CHAPTER 2
QUANTITY OF SEWAGE

2020

2.1 General

- "Sewage" includes domestic, municipal, or industrial liquid waste products disposed of, usually via a pipe or sewer or similar structure.

- Therefore, before any design attempt of sewer line, estimation of quantity of sewage that will flow through the sewer system is necessary.

- The domestic and industrial sewage discharge that has to pass through a sewer must be estimated as correctly as possible; otherwise the sewers may either prove to be inadequate, resulting in their overflow, or may prove to be of too much of size, resulting in unnecessary wasteful investments.

2.2 Types of Sewage

I. *Sanitary sewage* : Liquid wastes that originate from residence, commercial and institutional areas

II. *Domestic sewage:* If the sewage is a waste from residential areas or institutions.

III. *Industrial sewage:* if the source is industrial discharge.

IV. *Storm sewage* : The run-off resulting from the rainstorms which is deliberately introduced into sewers intended for its conveyance. But it is in the modern approach called as *storm drainage* or simply *drainage*, so as to differentiate it from sewage.

V. *Infiltration:* water that enters the sewers from the ground through leaks.

Sources of Sewage

Sewage is generally obtained from:

- Water from the water supply scheme
- Domestic water use,
- Industrial water use,
- Public water use, etc.
- Water from other sources such as private wells, rivers, etc.
- Infiltration of ground water into the sewer through loose joints,
- Unauthorized entry of rain water in sewer lines.
- Storm water is derived from the surface runoff generated by a storm rainfall.

Planning wastewater collection system

- In addition to the financial resource the following factors must be considered

1.The period of design:-should the facilities be designed to serve only the immediate needs of the population or should they also be adequate for the future? If so …until what time?

2.The population to be served:-what is the population likely to be at the end of the design period. How large an area to be served?

3.The quantity and quality of the waste water to be handled. How do they vary hourly, daily, seasonally with in changes in water supply available. Standard of living and industrialization. Is it likely that industry or large commercial enterprises will be attracted to the community after sewage system has been installed?

4.The choice between separate vs combined sewage system

5.Collection system layout:-when does it become economical to pump, as compared with extending gravity sewers over long distances and through deep cuts.

2.3 Quantity of Sewage

- Domestic sewage and industrial wastes are derived principally from the water supply.
- Thus, estimation of sewage flow should be prefaced by a study of both present water consumption and that expected in the future.

i) Domestic sewage

- The principal sources of sanitary sewage in a community are the residential and commercial districts. Other important sources include institutional and recreational facilities.
- The accounted water supplied to the public through the public distribution system is not necessarily the only water consumed by the public. Some private wells and tube-wells may sometimes be used by the public for their domestic needs; and similarly, certain industries may utilize their own sources of water
- The quantity of water that appears as sewage from such area should be added to the total sewage quantity, it is usually referred as additions due to unaccounted private water supplies.

ii) Industrial sewage

- If the water requirements for the industries are known, wastewater flow projections can be based on water flow projections.
- For industries without internal reuse programs about 85-95% of the water used in the various operations and processes will probably become wastewater.
- For large industries with internal water reuse programs separate estimates must be made.
- Average domestic wastewater contributed from industrial activities may vary from 30 - 95 liters/capita/day.

iii) Infiltration/Inflow

- The other quantity of water as sewage that should be accounted in determination of total sewage quantity is the addition due to infiltration.

Infiltration and Inflow

- Infiltration: groundwater entering sewers through defective joints, and broken or cracked or broken pipes and manholes.
  - High during wet period, especially sewers constructed in or close to streambeds
- Inflow: the water discharged into a sewer system, including service connections from such sources as roof downspouts; basement, yard, and area drains; manhole covers; surface runoff; street wash water; etc.
  - Quantity may vary from 35 to 115 m3/km.
  - Units: L/ha/day, L/km length, or L/cm diameter

Infiltration flow

Infiltration in a sewerage system occurs through defective pipes, connections, joints or manholes. The quantity of infiltrated water depends on various factors, such as the extension of the collection network, pipeline diameters, drainage area, soil type, water table depth, topography and population density (number of connections per unit area) (Metcalf & Eddy, 1991).

When no specific local data are available, infiltration rate is normally expressed in terms of flow per extension of the sewerage system or per area served. The values presented in Table 2.11 can be used as a first estimate, when no specific local data are available (Crespo, 1997).

Metcalf & Eddy (1991) present the infiltration coefficient as a function of the pipe diameter: **0.01 to 1.0 m^3/d.km per mm**. For instance, for a pipe diameter of 200 mm, the infiltration rate will range between 2 to 200 m^3/d.km.

The length of the network may be measured in the locality by using the map of the location of the sewerage system. In the absence of these data (for instance, for future populations), in preliminary studies of smaller localities, where the population density is usually less, values around 2.5 to 3.5 m of network per inhabitant may be adopted. In medium-size cities this value could be reduced to around 2.0 to 3.0 m/inhab and in densely populated regions, even smaller values may be reached (1.0 to 2.0 m/inhab or even lower). Figure 2.6, based on the 45 municipalities described in Section 2.1.2, presents the ranges of variation of per capita length of sewerage network for two population categories.

Based on the infiltration values per unit length and the per capita sewerage network length, per capita infiltration values may be estimated to range between **8 to 150 L/inhab.d**, excluding the extreme values. In areal terms, based on typical population densities (25 to 125 inhab/ha), infiltration rates between **0.2 and 20 m^3/d per ha** of drainage area (**20 to 2000 m^3/d.km^2**) are obtained. These ranges are very wide, and the designer should analyse carefully the prevailing conditions in the sewerage network in order to obtain narrower ranges, which could best represent the specific conditions in the community under analysis. The utilisation of good materials and construction procedures helps in reducing the infiltration rates.

In the calculation of the total influent flow to a WWTP, average infiltration values may be used for the computation of average and maximum influent flowrates. For minimum flow conditions, infiltration can be excluded, as a safety measure (in the case of minimum flow, the safety in a design is in the direction of establishing the lowest flow).

Table 2.11. Approximate values of infiltration rates in sewerage systems

Pipe diameter	Type of joint	Groundwater level	Soil permeability	Infiltration coefficient L/s.km	Infiltration coefficient m^3/d.km
< 400 mm	Elastic	Below the pipes	Low	0.05	4
			High	0.10	9
		Above the pipes	Low	0.15	13
			High	0.30	26
	Non-elastic	Below the pipes	Low	0.05	4
			High	0.50	43
		Above the pipes	Low	0.50	43
			High	1.00	86
> 400 mm	–	–	–	1.00	86

Source: Crespo (1997)

iv) Leakage

- Leakage sources include holes in the cover; openings in the masonry grade adjustment courses between frame and manhole structures.
- The water lost, due to leakage in the distribution system and house connections of the water supply scheme, does not reach the consumers, and hence, never appear as sewage.
- In addition certain amount of water may be used by the public and industries for such uses that may not produce any sewage at all.

These two categories of water quantity should be subtracted from the total sewage quantity computation. i.e.

1. subtractions due to water losses by leakage and
2. subtractions due to water not entering the sewerage system.

Net quantity of sewage

- The net quantity of sewage produced will be

  = the accounted quantity of water supplied from the water-authority

  +

  the additions due to unaccounted private water supplies

  +

  due to infiltration

  -

  the subtractions due to water losses and due water not entering the sewerage system.

- This net value may vary 70 to 130 percent of accounted water supplied from the water authority.

Wastewater Quantity Estimation

- ✓ The flow of sanitary sewage alone in the absence of storms in dry season is known as dry weather flow (DWF).

Quantity= Per capita sewage contributed per day x Population

- ✓ Sanitary sewage is mostly the spent water of the community draining into the sewer system. It has been observed that a small portion of spent water is lost in evaporation, seepage in ground, leakage, etc. Usually 80% of the water supply may be expected to reach the sewers.
- ✓ The per capita sewage that is produced in a community can be easily estimated by assuming it as 70 to 130%(the per capita water supplied to the public). However, it should also be kept in mind that the future increase in population may also increase the per capita water demand, and consequently increasing the per capita production of sewage.

2.4 Variations of sanitary sewage

The flows in these sanitary sewers, though fluctuate

- seasonally,
- monthly,
- daily, as well as hourly, with the water consumption

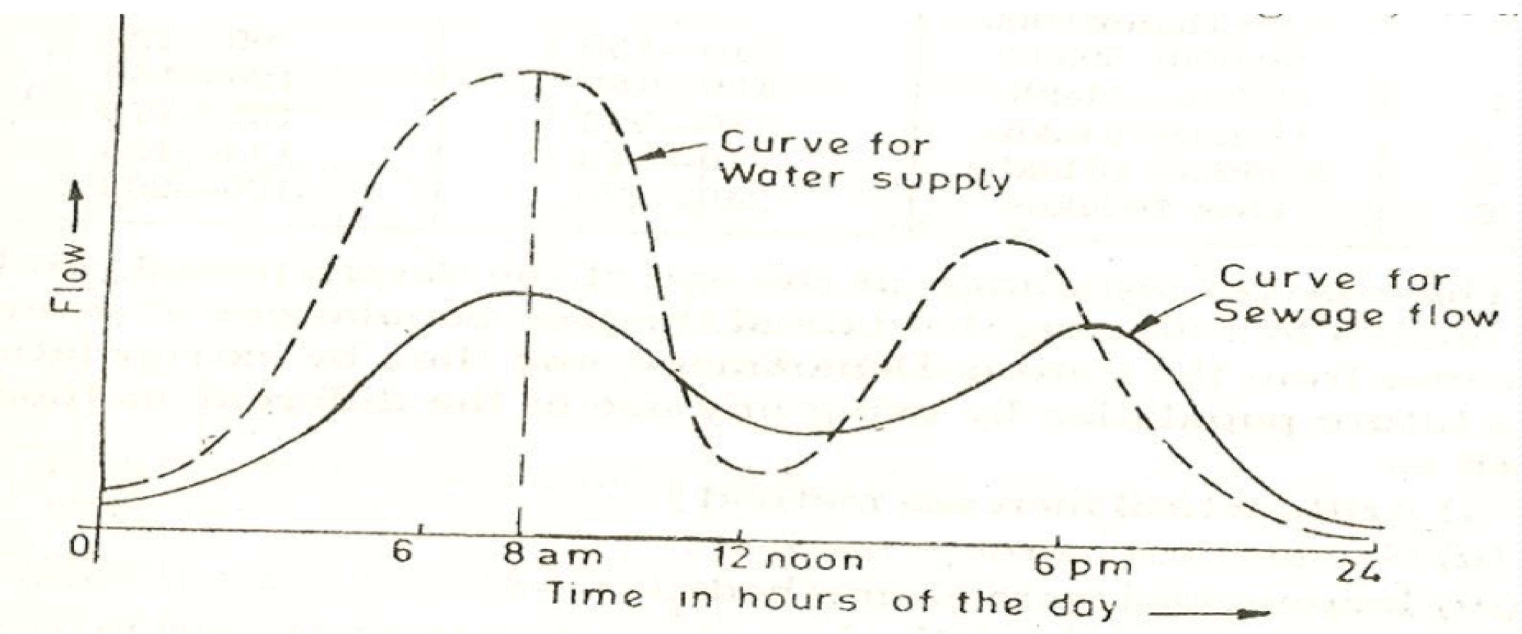


Fig.2.1. Hourly variation of sewage flow compared to that of water supply.

❖The consumption of water in dry season is more than in rainy season, and this change in consumption of water directly affects the quantity of sewage.

❖Since dry weather flow depends on the quantity of water used, and as there are fluctuations in rate of water consumption, there will be fluctuations in dry weather flow also.

❖In general, it can be assumed that

1) Maximum daily flow = 2 x average daily flow and

2) Minimum daily flow = 2/3 x (average daily flow).

3) Maximum hourly flow = 1.5 times the maximum daily

=3 times the a average daily

- Wastewater flow rate factors:
  - Maximum flows are determined by peaking factor (PF).

$$\frac{peak\ flowrate(e.g., hourly, daily}{average\ long - term\ flowrate}$$

Table 3-11
Terminology used to quantify observed variations in flowrate and constituent concentrations[a]

Item	Description
Average dry-weather flow (ADWF)	The average of the daily flows sustained during dry-weather periods with limited infiltration
Average wet-weather flow (AWWF)	The average of the daily flows sustained during wet-weather periods when infiltration is a factor
Average annual daily flow	The average flowrate occurring over a 24-h period based on annual flowrate data
Instantaneous peak	Highest record flowrate occurring for a period consistent with the recording equipment. In many situations the recorded peak flow may be considerably below the actual peak flow because of metering and recording equipment limitations
Peak hour	The average of the peak flows sustained for a period of 1 hour in the record examined (usually based on 10-min increments)
Maximum day	The average of the peak flows sustained for a period of 1 day in the record examined (the duration of the peak flows may vary)
Maximum month	The average of the maximum daily flows sustained for a period of 1 month in the record examined
Minimum hour	The average of the minimum flows sustained for the period of 1 hour in the record examined (usually based on 10-min increments)
Minimum day	The average of the minimum flows sustained for the period of a day in the record examined (usually for the period from 2 A.M. to 6 A.M.)
Minimum month	The average of the minimum daily flows sustained for the period of 1 month in the record examined
Sustained flow (and load)	The value (flowrate or mass loading) sustained or exceeded for a given period of time (e.g., 1 hour, 1 day, or 1 month)

[a] Adapted in part from Crites and Tchobanoglous (1998).

- Practically it has been seen that the ratio of maximum to average flow of sewage is from 1.5 to 1.0.
- Similarly the ratio of average to minimum is from 1.2 to 1.0.
- There is also change in the sewage quantity if the city has seasonal industries such as sugarcane crushing, fruit canning, brewing, etc.
- The quantity of sewage also changes from day to day. On the closing days of market, offices, industries, the quantity of sewage shall be more due to cloth washing, house cleaning, etc., therefore, the variation in the sewage quantity also depends on the local conditions.
- The magnitude of the variation in the sewage quantity differs from place to place adding a challenge on future predictions.

- Empirical formulae may be used for determining peak rates of flow for sewer design as given below.

i. Babbit's formula

$$M = \frac{5}{P^{1/6}}$$

ii. Harmon's formula

$$M = 1 + \frac{14}{4 + P^{1/2}}$$

Where,

M = the ratio of peak rate to average rate,

P = population in thousands.

cont'd...

- The flow in the sewers is minimum during nights.
- The effect of this flow is maximum in the laterals connected direct to the houses and minimum to the main trunk sewer.
- The minimum flow in laterals is below 30% of average flow while in trunk sewers it may be 60-70% of the average.
- The overall variation in the sewage is maximum in the smaller size sewers and goes on reducing as the size of the sewer increases.

Table: common values of hourly variation in sewage flow for different types of sewers.

Types of Sewer	Ratio of Max. to Average flow
Small size sewers including laterals	4
Sewers up to 25cm in diameter	4
Branch sewers up to 50cm in diameter	3
Main sewers up to 100cm in diameter	2
Trunk sewers up to 125cm in diameter	1.5

2.5 Quantity of storm water :

- The sewers and the drains of a separate sewerage system should be designed to carry
    - the maximum sewage discharge and
    - the maximum rain runoff, respectively.
- Where as, the sewers of a combined sewerage system should be designed to carry the sewage discharge plus the rain runoff.
- So, it is necessary to determine or estimate the urban storm drainage discharge that is likely to enter the sewers or drains.

- When a rain, falls in a certain area, a part of it
    - is intercepted by the soil,
    - a part of it is evaporated,
    - and the remaining water flows overland towards the valleys, as storm runoff.

❖ The maximum rate of storm run-off, popularly called *peak drainage discharge* that is produced from a particular catchments depends upon numerous factors; such as,

- *the type of precipitation,*
- *the intensity and duration of rainfall,*
- *the rainfall distribution,*
- *the soil moisture deficiency,*
- *the direction of the prevailing storm,*
- *the climatic conditions,*
- *the shape, size and type of catchments basin, etc.*

Estimating the peak drainage discharge /storm sewage

Hydrological analysis:

- Rational method,
- SCS technique,
- Hydrograph technique and
- Computer simulation techniques

Rational Formula

- Is a method of determining peak drainage discharge

$$Q_P = 1/36\ (CIA)$$

Where

Q_P= peak flow (m3/s)

C = dimensionless runoff coefficient

I = the mean intensity of precipitation (cm/hr)

A = drainage area in hectare

Assumptions inherent in the Rational Formula are as follows:

- The peak flow occurs when the entire watershed is contributing to the flow
- The rainfall intensity is the same over the entire drainage area
- The rainfall intensity is uniform over a time duration equal to the time of concentration,

Table 2.1: Runoff coefficients for Rational formula

Type of Drainage Area	Runoff Coefficient, C*
Business:	
• Downtown areas	0.70 – 0.95
Neighbor hood areas	0.50 – 0.70
Residential:	
• Single –family areas	0.30 – 0.50
• Multi- units, detached	0.40 – 0.60
• Multi-units, attached	0.60 -0.75
• Suburban	0.25 – 0.40
• Apartment dwelling areas	0.50 – 0.70
Industrial	
• Light areas	0.50 – 0.80
• Heavy areas	0.60 – 0.90
Parks, cemeteries	0.10 – 0.25
Playgrounds	0.20 – 0.40
Railroad yard areas	0.20 – 0.40
Unimproved areas	0.10 – 0.30

Lawns: • Sandy soil, flat 2% • Sandy soil, average, 2-7% • Sandy soil, steep, 7% • Heavy soil, flat, 2% • Heavy soil, average 2-7% • Heavy soil, steep, 7%	 0.05 – 0.10 0.10 – 0.15 0.15 – 0.20 0.13 – 0.17 0.18 – 0.22 0.25 – 0.35
Streets: • Asphalted • Concrete • Brick	 0.70 – 0.95 0.80 – 0.95 0.70 – 0.85
Drives and walks	0.75 – 0.85
Roofs	0.75 – 0.95

➢If an area that drains to a manhole consists of n land uses, the combined C value needs to be calculated by :

$$C = \frac{\sum_{i=1}^{n} C_i A_i}{\sum_{i=1}^{n} A_i}$$

Exercise

1. Assuming that the surface on which the rainfalls in a district is classified as follows 20% of the area consists of roof for which the run-of ratio is 0.9, 20% of the area consists of pavements for which the run-off ratio is 0.85, 5% percent of the area consists of paved yards of houses for which run off ratio 0.80, 15% of area consists of macadam roads for which run off ratio is 0.40, 35% of the area consists of lawns, gardens and vegetable plants for which the runoff ratio is 0.10, and the remaining 5% of the area is wooded for which the runoff ratio is 0.05.

a) Determine the coefficient of runoff for the area.

b) If the total area of the district is 36 hectares and the maximum rain intensity is taken as 5 cm / hr; what is the total runoff for the district?

2.6 Population Forecast

Design period

- The number of years for which the designs of the sewerage works have been done is known as the **design period.**
- This quantity should be worked out with due provision for the estimated requirements of the future . The future period for which a provision is made in the water supply scheme is known as the design period. It is suggested that the construction of sewage treatment plant may be carried out in phases with an initial design period ranging from 5 to 10 years excluding the construction period.

Design period is estimated based on the following:

- Useful life of the component, considering obsolescence, wear, tear, etc.
- Expandability aspect.
- Anticipated rate of growth of population, including industrial, commercial developments & migration-immigration.
- Available resources.
- Performance of the system during initial period.

Population forecasting methods

The particular method to be adopted for a particular case or for a particular city depends largely on the factors discussed in the methods, and the selection is left to the discretion and intelligence of the designer.

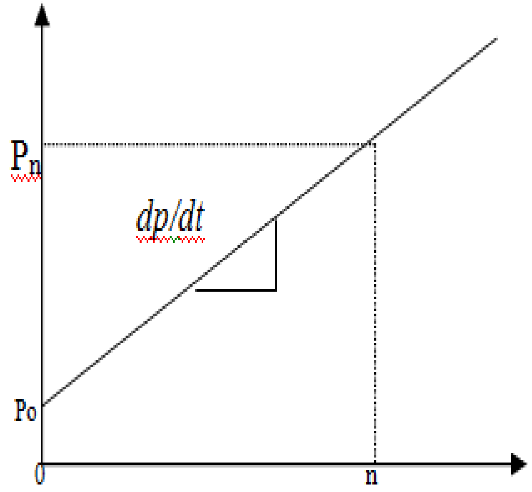
1. Arithmetic increase method
2. Geometric increase method
3. Incremental increase method
4. Graphical extension method
5. Logistic curve method
6. Master plan method
7. Ratio & correlation method
8. Method used by Ethiopians statistic Authority (geometric increase method)

1. Arithmetic increase method

This method is based on the assumption that the population is increasing at a constant rate i.e. the rate of change of population with time is constant.

$$\frac{dp}{dt} = k$$

$$\int_{P_o}^{P_n} dp = K \int_{o}^{n} dt$$



$P_n = P_o + nK$

Where; Pn = population at n decades or years

P_o = present/initial population at the base year

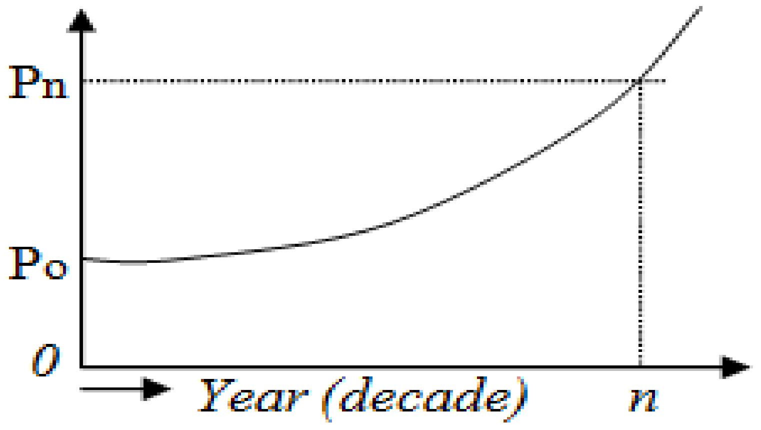
n = decade or year

K= arithmetic increase

- An average increment in the population of past three or four decades is worked out.
- For each successive decade, this average increment is added.
- This method gives too low an estimate.
- This method can be adopted for large cities which are achieved saturation condition.

2. Geometric increase method

This method is based on the assumption that the percentage increase in population remains constant.



$P_1 = P_o + K\, P_o = P_o\,(1 + K)$

$P_2 = P_1\,(1 + K) = P_o\,(1 + K)\,(1 + K)$

$P_3 = P_2\,(1 + K) = P_o\,(1 + K)\,(1 + K)\,(1 + K)$

$\mathbf{P_n = Po\,(1+K)^n}$

Where P_o = initial population

P_n = population at n decades or years

n = decade or year

K = percentage (geometric) increase

- The method gives high result (because the percentage increase gradually drops when the growth of the city reaches the saturation point but the method assumes it remain constant.)
- This method is mostly applicable for growing towns and cities having vast scope of expansion.

3. Incremental increase method

- This method is improvement over the above two methods.
- From the census data for the past several decades, the actual increase in each decade is first found.
- Then the increment in increase for each decade is found. From these, an average increment of the increase is calculated.
- The population in the next decade is found by adding to the present population the average increase plus the average incremental increase per decade.
- Thus, the future population at the end of n decade/year is given by:

$$P_n = P + nI + \frac{n(n+1)}{2} r$$

Where P = present population

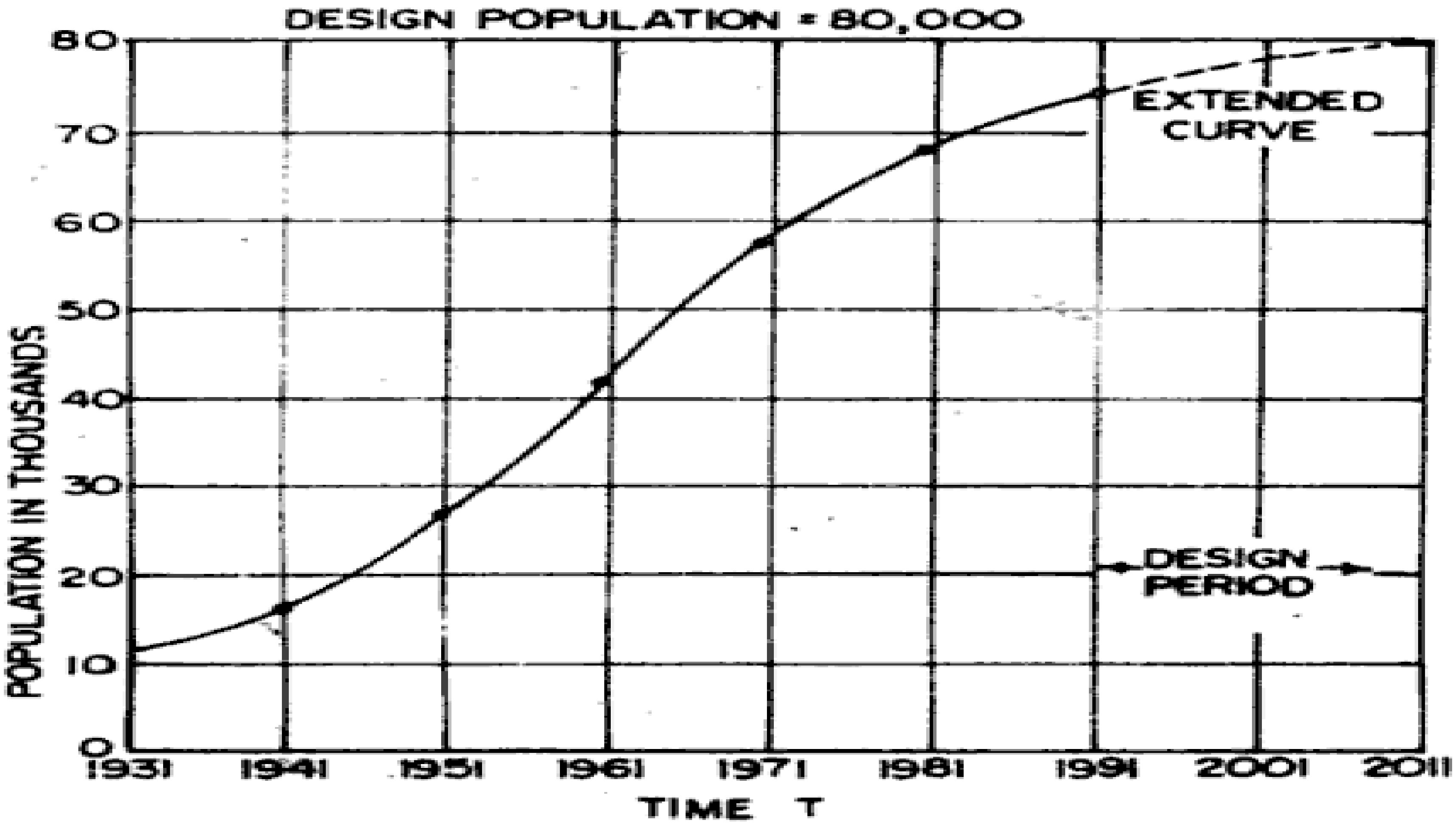
I = average increase per decade/year

r = average incremental increase

n = number of decades/years

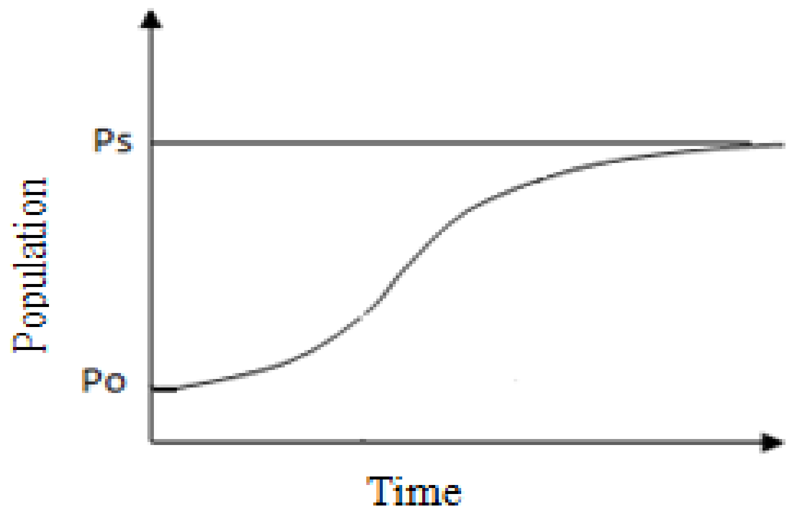
4. Graphical extension method

- In this method the population of last few years is correctly plotted to a suitable scale on the graph with respect to years.
- Then, the curve is smoothly extended to forecast the future population.
- The extension of the curve should be done very carefully.
- It is primarily based on personal judgment of the engineer.



5. Logistic curve method

- The rate of increase of population of a city never remains constant.
- The growth of a new city is very slow in the beginning. After a certain minimum level of growth the population of the city grows by a very high rate and lastly rate of growth progressively lowers down till a saturated limit of population is reached.
- The saturation limit of population depends up on the limit of economic opportunities which the city can provide.
- Thus if the population of a town is plotted with respect to time, for the full time of its growth it follows S- shape curve. This curve is known as S- curve or logistic curve.



6. Master plan method

- In the method, the master plan of the city or town is used to determine the future expected population.
- The population densities for various zones (residential, commercial, industrial and other zones) of the town are fixed and hence the future population of the city when fully developed can easily be worked out.

7. Ratio and correlation method

- In this method, the rate of population growth of a town is related to the rate of population growth of state or nation.
- Hence it is possible to estimate the population of a town under consideration by considering the rate of population growth of state or nation.

Example: Country, $P_{1980} = 1, 000,000$ $P_{2004} = 1,5000,000$

Town, $P_{1980} = 10,000$ $P_{2004} = 15,000$

8. Method used by Ethiopians statistic Authority (geometric increase method)

$$p_n = p_o * e^{kn}$$

Where, P_n = population at n decades or years

P_o = initial population

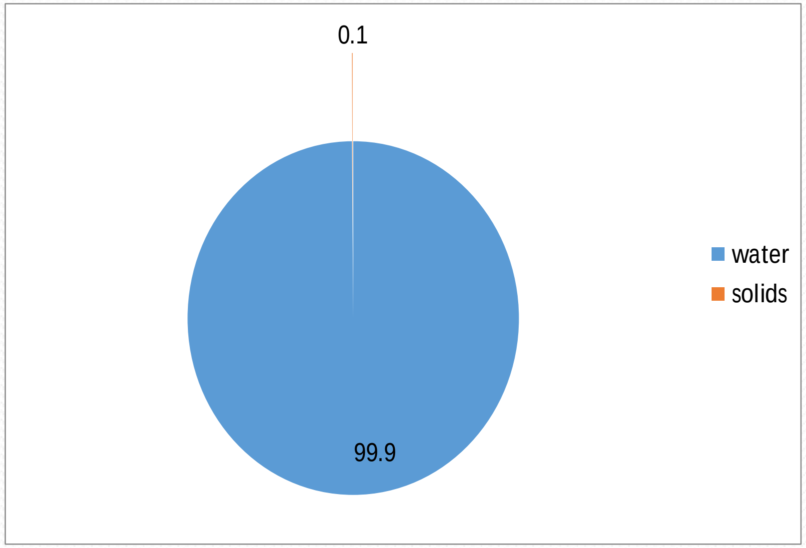
n = decade or year

k = growth rate in percentage

Example: According to CA the population of certain town is 15,640 in the year 1994. Determine the probable population in the year 2010 for k = 3%. *Ans. 25,257*

2.7 Waste water characteristics

- Wastewater (sewage) is over 99.9% water, but the remaining material has a very significant effects.
- Fresh domestic sewage has a slightly soapy or oily odour , is cloudy, and contain a recognizable solids, often of considerable size.
- Stale sewage has a pronounced odour of hydrogen sulphide, is dark grey, and contains smaller, but occasionally recognizable , suspended solids.



- wastewater
  - 70% organic
    - 65% protein
    - 25% carbohydrates
    - 10% Fats
  - 30% inorganic
    - sediments
    - salts
    - metals

- The contaminants in wastewater includes suspended solids, biodegradable dissolved organic compounds, inorganic solids,nutreints,metals and pathogenic microorganisms.
- The suspended solids in wastewater are primary organic particles, composed of;
  - Body wastes
  - Food wastes
  - Toilet paper

- The biodegradable organics in wastewater are composed of mainly;
  - ✓ Protein
  - ✓ Carbohydrate
  - ✓ lipids
- This all contains carbon and can be converted into Co2 biologically. Protein also contain N2 this biodegradable organics must be removed from wastewater or else they will exert an O2 demand in the receiving water course.
- Organic matters typically measured as either BOD(biochemical oxygen demand) or COD(chemical oxygen demand).
- BOD is the most widely used parameter to quantify organic solution of water

- BOD :-is the oxygen that is used by the microbes in the biochemical oxidation measurement of the dissolved of organic matter.
  - Dissolved O2+organic matter → co2+biological growth
- BOD measurements are used to

✓ Determine the approximate quantity of O2 required to react with organic matter

✓ Determine The size of the waste treatment works

✓ Measure The efficiency of some treatment process

- Only partial degradation of organics
- Cannot be used for mass balancing
- Very high (>1000mg/L) and very low (<10mg/L) values often unreliable
- Industrial wastewater can contain inhibitors, leading to low BOD results

COD:-Also measures oxygen required, but for **chemical** oxidation of organics

- COD: chemical oxidants used for oxidation of organics to CO_2, H_2O & NH_3
- Standard COD: $K_2Cr_2O_7{}^{2-}$ /H_2SO_4 @ 145°C
- During oxidation dichromate is used up and remaining oxidant is measured

- Wastewater constituents and analysis include : total suspended solids (TSS); Nitrites(NO2; the five day carbonaceous biochemical oxygen demand, CBOD5 .
- Principal constituents of concern in wastewater treatment include ; suspended solids , biodegradable organics , pathogens and nutrients
- The properties of sewage will be studied in the following three groups
  - Physical properties
  - Chemical properties
  - Biological properties

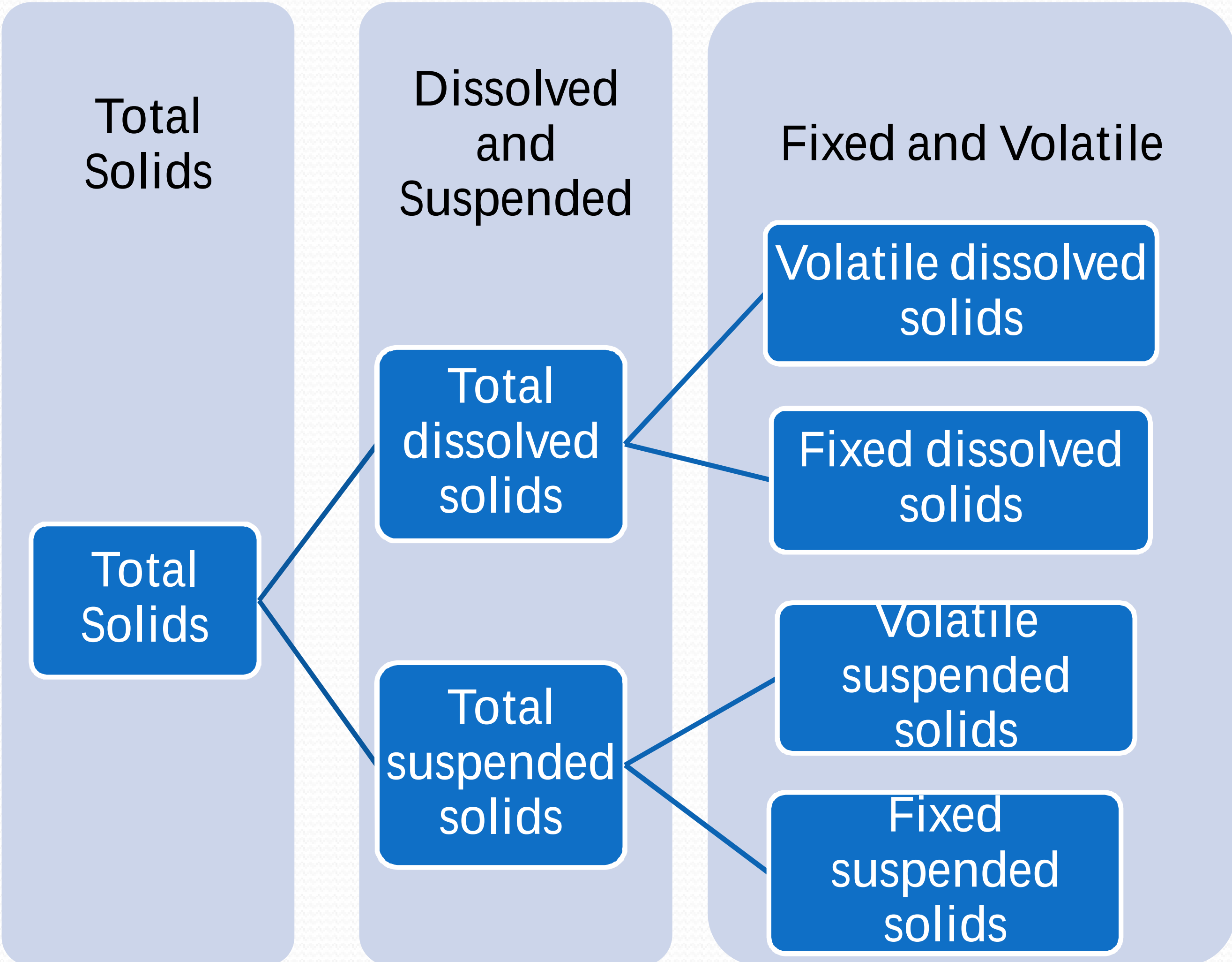
To design a treatment process properly, characterization of wastewater is perhaps the most critical step. Wastewater characteristics of importance in the design of the activated sludge process can be grouped into the following categories:

- Temperature
- pH
- Colour and Odour
- Carbonaceous substrates
- Nitrogen
- Phosphorous
- Chlorides
- Total and volatile suspended solids (TSS and VSS)
- Toxic metals and compounds

Physical characteristics

A. Solids (TS)

- Solids vary from rags to colloids
- Solids (TS) :
  - Total suspended solids
  - Total dissolved solids
  - Volatile and fixed solids
- TSS , total suspended solids : portion of the total solids (TS) retained on a filter.


Total Solids
Dissolved and Suspended
Fixed and Volatile
Volatile dissolved solids
Total dissolved solids
Fixed dissolved solids
Total Solids
Volatile suspended solids
Total suspended solids
Fixed suspended solids

TSS , total suspended solids :

- Portion of the total solids (TS) retained on a filter after being dried at a specific temperature of 105°C.
- Varies in size from 0.45µm to 2.0 µ m
- TSS is routinely used to asses the performance of a treatment plant and is one of the two universally used effluent standards by which the performance of treatment plants is judged for regulatory control purposes.
- The TSS is typically 220 mg/l for a raw sewage.

- ## TDS , total dissolved solids :
  - Is the solids contained in the filtrate that passes through a filter with a nominal pore size of 2.0 µm pr less
- Volatile and Fixed Solids :
  - Material that can be volatilized and burned off when ignited as 500 C is classified as volatile.
  - Volatile solids (VS), are presumed to be organic matter and fixed solids (FS) , is the inert residue.
  - The ratio of VS to FS, typically , 70% , is used to characterize the wastewater with respect to the amount of organic matter content.

In solids analysis, the following measurements were obtained:

- Sample size: 50 mL
- After filtration/evaporation:
  12 mg filter cake, 2.5mg solids in filtrate
- After high temperature oxidation:
  2.0 mg filter cake

What is TSS, VSS and TS in the sample? mg/ml

- TSS : 12 mg / 50 ml = 0.24 mg/ml
- VSS : (12 – 2.0 mg) / 50 ml = 0.2 mg/l
- TS : (12+2.5) mg /50 ml = 0.29 mg/l

Other physical characteristics

Turbidity - is a measure of the light transmitting properties of water and is used to indicate water quality with respect to colloidal and residual suspended matter.

- There is a direct relationship between turbidity and total suspended solids.
- Perhaps a primary criteria in clean water treatment.

Colour : Fresh aerated , wastewater is usually light brownish , gray colour. As the oxygen is consumed by bacteria the colour eventually changes to dark gray and eventually black. The colour change is typically due to the formation of metallic sulphide produced under aerobic conditions.

- light brown-gray => fresh, aerob
- dark brown-black => old, anaerob

Temperature - is important because of its effects on reaction rates and aquatic life but as a practical matter, accomplishing even a modest change in temperature would require an enormous and prohibitive amount of energy. Waste water is typically warmer than the local water supply because of warm fresh water and industrial contributions.

The optimum temperature for bacteria is between 25 – 35 °C

- Oxygen is less soluble in warm water than in cold water. The increase in the rate of biochemical reactions that accompanies an increase in temperature , combined with the decrease in the quantity of oxygen present in surface water , can often cause serious depletions in dissolved oxygen concentrations in the summer months **(Metcalf and Eddy, 2007)**.
- Conductivity : The EC of water is a measure of the ability of a solution to conduct an electric current. Since electric current is transported by the ions in solution, the conductivity may be used as a surrogate for TDS.

• Chemical characteristics

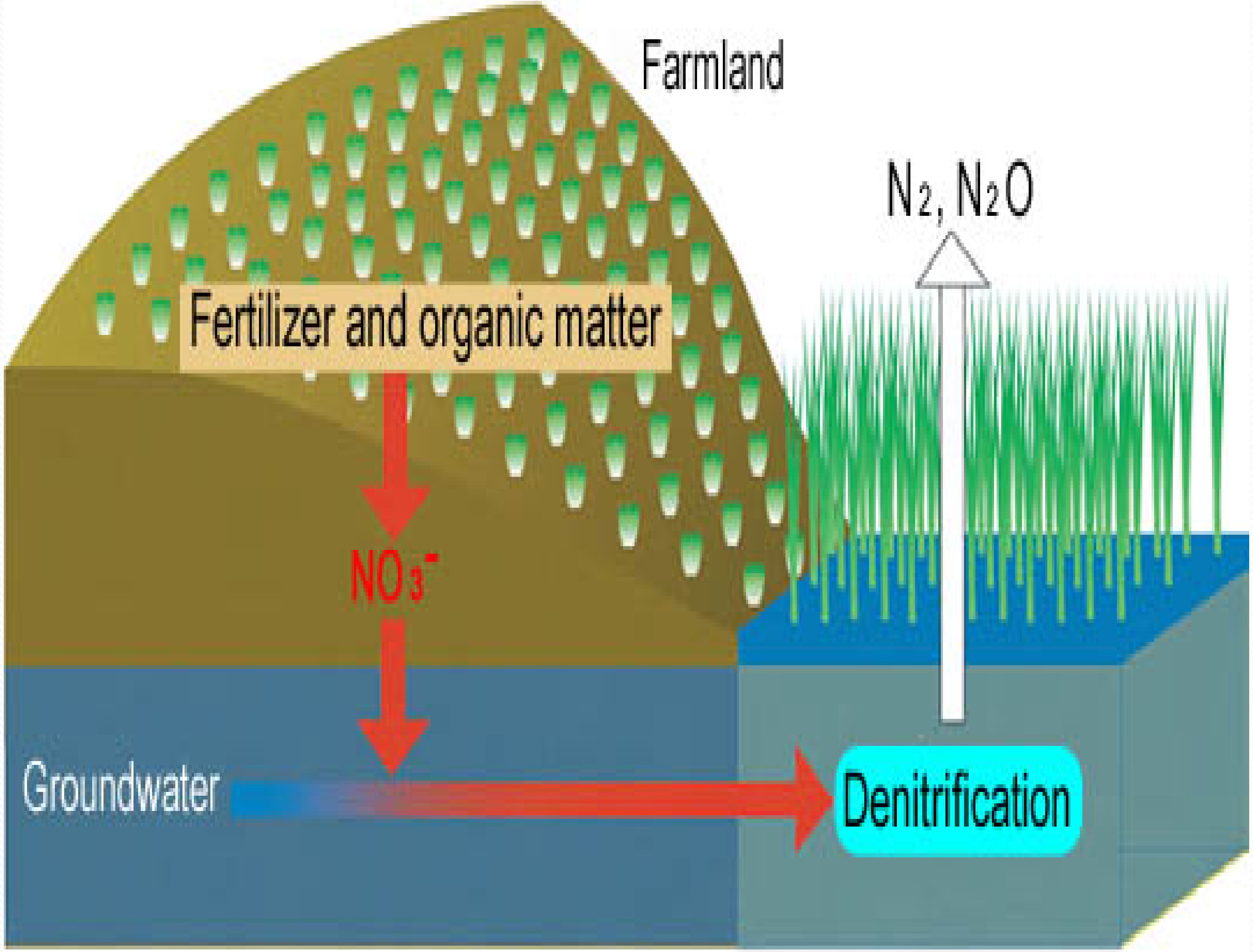
- **Inorganic Non – metallic constituents**
  - **pH**
    - is the negative logarithm of the hydrogen ion concentration
    - the range for most biological life is 6-9
    - for treated wastewater discharged to the environment the allowable pH varies from 6.5 – 8.5

- **Alkalinity**
  - results from the hydroxides , carbonates and bicarbonates .
  - is a buffering system that resists changes in the pH because of acids.
- **Nitrogen**
  - is one of the major bio stimulants in wastewater.
  - exists in various forms
  - nitrites the most oxidized form

- standard for a typical effluent range from 15-20 mg/l as N.

- **Phosphorous**
  - is one of the major bio stimulants in wastewater.
  - 4- 16 mg/l of phosphorous as P is typical in municipal wastewater system.
- **Sulphur**
  - is required in the synthesis of proteins.
  - H_2S gas, which is toxic , can form under bacterial action and collect on the crown one of the pipes major not flowing full. H2S can be oxidized biologically to sulphuric acid , which is corrosive.
  - Crown rot is a common and destructive phenomenon.

An entire lake swallowed by algae due to phosphorous pollution



Farmland
N2, N2O
Fertilizer and organic matter
NO3-
Groundwater
Denitrification

- Gases
  - include nitrogen, oxygen, carbon dioxide, hydrogen sulphide , ammonia and methane
- **Inorganic – metallic constituents**
  - Trace quantities of cadmium, chromium, lead etc are required for the growth of biological life but the presence of these materials in excessive quantities is toxic .
  - Sources metals in wastewater include the discharges from residential dwellings, groundwater infiltration , and commercial and industrial discharges.
- **Aggregate organic compounds**
  - Organic compounds consist C, H, O and sometimes N. wastewater is typically proteins (40-60%) , carbohydrates (25-50%) and oils and fats (8-12%).
  - Methods of identifying organic strength (organic content of water) of sewage
    - BOD_5 test
    - COD
    - Others

. BOD5

- BOD_5 stands for the biochemical oxygen demand and is typically 220mg/l for raw sewage.
- The test is taken over 5 days at a temperature of 20ºC and is the premier test in the wastewater field.
- The BOD_5 test is used to determine the oxygen demand needed to stabilize the organic matter present ; size of facilities ; measure the efficacy of the wastewater processes and to determine compliance with permits.

- BOD_5 test is used to determine the oxygen demand needed to stabilize the organic matter present ; size of facilities ; measure the efficacy of the wastewater processes and to determine compliance with permits.
- In an anaerobic process , the oxygen is used for energy, the creation of new cells and when organic matter is gone, the cells consume themselves in a process known as endogenous respiration.

- BOD_5 test :
  - The sample (wastewater is typically diluted) is placed is standard 300 ml bottle and the oxygen is measured immediately.
  - The sample is incubated at 20 °C for 5 days and the oxygen is measured again.
  - The difference in the values times any dilution factor is the BOD.
  - For non seeded dilution

$$BOD_5 = \frac{(D1 - D2)}{P}$$

D_1 = initial dissolved oxygen concentration, mg/l

D_2 = dissolved oxygen concentration after 5 days, mg/l

P = dilution factor, ml sample/300ml, 300ml is the standard volume of a BOD test bottle.

- The BOD test is 95 – 99 % complete in 20 days and a 5 –day test is used in which the oxidation of carbonaceous matter is 60-70% complete. The test is conducted at 20°C , which is the average temperature of slow moving streams in temperate climates and is duplicated in the laboratory.

- COD
  - The chemical oxygen demand , COD, is used to measure the oxygen equivalent of the organic material in the wastewater that can be chemically (not biologically) oxidized.
  - The COD is typically higher perhaps twice as high as the BOD5 and under certain conditions the ratio and the results can be correlated.
  - The COD has the major advantage in that it can be completed in less than 3 hrs and there is rapid 15 minutes test that has been developed.
- Others
  - TOC , total organic carbon test converts organic carbon to carbon dioxide , which is subsequently measured. The TOC can be related to BOD and takes 10 minutes to complete.

Biological Characteristics

- Biological characteristics of wastewater are of fundamental importance in the control of disease caused by pathogenic micro-organisms.
- Water born diseases include
  - Cholera
  - Typhoid
  - Shigella
  - Polio
  - Meningitis
  - Hepatites A and E

Biological Characteristics

- **Micro-organisms found in wastewater**
  - Bacteria
  - Fungi
  - Algae
  - Protozoa
  - Plants, and animals,
  - Viruses

Analysis of Constituent Mass Loading Data

- Wastewater characterization involves determination of the flow-rate and mass loading variations.
- Constituent loading
  - Concentration
    - Mass/volume
  - Mass loading

end of chapter two