a threat, than in front of a fire, thus potentially amplifying the severity of the damage.

The safety and risk assessment should evaluate the vulnerability of the system to EWEs like extreme precipitations and floods, following the approach presented in [7], and organizational and procedural measures to prevent the consequences of such accidents should be introduced among the established protection and prevention procedures.

The concern is mainly oriented towards the protection of emergency teams, but also workers and population can be involved in these kinds of events and then potentially exposed to undue radiation levels.

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Early-Warning Crisis Management Systems for CBRNe Attacks in High-Threat Infrastructures

Paolo Castelli

1 Introduction

The activities necessary for the defense of the population in the event of chemical, biological, radiological, nuclear, and explosive (CBRNe) attacks increasingly require appropriate tools to identify critical points in the detection of any threats that may be involved, for example, subways. Also it is useful for emergency planning a system to study the exodus of people in case of terrorist attacks, thanks to some scenarios prepared by the national system of American health that determines the corresponding number of the victims. Finally it is interesting a study prepared by the Finnish VTT to design a refuge of the population able to protect it in the event of a CBRNe attack.

2 Advancements in the Protect Early-Warning Crisis Management System

Below is an initial system called "Protect TM," presented by Dr. Anthony J. Policastro, who manages emergencies in the event of chemical attacks on infrastructure of particular complexity such as metropolitan and airports. The system under study was made in the Washington DC subway, two large transport terminals in New York, and a large transportation facility in Boston and specifically aimed at reducing the false positives of the detector [1].

The system employs chemical detectors, used together with closed-circuit cameras to see if an accident has actually occurred. The alarm detector activates the

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closest camera and allows current staff to evaluate whether it is a real incident. At this point, the system calls on rescuers, evacuating people in the stations and preventing access to public stations. The information collected by the operating unit can be viewed from laptops connected to the network. A single activation of a detector is not enough for the problem of false alarms and must have some evidence to support. In addition to the so-called false positives and false system alerts, false disturbance alarms may occur, for example, and can be detected for the presence of chlorine and could thus cause confusion. In this case, the sensor alarm arrives at the control console and the video search system or alarm detection from nearby detectors.

The false positives of the single sensor depend on the technology used and are tolerable only if their frequency is lower than that required by the user. The system's false positives are triggered by the activation of multiple sensors, and only the use of video tests is able to counteract erroneous detection. A survey was conducted in the Washington subway from October 1, 2007, to January 31, 2008. A transit site with about 100 detectors has shown four detector false positives and one detector fault (equipment failure) over the 5-month period. During that period, there were ZERO system false positives as the video cameras did not identify any distress for each of the detector activations.

To minimize false positives, a detector package has been introduced, which includes three different technologies: IMS (spectrometer), SAW (surface acoustic wave detectors), and TIC (electrochemical cells).

The use of mathematical models was made to study how the air dispersion in the event of chemical attacks varied and the results obtained showed that it was appropriate to hold the release to bring the trains slowly to the nearest station, stopping them slowly. On the contrary, the use of fans in the tunnels and in the stations leads to polluting the air of the exodus.

CWA and TIC detector data can be combined and sent over a local network to the control center or to a cell phone with which you can control the status of the detector at any time and possibly a video recording.

Small amounts of simulants can be used for system maintenance to perform periodic tests, the results of which can be displayed through the cell phone.

3 A Computational Modeling Framework for Counterterrorism Planning and Response

The conduct of Olympic Games or other similar events with large public attendance requires the preparation of emergency plans to ensure public safety even in the event of a terrorist attack. Chemical, biological, radiological, nuclear, and explosive (CBRNe) substances can be used in these attacks, and it is useful to simulate the behavior of the population by patterns simulating the behavior of the population. The aim is to reliably understand the risks associated with possible threat scenarios in order to protect critical infrastructures and plan event security.

The GENIUS project refers to a class of computational models that simulate the actions and interactions of independent agents with other agents and the environment. The GENIUS framework is divided into these components: agent module (AM) for decision-making and different agent behaviors, space and environmental module (SEM) modeling navigation space, form module visualization (VM) that allows the display of results during and after simulation, the target selection model (TSM) modeling the behavior of the specific agent during decision-making and achievement of a specific target, and the generation module events (EGMs) that generate threats in a timely fashion.

Agent Module (AM) Computational Agent modeling (AM) is a method that allows the researcher to create, analyze, and experiment with compound agent models that interact with each other and within a localized environment. This modeling technique uses a nonrandom approach that allows agents to make local decisions for themselves and can observe overall behavior globally.

The agent behavior engine in GENIUS employs swarm intelligence (SI), which is an expression introduced by Beni and Wang in a context of cellular robotic systems [2]. SI is a decentralized and self-organized system in which collective behavior of agents interacting locally with their environment causes consistent functional behaviors. Typically, agents are autonomous mobile actors representing individuals moving around in an urban environment that can take on different roles, such as citizens, visitors, or police. Numeric parameters can be used to control the behaviors of the agent [3].

Parameters can change independently the behavior of a specific agent (e.g., walking speed, memory, decision rules, etc.). The entire set of parameters can be defined as follows:

1. Perception: the agents can sense their environment and other agents in their vicinity.
2. Performance: the agents have a number of things that may carry and often include movement, communication, and action.
3. Memory: agents can record their perceptions of states and previous actions.
4. Politics: agents operate using a set of rules.

You can combine these parameters and create three types of agents: (1) police, (2) citizen, and (3) visitor setting the following parametric qualities—age (small children, adults, seniors), sex (male and female), and personality (bold or fearful).

Space and Environmental Module (SEM) The environment is part of the space and environmental module (SEM) and simulates where an agent is located and typically also includes simulated physical elements and other agents. In SEM, there are two kinds of threats: gas and bombs. The bomb explosion is unidirectional, where the gas explosion can be affected by the wind and therefore the affected area will be an ellipse in shape with respect to a circular shape. You can create an elliptical shape of the plume with different urban environments in 3D (*visualization* *module*, *VM*) and put some terrorist attacks (such as bombs or toxic gases) into specific locations and timelines.

Generation Module Events (EGMs) In the event generation module (EGM), the user can create multiple real-time events while simulation is running or creating multiple timed events.

To study the potential of the program and to demonstrate its applicability to real problems, some scholars such as Herbert H. Tsang, Andrei J. Park, and others performed a series of simulations. Through these simulations, various evacuation strategies were examined and demonstrated the effectiveness of GENIUS as a tool to study such behaviors.

The first simulation is an evacuation scenario where 30 citizen agents are placed in a confined building where there are only 4 exits available. A bomb bursts inside the building, and we expect our citizen agents to find evacuation routes.

The explosion of a bomb was simulated with a realistic display of people's behaviors that were animated in real time, and it shows the configuration of the building and the agents. When the bomb exploded, people tried to escape the building. However, many of them were unable to get out, and there are still ten people inside the building at the end of the program execution.

In the second simulation, four rescue teams have been added near the outputs in the same scenario. After the bomb exploded, about 93% of agents escaped. In the end, all civil servants leave the building.

Another simulation scenario concerns a Vancouver center environment during the 2010 Winter Olympic Games, and it is assumed that there are 59 people in the square where opening and closing ceremonies are held. The outbreak of a toxic gas canister is expected to spread south.

The first experiment has the setting showing the top view of the area, and the agents were placed inside the square. In this case, there were still half of the people who could not escape the dangerous area.

In the second experiment, six rescue workers were placed in strategic locations in anticipation of terrorist attacks. When toxic gas spreads, these people begin to drive people out. Although another bomb exploded, rescuers helped gather people out of the dangerous area.

When comparing the results, there is a significant difference in the escape speed. Almost 80% of the population can be rescued during the initial critical crisis period when rescue workers were in strategic locations. However, only 56% managed to escape in the absence of rescue personnel.

The third experiment investigates the effect of the number of rescue personnel. Only 25% of agents managed to escape when two rescue personnel were present, compared to 40% in the case of six rescue workers.

4 EMCAPS: Development and Application of Computer Modeling to Selected National Planning Scenarios for High-Consequence Events

The US health system must be able to cope with incidents involving many victims, and the National Security Department has prepared 15 incident scenarios which describe medical and logistic effects [4]. Then EMCAPS developers chose the nine most significant scenarios, and they were developed in Excel. Algorithms and formulas were converted into C ++ language, and the new program is compatible with any Windows-based system. All references, assumptions, conditions, and calculations for each scenario are described in the hyperlink sections "Calculation Method" and "Scaling" in the EMCAPS tool itself, allowing the user to perform an independent validation and make changes as desired.

One of these scenarios is an accident involving a tank carrying hydrogen chloride gas that, following a bomb, spreads a toxic chlorine cloud and was published just by the National Security Department.

The basic assumptions embedded in EMCAPS for this scenario are as follows:

- 4850-gallon tank, all contents released through a 3-foot hole.
- Fifty percent of people in the plume area are inside the home.
- First effects on humans with a concentration of 10 ppm.
- Minimum lethal dose = 430 ppm for 30 minutes.
- Lethal dose (short-term exposure) = 1000 ppm.

The input data is the geographic location, wind speed, outdoor temperature, and population density. Population density is defined as the average number of people per square mile, assuming a homogeneous distribution within the localization of the event. EMCAPS provides a population density chart, based on US census data [5].

Among the limitations of the program are, among other things, the hypotheses and calculations that are the basis of incident scenarios, and the result is determined by exposure to the 1 hour toxic cloud.

Despite these limitations, EMCAPS provides randomness estimates for selected Department of Homeland Security scenarios based on inputs of user variables that have not previously been widely available. In particular, as a flexible and scalable, portable, and easily shared EMCAPS tool, it can help emergency planners better understand and prioritize promptness and response efforts based on their unique and localized situation. Additionally, generating a set of scenario output scripts, EMCAPS is specifically formatted to encourage discussion, exercises, and collaborative skills-based training as part of a general preparation planning process.

5 A Tool for Determining Sheltering Efficiency of Mechanically Ventilated Buildings Against Outdoor Hazardous Agents

To protect populations from harmful external agent emissions, it is possible to think about the implementation of public sanitation to be used in the event of war or terrorist act. Among the recommendations provided by the available guidelines are those that close doors and windows and turn on the radio for further instructions; the protection can be improved by air filtration and air conditioning.

The main factors influencing the efficiency of building protection against external toxic agents are the duration of the event and the infiltration of contaminants. The duration of the event depends on the source. Accidental accidents from tanks can be under control in a few hours, while in the case of disasters such as those of the nuclear power plants in Fukushima and Chernobyl, the main release of radioactive substances has continued for several days.

The infiltration rate of contaminants from the outside inside depends on both the construction and the characteristics of the toxic material and is particularly dangerous for gases with high vapor pressure.

A key parameter in the penetration of external pollution is the exchange of air between indoor and outdoor environments; several studies have been conducted to estimate infiltration and the rate of natural ventilation [6].

Experimental studies have also been carried out on the effect of the type of ventilation on the levels of indoor air pollutants. Irga and Torpy [7] measured indoor concentrations of different contaminants in 11 different office environments in Sydney for a year and found correlation with the type of ventilation and level of contaminants. Pollutant levels, including particles, were generally lower for buildings with mechanical ventilation.

Chen [8] examined particle concentrations inside and outside in a typical mechanically ventilated office building during and after Singapore's haze and found a clear relationship between the ventilation system's features and the I/O ratio of particles in the range of 0.3–1 mm. Ward [9] concluded that a representative air purifier in a typical US home would reduce the internal concentration of particulate contaminants from the outside from 40 to 60% in the 0.1–2 mm range. Several models have been developed to calculate the efficiency of building shelters.

A significant fraction of radio nuclides released by nuclear accidents are in the form of radioactive particles. Measurements showed that after the Fukushima incident, the air contained radioactive particles with a mean aerodynamic average activity (AMAD) ranging from 0.25 to 0.71 mm for 137 Cs, from 0.17 to 0.69 mm for 134 Cs, and from 0.30 to 0.53 mm for 131 I [10].

The key factors influencing predicted dose estimation are the concentration and duration of toxic clouds in a given location and the penetration of contaminants from the inside to outdoors. The anticipation of release times is difficult due to the wide range of potential accidents, and the duration of a release may vary from less than one to several days.

Although several models have been developed for the calculation of internal contamination levels due to external pollutants, there are still considerable uncertainties in the results of the analysis due to the uncertainties associated with the key parameters. The accurate determination of indoor/outdoor concentration ratios is difficult due to the temporal variations in levels of external pollutants and also due to internal sources. The purpose [11] is to develop an internal contamination model for a mechanically ventilated building and present an experimental measurement system. The efficiency of the mechanical ventilation system depends on several factors such as the toxicity characteristics, the mechanical ventilation rate, and the infiltration of outdoor air into the buildings. A simplified model scheme used in this study is that external contaminants enter the building and are removed by ventilation, deposition, and filtration. There may also be recirculators of ambient air that capture contaminants when the air passes through the filtration system.

Assuming a complete mixing and uniform concentration within the building, the mass balance for the concentration of particular particles of contamination can be written as:

$$VdC = [q_{\mathrm{inf}}PC_{\mathrm{OA}}(t) + q_{\mathrm{s}}C_{\mathrm{OA}}(t)(1-E) + q_{\mathrm{E}}C(t) - q_{\mathrm{AC}}E_{\mathrm{AC}}C(t) - q_{\mathrm{EXF}}C(t) - \beta VC(t) + G] \times dT \tag{1}$$

where

V is the volume of the building (m^3)
$C_{\mathrm{OA}}(t)$ is the time-dependent external particle concentration ($1/\mathrm{dm}^3$)
$C(t)$ is the time-dependent concentration of the particle size ($1/\mathrm{dm}^3$)
Q_{INF} and q_{EXF} are the flow of infiltration and the flow of filtration
P is the penetration of contaminants through the building casing
Q_{S} and q_{A} are the mechanical ventilation and exhaust ventilation (m^3/s)
E is the efficiency of removing the air supply filter
Q_{AC} is the flow rate of the air filter
E_{AC} is the effective removal of the air filter for the specific contaminant
G is the rate of generation of internal contaminants

The term β in Eq. (1) can be evaluated by the rate of deposition on different surfaces.

If the mechanical and exhaust ventilation flows are balanced ($q_{\mathrm{VS}} = q_{\mathrm{VE}}$), the infiltration and exhalation rates are the same.

To solve Eq. (1), the model parameters must be determined. Some of them are available as building volume and mechanical ventilation rates, but there are also parameters that need to be measured or estimated. A key parameter is the external concentration, which usually varies during the day. After determining the necessary parameters, the equation can be resolved numerically.

6 Contamination of Buildings and Use of the GENIUS Program

The research identifies test methods and analytical procedures offered by computer programs to carry out studies and simulations in the field of protection. The purpose is to defend civilian buildings against threats due to CBRNe attacks and environmental accidents caused, for example, by road accidents. An experiment in the field involves the test procedures, being the not-normed method, and then it illustrates the results obtained. In our case, the result is expressed by a protection factor that allows to judge the effectiveness of protection under environmental conditions marked by wind pressure or temperatures between inside and outside.

However, in the case of accidents and terrorist attacks, it is also useful to simulate the behavior of the population with mathematical models. The aim is to understand the risks that must be faced based on the scenarios assumed. The GENIUS project refers to a class (ABM) of computational models that simulate the actions and interactions of autonomous agents with other agents and with the environment. In particular, the program is used to study the exodus of people from various types of buildings to verify both the timing and the effectiveness of emergency plans. The characteristics of the behavior of the crowd are modeled on the results of research in social sciences and experiments on the virtual environment with real human participants. These computational and mathematical methods offer new approaches and tools to study the risks associated with CBRNe terrorist attacks and to provide appropriate responses.

7 Conclusions

The performance of computing and mathematical models presented has been validated in field experiments conducted in different research and study locations. In particular, experimental determination of the key parameters in the various models is required, and these tools can be generally useful to emergency management authorities to provide quantitative knowledge to support their decisions when public protection measures are foreseen.

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Sampling and Analytical Biological Screening on Letters and Parcels by the Italian Department of Firefighters Public Rescue and Civil Defense National Fire Corps: The Experience of CBRN Advanced Team of Venice for the Realization of Standard Procedures

Salvatore Minghetti, Francesco Pilo, and Giovanni Battista Bolzon

1 Introduction

The Italian Fire Department has the obligation of intervention and first response in case of intentional or unintentional release of suspected biological aggressive organisms and substances potentially dangerous for the public health and safety.[1] It is therefore equipped with biological laboratories and scientific tools for the first analytical response in order to exclude the presence of some dangerous pathogens such as *Bacillus anthracis*, *Brucella* spp., *Francisella tularensis*, *Yersinia pestis*, and variola major, also stipulating agreements with other public institution's laboratories to integrate the results with other analytical techniques and studying new methods for the detection of viruses, biological toxins, toxins from aquatic microorganisms, fungi, and fungal spores, especially for those listed in "A" category[2] (extremely dangerous) by CDC (Centers for Disease Control and Prevention) of Atlanta, Georgia, USA, in samples consisting of mail, packets, parcels, and envelopes.

The experience gained in the last 16 years revealed recurring critical issues.

It's interesting that the majority of the samples (letters and packs with inside unknown and suspicious powders or liquids) come from the postal network. It happens when operators, employees, or the recipient comes in contact with the

[1] Ref. Legge 13 maggio 1961 n. 469–Decreto LGS 300/1999–Circ. Min. Interno n.6 del 22/05/2002.
[2] Ref. CDC site: http://www.cdc.gov/agent/agentlist-category.asp, 03.31.2010.

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Table 1 Main measures and characteristics of the mobile biological laboratory of the advanced CBRN team of Venice

Length	m 6.60 (20 ft)
Width	m 2.44
Weight	Kg 5580
Biosecurity level	BSL 3
Year of construction	2007
Purposes	Handling, storage, and rapid and safe biological analysis of extremely dangerous pathogens even in difficult environmental situations

substance, determining a series of no less important problems than those of sampling and analysis.

Also fundamental are the relationships with other involved public institutions such as the postal service, the healthcare service, the police, and the judiciary, for a better coordination in the mutual respect of competencies, even for a proper conduct of the investigations that often, as we will see later, involve substances that are not the direct object of our research, such as food substances, GMOs (genetically modified organisms), drugs, and pharmaceutical substances not allowed on the Italian territory as well as explosives.

The postal monitoring is a worldwide emerging problem that is getting worse with the e-commerce emergence and spread (in the last 4 years, 80% of the biological interventions performed by CBRN advanced team of Venice were samples retrieved in national postal service sites).

Describing our experience is not for the intention to provide solutions but only suggest useful ideas to share with other public and private institutions involved, also in terms of proper implementation of common operating procedures.

Before developing the subject matter of this work, we briefly describe a list of structures, scientific instruments, and procedures that we currently use to deal with such emergencies (Table 1).

2 Materials and Methods [1–14]

2.1 The Biological Mobile Lab

In 2007, for the operator's safety and the correct sample manipulation and analysis, the CBRN advanced team of Venice designed and built a fully equipped BSL3 mobile biological laboratory (Fig. 1).

Fig. 1 Images 1–4. The mobile laboratory of the advanced CBRN team of Venice

Fig. 2 Images 5–7. Postal mechanographic center views and details

2.2 Procedures and Scientific Instruments

The procedure includes the samples' collection, proper packaging, and transportation to the lab and there the proper division, sterilization, and analysis.

The location of samples is often a postal office or a mechanographic mail center. The postal samples consist of mail packets, parcels, and envelopes.

The main problems are derived from the shape, dimensions, and the quantity of samples, from the scarce or partial preparedness of the postal service's operators, and from the lack of devices suitable for the management of the problem posed by Italian postal service.

Transportation of the samples to the laboratory is made with preventive triple packaging of the sample that involves the decontamination of each container before being introduced into the next one and the proper labelling of all three containers (Fig. 2).

The procedure include the sample's collecting, the sample's proper packaging and transportation to the lab and there the proper divide, sterilization and analysis.

For best response we have provided, in our biological laboratory, a three-step analysis that includes immunological, biomolecular, and microbiological analytical tests (Fig. 3).

For the first step, for a rapid parallel testing of samples for pathogenic microorganisms and biological toxins, we employ specific immunological based tests (bio-strips) to have a first, not conclusive response. The time for the first response is 20 minutes.

Fig. 3 Images 8–12. Sample processing and division (8–10) and onboard operators at work (11–12)

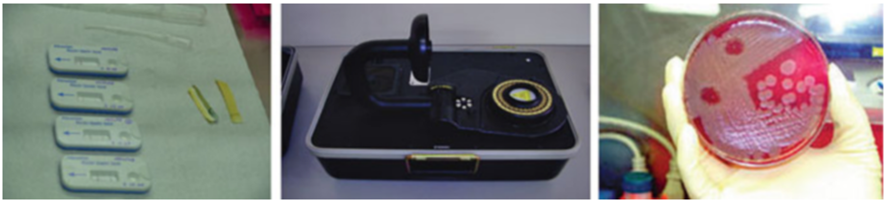

Fig. 4 Images 13–15. Immunological-based (bio-strips) devices (13), biomolecular based (RT-PCR) portable instrument (14), microbiological bacterial culture (15)

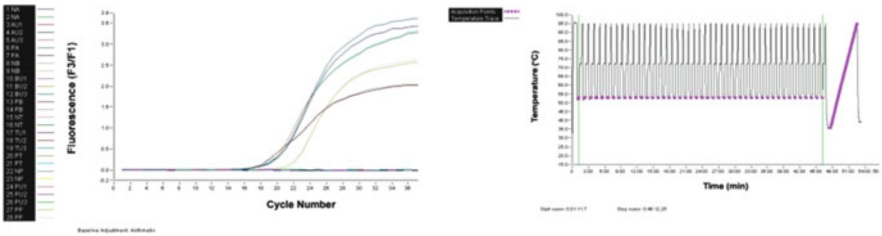

Fig. 5 Images 16–17. RT-PCR graph of amplification cycles (16). RT-PCR amplification cycles (17)

The second step is a conclusive laboratory response with a biomolecular analysis based upon the research with a rapid and very accurate technique named RT-PCR (real-time polymerase chain reaction) that provides an accuracy level of 99 %, to exclude the presence of some dangerous microorganisms (US-CDC high-priority bioterrorism agents—"A" category). This technique works well also with sterilized samples. The time for the second conclusive response is about 45 minutes (Fig. 4).

The third step consists of the confirmation response by the Zooprophylactic Institute of Padua Diagnostic Laboratory (with microbiological cultural essays); the third response takes 48 hours.

The complete test cycle in firefighter biological laboratory takes a total of 5 of 6 hours from the time the sample was received, until the second analytical result, and also includes autoclave sterilization times (approximately 2 hours) (Fig. 5).

Fig. 6 Images 18–20. Envelope samples (19) and threatening notes (18–20)

3 Results

Since 2001, the biological laboratory of the advanced CBRN team of Venice conducts about 12 interventions per year. The results of the analysis have always been of negativity (no presence of the researched targets), except in some cases described below.

3.1 A Case of Positivity

In 2016 we had several cases of positivity in microbiological analysis for *Bacillus cereus*, a not particularly dangerous agent but which was deliberately inserted in some letters addressed to the offices of a public authority. These bacteria, not being among the biological agents that we are required to look for, have been identified by Padua University labs, through our system of agreements and cooperation with other research institutions (Fig. 6).

4 Discussion

1. It is really important to identify those situations where operations of sampling and analysis (environmental samples, food, drugs, no evidence of threat) are not necessary. As a matter of fact, it is not always that there is a direct threat, but in some cases we detect the mere presence of dust or suspected substances of various natures. It is also important to verify the inside of an envelope or the packet of a letter with wording containing threats that mention the presence of aggressive substances.
   In other cases, samples of environmental origin come to the lab, for which we have no obligation to perform any analysis.

The reason is to exclude any unnecessary economic expense and waste of time. It will also be important for the public and private institutions involved, such as the postal service, to have suitable chemical, biologic, radiometric, and explosive-detecting instruments for the first check. This is also in order to reduce the amount of samples to process by the firefighter labs.

2. Explosiveness: it is very important, in the first place, to exclude the presence of an explosive device or substance and other threats (chemical, nuclear, or radiological threats).

   This is true especially in case of envelopes and packages essentially closed and from which suspicious substances like powders or liquids leak out.

   In probabilistic terms the threat with an explosive device is more concrete than any other. The record in fact shows the level of the current use of explosives in wars and in acts of terrorism, while the proven cases of the use of biological agents can be counted on the fingertips. In order to cope with this threat, it is advisable to have appropriate equipment and develop close cooperation with the army's bomb disposal experts (and other experts). In one of the interventions within a mail envelope, already verified with the detector at the mechanographic mail center and subsequently arrived at our laboratory, a considerable amount of gunpowder was found. This brings to light the system flaws that by taking the biological threat for granted, it does not consider any other possible threat.

   Also, a preventive and rapid screening with chemical and radiometric instruments would be very desirable in such cases.

3. Other problems are the sanitation and remediation of places; the personnel's decontamination; the transport, isolation, and the appropriate prophylaxis for the involved people; the presence in the operation area (red zone) of other public (healthcare service or police) or private operators without the proper safety equipment (DPI: individual protection devices); and, last but not least, the difficulty in maintaining the zoning of sampling sites, often not respected by the same security authorities (Fig. 7).

5 Conclusion

In the end, in order to fully achieve the purposes, what is strongly desirable is a better coordination of firefighters (first responders), police, healthcare service operators, and all the other public institutions involved and the study of the operational differences and similarities of the procedures applied by public and private authorities and institutions which will hopefully lead to establishing common operational plans that will enhance the competencies for emergency management in the field of public security involving suspect biological substances (Fig. 8).

Fig. 7 Image 21. Operator with personal protective device of maximum biological safety—with air bottle and integrated SCBA (1aET safety suit)

Fig. 8 The mobile labs during an on-field operation

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CDC website, Georgia, USA

CDC Centers for Disease Control and Prevention. Website: http://www.cdc.gov

BioFire Diagnostics (formerly Idaho Technology): RAZOR® EX. Website: http://www.biofiredx.com

BioFire Diagnostics (formerly Idaho Technology): R.A.P.I.D®. Website: http://www.biofiredx.com

Part VI
Training, Education and Communication

CBRN Innovation Lab: A Platform for Improving Risk Knowledge and Warning of CBRN Hazards in Abu Dhabi

Abdulla Al Hmoudi

1 Introduction

Early warning system (EWS) being one of the essential activities in the preparedness phase for any disruptive event is very important, though underemphasized [1, 2]. Among other preparedness activities such as training programs, mutual aid agreements, exercises, and resource inventories and management [1, 3], EWS require monitoring and good level of understanding of actions required for mitigating the impacts of hazards [4]. EWS often tend to be overlooked or inadequately conducted during the preparedness phase [5]. The limited attention to EWS often influences response arrangement and impact of hazards on the communities prone to hazards [6]. Past hazards and the impacts experienced have exposed the susceptibility of communities to hazard especially those without adequate EWS [5]. The concerns about hazards and safety can preoccupy people to the extent that fear overwhelm them to inaction [6], but this should not be to the neglect of basic EWS. Though such inaction has been linked to lack of public education, awareness and information [2], EWS can be used to improve level of awareness and education required for actions.

The negative impacts of hazards should be a strong basis for embarking on and investing in effective EWS [1]. But the role of emergency officers/agencies and the community in planning for response and the indicators for hazard EWS can be vague in many countries, the UAE inclusive [5, 7], which is why this paper aims to examine components of EWS. Thus, this paper examines concepts of EWS from literature to identify key elements of effective EWS. These elements are used to evaluate hazard knowledge in Abu Dhabi, while they also influence the use of innovation lab to increase knowledge level, educate emergency organizations and

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communities on impacts of hazards and clarify their roles in response to CBRN hazards.

2 Innovation Lab: Concepts and Application in the UAE

The UAE faces various sociotechnical challenges, one of which is the vagueness around EWS for communities and the role of communities and emergency organizations for implementing EWS. Community or residents in Abu Dhabi, for example, are unaware of emergency plans that stipulate their role and the procedures for EWS [6]. In addition, there is low knowledge of hazards and lack of education regarding EWS signals and receipt of EWS in the event of hazards [8]. The consequences of lack of end-to-end approach to preparedness in general can have implications for response procedures [6]. But lack of people-focused approach to preparedness especially EWS can be devastating both in the immediate and the long term in Abu Dhabi [9]. Undeniably, the presence of many non-Arabic-speaking expatriates further creates communication challenges and the need for careful consideration of EWS tool and public education that is presented in different languages [9].

The lack of understandable warning messages and lack of known established medium and preparedness information to those at risk continue to threaten safety of Abu Dhabi residents [10]. Lack of networking and communication among all stakeholders in the past as identified by Al Ameri has reinforced the relevance of using the innovation lab to generate ideas for brainstorming models that may be used to communicate risks of CBRN. Brainstorming ideas in the innovation lab has led to identifying solutions for CBRN response, and EWS have been created that may lead to more effective integration of technologies for EWS and response processes for CBRN hazards in Abu Dhabi [8]. The model created integrates monitoring and control measures for hazards and the means of creating community awareness around potential risks of CBRN in Abu Dhabi. The use of technology in this space has further enabled the use of modern detectors at the hazard sites and the control.

The model incorporates the four elements of effective EWS identified from the United Nations recommendations. The four elements of effective EWS are risk knowledge which include data collection and risk assessment, monitoring and warning, warning dissemination and communication and response capability [11]. Taking a clue from these elements, more comprehensive ideas were created in the innovation lab, which were then tested through semi-structured interviews and questionnaire.

3 Methods

Primary data were collected through qualitative and quantitative methods in the UAE. The qualitative data which focused on investigating the existing deployment of EWS and the role of innovation lab in improving knowledge of CRBN in the UAE involved series of semi-structured interview sessions with emergency organizations in Abu Dhabi. Eight people were interviewed in Abu Dhabi, who were asked a total of 11 questions. Each session lasted between 45 and 90 minutes depending on the level of engagement.

The survey focused on determining the risk knowledge level and perception of CBRN by people in Abu Dhabi. A random sampling technique was used to determine number of participants to administer to [12]. Paper questionnaire was used in order to encourage wide participation of people living, working and conducting business activities within the proximity of potential CBRN hazard. Through this method, a total of 845 which is a sample size was decided. This was calculated using confidence level which is the percentage representation of the population that are likely to participate in a research [13].

The questionnaire was designed to have 25 questions grouped into 4 main sections based on 4 interrelated elements or themes for effective EWS. Due to vast numbers of foreigners in Abu Dhabi, the questionnaire was designed in both English and Arabic and were collected after 5 days of drop-off at homes, business offices, commercial centres such as malls, stations, community centres, schools and staffs of hotels and other public ministries and organizations.

3.1 Data Analysis

The interview data was analysed using NVivo 10 software and categorized according to the elements of effective EWS. The questionnaire data was analysed using SPSS, which allowed descriptive and inferential statistics to be conducted on the primary data collected [14]. By using SPSS software version 16, the important data from community at risk were generated to determine the level of risk knowledge and the potential impacts of EWS and concepts developed in the innovation lab. Through this process, data were generated which helped to develop the framework for effective EWS that can help to mitigate the impacts of CBRN hazards in the UAE more effectively.

4 Results and Discussion

The result revealed that risk knowledge of CBRN hazard is low among the community, while community or members of the public believed hazard monitoring and warning ought to be conducted by the police and disseminated using the media or mobile phones through SMS. The result also revealed that the community is unaware that the police run exercises and are trained to respond to CBRN hazards. A further examination of this finding also indicates that the community believes they should be involved in exercises run by the police to enable them to test hazard early warning and evacuation process. For instance, 48% of the participants revealed that participating in exercises of this nature will help to improve awareness and knowledge of CBRN risks, as well as build confidence in taking actions when required. The semi-structured interview with managers in emergency organizations revealed the innovation lab can be used to increase risk knowledge level of officers. Though views vary on which organization should lead the EWS for CBRN hazard, all managers interviewed emphasized that several multicultural mediums should be used to disseminate warning for CBRN hazards to Abu Dhabi community. Results from the interview indicate that response capabilities of emergency organizations vary. Only the civil defence confirmed that they have sufficient capability to respond to CBRN hazards. However, ADP confirms their ability to use innovation lab to create effective EWS model that may be used to improve knowledge of CBRN risks and warning that may help to preserve lives of people living in Abu Dhabi.

4.1 Discussion

The pattern of results generated in this research shows that improvement is needed in the areas of risk knowledge, monitoring and dissemination of warning regarding CBRN hazards. While the interview results on risk knowledge reveal the limited understanding of EWS in Abu Dhabi, the entire results reveal that any preparedness activities fail to involve the community. The practice of EWS in the UAE and response lacks the four interrelated elements of EWS identified in literature. Though a structured process exists for communicating warning between organizations, it lacks involvement of the community. Such communication suggests horizontal communication process which is limited for disseminating warning messages for any hazard [15]. The results show that there is no effective EWS in Abu Dhabi since the four elements are not sufficiently identified through the survey nor explained by the managers during any of the interview sessions. Thus, the results were subjected to further brainstorming sessions in the innovation lab, from which the EWS model in Fig. 1 is generated.

The EWS model shows that multicultural public education is strongly advised and registered as important component of any EWS in Abu Dhabi. This recommendation considers the high population of expatriates and other foreign nationals

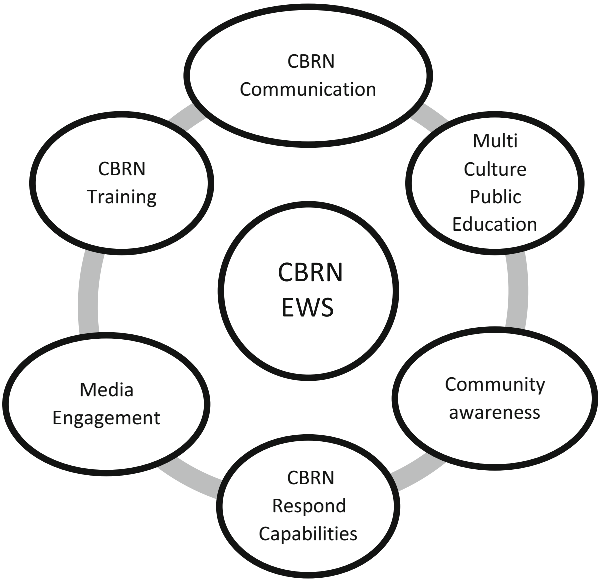

Fig. 1 EWS model generated from UAE innovation lab

residing and trading in the city. In addition to this, community awareness is added in addition to community participation, media engagement and CBRN training and communication. It is decided in the innovation lab that these elements will enhance response capabilities and the overall early warning systems for CBRN hazards in Abu Dhabi.

5 Conclusions

The four elements of effective EWS derived from the UN were instrumental in determining the scope and minimum requirements for EWS in Abu Dhabi. The results however reveal that improvement is required in Abu Dhabi, through which the innovation lab provided the platform for ADP officers to embark on a brainstorming session and investigation that involved the communities at risk. While this combined method of inquiry is unprecedented in Abu Dhabi and by ADP, it has emphasized the importance of the innovation lab and its role in enhancing knowledge and in creating ideas that can lead to improvement of systems, procedures and preparedness for CBRN hazards in Abu Dhabi and in UAE as a whole. Though the innovation lab was not popular prior to this investigation, its role in helping officers to brainstorm and create ideas has pushed the lab to the forefront in ADP. Evidence-based outcomes such as presented in this paper make the innovation lab an essential tool for improving preparedness level and capabilities for responding to CBRN hazards.

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Definition of a Model to Perform and Evaluate Training Activities on External Emergency Plans of the "Seveso III" Industries

Salvatore Corrao, Luigi Capobianco, Roberto Emmanuele, Andrea Malizia, Orlando Cenciarelli, Mariachiara Carestia, Daniele Di Giovanni, and Pasquale Gaudio

1 Introduction

The Department of Firefighters, Public Rescue and Civil Defence has been cooperating with the University of Rome Tor Vergata since 2009, as part of the activities of the 1st- and 2nd-level International Masters in "Protection Against CBRNe Events" for educational and scientific purposes. The training process of the masters provides that, for the verification of the knowledge acquired during the course, the roles that the individual stakeholder assumes during the management of a conventional and nonconventional emergency are exercised. The model of these exercises for command posts is well-known as the tabletop exercise (TTX). The work carried out over the years with the master courses has allowed an organic and functional development for all the parties, based on NBCR civil defence scenarios, (dirty bomb, attack, or industrial accident involving dangerous substances). To

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analyse the results of these exercises and to allow (where necessary) an improvement in the performances of the participants in the TTXs proposed, researchers from Tor Vergata developed an IT tool called GATE (Gap Analysis for TTX Evaluation). This application, usable through Excel, is aimed at identifying the strengths and possible shortcomings of the decisions taken by the participants in a TTX exercise, in order to evaluate the suitability of the answers provided by them, with reference to one or more hypothesized incidental scenarios.

The aim of this work is to demonstrate the applicability of the software to the exercises for command posts, whose reference scenarios, roles and functions are defined in the external emergency plans in industrial plants categorized as "at risk of a major accident" by the Seveso III Directive.

2 The EU Regulation 428/2009 External Emergency Planning in Plant at Risk of Major Accident (Directive 2012/18/EU or "Seveso III" Directive)

The Directive 2012/18/EU—Seveso III on the control of major accident hazards related to dangerous substances (implemented in Italy under Article 21 of Legislative Decree 105/2015), regarding the obligations and procedures envisaged for the preparation of external emergency plans (in Italian "PEE—Piani di Emergenza Esterna") establishes:

- The obligation to prepare an external emergency plan for all establishments covered by the legislation in question
- The competence of the prefect in the preparation of the plan
- The obligation to consult the population before its adoption

With respect to the previous legislation, there is the possibility of not preparing the plan is envisaged if effects outside the establishment of major accidents are not reasonably foreseeable.

Another fundamental point is the review, updating and testing of the plans: here too, the choice at European level was to maintain a 3-year time frame for these obligations. The fulfilment of this provision is rather demanding: in this regard in 2014, a working group, made up of representatives of all the administrations and bodies involved in the "management of Seveso activities" (Department VVF, Min. Environment, ISPRA, ARPA, Civil Protection Dept., etc.), conducted an analysis of the state of implementation of PEE in plants at risk of major accidents. From this analysis, in addition to some critical issues related to the contents of the plans themselves (e.g. the plan often appears to be excessively articulated or detailed or not calibrated on the real capabilities of the support authorities or on the actual possibilities of the communication and alarm systems), it emerged clearly that testing PEEs is a critical element, not easy to implement, while being aware that the latter is the most appropriate instrument, in "peacetime", able to test and improve the general contents, the mechanisms of alerting and communication and the operational procedures of the plans themselves. In this regard, real-scale exercises would be the most effective means of assessing all aspects of emergency planning, for example, problems related to the overall dynamics of the scenario or to the impact on the population would emerge only as a result of such exercises. However, the increasing shortage of funds and human resources and the organizational complexity, together with the large number of industrial plants subject to Legislative Decree 105/2015 (more than 1000 in Italy), do not allow the possibility of carrying out exercises of this type for all the plants, hence the need to decrease the costs and the complexity of the exercises and such as those for command posts.

3 Tabletop Exercises

Tabletop exercise (TTX) are a particular type of exercises included within the wider category of emergency management exercise [1–3]. The TTX, exercises for command posts, are based on the fact that the stakeholders, each with their own role, have to face a hypothetical scenario, taking into account their role and function and the established response plan to this scenario. This type of exercise is used to evaluate the plans and procedures provided for the management of the emergency cycle (prediction, preparation, over/recovery response).

During a TTX, the involved operators gather in a predefined environment to discuss and deal with simulated situations. Typically, a TTX involves representatives from all agencies and administrations, who would come into action in all emergency situations or in response to emergencies for which specific planning exists. The management model for a command postexercise is presented below (Fig. 1):

TTXs are characterized by predetermined and clearly defined objectives, including the criteria used to quantify their success [5]. They are then selected by the organizers of the exercise, of the evaluators, equipped with an adequate range of skills. A TTX can be aimed at revising the data contained in the plan (e.g. telephone numbers), up to the redefinition of roles and responsibilities and also approaches to emergency management.

4 The Software "GATE"

GATE ("Gap Analysis for the TTX Evaluation") is an IT tool developed in the context of the international CBRNe master courses to assess the ability of master students in managing CBRNe events during training activities [6].

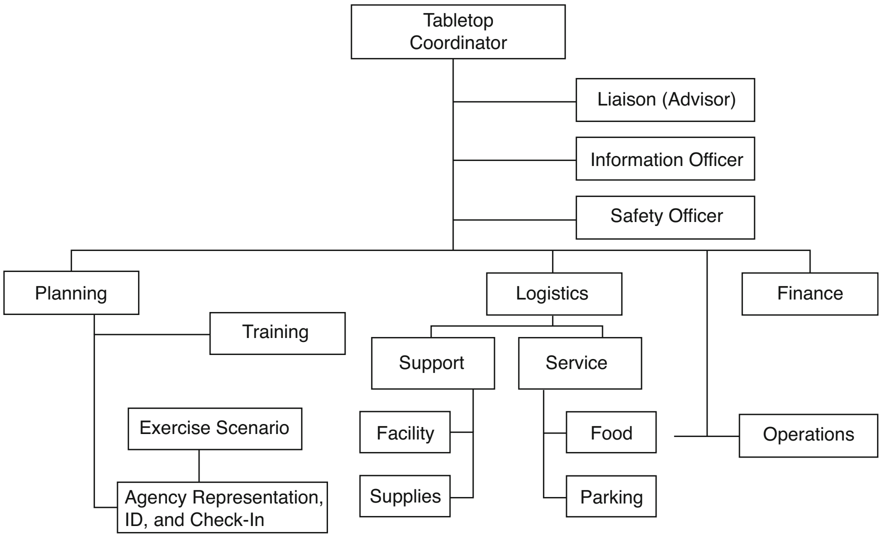

Fig. 1 Command and management structure of a TTX [4]

GATE tool allows:

- A more efficient and systematic collection and storage of the data of the exercises
- A quantitative treatment of the data at its disposal, developing, for example, statistical processing
- A "cold" analysis of the exercise

The software is designed to guarantee maximum flexibility of use. This feature makes it suitable for evaluating a wide range of exercises, organized, for example, for staff training and so on.

Developed as a collection of Excel spreadsheets, GATE allows to acquire, analyse and process information related to [7, 8]:

(a) Preparation and management of the exercise/training event ("Check" sheet)
(b) Organization and architecture of the exercise/training event ("Info" sheet)
(c) Previous competences and knowledge of the participants ("players info" sheet)
(d) Management of working groups ("players info" sheet)
(e) Proposed solicitations ("injects") and answers given to them (multi-sheet "inject x")
(f) Final summary and cumulative evaluation of the responses of the players to the solicitations ("Results" sheet)

The final evaluation is based on the relationship between the average of the evaluations of the responses to the inject, pure or weighted by the time factor, and the factors of expertise of the team, pure or weighted for the level of knowledge. The method is very versatile and adaptable to different contexts, allowing to modify the characteristics of the training exercise/event considered.

The developed method allows to:

- Assess the skills of the individual players and the entire team as a whole, providing expertise factors for each area of interest, based on the background and level of knowledge of the participants and based on curriculum or previously administered questionnaires.
- Obtain an evaluation of the responses to the solicitations, and provide an overall assessment of the answers belonging to the same area of interest, considering the influence of the team's skills and of the reaction time on the quality of the response.
- Identify the "gap" between the response given to a specific and the expected stress, assigning a numerical estimate that can be converted into a qualitative assessment, on the basis of appropriately set numerical ranges.

5 A TTX Diagram for an External Emergency Plan and Adaptation of "GATE"

In this section we propose a first TTX model to be carried out (in Italy as indicated in the DPCM 25.02.2005) as a test for level c exercises, referring to an external emergency plan taken as a reference. To effectively deal with rescue interventions in industrial plants at risk of a major accident and the coordination of assistance, the competent Prefect for the territory could develop specific TTX for each individual company falling within the province of competence and for which he developed appropriate planning. The execution of a tabletop may require the convening of the Local Coordination Assistance Center (that in Italy is represented by the "CCS—Centro di Coordinamento Soccorsi") and of the manager. The members of the CCS are the recipients of the training, while the injects (events that must determine a series of actions by the subjects of the CCS) are provided by the top events presented in the plan.

TTX Structure
Step 1—The request for intervention (simulated) can be done either by phone or through an alarm communication, which arrives at the Prefecture. In this communication of intervention the manager will refer to a graduated scale of danger levels:

- Yellow code (attention)—Events that, although lacking any repercussions on the outside of the establishment, can be felt by the population giving rise to alarm or concern
- Orange code (warning)—Events of limited extension: referable to accidents caused by toxic and/or energy releases having a limited impact within the area of establishment
- Red code (alarm)—Extended events: events related to accidents caused by toxic and/or energy releases having a potential impact outside the plant area

Step 2—The Prefecture will transfer the news to the other institutions and structures involved (simulation) through the procedures set out in the emergency plan itself. Events that fall into the type of Warning (yellow code) do not activate the PEE. In this case, the intervention seems to be ordinary; the rescue units deemed necessary are also sent to allow the management of any panic situations.

Step 3—For interventions that fall within the red or orange classification, the prefecture activates the plan (in the simulation), effectively convenes the CCS and brings it together. Within the CCS the plan is examined and defined, based on the communications received from the plant manager:

- *First area of safe impact* contained within the deposit
- *Second damage zone* contained within the deposit
- *Third zone of attention* having the extension within which there are no residential settlements

TTX Solicitations

As part of the definition of the model, for each entity involved (plant manager, prefect, Provincial Fire Brigade, Mayor, Local Police, Police Headquarters, Local Health Authority, Health Emergency Service, Regional Agency for environmental protection, regional civil protection agencies, voluntary representatives and port authorities) of the checklists containing the actions "to be carried out" according to the plan. Below has been reported the one relating to the mayor actions (Table 1).

Given the series of injects generated for the development of the scenario, it would be already possible to fill in a checklist, answering the question "action carried out", "action not taken" and have a first measure of the correspondence of the actions carried out compared to those provided for in the plan. This first basic evaluation could be added to that of GATE. The informative content of an exercise often remains imprisoned in the large amount of paper documents produced at that time. Using GATE it would be possible to deepen the evaluation of the TTX and of the

Table 1 List of action to be carried out by the mayor

Inject	Role: Major	Action carried out	Action not taken
Accident	Activate the municipal structures of prot. (Civ. Local Police, Technical Office, Volunteering, etc.)	Yes/No	Yes/No
	Inform the population about the accident and communicate the protective measures to reduce the consequences	Yes/No	Yes/No
	Implement the actions under the operational plan for traffic and assisted evacuation	Yes/No	Yes/No
	Establishes the use of the areas of hospitalization identified for the eventual evacuation	Yes/No	Yes/No
	Adopts ordinances for the protection of public safety	Yes/No	Yes/No
	It follows the evolution of the situation and informs the population of the revocation of the state of emergency	Yes/No	Yes/No
	If the emergency is over, it works to restore normal conditions	Yes/No	Yes/No

actions taken, having the further advantage of being able to take into account the effect of additional actions taken by the players. It is in fact possible that the appearance of variables that cannot be planned a priori (e.g. the insertion of inject that suddenly alters the course of events) leads players to make different or additional decisions with respect to those provided by the plan, creating a moment of reflection on the implementation of the plan itself. It would also be possible to evaluate the time factor with which the responses follow the solicitations, obtaining information about the readiness with which the players implement the various phases of the plan and, possibly, the presence of factors that make it difficult to act according to the established time schedule (if present).

6 Conclusions

The current regulations establish the obligation of the Prefectures to test external emergency plans through exercises; over time it has become clear how difficult it is to cope with this commitment, which is also considered essential for a correct management of the emergency. In Italy, the Prime Ministerial Decree of 25 February 2005 has already provided general indications both in terms of the contents of the emergency plans and as regards the exercises, dividing them into three categories. The increasing lack of funds and human resources and the organizational complexity, together with the large number of industrial plants subject to Legislative Decree 105/2015, do not actually allow the possibility of carrying out exercises on a real scale for all establishments subject to the directive “Seveso III”, hence the need to orientate more and more towards exercises of lower cost and organizational complexity such as those for command posts (TTX).

The purpose of this article is to provide an example of a structure of such an exercise and to suggest the use of an easy and economic tool (GATE) to test the response capacities of the institutions responsible for the emergency during an exercise.

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A Framework for TTX Specification and Evaluation

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1 Introduction

A *tabletop exercise (TTX)* involves key emergency response personnel to discuss a simulated or imaginary emergency situation. Participants are typically tasked to review and discuss the proper exchange of information and the related actions they would take while dealing with the emergency.

As an exercise designed for analyzing relevant information and making key decisions, TTXs are often used to clarify roles and responsibilities. Furthermore, TTXs provide support to identify additional actions for threat mitigation.

Moreover, this approach is an effective test for emergency risk communication plans in an informal, low-stress environment.

In addition, the exercise should result in action plans for the continual improvement of the emergency plan. In order to deal with the activities of TTX data collection and analysis, a gap analysis tool has been developed to enable the comparison between the actual performances and the expected ones: the *GATE*

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tool [1]. Developed in *visual basic language* and consisting of several *Excel spreadsheets*, the aforementioned tool is a first significant step toward the direction of giving the *evaluator* (i.e., who has the responsibility of analyzing the TTX results) a valid support for collecting and analyzing data.

However, since it is bound to a specific technology, and due to the limited expressive power of spreadsheets, the aforementioned tool still leaves great room of improvement in terms of modularity, usability, flexibility, and customizability.

To overcome these limitations, a software engineering approach is needed to develop a structured and well-engineered software system to implement the GATE tool, which enables the specification, evaluation, and analysis of TTX in a more efficient and effective fashion.

The main contribution of this paper is the analysis and the design of a software system implementing all the functional requirements satisfied by the GATE tool. Furthermore, a model-driven simulation-based framework for TTX analysis and training is introduced.

This contribution places its basis on previous efforts in different directions: the development of the GATE tool [1] and model-driven frameworks to generate executable code from business process models by use of automated model transformations [2–6].

The remainder of this paper is structured as follows: Sect. 2 provides a brief overview of the GATE tool and an adequate technical background. Section 3 introduces the proposed software system for supporting TTXs; Sect. 4 introduces the proposed model-driven framework for the TTX simulation and analysis; and finally, Sect. 5 outlines the conclusions.

2 Background

2.1 GATE: Gap Analysis for TTX Evaluation

While there are no uncertainties about the usefulness of TTX, one of the issues often discussed by practitioners and experts is that the amount of data which can be collected and elaborated after an exercise is somehow smaller, when compared to all the information exchanged and actions performed during the exercise. To some extent, this results in a reduced possibility to identify lessons learned and feedbacks which can be elaborated after the end of a TTX. Moreover, it is desirable to support qualitative evaluations with quantitative results.

GATE has been developed to support TTX evaluators to perform a gap analysis (the comparison of the actual performance with the expected one), in order to reveal areas that can be improved. Since the "gap" is defined as "the space between where we are and where we want to be," the gap analysis provides a tool to bridging that space. Gap analysis involves determining, documenting, and approving the variance between the optimal requirements and current capabilities and can be performed at the strategic or operational level of an organization. GAP can be used as a ranking of *good*, *average*, or *poor*, taking into account that the gap could be positive (above the expected position) or negative (below the expected position). On the basis of these considerations, a gap analysis tool could represent a very useful and functional instrument in the context of emergency management exercises in the safety and security fields, allowing to provide an impartial evaluation of the arranged trainings.

GATE has been originally designed and customized for the evaluation of CBRNe TTXs, which, to some extent, represent the "worst-case scenario" for a TTX gap analysis, as the unpredictability of the release of chemical, biological, and radiological agents and the complexity of the subsequent events make it more difficult to evaluate the performance of the players, as, most of the time, there is no single right answer to a set of solicitations [1]. The tool is designed to gather homogeneous information about (1) TTX preparation and management, (2) TTX organization and structure, (3) players' knowledge and skills useful to accomplish the exercise (which allows to weigh the results according to the level of expertise of the players), (4) solicitations and answers given for each step of the exercise and by multiple players, and (5) final and cumulative evaluation of players' replies to all proposed injects.

2.2 *Software System Modeling*

By applying the principles of software engineering [7], the product to be developed is strictly structured as an engineering product, with a formal life cycle model that starts from the user requirement analysis and goes down to the release of the product itself, also managing the subsequent maintenance and adjustment phases.

The advantages of this approach allow us to overcome the limitations from the current version of the GATE tool, currently made up of Excel spreadsheets. In fact, in order to obtain a product that is as usable, modular, maintainable, and flexible as possible, one cannot fail to adopt an engineering approach to software creation.

This methodology uses a number of formalisms throughout the development process. In this paper, we focus on the main aspects to be described, involving the structural model and the behavioral model, respectively. In our case, we choose a model-based approach, using UML [8] and BPMN [9] formalisms, that will be discussed in the following.

A thorough discussion of the software development process is out of the scope of this contribution, which seeks to emphasize the importance of the first stages of the software engineering approach, the analysis of the requirements and the design of the abovementioned models, which are not bound to the implementation and underlying technology. The reader who is interested in a detailed discussion regarding the software engineering principles and the software development process is sent to [7, 10].

UML for the Structural Model *Unified modeling language (UML)* [8] is a standardized modeling language enabling developers to specify, visualize, construct, and

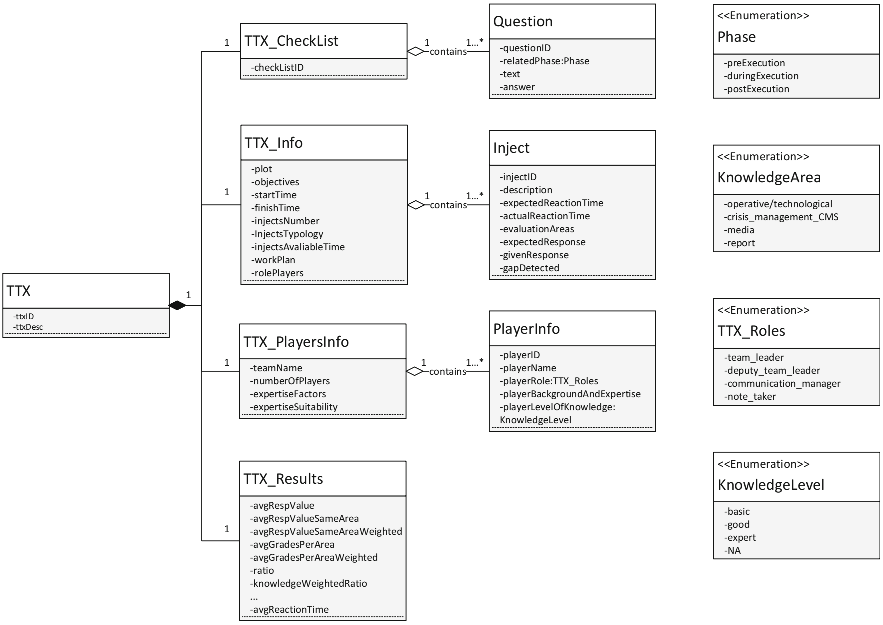

Fig. 1 Structural model of the proposed software system

document artifacts of a software system. UML diagrams represent static (structural) and dynamic (behavioral) views of a system model. The static view includes class diagrams and composite structure diagrams, which emphasize static structure of systems using objects, attributes, operations, and relations. Structure diagrams are used in documenting the architecture of software systems and are involved in the system being modeled. The structure diagram used to represent the proposed software system static view is the class diagram, as depicted in Fig. 1.

BPMN for the Behavioral Model *Business Process Model and Notation (BPMN)* [9] is considered as the de facto standard for graphical modeling of a business process (i.e., a collection of related, structured activities that serve a particular goal). Due to its expressive power and its capability of representing different interoperating sets of activities, BPMN can be effectively adopted to specify the behavioral model of a software system. In the case of a software system to support TTX exercises, a BPMN model can be easily specified to describe the set of tasks that are in charge of different roles and players, along with related expected performance attributes. In addition, it is possible to represent interactions with the command and operative center (COC), in the form of solicitations (injects) addressed to the players. In other words, the plot of a TTX can be represented by means of a BPMN collaboration diagram.

3 Overview of the Software System Implementing GATE

This section provides a high-level view of the proposed software system, with particular attention to the structural diagram, which specifies a modular structure that aims at capturing all present requirements and, through extensibility, also future ones. As for the static view, the model is composed by the following elements:

– *TTX class* is responsible for identifying a particular instance of a TTX by means of an ID and a brief description. A TTX class is a composition of four classes: *TTX CheckList*, *TTX Info*, *TTX PlayersInfo*, and *TTX Results*.
– *TTX CheckList class* is responsible for verifying the conformity to all the requirements for the evaluation process. A TTX CheckList class contains a set of one or more *Question*.
– *TTX Info class* is responsible for providing useful information to the evaluation process. Such information contains a plot and the objectives of the exercise, start and finishing time, details about the injects, and a description of the role players. A TTX Info contains a set of one or more *Inject*.
– *TTX PlayersInfo class* is responsible for the description of the team players, specifying the team name, number of players, and a player profile, expressed through attributes related to expertise factors and expertise suitability for the task. A TTX PlayersInfo class contains a set of one or more *Playerinfo*.
– *TTX Results class* is responsible for assembling the final data from the exercise, reporting different metrics as pure and time-weighted average values of the numerical evaluations assigned to each question. Takes into account the reaction time to reply to each inject, reporting the related average value.
– *Question class* represents a single question contained in the TTX CheckList class. A question is identified by a unique ID and is related to a specific phase of the exercise (i.e., pre-, during, and post-execution). This class also contains text attributes to store the actual question and the answer.
– *Inject class* is the key class in the proposed system which contains information related to each inject played in the exercise. An inject is uniquely identified by means of an ID and has attributes containing an inject description, expected and actual reaction times, expected and given responses, gap detected, and evaluation areas involved.
– *PlayersInfo class* represents a single player contained in the TTX PlayersInfo class, which in turn represents the team. A player is identified by a unique ID and a name and has an assigned role. This class also provides information related to the background and expertise as well as the knowledge level of each player.

The following enumerations allow to specify a collection of constants used in the aforementioned classes:

– *Phase Enumeration:* used to specify the phase of the TTX to which a particular question is related. Legal values are *preExecution*, *duringExecution*, and *postExecution*.

– *KnowledgeArea Enumeration:* used to specify the knowledge areas that are impacted by an inject. Legal values are *operativetechnological*, *crisis management CMS*, *media*, and *report*.
– *TTX Roles Enumeration:* used to specify the role of a player in the exercise. Legal values are *team leader*, *deputy team leader*, *communication manager*, and *notetaker*.
– *KnowledgeLevel Enumeration:* used to specify the level of knowledge of a player. Legal values are *basic*, *good*, *expert*, and *NA*.

As for the dynamic view (i.e., the behavioral model), it can be specified via BPMN, as introduced in Sect. 2. The main interaction pattern during a TTX is represented by a tightened succession of numerous solicitations (i.e., injects) sent to the players by a Command and Operative Center (COC). This requirement can be easily addressed by the BPMN information flow, specifying the exchange of messages among different players in a collaboration diagram, thus modeling the whole plot of the exercise.

4 Overview of the Model-Driven Framework for Enabling the Automated Generation of TTX Simulations

This section introduces the enabling concepts of a model-driven framework for delivering a simulation support to the TTX domain.

The proposed framework exploits the precepts introduced by model-driven development and MDA (model-driven architecture), which support the development of software systems through the transformation of abstract models to executable components and applications. MDA emphasizes the role of models as the primary artifacts of development by providing a set of guidelines for structuring specifications expressed as models and the *transformations* between them. The transformation maps the elements of a source model to the elements of a target model that is specified in terms of the same or of a different language [11].

The proposed model-driven framework for the simulation-based TTX analysis provides an effective support along the whole TTX development life cycle, from the TTX specification down to the TTX execution, monitoring, and evaluation.

The framework consists of the following steps, which go from the BPMN-based *TTX Plot* specification down to the execution of the TTX simulation code:

– *TTX Model Specification*: at this step the *TTX* is specified in terms of a standard BPMN model according to the specific scenario requirements.
– *TTX Model Annotation*: the abstract BPMN model obtained from the previous step is enhanced with textual annotations describing nonfunctional requirements of the *TTX*. Specifically, the performance properties, as well as the constraints in terms of relevant metrics, are specified (e.g., expected response times and

response accuracy/quality). The resulting model is referred to as the *TTX annotated model*.

- *Model-to-Model Transformation*: the transformation takes as input the *Annotated BPMN model* produced in the previous step and maps the BPMN annotations to the corresponding TTX elements, thus yielding as output the TTX Simulation model. Such transformation can be specified in QVT Operational Mappings [12], the standard language for the specification of *model-to-model* transformations, provided by the Object Management Group (OMG) as part of the MDA effort [11].
- *Model-to-Text Transformation*: this step is responsible for the generation of the simulation code. The *model-to-text* transformation takes as input the *TTX Simulation model* and yields as output the *Simulation Executable Code*. The *model-to-text* transformation can be specified in Acceleo [13], the standard language for the specification of *model-to-text* transformations, provided by OMG as part of the MDA effort [11].
- *Simulation Execution*: in this final step, the *Simulation Executable Code* is executed, and the *Performance Results* are obtained. The evaluator is thus enabled to use the feedback provided by such results and compare various alternatives. Indeed, a what-if analysis can be easily carried out by simply varying the nonfunctional parameters specified in the *TTX Model Annotation* step.

The last two steps of the method, i.e., obtaining the executable code corresponding to the TTX under study and executing the simulation code and evaluating the performance, are part of the *TTX analysis* activity. Such activity allows the evaluator to check whether or not the relevant requirements are met by the specified TTX and, in the negative case, easily evaluate corrective actions (e.g., adjust expected performance values, tune the distribution of players and skills among teams, plan training for particular roles, etc.).

The adoption of a model-driven approach, along with a structured software system, also enables the development of additional features such as automatic generation of scenarios for TTX simulations, the ability to evaluate different alternatives in terms of resources employed (i.e., *what-if analysis*), or the possibility to simulate only a few roles for training purposes (i.e. *human-in-the-loop*).

5 Conclusion

In this contribution, we introduced the high-level design of a software system to support the definition, execution, and analysis of tabletop exercises (TTX).

This tool allows to reach new levels of usability (i.e., no technical skill required for the evaluator), flexibility (i.e., ability to adapt to any scenario), modularity (i.e., possibility to introduce new features with a limited effort), and customizability (i.e., possibility of varying nonfunctional parameters such as expected performance).

Identifying room for improvement in the existing tools and taking care of the initial phases of requirement analysis and high-level design, this article is a first step toward the implementation of a complete software system.

A conceptual model-driven framework for the automated generation and execution of TTX simulations has also been introduced. Future developments will be directed to the subsequent implementation phases of the proposed approaches.

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International Training Curriculum for Advisors in Emergencies and CBRNe Events Management

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1 Introduction

The aim of the emergencies and CBRNe events management training curriculum is to prepare subject matter experts as advisors that can support decision-makers and facilitate increased effectiveness of a prompt response to crises, emergencies and disasters. It provides an overview of all aspects of emergencies and the possible effects that particular events can produce. A thorough understanding of the full range of aspects supports effective decision making and limits possibilities of taking actions that could undermine or frustrate response. A complete knowledge of all aspects of emergencies and the possible effects that particular events can produce is fundamental. According to the definition of emergencies and CBRNe events management, there are several possible effects and consequences that decision-makers are unaware of. As a result, wrong decisions are taken, and these can hinder or negatively affect the effectiveness of field operations. The advisor will be at decision-makers' disposal from the beginning until the very end of an event, thus during all management phases. At a strategic level, they have to support decision-makers in their strategic decisions to face emergencies and events. His advice should be in keeping with the management system in place and must adhere to policy, plans, predefined roles, responsibilities and official tactical procedures. At a tactical level, the advisor has to supervise coordination of entities, and first responders involved in the field operations, in accordance with plans and official tactical procedures. An advisor thus needs to have full competences in the organization of field relief operations, populace protection, risk communication and coordination among different entities, among others. However, the advisor also needs to be prepared for

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unplanned requests, to face the unexpected. The CBRNe training curriculum helps students to be prepared to take on these demanding tasks.

The curriculum is intended for all those who want to gain a better understanding and have a comprehensive overview of all aspects related to emergencies management, international cooperation and coordination, main entities that can be involved, possible responses to specific threats, consequence management and practical procedures. This training proposal is designed for students (professionals) from the national civil protection and firefighting departments; the ministries such as the Ministry of Foreign Affairs, the Ministry of Defence but also subordinate military headquarters, units or agencies; National and International Organizations; Research Institutes and Private Companies dealing with emergencies; and CBRNe events management.

2 Aim of the Project

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3 Structure of the Curriculum

The curriculum consists of different modules with each module having an aim related to certain aspects of the management of emergencies. Each module should be developed in different EU locations and hosted by International Organizations officially recognized as key players.

The modules have been developed taking into account a different Depth of Knowledge (DOK) to encourage a progression in learning moving from the basic recall of facts, concepts, information or procedures to a more complex and extended way of thinking. Module 1 (e-learning) requires a level of comprehension that enables a learner to use foundational, conceptual and procedural knowledge. From Module 2 to Module 7, an intermediate level of comprehension is required, and it enables the learner to identify, analyse and interpret concepts, patterns and relationships in order to develop a plan and course of actions. This requires the ability to make some decisions and justifications using abstract and complex analytical skills thus offering more than one possibility to solve a problem. The last module is the most complex and challenging for the students, and it requires a level of comprehension that enables a learner to investigate and apply solutions to complex problems. This module encourages students to research and process multiple conditions of problems or task, based on in-depth complex reasoning, planning and development skills (Fig. 1).

4 Modules and Main Contents

The curriculum starts with an e-learning phase (Module 1) that is comprised of publications and documentations of different international organizations that are responsible for crisis, emergency and disaster preparedness and planning. The importance of the correct management of sensitive information and the necessity of a prompt and effective communication when an emergency occurs are other crucial aspects emphasized in the module. This individual study facilitates the development of schemas and mental models that the students must use to organize and simplify their knowledge and classify concepts and notions. These conceptual structures help students fill in the gaps in order to gain a comprehensive and well-

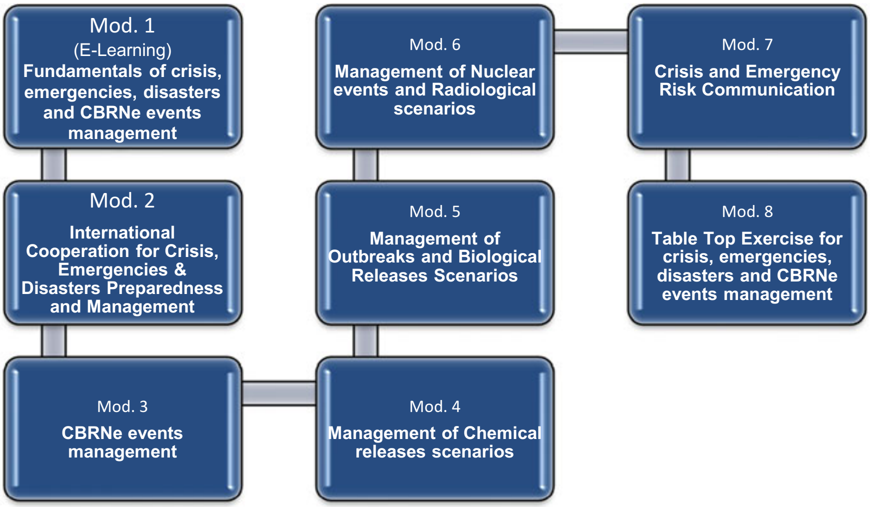

Fig. 1 Modules of the curriculum

organized educational background and a common level of knowledge on these specific aspects.

An overview of the international law and human rights and the importance of coordination in the management of emergencies are some of the other contents of the course (Module 2). It is crucial to include human rights principles and standards in early recovery and reconstruction work to re-establish the livelihoods of the population and ensure access without discrimination to food, water, sanitation and housing. Emergencies require rapid and coordinated response in order to deliver essential services to the affected population. These events tend to attract several international organizations like the United Nations (UN), the Office for the Coordination of Humanitarian Affairs (OCHA) [1], the World Health Organization (WHO) [2], the European Union (EU), the Organization for Security and Co-operation in Europe (OSCE) [3], the North Atlantic Treaty Organization (NATO), governmental organizations (GOs) and non-governmental organizations (NGOs). As a consequence, these organizations take part in field operations and a coordination entity is essential to direct the multitude of bodies involved. For instance, a well-coordinated response has been established at the European level. The European Civil Protection Mechanism enables the cooperation among national civil protection authorities across Europe [4]. Furthermore, NATO recognizing the importance of enhanced international cooperation in the field of disaster relief, created the Euro-Atlantic Disaster Response Coordination Centre (EADRCC) [5], and this resulted in closer partnerships with the UN, the EU, the OSCE, the African Union (AU), the World Bank (WB) and some other non-governmental organizations [6]. In complex emergencies, having a strong coordinating frame is a key factor to the successful delivery of services to affected populations. Where there is no coordination, different players involved may end up having duplicate projects in the same area or may all be working in one location and thus abandoning other affected areas. It is necessary for all those actors involved to come together and formulate a common response to complex emergency, maximizing on the strengths of different players for a rapid and effective service delivery to the affected populace. Every major emergency can pose a threat to national and international security and stability. States can no longer rely on purely national solutions for large-scale emergencies. The cooperation between the national and international military representatives and civil experts of the industry, business, government and other public administrations is fundamental during a crisis. These possible events do not respect national borders.

This curriculum provides an overview on main aspects of CBRNe events preparedness and management in the context of the international cooperation activities and initiatives (Module 3). Due to the complexity of CBRNe events management, the specific aspects of these scenarios are the focus of the following three modules (Module 4, Chem; Module 5, Bio; and Module 6, RAD/NUC). Despite the international legal framework, arms control agreements and non-proliferation initiatives, some countries and non-state actors continue to develop CBRN weapons or capabilities. This trend is most pronounced in areas of chronic political instability. There have been recurring instances of terrorist groups that embrace CBRNe technologies as a powerful means of prosecuting their interests. At the same time, the continuing process of global industrialization opens up the wider possibilities of accidental release or deliberate misuse of toxic industrial materials (TIM). This means it is essential to consider the possible emergence of CBRNe hazards and develop appropriate CBRNe response measures to mitigate possible effects [7]. Fortunately, the number of incidents involving such materials has been limited; the commonly held view is that the risks involved are such that coordinated actions in terms of prevention, detection and response are indispensable. There is also a consensus amongst experts that the case of a somewhat limited attack needs to be carefully considered, because the psychological, health and economic effects on the population of even a small-scale attack using such materials would be significant [8]. Several international agreements and treaties have been signed by numerous countries, such as the Chemical Weapons Convention (CWC), the Biological and Toxin Weapons Convention (BTWC), the Convention of Physical Protection of Nuclear Material (CPPNM), the Nuclear Non-Proliferation Treaty (NPT) and further initiatives related to the non-proliferation of CBRN materials. In April 2004, the UN Security Council adopted Resolution 1540, which establishes legally binding obligations on all UN member states to have and enforce appropriate and effective measures against the proliferation of weapons of mass destruction (WMD) and their delivery systems, by establishing controls [9]. The improvement of the CBRNe security in the European Union is the aim of the EU CBRNe Action Plan. Its overall goal is to reduce the threat and damage from CBRNe incidents of accidental, natural and intentional origin [4, 10]. CBRNe incidents are very often assessed as low-likelihood, high-impact events. Consequently, some decision-makers consider the low likelihood of a CBRNe incident occurring, coupled with rearrangement of national financial priorities, as justification for disregarding CBRNe protective measures. Due to financial constraints, more and more decision-makers are carefully considering the procurement of materials and are searching for other, less expensive mitigation measures. They are even accepting some or all of the potential or actual consequences of the CBRNe threats. Appropriate security for information technology structures, data exchange mechanisms at CBRNe facilities and critical infrastructures and technical security controls are needed to safeguard key information from potential adversaries and to permit the secure sharing of information with authorized users [11].

During emergencies and CBRNe events, the communication and information management play another very important role that cannot be ignored (Module 7). Developing crisis communication plans is an integral part of public health emergency preparedness. Timely, consistent and accurate communication can impact how the media, public and emergency response/healthcare communities react to an emergency, fostering appropriate behaviours and awareness [12]. The lack of resources, competences and cooperation in the response network are the main and common issues required to develop an effective crisis response system and the related communication strategy. In such scenarios, crisis communicators are vital. If citizens follow the rules during and after an emergency by following the procedures and guidelines provided by authorities, they can avoid further risks, and the first responders can carry out their operations effectively, saving lives.

The final tabletop exercise (TTX) (Module 8) provides the students with different scenarios in order to put into practice notions learned during previous modules and apply techniques and procedures for the management of specific aspects and consequences of crisis, emergencies, disasters and CBRNe events, in the context of the international policy and main references. Emergencies can affect countries anywhere and at any time. They can turn into disasters if governments and people are not well prepared. Joint approaches in case of emergencies are more effective than separate national actions. As already mentioned before, in complex emergencies, a strong coordinating frame is a key factor to the effective delivery of services, to avoid duplication of projects in some areas and the lack of support in other locations. It is necessary for all actors to come together and formulate a common response to complex emergencies, maximizing on the strengths of different players to provide a rapid and efficient service. International training, among different international and national institutions, is essential. The emergency management exercises consist of realistic simulations of an emergency situation which are planned and conducted in order to evaluate the operators' capability to execute one or more portions of a comprehensive emergency management plan. Different typologies of exercises can be organized and carefully planned to achieve one or more of the identified learning objectives. An effective exercise programme is made up of progressively complex exercises, each one expanding on the previous exercise, until the exercises are as close to reality as possible. The TTX, as the decisive stage of the curriculum, should be divided into two parts, each one demanding a different level of commitment from the students. The first phase should be characterized by simple stand-alone events that students have to analyse without an imposed time limit, while the second part should represent more complex emergencies with a time limit to make it more realistic. The second phase is typically characterized by extensive loss of life; the displacement of a large number of people; the difficulty of humanitarian assistance due to political and military constraints, significant security risks for humanitarian relief workers and first responders in some areas; the widespread damage to the society and economy; and the need for a large-scale and multi-faceted humanitarian assistance. The TTX should focus on the management of several possible events like landslides and mudslides, floods, earthquakes, the accidental TIM releases, natural outbreaks and epidemics, the intentional release of agents or radiological sources, sabotage to nuclear power plants and the consequent fallout and cyberattacks to critical infrastructures. The development of scenarios has to include the above-mentioned situations in different contexts that, in real life, would involve different national and/or international organizations, activating different mechanisms and procedures. In particular, the events should occur in a European country, between different EU countries, outside EU and finally implicating EU and non-EU countries of the neighbouring areas. The approach consists of exposing participants to training exercises which become more complex. The scenarios have to be founded on real case studies and lessons learned. The European Civil Protection Mechanism and the related predefined procedures, roles and responsibilities are the foundation for the management of the different scenarios. The aim of this final module is to have a tangible and clear knowledge about the cooperation and coordination activities among entities usually involved in the management of emergencies. Students, as advisors to decision-makers, put into practice specific notions and apply the techniques and procedures learned during the course. This practical stage of the programme reinforces the learning objectives of the previous modules. The scenarios should include the organizations that normally take part in disaster field operations or that support related activities.

5 Conclusions

As the devastating impact of recent natural disasters indicates, mankind is vulnerable to extreme weather events. Clearly such events have always been part of life, but the likelihood of these catastrophes is increasing due to global climate change. As emphasized several times throughout the entire curriculum, every emergency can pose a threat to security and stability.

Many programmes and exercises for educating and training personnel in the field of emergency planning and management are in place at a national and international level. The existing standards to ensure comparability and international compatibility are periodically reviewed and improved taking into consideration field operations experiences. This proposal for an innovative curriculum to prepare high-qualified experts to intervene quickly as advisors in the management of all kinds of emergencies represents the commitment to contribute to the international security for a prompt and effective response in case of disasters.

The curriculum covers a wide range of topics which are remarkable in their complexity. Students will have the support of several International Organizations and experts that are working in the field of emergencies. During the course they will learn to face extreme, complex and challenging scenarios, making it a real and unique experience.

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A Facebook Page Created Soon After the Amatrice Earthquake Provides a Useful Communication Tool for Deaf People, Their Relatives and Caregivers

Luca Rotondi, Marta Zuddas, and Paola Rosati

1 Introduction

Even though during natural or human catastrophic events, disadvantaged people are universally known to be at a greater risk than others, rarely is specific attention given to provide them with tailored information.

In 2006, the United Nations (UN) Convention on the Rights of Persons with Disabilities launched the largest human rights treaty [1], and Italy ratified it with Law No. 18 of March 3, 2009. In Article 9, comma (1), letter (b), this Convention required governments to ensure accessibility to "information, communications and other services, including electronic services and emergency services". In 2007, a UN optional protocol (effective since May 3, 2008) included a statement in Article 11 on the "humanitarian and risk situation" regarding the protection and safety of people with disabilities in the event of risk situations (armed conflicts, humanitarian emergencies and natural disasters) [2]. In 2007, the "Charter of Verona", drafted by the Italian Civil Protection Institution and signed by other international organizations and various associations of people with disabilities stated again the need for avoiding discrimination and providing equal opportunities, particularly to disadvantaged people [3]. This document described the operations needed, from planning to implementing, to involve people with disability aiming at minimizing the risks and seeking suitable interventions. It also provided specific training for operators involved in risk management and in rescuing people with disabilities during emergencies and maxi-emergencies. In 2010, the European Parliament resolution on natural and man-made disasters underlined this statement giving special attention

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to "the specific needs of people with disabilities, in all actions taken using civil protection mechanisms" [4].

Despite authoritative international regulations ratified by several countries, difficulties still arise in the first emergency response during natural disasters or other maxi-emergencies involving people with disabilities. During disaster interventions, operators and practitioners are frequently unaware of the various communication tools needed by disabled people and fail to request access to services for interpreting and translating tailored information. Accordingly, disabled vulnerable people can experience physical, sensory and cognitive dysfunctions in receiving and understanding alarm and emergency information, making it difficult to take appropriate measures. Generally, operators and practitioners tend to rely on the relatives of people with disabilities to disseminate specific information [5]. Additionally, natural disasters lead to a state of poverty. Hence, people with disabilities, regardless of their health status and caregiver assistance, need free access to prolonged tailored services [3].

In Italy, another important concern is the lack of specific municipal, regional or national disability databases. Hence, despite the ratified international conventions and applied Italian norms, during the Amatrice earthquake disaster in August 24, 2016, information on disabled people came from the data available from the Italian National Provident Institution (INPS) (only deaf recognized by Italian Law No. 381/70) [6]. Unfortunately, according to the Italian government protection rules on sensitive data against possible computer attacks, the data on disabled and deaf persons involved in the earthquake were unavailable for several days. Many difficulties therefore arose in identifying people with specific needs.

Today, most people including disabled people who easily access new media communication use mobile devices and information channels such as social networks (Facebook, Twitter, Instagram, Telegram and WhatsApp). Whereas hearing people use both passive mass media (radio, television and newspapers) and social media to gain information, deaf persons nowadays, favouring the language of signs and video subtitles, have moved easily and affordably to social media. These deaf-deployed media platforms, technically adapted to deafness needs, provide evidence of easy social integration and support even in natural disasters [7, 8]. These socially effective means should therefore be exploited during emergency for disseminating information to disabled people with hearing loss [9].

Prompted by the impossible passive media access to people who have deafness or hearing loss, to improve fast access and give safety information soon after the Amatrice earthquake, we designed a new online information tool entailing a Facebook page tailored to deaf people.

2 Methods

Within few hours after the Amatrice earthquake, we created a Facebook page (called "Emergenza Sordi a 360 gradi" in Italian accessible by https://www.facebook.com/EmergenzaSordi/) (see Fig. 1), aiming to create a "bridge" of information on the service available and favouring communication among deaf people, their family members and the rescuers. This information would help to find deaf people's location and direct the rescue services. To provide information also on safety measures, one of the authors (LR), a deaf person qualified in "Protection Against CBRNe Events", created a video on safety in maxi-emergencies, in the Italian sign language including subtitles [9] (see Fig. 1). The Facebook page included also current news and service numbers. People who access the page could distribute the information through other social media (Twitter, Telegram and WhatsApp). The page followed the basic rules, called "Deaf Emergency Communicator Theory" (DECT), designed for preparing an emergency video for deaf people [10]. According to these rules, the short video (up to 150 seconds) included on the page explained what safety measures to take during an earthquake. The video used fixed non-sliding subtitles, to offer clear, straightforward and direct language. To reach illiterate or nondigital users with hearing disabilities, thus improving information spread, a voice for the hearing population was added to help deaf people further by directing information to their relatives and caregivers. To implement and disseminate the

Fig. 1 Screen shot from the Amatrice deaf tailored online video showing likes and shares on 2016/8/24

video information, those people with the latest generation mobile devices were also allowed to shoot the video at high resolution (1080p or 4 K). The video included also an integral text providing technologically accessible contact with other deaf people. To ensure clarity and accuracy, the statements in the text were incisive. They contained as few words as possible and avoided difficult-to-understand terms, favouring the same language used by the deaf public. Accuracy was assured by copying immediately written and broadcasted news provided by official sources [11]. The Facebook page also contained an online checklist designed to record data and measure the results, including hearing conditions or hearing disadvantages and satisfaction or dissatisfaction with the information provided. Automatically, the Facebook software page numbered all the contacts (liked, viewed and shared). The checklist data containing information on hearing and deaf people and satisfaction were recorded in percentages.

3 Results

In a total of 43,507 Italian deaf persons, recognized by Italian Law No. 381/70, about 0.4% lived in the earthquake territory. The municipality of Amatrice had 2657 inhabitants (January 1, 2016). Statistically an estimated 15 person in a 1000 could be affected by deafness as recognized by the Italian Law No. 381/70. The Facebook page online accessed 90% of Italian deaf persons and 60% of hearing people (relatives and caregivers). Satisfaction level was 95% in deaf people and 50% in hearing people. A total of 60% of deaf and 10% of hearing people asked for more information, especially on the real state of research for missing deaf persons, on how to behave during an earthquake.

The video 360-Degree Deaf Emergency received a total of 443 likes, over 1200 shares at the end of August 2016 (see Fig. 1) and 57,000 views accessing https://www.facebook.com/EmergenzaSordi/ (last accessed 2018/1/23).

4 Discussion

The results the new online information tool obtained with a Facebook page tailored to people who are deaf or have hearing loss exceed our expectations. Although we predicted that a 1000 people would share our Facebook page, and 2–300 people would benefit from our video, the numbers were higher. We recorded fast access to the information provided. Within hours after the earthquake, a total of 85% of deaf persons accessed Facebook. The numerous requests for more explanations on the video showed that a well-received social question-answer service could help to spread information on safety practices in a day-to-day, easy and affordable way. Despite limitations, our efforts to create a Facebook page tailored to deaf people in Italy increase fast access and safety soon after an earthquake.

The video we created in the Italian sign language with subtitles proved remarkably effective. Even if Italian deaf people are a sociolinguistic minority, the entire deaf community should have access to advanced technologies, guaranteeing equity, also to deaf foreigners or other excluded, potentially advisable, disadvantaged populations, even those staying in Amatrice as tourists [12–14]. Thanks to the advanced technologies used in the latest generation mobile devices, high-quality video will be made available at a low cost.

The results from our experience on using a social media to disseminate information quickly to deaf people soon after the Amatrice earthquake show how a tailored tool in a Facebook page can overcome the lack of territorial disability databases. During natural disasters and maxi-emergencies, an appropriate use of social databases should help in mapping and categorizing people with disabilities, so as to permit official institutional services to use well-defined protocols thus enhancing safety.

Thanks to the results of our online tailored tool, another project called "#perfarcisentiredatutti" is now used by Roma Capitale (Rome Town Hall). This project is an online communication technique aimed at providing general information and pre-emergency and emergency alert with full accessibility for deaf and hearing people through several social media including Facebook, Twitter, Instagram and YouTube [12]. The Rome Town Hall video (project "#perfarcisentiredatutti") giving information on what to do during an earthquake received 1300 likes and over 8300 shares (see Fig. 2). The video received over 474,000 views accessing https://www.facebook.com/RomaCapitaleOfficialPage/videos/1141406752593563/ and over 1900 views accessing https://www.youtube.com/watch?v=qfNW0BmqyUA (last accessed 2018/1/23).

4.1 Conclusions

In conclusion, emergency coordinators and disaster managers should be aware and trained in giving emergency information and tailoring their communication to the needs of deaf people. To improve fast access and safety, during natural disasters and other mass emergencies, online communication, tailored to deaf people who use signed language, needs to follow international guidelines [10].

A tailored survey designed specifically to investigate the barriers and facilitators in Italian and foreign deaf people who access the tool and the video proposed with the Facebook page should widen the information provided and shorten the time needed to gain the information, thus increasing satisfaction. Further studies need to investigate new online tools tailored to other disabled populations, living in various settings and countries to disseminate information on services and safety measures quickly, using fast accessed social media after natural disasters and maxi-emergencies.

Fig. 2 Screen shot from the Rome Town Hall deaf tailored online video showing likes and shares

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Academic Outreach in Non-proliferation: The Dual Space System Course

Angelo Minotti

1 Introduction

The international events, of the last decades, undoubtedly oblige a new approach towards non-proliferation and disarmament.

In fact, in this context, the UN1540 Resolution has been adopted on 28 April 2004 [1].

The UN1540 Resolution, the first binding resolution, affirms "proliferation of nuclear, chemical and biological weapons, as well as their means of delivery, constitutes a threat to international peace and security".

It states, among all, that:

– "all States shall refrain from providing any form of support to non-State actors that attempt to develop, acquire, manufacture, possess, transport, transfer or use nuclear, chemical or biological weapons and their means of delivery".
– "all States, in accordance with their national procedures, shall adopt and enforce appropriate effective laws which prohibit any non-State actor to manufacture, acquire, possess, develop, transport, transfer or use nuclear, chemical or biological weapons and their means of delivery, in particular for terrorist purposes, as well as attempts to engage in any of the foregoing activities, participate in them as an accomplice, assist or finance them".
– "all States shall take and enforce effective measures to establish domestic controls to prevent the proliferation of nuclear, chemical, or biological weapons and their means of delivery, including by establishing appropriate controls over related materials…".

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In addition it calls upon all States:

- "to promote the universal adoption and full implementation, and, where necessary, strengthening of multilateral treaties to which they are parties, whose aim is to prevent the proliferation of nuclear, biological or chemical weapons"
- "to adopt national rules and regulations, where it has not yet been done, to ensure compliance with their commitments under the key multilateral nonproliferation treaties"
- "to renew and fulfil their commitment to multilateral cooperation, as important means of pursuing and achieving their common objectives in the area of non-proliferation and of promoting international cooperation for peaceful purposes"
- "to develop appropriate ways to work with and inform industry and the public regarding their obligations under such laws"

According to the UN1540 Resolution [1]:

- The means of delivery are "missiles, rockets and other unmanned systems capable of delivering nuclear, chemical, or biological weapons, that are specially designed for such use".
- Non-State actors are "individual or entity, not acting under the lawful authority of any State in conducting activities which come within the scope of this resolution".
- Related materials are "materials, equipment and technology covered by relevant multilateral treaties and arrangements, or included on national control lists, which could be used for the design, development, production or use of nuclear, chemical and biological weapons and their means of delivery".
- The multilateral control regimes and the relative non-proliferation treaties are "the Nuclear Supplier Group (Non-proliferation Treaty) [2], the Missile Technology Control Regimes [3], the Wassenaar Arrangement (Potentially Arms Trade Treaty) [4], the Australia Group and the Chemical Weapons Convention (Biological and Toxic Weapons Convention) [5, 6]".

At EU level, in order to fulfil the UN indications, Regulation 428/2009 on dual-use goods and technologies [7] has been adopted. Armaments, and the relative technologies, are instead under the control of the single nations: in Italy the law L.185/90 is in force [8]. Both the EU Regulation and the Italian law report annexes in which there are lists that implement the internationally aforementioned control agreements. Dual-use and arms export controls are strategic because they address security, research and development (R&D) and production and trade of typically high-tech, advanced products across a wide range of industries (e.g. energy, aerospace, defence and security, telecommunications and information security, life sciences, chemical and pharmaceutical industries, material-processing equipment, electronics, semiconductor and computing industries, lasers and navigation).

In this new context, the fundamental role of academia in researching, teaching, outreaching, spreading knowledge and supporting institutions/private companies is evident. In the light of the above, the first technical academic course on dual-use and arms control, namely, "Dual Space Systems", has been set up at the School of Aerospace Engineering of the Sapienza University of Rome.

The present paper reports, respectively, in Sects. 2 and 3, the main points of the EU Regulation 428/2009, on dual-use goods and the Italian law 185/90, on arms control, in Sect. 4, the description of the academic course and in Sect. 5, the conclusions.

2 The EU Regulation 428/2009

According to the EU Regulation 428/2009, an authorisation shall be required for the export of dual-use items listed in Annex I. By definition, *dual-use items* are items, *including software and technology, which can be used for both civil and military purposes and shall include all goods which can be used for both nonexplosive uses and assisting in any way in the manufacture of nuclear weapons or other nuclear explosive devices.*

Technology *means specific information necessary for the development, production or use of goods*. This information takes the form of 'technical data' or 'technical assistance': (1) 'technical assistance' may take forms such as instructions, skills, training, working knowledge and consulting services and may involve the transfer of 'technical data'; (2) 'technical data' may take forms such as blueprints, plans, diagrams, models, formulae, tables, engineering designs and specifications, manuals and instructions written or recorded on other media or devices such as disk, tape and read-only memories.

Annex I is organized according to a fixed structure: ten categories (0–9), five subcategories (A–E), the identification of the regime of origin (0–4) and the final description; see Fig. 1 for a clearer explanation. Among all the goods, listed in Annex I, there are some, particularly sensitive, for which an authorization is required even for intra-community transfers (i.e. items of stealth technology, of community

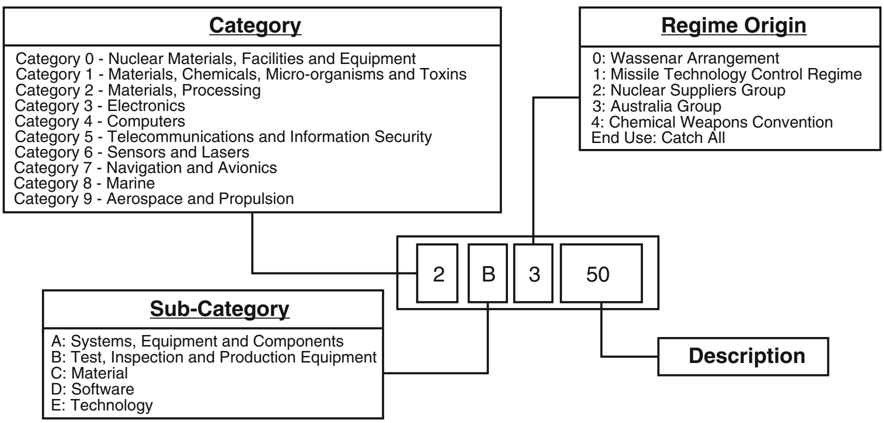

Fig. 1 Structure of the entries in Annex I

strategic control, of MTCR technology, of Chemical Weapons Convention, of NSG technology).

3 The Military List

Besides the dual-use goods regulation, there is the national law L.185/90. It delineates the frame of control of military goods. According to the law, armaments are "those materials that, for technical or constructive requirements or features are designed to be constructed for a predominantly military or armed or police use".

Those military goods, and the relative technologies, are listed in the annex, which is organized according to 22 categories (Cat.):

– Nuclear, biological, chemical and electrical weapons; Cat. 7, 21
– Automatic firearms and ammunition; Cat. 1, 3, 16, 21
– Weapons of medium and large calibre and relative ammunition; Cat. 2, 3, 16, 21
– Bombs, torpedoes, mines, rockets, missiles and torpedoes; Cat. 4, 16, 21
– Wagons and dedicated vehicles for military use; Cat. 6, 16, 21
– Ship and its equipment especially designed for military use; Cat. 9, 21
– Aircraft and helicopters and related equipment specially designed for military use; Cat. 10, 16, 21
– Powders, explosives, propellants; Cat. 8, 21.
– Systems or electronic devices, electro-optical and photographic specially designed for military use; Cat. 5, 11, 15, 18, 21
– Special materials armoured specially designed for military use; Cat. 13, 21
– Specific materials for military training; Cat. 14, 21
– Machinery, equipment and facilities built for the manufacturing, testing and control of weapons and ammunition; Cat. 18, 21, 22
– Special equipment specially designed for military use; Cat. 12, 13, 16–21
– Technology; Cat. 22

The EU Regulation and the Italian law share several fundamental definitions (i.e. technology, technical assistance, etc.) and recall each other in many points; this is due to the fact that it is not always easy to distinguish the real application, civil or military, of some items and then some overlapping is physiologic.

4 The Dual Space System Course

In the light of the above, it is evident that the control of dual-use and military goods involves industries, together with thousands of small, medium-large companies, research centres/universities and institutions, requiring high value-added expertise across key sectors of the EU economy and knowledge. In particular the new field of "dual-use" items represents a significant portion of EU trade with key partners, and they are crucial to the EU's drive towards technological innovation and competitiveness [9]. To reply to these new necessities, an academic course, which faces both the legal and, in particular, the technical insights of the dual-use and arms control aspects, has been set up (nowadays at its second edition).

This course, unique in its kind, is held at the Aerospace School of Engineering of the Sapienza University of Rome; it is organized in 72 hours, 9E.C.T.S. (university credits), within the Special Master in Aerospace Engineering, and it is delivered to graduated students in the engineering disciplines.

The legal-political aspects are investigated in 8–10 hours, while the technical ones require 62–64 hours. In particular the UN Res.1540, the relative agreements and treaties, the EU Reg.428/2009, the L.185/90, the countries under specific restrictions or embargoed (i.e. Iran, Myanmar, Russia, etc.), the relative administrative and criminal sanctions for illicit traffics, the organization of the institutional entities in charge for these issues and the mandatory authorizations are the topics investigated during the first part.

During the technical part, the following topics are examined:

- Directed energy weapons
- Ammunitions, explosives and their storage
- Space rocket systems (liquid-solid-hybrid) and main components (i.e. feeding systems, navigation systems, nozzles, cases, umbilical lines, etc.)
- Ballistic missiles systems and main components (ICBM)
- Propellants (liquid and solid)
- Re-entry vehicles and MIRV (nuclear warheads)
- Quantum mechanics and its applications in infrared signature (theory and special materials and equipment) and in cryptography
- Unmanned ground and aerial vehicles (systems and components)
- Civil nuclear fuel cycle and industrial equipment-related items
- Biological and chemical issues and their relative equipment

In order to provide the highest possible level of knowledge, lectures are delivered, or supported, by external experts, coming from all the entities directly involved in non-proliferation. In fact, people coming from the Ministry of Defence, Ministry of Economic Development, Customs, international private and institutional companies, international research centres, international law firms and supranational institutions characterize the entire course.

5 Conclusions

International events have increased the concern on proliferation of goods and technologies, broadening the attention not only to the military items but also to dual-use ones. By definition "dual-use" items are goods that *can be used for both civil and military purposes and shall include all goods which can be used for both* *nonexplosive uses and assisting in any way in the manufacture of nuclear weapons or other nuclear explosive devices.*

These goods are high-technological products; therefore their control requires skills that encompass legal and high-technical aspects.

Dual-use experts are, therefore, fundamental in private companies (in order to be compliant with the law), in research centres-universities (in their core activities, when related with this sensitive issue), in supranational organizations (to supervise the international illicit traffics) and finally, to support delegated institutional authorities (for instance, in the international non-proliferation assemblies and/or alerting on future sensitive technologies and/or in their internal committees or boards, etc.).

To reply to these new necessities, an academic technical course in non-proliferation has been set up at the School of Aerospace Engineering of the Sapienza University of Rome.

The course aims, among all, at increasing the overall knowledge and efficiency in this field, improving collaboration among all the institutions and encouraging the sharing of expertise with other nations.

In the light of the above, widening the actual scientific sectors to the dual-use field could be a plus for the academy.

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Best Practices in Nuclear Medicine

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During the daily work in any health-care facility, in every department, wastes are produced. The amount and composition of those wastes differ in each department, depending on the duties of the department. This problem is even more relevant when nuclear medicine departments are interested. In this case radioactive wastes are produced and must be properly treated to ensure that those wastes cannot be used to produce residual radioactive garbage useful to prepare a dirty bomb. A rough estimate of the amount produced in an ordinary health department is the (1) number of beds in the hospital, (2) occupation rate in percentage of hospital days, and (3) waste generation per treatment day per patient in kg/bed/day. (If not available, the rough estimate for this value is 1.3 kg/bed/day.) However, the amount of waste generated in a nuclear medicine department is very less dangerous relative to that of other departments. It must be noticed that nuclear waste may be not particularly hazardous relative to other toxic industrial wastes but only when suitably treated. For this, nuclear medicine nurses need a special training in order to properly manage

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those wastes. For radioactive waste, this means isolating or diluting it such that the rate or concentration of any radionuclides returned to the biosphere is harmless. To achieve this, practically all radioactive wastes are diffusely stored in a fiberglass bath. Every radionuclide has proper half-life, i.e., the average time taken for half of its atoms to decay (i.e., for it to lose half of its radioactivity). Radionuclides with long half-lives tend to be alpha and beta emitters—making their handling easier—while those with short half-lives tend to emit the more penetrating gamma rays. Eventually all radioactive waste decay into nonradioactive elements. The more radioactive an isotope is, the faster it decays. Radioactive waste is typically classified as either low-level (LLW), intermediate-level (ILW), or high-level (HLW). Dependent, primarily, on its level of radioactivity:

Low-level waste: Low-level waste (LLW) has a radioactive content not exceeding 4 giga-becquerels per tons (GBq/t) of alpha activity or 12 GBq/t beta-gamma activity. LLW does not require shielding during handling and transportation.

Intermediate-level waste: Intermediate-level waste (ILW) is more radioactive than LLW, but the heat it generates (<2 kW/m^3) is not sufficient to be taken into account in the design or selection of storage and disposal facilities. Due to its higher levels of radioactivity, ILW requires some shielding.

High-level waste: High-level waste (HLW) is sufficiently radioactive for its decay heat (>2 kW/m^3) to increase its temperature, and the temperature of its surroundings, significantly. As a result, HLW requires cooling and shielding. Therefore, the first question they must answer is as follows:

1 What Is Nuclear Medicine?

This is a branch of medicine that uses radiation to provide information about the functioning of a person's specific organs or to treat disease. In developed countries (26% of world population), the frequency of diagnostic nuclear medicine is 1.9% per year, and the frequency of therapy with radioisotopes is about one tenth of this. Of course the second question is the following:

2 How Could Diagnosis Be Improved by Nuclear Medicine?

Diagnostic techniques in nuclear medicine use radioactive tracers which emit gamma rays from within the body. These tracers are generally short-lived isotopes (not more than few minutes) linked to chemical compounds which permit specific physiological processes to be scrutinized. A more recent development is positron emission tomography (PET), which is a more precise and sophisticated technique using isotopes produced in a cyclotron. New procedures combine PET with CT scans to give co-registration of the two images, enabling 30% better diagnosis than

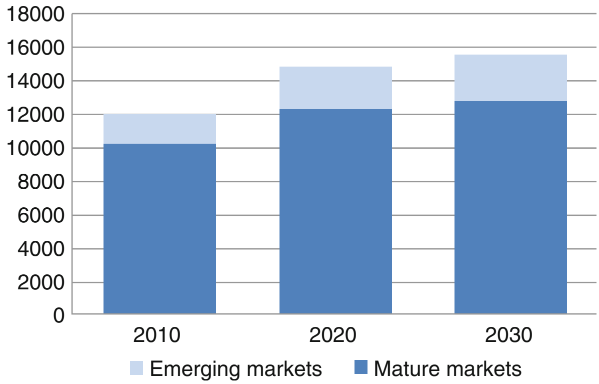

Fig. 1 Forecasted ^{99}Mo demand per week

with traditional gamma camera alone. Positioning of the radiation source within the body makes the fundamental difference between nuclear medicine imaging and other imaging techniques such as X-rays. The amount of nuclear medicine analyses is drastically increasing, so the further question unavoidably must be the following:

3 What We Must Expect for the Next Decades?

The use of unsealed radionuclides in medicine is increasing throughout all advanced or developing countries both as radiopharmaceuticals and as diagnostic tools through positron emission tomography (PET) imaging. They are becoming more and more common in the clinical environment. In Fig. 1 [1, 2] is depicted the need of radionuclides foreseen for three future decades either in emerging markets. This plot clearly shows that in the next three decades, the request of nuclear medicine applications will quickly increase push up also thanks to the contribution of emerging markets. This will imply a severe worldwide increase of the nuclear medicine departments with a consequential increase of the quantity of radionuclides required.

In radioactive medicine, we use unstable isotopes thus the following question:

4 What Are Stable Isotopes? (Moreover, Why Do They Differ from Unstable?)

Stable isotopes are tools used to look in a new way a health problem. They help to a better understanding of a process from a particular source. Anyway, stable isotopes already play an important role in research today. Many of the chemical elements have a certain number of stable isotopes. There are 82 stable elements and about 275 stable isotopes of these elements. They cover a huge range of diagnostic possibilities. If we take into account also radioisotopes, we meet a wider range of

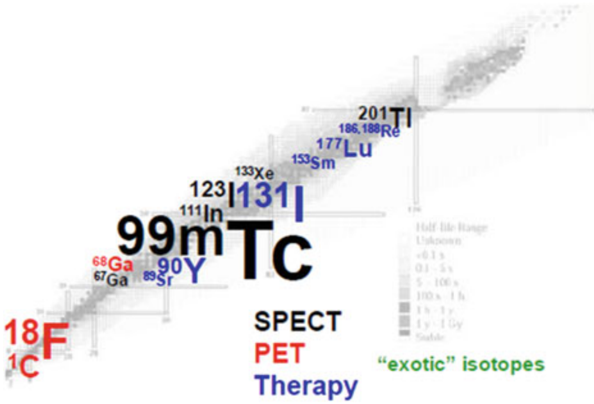

Fig. 2 Distribution of the radionuclides and their halftimes [3]

diagnostic facilities since we dispose of at least 3800 each one having special analysis properties and capabilities.

5 What Happens When We Use Unstable Isotopes?

Due to their instability, they are radioactive; thus, they must carefully be treated to avoid any contamination (Fig. 2).

6 Why Use Unstable Isotopes Which Are Also Radioactive?

Some of the most widely used radionuclides in mature market and their typical applications are the following:

1. Technetium-99m is a metastable nuclear isomer of technetium-99 (itself an isotope of technetium), symbolized as ^{99m}Tc, that is used annually in tens of millions of medical diagnostic procedures, making it in this way the most commonly used medical radioisotope [3] (Fig. 3).
2. Iodine-123-metaiodobenzylguanidine (123I-MIBG) scintigraphy is a nuclear medicine technique, which describes the functional status of the cardiac sympathetic nervous system.
3. A gallium scan or gallium 67 scan (also called “gallium imaging”) is a type of nuclear medicine that studies a specific type of tissue or disease state of tissue. Gallium salts like gallium citrate and gallium nitrate are used.
4. Superiority of nitrate-enhanced 201Tl over conventional redistribution 201Tl imaging for prognostic evaluation after myocardial infarction and thrombolysis.

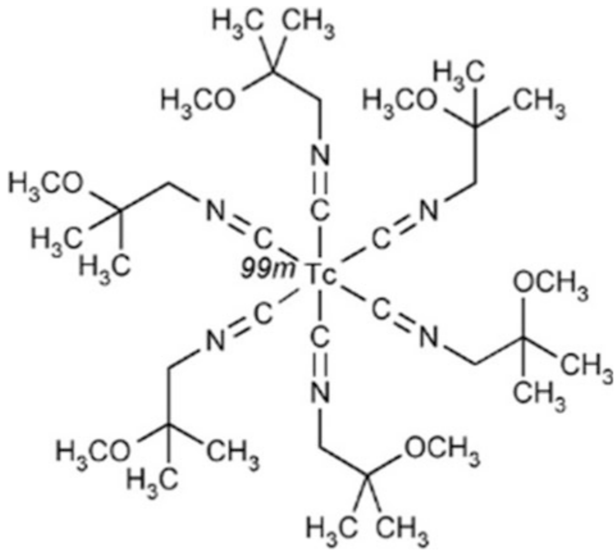

Fig. 3 Technetium Tc-99m sestamibi injection [3]

We will focus the attention on TC-99m for its large diffused use in nuclear medicine as tracer and to define some common medical best practices to avoid CBRNE risk scenario [4].

7 Which Is the Most Used Isotope as Radionuclide and Why?

Technetium-99m is used in 20 million diagnostic nuclear medical procedures every year. Therefore, approximately 85% of diagnostic imaging procedures in nuclear medicine use this isotope as radioactive tracer for about 70,000 diagnostic scans per day. As otherwise signaled according to the Klaus Schwochau's book, *Technetium* lists 31 radiopharmaceuticals based on Tc-99m for imaging and functional studies of the brain, myocardium, thyroid, lungs, liver, gallbladder, kidneys, skeleton, blood, and tumors (Fig. 4).

8 How to Produce ^{99m}Tc for Medical Purposes?

To understand how important tc-99m in nuclear medicine is, in 2009, two nuclear research reactors shut down for maintenance, but these reactors happened to produce most of the world's supply of the radioactive tracer technetium-99m. Hospitals around the world went into panic [5].

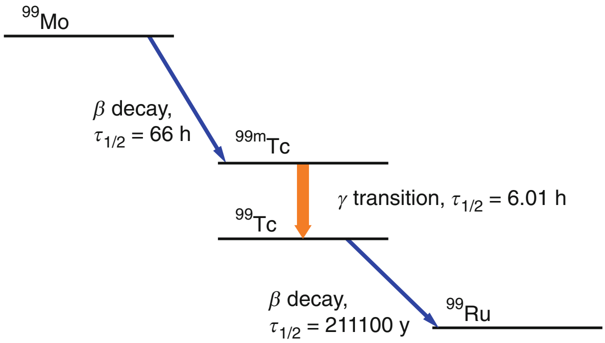

Fig. 4 Typical decay from the ^{99}Mo to the ^{99}Tc [5]

9 Do We Really Need Nuclear Reactors?

For the production and transportation, OECD Nuclear Energy Agency (NEA) created the High-Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR). Since 2009, this group has identified the reasons for the isotope shortages and developed a policy approach to address the challenges to a long-term secure supply of these important medical isotopes [4]; see Fig. 5.

10 What Is a Dirty Bomb?

Transportation and use of low and medium active isotopes produce a considerable risk scenario. The high number of “users,” potentially not properly skilled, increases the availability of radiological sources for terroristic aims. If the production of an illegal nuclear weapon can be considered definitely not possible, terror strategy can use dirty bombs with low active sources to spread out isotopes in crowded objectives. To understand the risk scenario related to Tc-^{99}m, it is important to follow the entire production and use chain to analyze weak points. Medical personnel (usually nurses) could represent a weak ring of this chain; if not clear and accepted, “best practices” are created and understood from them.

11 How to Produce 99Technetium for Medical Purposes?

^{99}Mo can be shipped from a nuclear reactor where it is created as a fission product, to the point of use as it has a reasonably long half-life of 66 hours. Nuclear plants are thus required for the production of medical tracer. For the production and

Fig. 5 Distribution of ^{99}Mo resources presently available [4]

transportation, OECD Nuclear Energy Agency (NEA) created the High-Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR). Since 2009, this group has identified the reasons for the isotope shortages and developed a policy approach to address the challenges to a long-term secure supply of these important medical isotopes [4].

12 Which Is the Amount of Radio Nuclide Used in IT/EU?

The following histogram depicts the distribution of the radionuclides used in the different countries of Europe (including Italy). As it appears evident from this plot also in Europe, the most used radionuclide is the ^{99m}Tc considering the past medical testing crisis. The color list within the plot indicates the kind of radionuclide and the number of medical radio procedures per millions of inhabitants vs year [4] (Fig. 6).

To make simple the identification of each percentages of radionuclide, we add the following pie chart. The color chart is the same used in the previous plot.

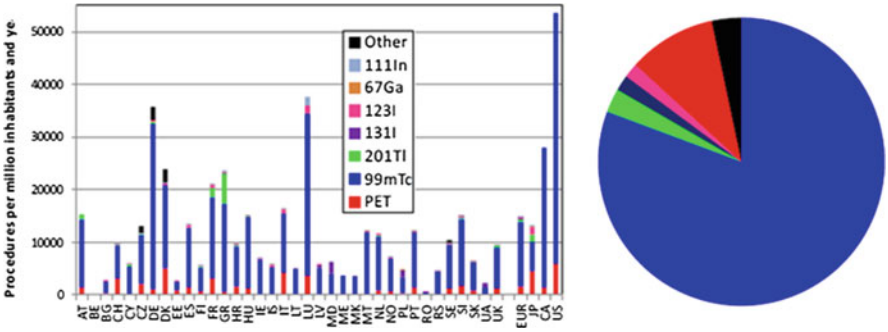

Fig. 6 Cum. use of diagnostic isotopes in Europe (left). Stat. of radionuc. in Europe (right) [1]

13 What to Do When Dealing with the Medical Radionuclides?

Keep in mind: all exposures to ionizing radiation are subject to the principle of justification and optimization. In other words, each exposure to radiation during a medical procedure needs to be justified by weighting up the benefits against the detriments that may be caused. Remember that multiple procedures can be foreseen (and as possible, they must be avoided since they correspond to a summation of the dose used).

14 Which Is the Dose Actually Usable?

As shown in the previous table, most diagnostic procedures expose the patient to considerably less than 20 mSv (millisievert). As said before, however, often patients may undergo multiple investigations in order to improve the diagnostic result. So minimizing dose is a prudent approach. Thus, it is safe to mind the amount for any application! As a rule remember that the amount equivalent to the natural irradiation in Italy (and in most part of Europe) is roughly 3.3 mSv per year (actually a dose of amount 10 mSv per year can be accepted).

15 Which Is the Situation in Italy

In Italy, an amount of 60,000–90,000 m^3 a year of low-activity radioisotopes with short halftime is foreseen (halftime from 3 years to 100 years). As a basic rule, the radiation protection optimization in nuclear medicine applications involves a critical analysis of the different phases of the use of radioisotopes and an examination of possible ways of reducing all forms of exposure (both medical staff members and

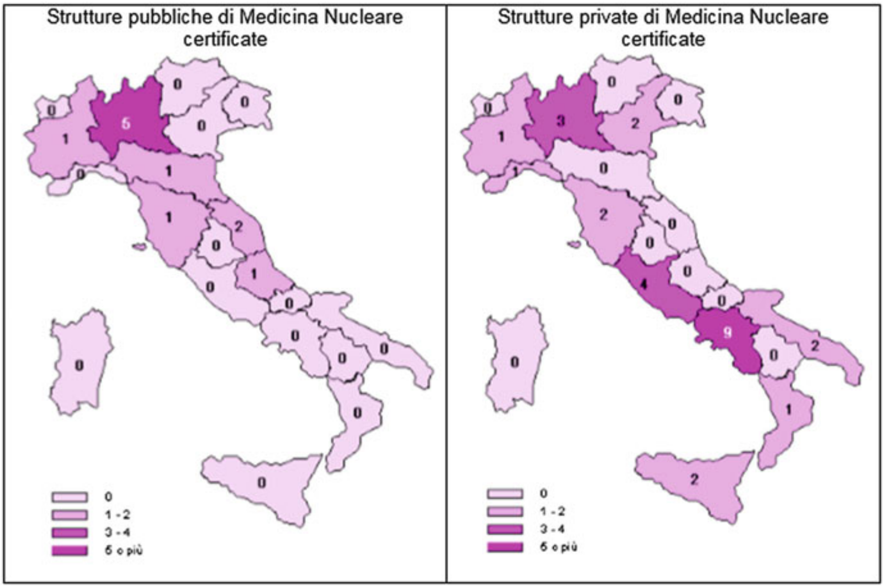

Fig. 7 Public structure (left), private (right) [7]

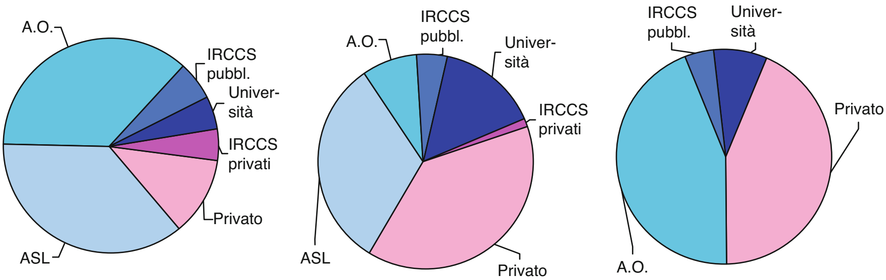

Fig. 8 Distribution of the diffusion of activity in Italy among private and public structures [7]

patients) [6]. It has issued the following distribution for the public/privates structures of nuclear medicine as for the private structures. The overall distribution per million of inhabitants can be summarized from the following maps. In some regions, a clear unbalance appears among the distribution of the structure public/private (Fig. 7).

To make clearer the geographical distribution all over the three parts of Italy, please refer to the following pie charts (Fig. 8):

The diagnostic activity developed in Italy can be summarized by the following histograms [7] (Fig. 9):

With the following irregular distribution of nuclear devices (cyclotron and PET all included) [7, 8] (Fig. 10):

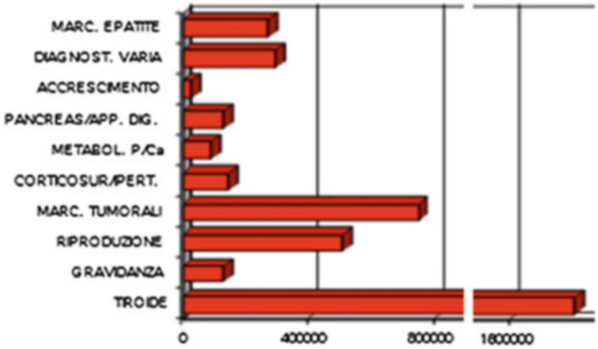

Fig. 9 Diagnostic activity in Italy [7]

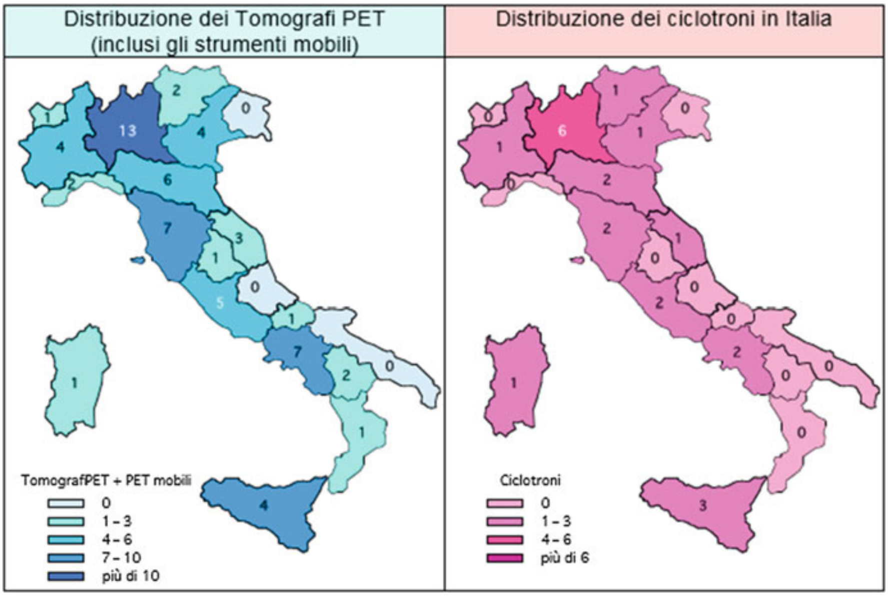

Fig. 10 PET tomography distributions (left), cyclotron distributions (right) [7]

16 Conclusion

Good practice for storage/disposal of hospital waste is to make waste accumulation difficult, to make waste accumulations very expensive, or to make waste accumulations expensive exceeding the 1Mbe limit. So we can suggest that the waste in question can be immersed in a plastic bath, from which it is complicated to extract them once they are immersed. In Italian history, we can note that the ancient

Castelmauro (Cb) website is quite far from having the characteristics that have been identified by the national store. As a matter of fact, it is unknown where the residues will be dispersed (probably will be brought to Germany, and only after radioactivity is definitely reduced to 2% of the initial value will it be reported in Italy to be stocked by Enea). The future development of nuclear medicine is linked to the availability of tomographic investigation systems, which allow for three-dimensional morphological and functional investigations. The availability of medium ± emitters with very short life times, with values ranging from a few minutes to a hundred minutes, will reduce even more so that the amount of radioactivity discharged into the environment will be reduced.

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Multidisciplinary Education in Managing Maxi-Health Emergencies in Unconventional Events: Preliminary Results from the International Security/Safety/Global Strategy and Medical Maxi-Emergency (ISSMMdelta) Master

Giorgio Pistilli, Paola Rosati, Roberta Villanacci, Maria Luisa Maniscalco, Fabrizio Fontana, Matteo Martini, Gianluigi Sergiacomi, and Roberto Fiorito

1 Introduction

Throughout all of its history upon the Earth, mankind has always had to face different kinds of disasters, but the last few centuries have been characterized by an increased variety and a number of catastrophic events [1]. Also, we have witnessed unprecedented scenarios especially in the last 100 years: the unstable political climate has increased the likelihood of disasters caused by terrorism [2] and wars (not known before), and the climate changes have been responsible for the more and more frequent natural catastrophic events.

No doubt, whatever their nature and origin, the first problem catastrophic events raise is a medical [3] one given by their impact on morbidity and mortality rates in the population involved and among the first responders. Yet because emergencies

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cannot and should not be improvised, it is fundamentally important that the university—through a strategic qualified high-level training course—plans and manages emergencies of all types. In 2008, the European Community issued a specific directive (114) [4] on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection. In particular, it required the European critical infrastructure operators to designate a Security Liaison Officer (SLOs). These professionals must necessarily undergo specialist courses grafted on wider cultural training, within which security/safety and medical mass casualty disaster management integrate perfectly with the wider concept of Homeland Security [5, 6]. However, there is the lack [7, 8] of such specialist courses in the European Union, as Ingrassia et al. [9] pointed out in 2014. Also, they found out that the curricula of each course analyzed do not cover all key elements of disaster management in a standardized and competency-based structure.

The ISSMMdelta Master [10], born in 2015, is the only multidisciplinary European academic course with highly specific strategic-formative profile, unique in the European Panorama for its content and occupational openings.

2 The International Security/Safety/Global Strategy and Medical Maxi-Emergency (ISSMMdelta) Master

2.1 General Information

The ISSMMdelta Master is an International University Post-degree Master of Science of second level, run at the faculty of Medicine and Surgery at the University of Rome Tor Vergata. The Master's study program, focused on giving enrolled students a multidisciplinary education in managing maxi-health emergencies in unconventional events [11], is addressed to graduates from medicine and surgery, biology, pharmacy, engineering, political science, communication sciences, information technology, economics and finance, and law.

The ISSMMdelta Master is also open to individuals with disabilities thanks to the facilities and the support available at the Faculty of Medicine and Surgery at the University of Rome Tor Vergata.

The courses are taught both in Italian and in English so as to provide a background, a knowledge, and a culture which could be useful in any worldwide setting. It has a duration of 18 months, and lessons take place on the weekends.

2.2 The Structure

Organogram It provides a total of 475 hours of tutoring activities divided in teaching sessions and traineeship and 300 hours of workshops organized in synergy with the affiliated institutions, universities, or associations throughout a period of three semesters. At the end of each semester, all students are examined by the different experts on all the subjects taught, and they are required to choose a topic to present a power point presentation on the day of the exam. At the end of the last semester, all students need to write a thesis on the topic chosen.

The Master study program is made up of three different integrated modules. The synergy achieved by recruiting university lecturers and external experts all having unquestionable experience in their own field, and also thanks to the cooperation with national and international public/private, civil/military, lay/religious, societies/institutions, is the strong point of the ISSMMdelta Master.

Module 1 The first module is focused on terrorism and its sociocultural-economic-juridical-ethical and religious features and analyzes the historical-geographic, socio-political, economic, juridical, psychological, philosophical, communication, ethics, and religious science competencies aimed to promote a greater knowledge of unconventional events, existing terrorist movements, and expected challenges from new-generation threats. The module intends to introduce the cultural background in which these new global threats emerge and expand.

Module 2 The second module is about international Homeland Security and global strategies [12]: preparedness planning for global threats requires to mobilize a global response based on specialist institutional synergies. With this aim in mind, Module 2 aims to provide participants with the specific competencies required for intelligence and for analyzing and managing security at various levels—computer information, aerospace, maritime ports, energy, environment/terrestrial overland, food and water, and pharmacological safety.

Module 3 The third module is about natural, accidental and terrorist disasters, and major health emergencies. It covers the specific competencies needed to prevent, forecast, quickly respond to, and recover from clinical-surgical emergencies caused by unconventional events. It also addresses the most effective methods and competencies for managing major health emergencies caused by unconventional events and CBRNe (chemical, biological, radiological, nuclear events), weapons of mass destruction (WMD), and improvised explosive devices (IED) [13, 14].

2.3 Professional Career Opening

The aim of the ISSMMdelta Master Course is to train the Security Liaison Officers (SLOs) required to each member of the European Community by the directive issued in 2008. Among its aims, it also intends to train Emergency Medical Managers (EMM), whose professional skills will be increasingly sought at international and national levels, especially in those "high-risk" countries in which catastrophic events ever more frequently disrupt daily life. The competencies and skills acquired during the Master program will also be fundamentally important in forming and valorizing the various Public Health Managers (PHM), at the national and European level (Decision 1082/2013/EU) and in training experts in risk assessment and risk management. The rationale underlying the Master program reflects the term "academy," understood in its original meaning as the primary site for the integrated development of knowledge. For this reason, the course involves lecturers whose primary teaching focus centers on the most advanced research methods [15] appropriate for forming and consolidating the profession of researchers at administrations, institutions, or companies/foundations/private research centers or both to meet market requirements.

3 Results

The first edition of the ISSMMdelta Master started in November 2015 (see the student's expertise in Fig. 1) and ended in July 2017. In addition, for this first edition, 5 more drill days (days of deepening) were organized during the 18 months. The ISSMMdelta Master has given its patronage to 24 conferences planned by the affiliated associations and institutions.

There were a total of six enrolled students (Fig. 1). The basic expertise of a half of them was from medicine and surgery, 30% from biology, and 16% from other faculties (such as law, political science, etc.).

The outcoming data from the final analysis of the attendance list showed an overall attendance of 95% at the tutoring activities, a little bit more at the trainee sessions than at the teaching ones, and an attendance of 82% at the workshops (Fig. 2).

Also, we analyzed the attendance of all the three different basic expertise in each kind of activities, and they are shown in Fig. 3.

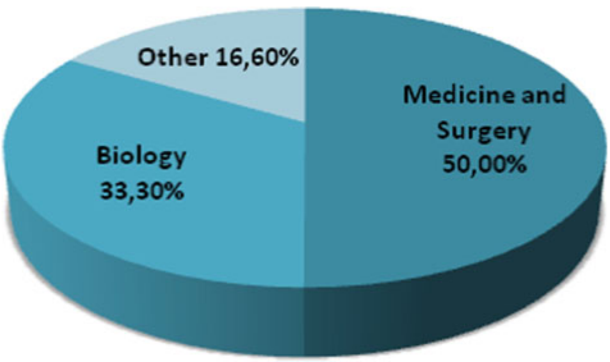

Fig. 1 Basic expertise of Master's students

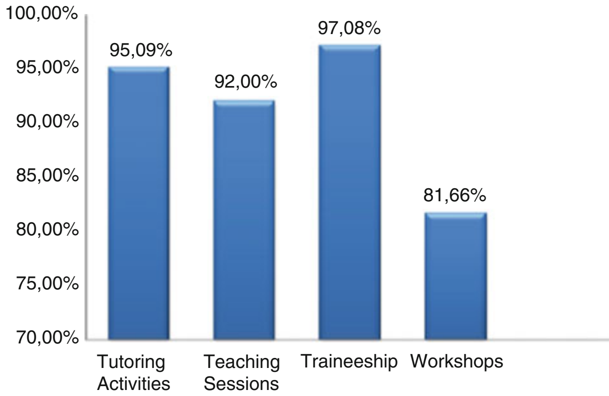

Fig. 2 Attendance graph

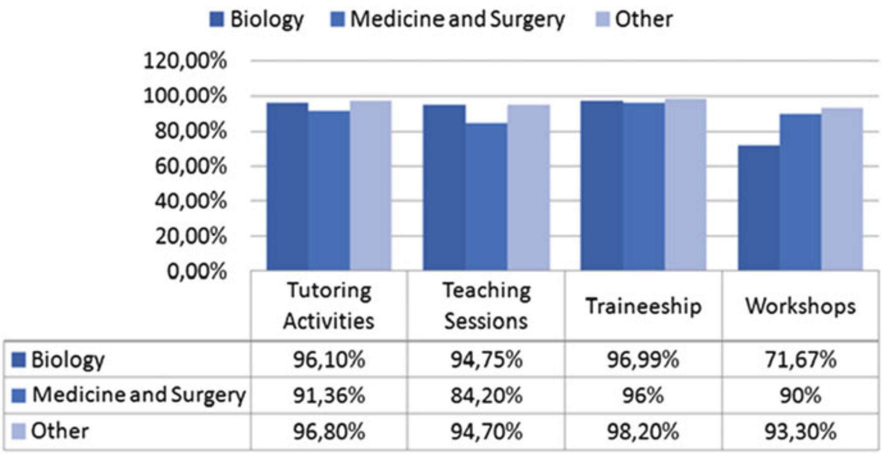

Fig. 3 Attendance graph of the three different expertise

4 Conclusion

We have encountered some barriers due to the fact that this is the first running academic year. The most important ones were the decentralized (off-center) location, fund raising, and the difficulties encountered in organizing all the activities.

Despite these difficulties, we managed to twin with institutions like IGESAN (Ispettorato Generale della Sanità Militare, General Inspectorship of Military Health), CESMA (Centro Studi Militari Aeronautici "Giulio Douhet," Air Force Study Center "Giulio Douhet"), AFCEA (Armed Forces Communications and Electronics Association), and ANSMI (Associazione Nazionale Sanità Militare, National Association of Military Health), which have recognized the importance and the uniqueness of the ISSMMdelta Master [1].

With the next editions (October 2017), we hope to strengthen the third mission of the university and to become a point of reference in terms of Master of Science for the European Community with respect to the aims and goals mentioned in Sect. 2.

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Conclusion

Michael Ian Thornton

The world has changed. The use and potential misuse of chemical, biological, radiological, nuclear and explosives or CBRNe, once considered to be solely the concern of the military, now needs to be considered also in the public domain.

The University of Rome "Tor Vergata" has years of experience in running master's courses in CBRNe and in combination with HESAR (Health Safety Environmental Research Association Rome) has promoted the spread of education beyond traditional boundaries, with the final objective of obtaining the recognition that CBRNe should become an academic, scientific discipline. To support this ambition, the first Scientific International Conference on Safety and Security Issues in the CBRNe was held in Rome between the 22nd and 24th of May 2017.

The conference had a distinguished list of speakers from many institutions and countries involved in CBRNe matters, coming together to share their wealth of knowledge and experience in this complex and often misunderstood field. From the USA to the UAE and NATO to OSCE, representatives came to speak and share, but above all they came to meet, to listen and to learn.

It is a rare occurrence that academics, educators, students, government representatives, the military, industry and other relevant stakeholders can join together, offering an opportunity for all to maintain existing networks within the CBRNe community and to establish new ones. With papers, posters and demonstrations from students, first responders and industry, the conference highlighted both the many achievements and exposure of the multitude of issues still facing us within the CBRNe sphere.

It was 20 years since the establishment of the Chemical Weapons Convention, and amongst the celebrations around the world in 2017 to mark this auspicious

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occasion, the Scientific International Conference on Safety and Security Issues in the CBRNe in Rome was selected to honour and recognize it with the presence of Ambassador Ahmet Üzümcü, Director General of the Organisation for the Prohibition of Chemical Weapons (Nobel Peace Prize winner 2013). During his keynote speech to the conference, he highlighted the verified destruction of 95% of the world's stockpile of declared chemical weapons, and discussed the new approaches that are followed and new capabilities acquired by the OPCW, as the focus shifts away from destroying existing chemical weapons to preventing their re-emergence. However, he also sounded a note of caution, stating that "the people of the world are not yet free from the scourge of chemical weapons" and that we must continue to work together to remove all chemical weapons from the earth. He called upon states parties, scientists, academia, industry and international organizations to help in the cause.

The collection of peer-reviewed articles contained herein gives an insight to what was discussed and presented at the conference. A prestigious scientific committee led by Ambassador Bonnie Jenkins formerly of the US Department of State—Bureau of International Security and Nonproliferation—Coordinator for Threat Reduction Programs, reviewed and selected the papers to be published here. The conference and the published papers combine to demonstrate what has been achieved, and the reader will discover that both common challenges and creative solutions emerge from very diverse settings.

The global CBRNe community has a duty to work together as one. We must raise awareness at all levels, and we need to continue to educate and train, meet and discuss, so that we can all live in a safer and more secure world, where CBRNe materials are used not as a threat, but as a benefit to mankind.