

Principles and Practices of Water Supply Operations

WATER QUALITY



Student Workbook



American Water Works
Association

The Authoritative Resource on Safe Water®

Advocacy
Communications
Conferences
Education and Training
Science and Technology
Sections

Water Quality

Student Workbook



American Water Works
Association

Water Quality Student Workbook
Principles and Practices of Water Supply Operations Series

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**American Water Works
Association**

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Foreword

This workbook is designed for use with the text *Water Quality* in the series *Principles and Practices of Water Supply Operations*, fourth edition. This edition provides detailed information on the technology and information of commonly used practices for potable water treatment.

Other volumes in the series are

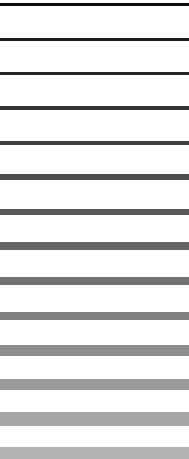
- *Water Treatment*
- *Water Transmission and Distribution*
- *Water Sources*
- *Basic Science Concepts and Applications*

The workbook provides assignments, review questions, and a convenient method for keeping organized notes of important points as the text is reviewed. It is designed for use in either classroom or independent study.

Basic Science Concepts and Applications is a reference handbook that is a companion to all the other text books. It contains basic reviews of mathematics, hydraulics, chemistry, and electricity fundamental to water utility operation, as well as explanations and examples of many specific water system operating problems.

A special thanks to Nancy McTigue for the revision of this workbook.

Acknowledgments



The student workbooks have been added to the series in conjunction with the fourth edition updating of the texts. The editor of this edition of the *Water Quality Student Workbook* is Nancy McTigue. Special thanks to Bill Lauer, AWWA Senior Technical Services Manager, and Joseph Ritter, author of revision for Water Quality textbook, for reviewing this workbook.

Introduction: Using Your Student Workbook

This *Student Workbook* is provided to assist you in studying the basic concepts of water quality. If you carefully maintain your own personal workbook with notes and supplemental information, you will likely reference it throughout your water utility career.

FORMAT

This workbook provides the following sections for each chapter of the text:

- *Objectives.* This is a listing of some of the major concepts that you should be able to identify and explain when you have completed study of the chapter. You should preview the list at the beginning of study to assess what will be covered. You should review it again when you have completed study of the chapter to see if you adequately understand the listed concepts.
- *Reading Assignments.* A list is provided indicating the chapters and sections from *Water Quality* and other texts that should be read in conjunction with the study of the chapter.
- *Other Assignments.* If you are attending a class, this space can be used to make a record of additional reading and study assignments made by the instructor. If you are using the workbooks for self-study, you can make notes for future reference on additional sources of information.
- *Class Notes.* Space has been provided for you to keep notes of points you feel are important as you read the text or of points made by the instructor during class discussions.
- *Review Questions.* The review questions are intended to emphasize some of the important concepts in the chapter.
- *Study Problems.* A few problems are provided to be used for additional study.
- *Additional Notes.* Each chapter concludes with a few extra pages for note taking.

TEXTS AND REFERENCES

It will be necessary for you to have copies of both *Water Quality* and *Basic Science Concepts and Applications* available while studying the subject. You should also have access to the other volumes in the series *Principles and Practices of Water Supply Operations* because there are some references to them in the reading assignments. If the copies you are using belong to your water utility or someone else, it is best not to mark or highlight in the books. Your notes on important points can instead be made in the workbook.

A list of supplementary sources of information is provided at the end of each chapter in the text. You should try to make use of some of them, particularly if you have a special interest in certain subjects. For example, if you are presently working at a water treatment facility, you will probably want to know more about the particular types of treatment of operating problems experienced by your utility.

The supplementary reading list is, of course, current only as of the publication of the text. Many additional handbooks, manuals, and articles are published yearly. If you have a special interest in obtaining the latest information on a subject visit the American Water Works Association at www.awwa.org. You may contact the American Water Works Association (AWWA) and some of the other publishers and information sources for their current publications list. If you have access to a file of back issues of the *Journal of the American Water Works Association and Opflow*, you will find that an index of all articles for the previous year is listed in each December issue. The “Water Library” section of the www.awwa.org website also has a searchable database of *Journal of the American Water Works Association* and *Opflow* articles, conference proceedings and AWWA Standards.

If you are presently working for a water utility, you probably have access to old editions and copies of some texts that are no longer in print. You will find it is helpful to look through these books and read about subjects you are studying, using this workbook. Sometimes there may be more detail, or subjects may be presented in a different way in another text. You must be aware, though, that water treatment technology and state and federal regulations have changed greatly in recent years, so some information in an older text may no longer be valid.

The principal publications that are frequently referenced and will be particularly useful to have on hand during study of *Water Quality* include:

- *Water Quality and Treatment*. 6th ed. 2010. New York: McGraw-Hill and American Water Works Association (available from AWWA).
- *Manual of Water Utility Operations*. 8th ed. 1988. Austin, Texas: Texas Water Utilities Association.
- *Manual of Instruction for Water Treatment Plant Operators*. 1975. Albany, N.Y.: New York State Department of Health.
- Back copies of the *Journal of the American Water Works Association* and *Opflow*.

USE OF THE WORKBOOK

If you are using this workbook in conjunction with class instruction, you are urged to keep a loose-leaf notebook for supplementary sheets distributed by the instructor, filed in the order in which the subjects are studied. When your notes are carefully kept in order, they provide an excellent personal information source for later review and reference.

The review questions are designed to highlight some of the major points of each chapter. You should reread sections covered by the review questions until you can completely answer the questions. The instructor will review the answers during a class period to make sure everyone understands the subjects and has provided the correct answers.

Your instructor may also provide supplemental assignments and provide handout material for each chapter. When the length of class meetings is limited, some chapters will be broken into segments and covered during two or more meetings.

The workbook can also be used for individual study. Notes should be made of important points as the text and references are read, and the review questions should be answered completely to ensure that the full significance of important points is understood.

STATE AND FEDERAL REGULATIONS

Many aspects of water treatment and distribution system operations are now directed and regulated by federal regulations. A review of federal regulations in effect at the time the fourth edition of this volume was published is provided in *Water Quality*. But many changes are expected within coming years.

Although the states are generally required to enact regulations that are as stringent as the federal requirements, they may, at times, vary, be more stringent, or include additional requirements. It is therefore

important that you obtain a reference copy of the latest state drinking water regulations for the state for which you are working. Applicable sections of the regulations should then be reviewed in conjunction with your study of each chapter.

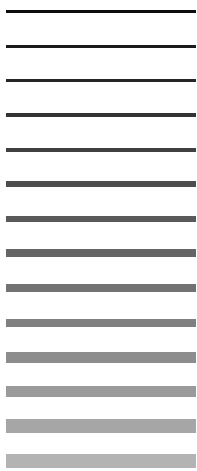
QUIZZES AND EXAMINATIONS

If you are attending training classes, the instructor will probably give you a few quizzes during the course. These are important because they indicate whether you are adequately learning the material; they are also important to the instructor to determine if the material is being properly presented.

If you are studying this subject in preparation for taking a state certification examination, it is particularly important that you become comfortable in taking exams of the type used by the state. If you would like more review and practice in answering questions of the type used on certification exams, it is suggested that you obtain the AWWA publication *Operator Certification Study Guide*, 6th ed., Denver, Colo.: American Water Works Association, 2010.

Good Luck in Your Water Utility Career!

CHAPTER 1



Public Water Supply Regulations

OBJECTIVES

After completing study of this chapter, you should understand:

- why the Safe Drinking Water Act was passed by Congress
- why amendments to the SDWA were passed
- the classes of public water systems covered by the act
- the principal requirements of the act
- special regulation requirements that have been enacted by USEPA

READING ASSIGNMENTS

1. *Water Quality*: Read chapter 1, Public Water Supply Regulations.
2. State public water supply regulations: Review the history of these regulations and look over the organization of the material included.

OTHER ASSIGNMENTS

REVIEW QUESTIONS

1. List some of the responsibilities delegated to the US Environmental Protection Agency by the Safe Drinking Water Act.
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2. What is the responsibility of states that have accepted primacy?

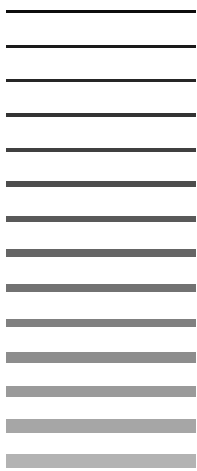
3. What are the three classes of public water systems covered by Safe Drinking Water Act requirements?
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4. Which of the three classes of water systems are subject to MCLs designed to prevent adverse health effects caused by drinking contaminated water over a long period of time?
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5. What are primary drinking water regulations?

STUDY PROBLEMS

1. You have just been hired as a chief operator of a water system that draws water from a large river and uses conventional treatment. You have no information on the system's status in meeting various drinking water and environmental laws.
 - Prepare a list of the state primacy agencies and USEPA requirements that affect the operation of the water system and must be met or considered in operating the system.
 - Also prepare a list of other state and federal agencies that might have requirements that would impact your water system's operation and suggest what their requirements might be.

ADDITIONAL NOTES

CHAPTER 2



Water Quality Monitoring

OBJECTIVES

After completing study of this chapter, you should understand:

- the importance of representative sampling
- the way in which grab and composite samples are collected and under what circumstances each method is used
- the selection of proper sample volumes
- methods of establishing representative sampling points
- the importance and limitations of sample preservation
- the importance of proper sample labeling and record keeping

READING ASSIGNMENTS

1. *Water Quality*: Read chapter 2, Water Quality Monitoring.
2. State public water supply regulations: Read sections pertaining to water quality monitoring.

OTHER ASSIGNMENTS

REVIEW QUESTIONS

1. What two general types of monitoring must be done by most public water systems? Give examples of each.
 -
 -
2. What is the difference between a grab sample and a composite sample?
3. Aside from constituents for which a sample is to be tested, what may affect the required volume of the sample?
4. In what three general areas of a water system are samples usually collected? Give examples of each.
 -
 -
 -
5. What precautions should be taken in selecting in-plant sample points?
6. What factors can cause distribution system samples to be of different quality than samples of water entering the system from the well or treatment plant?

STUDY PROBLEMS

1. Your water system has just developed a new surface water source, and a water treatment plant has been constructed. The new water source is a stream that originates in a heavily wooded watershed containing abandoned gold mines. Treatment processes consist of coagulation, flocculation, sedimentation, filtration, fluoridation, and chlorination.

The city manager has asked you to develop a sampling program that will ensure effective plant operation.

- What constituents would you sample for in the source water?
- What locations would you select for selecting the raw-water samples?
- What constituents would you sample for in the treatment plant?
- Draw a sketch showing where your sampling points would be located in the treatment plant and list the constituents that would be analyzed for at each sampling point.
- At what frequency would you take the samples? Specify if different frequencies would be used for different constituents.

ADDITIONAL NOTES

CHAPTER 3

Water Laboratory Equipment and Instruments

OBJECTIVES

After completing study of this chapter, you should understand:

- general labware and laboratory equipment
- analytical instruments commonly used in a laboratory
- basic labware and instruments necessary to conduct routine process control tests

READING ASSIGNMENTS

1. *Water Quality*: Read chapter 3, Water Laboratory Equipment and Instruments.

OTHER ASSIGNMENTS

REVIEW QUESTIONS

1. What are some of the advantages and disadvantages of plastic labware?
 - Advantages:

 - Disadvantages:
2. What class of glassware (volumetric flasks, pipettes) must be used for performance monitoring?
3. What is the advantage and what is the limitation of measuring liquids with a graduated cylinder?
4. List five pieces of information that should be included on the label of a reagent bottle.
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5. What are the four steps of good labware cleaning?
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6. What are the principal parts of a membrane filter apparatus when used with a vacuum filter flask?
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7. What is an autoclave used for in the laboratory?
8. What is a deionizer used for in the laboratory? For what purposes can deionized water be used?
9. What are the three types of filters commonly used in laboratories?
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10. Why is time a factor in the accuracy of weighing procedures?
11. Why are photometers more accurate than colorimeters?
12. What type of instrument is used to analyze drinking water for organic contaminants?

STUDY PROBLEMS

1. You are the chief operator of a surface water treatment plant. Traditionally, you have not conducted process control tests at the plant.

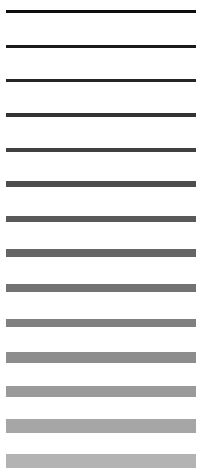
The new city manager has issued a directive to the water department requiring operators at the plant to begin routinely testing:

- turbidity
- alkalinity
- pH
- temperature
- chlorine residual and demand

Prepare a report to the city manager itemizing the labware and instruments required for the new water-testing program. Create a set of standardized testing procedures for plant operators to use in accordance with federal and state regulations.

ADDITIONAL NOTES

CHAPTER 4



Microbiological Contaminants

OBJECTIVES

After completing study of this chapter, you should understand:

- the significance of pathogens in drinking water
- why coliform bacteria are used as an indicator of pathogenic organisms
- the general procedures involved in the commonly used microbiological tests of drinking water
- the important new concepts in the Total Coliform Rule

READING ASSIGNMENTS

1. *Water Quality*: Read chapter 4. Microbiological Contaminants.
2. State public water supply regulations: Review sections relating to required microbiological monitoring.

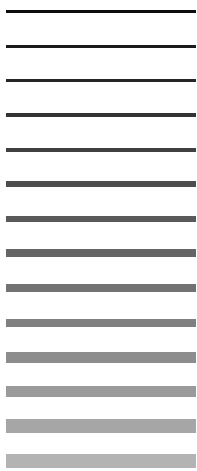
OTHER ASSIGNMENTS

STUDY PROBLEMS

1. Routine sampling of your water system yielded three positive samples, all from an area served by a single transmission main. Samples from other parts of the distribution system collected on the same day and time were all negative.
 - Develop a step-by-step procedure to determine where the contamination may have come from by sampling to see if the contamination is still present or may have spread. Also, list the steps required to eliminate it.
 - At what point should the state primacy agency and the public be informed?

ADDITIONAL NOTES

CHAPTER 5



Physical Tests

OBJECTIVES

After completing study of this chapter, you should understand:

- the significance of the more common physical tests required for public water system operation
- the methods of sampling for physical tests of water
- the methods of performing physical tests of water

READING ASSIGNMENTS

1. *Water Quality*: Read chapter 5, Physical Tests.
2. State public water supply regulations: Review state requirements for monitoring and reporting physical test information.

OTHER ASSIGNMENTS

CLASS NOTES

1. Acidity and Alkalinity:
2. Coagulant effectiveness:
3. Color:
4. Conductivity:
5. Hardness:
6. pH:
7. Taste, odor, and color:
8. Temperature:
9. Total dissolved solids:
10. Turbidity:

6. Why are odor tests preferred over taste tests for drinking water?

7. How does temperature affect chemical reactions?

8. Are suspended solids and turbidity the same thing? Explain.

9. How are turbidity and bacteriological quality related?

10. What method of turbidity measurement is specified by USEPA drinking water regulations?

STUDY PROBLEMS

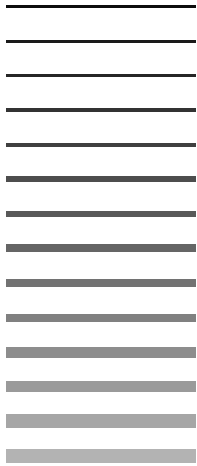
1. You have been asked to develop a monitoring program to assist in achieving a more effective operation of a water treatment plant. Treatment processes consist of presedimentation, addition of aluminum sulfate, rapid mix, flocculation, sedimentation, filtration, chlorination, and fluoridation.
 - List the raw-and treated-water data necessary for effective operational control.
 - What in-plant data are necessary?
 - Where would you recommend that the samples be taken?
 - What laboratory equipment is required to conduct the tests that would provide the necessary data?
2. Taste and odor complaints have been received by your utility from customers complaining of off flavors and odors in the water coming from their taps. Which tests should you run on the tap water to help determine the cause of the odors and flavors?
3. A water has the following chemical constituents:

Alkalinity	80 mg/L as CaCO ₃
Temperature	12°C
Total dissolved solids	400 mg/L
pH	7.8
Ca ⁺²	200 mg/L as CaCO ₃

 - Determine the Langelier index for the water.
 - Is the water stable?
 - If not, what should you do?

ADDITIONAL NOTES

CHAPTER 6



Inorganic Chemicals

OBJECTIVES

After completing study of this chapter, you should understand:

- the significance of the more important inorganic chemicals of concern in drinking water treatment
- methods of sampling for inorganic chemicals
- methods of analysis for inorganic chemicals

READING ASSIGNMENTS

1. *Water Quality*: Read chapter 6, Inorganic Chemicals.
2. State public water supply regulations: Review state requirements for monitoring and reporting the concentration of inorganic chemicals in drinking water.

OTHER ASSIGNMENTS

CLASS NOTES

1. Inorganic compound:
2. Carbon dioxide:
3. Chlorine residual and demand:
4. Dissolved oxygen:
5. Fluoride:
6. Iron:
7. Manganese:
8. pH:

REVIEW QUESTIONS

1. What is the definition of an inorganic chemical, substance, compound, or contaminant?
2. Which inorganic contaminants are regulated by the USEPA?
3. Destruction of pathogenic organisms by chlorine is directly related to which two factors?
 -
 -
4. What are some possible reasons for being unable to maintain a free chlorine residual in a distribution system?
5. What is *chlorine demand*?

STUDY PROBLEMS

1. Your water supply has an iron concentration slightly below the secondary MCL, but it has not been a problem until lately. There have recently been increasing numbers of customer complaints about rusty water.
 - First, develop a list of possible reasons for the sudden increase in customer complaints.
 - Second, list the alternative methods of dealing with the problem for each possible reason.
 - Third, set up a monitoring plan that will identify the cause or causes of the problem.
2. Your water utility is considering beginning fluoridation. What are the benefits of a fluoridation program?

ADDITIONAL NOTES

CHAPTER 7

Organic Chemicals

OBJECTIVES

After completing study of this chapter, you should understand:

- the basic properties of organic chemicals
- the principal sources of natural and synthetic organic substances in water
- the adverse health effects of organic chemicals
- the methods of measuring the concentration of organic chemicals in water
- the methods of controlling organic chemicals in drinking water

READING ASSIGNMENTS

1. *Water Quality*: Read chapter 7, Organic Chemicals.
2. State public water supply regulations: Review state requirements for monitoring and reporting organic chemicals.

OTHER ASSIGNMENTS

CLASS NOTES

1. Organic chemistry:
2. Natural organic substances:
3. Synthetic organic substances:
4. Health effects of organic chemicals:
5. How MCLs are set:
6. Measurement of organic compound:

REVIEW QUESTIONS

1. Why is it not always possible to fully describe an organic compound with a simple formula?
2. What are *hydrocarbons*?
3. What are organic *halogen compounds*?
4. List some of the more common causes of natural organics in surface water sources.
 -
 -
 -
 -
5. Is it likely that VOCs will be found in a surface water source? Why or not?

STUDY PROBLEMS

1. Your water system obtains all of its water from a well field consisting of ten wells located close to each other in a dry stream bed. Analysis of the last organic chemical samples from the individual wells showed trace amounts of trichloroethylene in two wells in the well field that is upstream of groundwater flow.
 - On the assumption that there is a plume of contamination approaching the well field, discuss what actions should be taken immediately to determine the severity of the problem.
 - If there is chemical contamination in the groundwater that will eventually reach all of the wells and cause them to exceed the MCLs for organic chemicals, list the alternatives that should be considered for preventing or avoiding the problem or for providing treatment if it should become necessary.

ADDITIONAL NOTES

CHAPTER 8

Radiological Contaminants

OBJECTIVES

After completing study of this chapter, you should understand:

- the basic theory of radioactive materials
- the radioactive materials of principal concern in drinking water
- the adverse health effects of radioactivity in drinking water
- radionuclide monitoring requirements
- methods of treating water for radioactivity removal

READING ASSIGNMENTS

1. *Water Quality*: Read chapter 8, Radiological Contaminants.
2. State Public water supply regulations: Review state requirements for monitoring and reporting radiological contaminants.

OTHER ASSIGNMENTS

REVIEW QUESTIONS

1. What are the three primary emissions from the nucleus of a radioactive atom?
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 -
 -
2. Why are alpha particles of primary concern as a radioactive contaminant in drinking water?
3. What is the half-life of a radioactive element?
4. After a radioactive element has completed all stages of radioactive decay, what element does it end up as?
5. What two isotopes of radium are of concern as drinking water contaminants?
 -
 -

STUDY PROBLEMS

1. You are the chief operator of a groundwater system serving about 5,000 persons. Describe the type of testing that must be done under the Radionuclides Rule for the radionuclide contaminants. Discuss the frequency at which these samples must be taken, and describe the MCLs that the samples must be in compliance with. Assuming that one of your samples exceeds the MCL for uranium prepare a statement that your General Manager can give at a concerned citizen's meeting. Describe:
 - The potential health effects of uranium
 - How the uranium got into the water supply

ADDITIONAL NOTES

CHAPTER 9



Customer Complaint Investigation

OBJECTIVES

After completing study of this chapter, you should understand the general principles of:

- conducting an investigation in response to a customer complaint on water quality
- conducting a taste-and-odor complaint investigation
- conducting a physical appearance complaint investigation
- conducting an investigation of staining on laundry and plumbing fixtures
- conducting an alleged illness complaint investigation

READING ASSIGNMENTS

1. *Water Quality*: Read chapter 9, Customer Complaint Investigation.
2. State public water supply regulations: Review sections pertaining to (1) secondary drinking water regulations and the aesthetic qualities of drinking water, and (2) steps that should be taken in the event a waterborne illness occurs.

OTHER ASSIGNMENTS

CLASS NOTES

1. General principles:

2. Specific complaints:

REVIEW QUESTIONS

1. Why is it important to respond promptly to the concerns of customers regarding water quality?
2. What philosophy should a person receiving a complaint from the public always keep in mind?
3. Name the three parts of a complaint form.
 -
 -
 -
4. Why should water samples be collected in response to most complaints?
5. What is a general way of distinguishing between tastes and odors caused by natural compounds and those caused by industrial and agricultural chemicals?

6. What is the most frequent complaint received by water utilities?
7. Why is it important to take samples from exactly the same faucet from which the customer has complained of receiving poor water quality?
8. How can you determine if a physical appearance complaint about “cloudy” water actually only involves entrained air in the water?
9. What are the principal chemicals that can cause staining of laundry or plumbing fixtures?
10. If an investigation shows that a waterborne illness may be occurring, what action should be taken?

STUDY PROBLEMS

1. Develop an investigation and a disposition from the following scenario:

Mrs. Robert Jones of 1267 Way Street, phone 123-4567, called the water utility at 2:45 PM, Friday, August 11, 1995. She had heard over the radio of an oil tanker spill on the river located a short distance from her house. Her water has since turned cloudy, and she thinks it smells like gasoline. Her children have also become ill since they drank the cloudy water.

Your water system draws water from the river and provides full treatment, but until this phone call, there have been no other complaints of water quality that could be associated with the oil spill.

ADDITIONAL NOTES