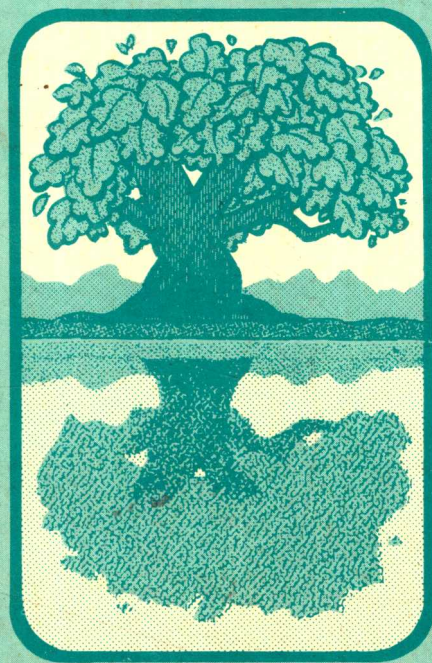


WATER TREATMENT PLANT OPERATION

Volume I



**A
Field
Study
Training
Program**

- California Department of Health Services, Sanitary Engineering Branch •
and
- U.S. Environmental Protection Agency, Office of Drinking Water •

WATER TREATMENT PLANT OPERATION

Volume I

A Field Study Training Program

prepared by

California State University, Sacramento
School of Engineering
Applied Research and Design Center

in cooperation with the
National Environmental Training Association

Kenneth D. Kerri, Project Director

for the

California Department of Health Services
Sanitary Engineering Branch
Standard Agreement #80-64652

and

U.S. Environmental Protection Agency
Office of Drinking Water
Grant No. T-901361-01-0

1983

OPERATOR TRAINING MANUALS IN THIS SERIES are available from Ken Kerri, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819-2694, phone (916) 278-6142.

1. *WATER SUPPLY SYSTEM OPERATION*, 1 Volume,
2. *WATER TREATMENT PLANT OPERATION*, 2 Volumes,
3. *OPERATION OF WASTEWATER TREATMENT PLANTS*, 4 Volumes,
and
4. *OPERATION AND MAINTENANCE OF WASTEWATER COLLECTION SYSTEMS*, 1 Volume.

NOTICE

This manual is revised and updated before each printing based on comments from persons using this manual.

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PREFACE

The purposes of this water treatment field study training program are to:

1. Develop new qualified water treatment plant operators,
2. Expand the abilities of existing operators, permitting better service to both their employers and the public, and
3. Prepare operators for civil service and *CERTIFICATION EXAMINATIONS*.¹



To provide you with the knowledge and skills needed to operate and maintain water treatment plants as efficiently and effectively as possible, experienced water treatment plant operators prepared the material in each chapter of this manual.

Water treatment plants vary from city to city and from region to region. The material contained in this program is presented to provide you with an understanding of the basic operation and maintenance aspects of your water treatment plant and with information to help you analyze and solve operation and maintenance problems. This information will help you operate and maintain your plant in a safe and efficient manner.

Water treatment plant operation and maintenance is a rapidly advancing field. To keep pace with scientific and technological advances, the material in this manual must be periodically revised and updated. *THIS MEANS THAT YOU, THE OPERATOR, MUST RECOGNIZE THE NEED TO BE AWARE OF NEW ADVANCES AND THE NEED FOR CONTINUOUS TRAINING BEYOND THIS PROGRAM.*

The Project Director is indebted to the many operators and other persons who contributed to this manual. Every effort was made to acknowledge material from the many excellent references in the water treatment field. Reviewers Leonard Ainsworth, Jack Rossum, and Joe Monscivitz deserve special recognition for their extremely thorough review and helpful suggestions. John Trax, Chet Pauls, and Ken Hay, Office of Drinking Water, U.S. Environmental Protection Agency, and John Gaston, Bill MacPherson, Bert Ellsworth, Clarence Young, Ted Bakker, and Beverlie Vandre, Sanitary Engineering Branch, California Department of Health Services, all performed outstanding jobs as resource persons, consultants and advisors. Larry Hannah served as Education Consultant. Illustrations were drawn by Martin Garrity. Charlene Arora helped type the field test and final manuscript for printing. Special thanks are well deserved by the Program Administrator, Gay Kornweibel, who typed, administered the field test, managed the office, administered the budget, and did everything else that had to be done to complete this project successfully.

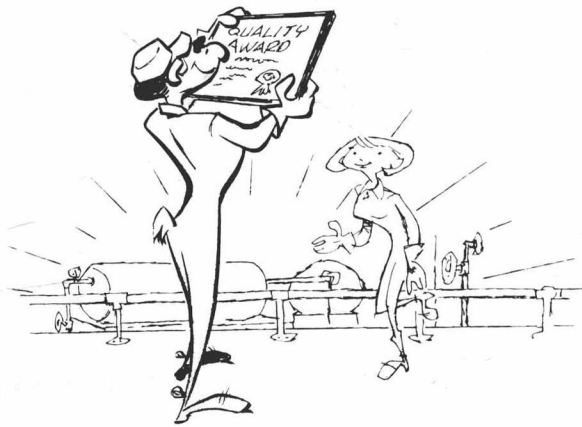
KENNETH D. KERRI
PROJECT DIRECTOR

¹ *Certification examination. An examination administered by a state or professional association that operators take to indicate a level of professional competence. In most states the Chief Operator of a plant must be "certified" (successfully pass a certification examination). Certification is voluntary in a few states. Current trends indicate that certification of operators will be mandatory in all states in the near future.*

OBJECTIVES OF THIS MANUAL

Proper installation, inspection, operation, maintenance, repair and management of water treatment plants have a significant impact on the operation and maintenance costs and effectiveness of the plants. The objective of this manual is to provide water treatment plant operators with the knowledge and skills required to operate and maintain water treatment plants effectively, thus eliminating or reducing the following problems.

1. Health hazards created by the production or output of unsafe water from the plant;
2. System failures that result from the lack of proper installation, inspection, preventive maintenance, surveillance and repair programs designed to protect the public's investment in the plant;
3. Taste and odor complaints from consumers;
4. Turbid or colored waters which are unacceptable to consumers;
5. Corrosion damages to pipes, equipment, tanks and structures at the water treatment plant and in the distribution system;
6. Complaints from the public or local officials due to the unreliability or failure of the water treatment plant to perform as designed; and
7. Fire damage caused by insufficient water at a time of need.



SCOPE OF THIS MANUAL

This manual on water treatment plant operation is divided into two volumes. Volume I stresses the knowledge and skills needed by an operator working in a conventional water treatment plant used for treating surface waters. Volume II emphasizes material needed by operators trying to control iron and manganese, softening hard waters, and trihalomethanes. Also contained in Volume II is information needed by all operators responsible for the administration and management of a water treatment plant, such as maintenance, instrumentation, safety, and laboratory procedures.

Volume I contains information on:

1. What water treatment plant operators do;
2. How to manage reservoirs and intake structures;
3. How to operate and maintain coagulation, flocculation, sedimentation and filtration water treatment processes;
4. Disinfection of water;
5. Procedures for controlling corrosion;

6. Techniques for identifying the causes of taste and odor problems and suggestions for correcting such problems;
7. Procedures for operating, maintaining, and administering a water treatment plant; and
8. Basic laboratory procedures.

Volume II contains information on:

1. How to control iron and manganese;
2. Procedures for fluoridating water;
3. Techniques for softening water;
4. How to control trihalomethanes;
5. Techniques for treating dissolved solids in water;
6. Handling and disposal of process wastes;
7. Procedures for maintaining processes, equipment, and facilities;

8. How to maintain and troubleshoot instrumentation;
9. Techniques for recognizing hazards and developing safe procedures and safety programs;
10. Advanced laboratory procedures for analyzing samples of water; and
11. Water quality regulations and administrative considerations for supervisors and managers.

Material in this manual furnishes you with information concerning situations encountered by most water treatment plant operators in most areas. These materials provide you with an understanding of the basic operational and maintenance concepts for water treatment plants and with an ability to analyze and solve problems when they occur. Operation and maintenance programs for water treatment

plants will vary with the age of the plant, the extent and effectiveness of previous programs, and local conditions. You will have to adapt the information and procedures in this manual to your particular situation.

Technology is advancing very rapidly in the field of operation and maintenance of water treatment plants. To keep pace with scientific advances, the material in this program must be periodically revised and updated. This means that you, the water treatment plant operator, must be aware of new advances and recognize the need for continuous personal training reaching beyond this program. *TRAINING OPPORTUNITIES EXIST IN YOUR DAILY WORK EXPERIENCE, FROM YOUR ASSOCIATES, AND FROM ATTENDING MEETINGS, WORKSHOPS, CONFERENCES AND CLASSES.*



USES OF THIS MANUAL

This manual was developed to serve the needs of operators in several different situations. The format used was developed to serve as a home-study or self-paced instruction course for operators in remote areas or persons unable to attend formal classes either due to shift work, personal reasons or the unavailability of suitable classes. This home-study training program uses the concepts of self-paced instruction where you are your own instructor and work at your own speed. In order to certify that a person has successfully completed this program, an objective test is included at the end of each chapter.

Also, this manual can serve effectively as a textbook in the classroom. Many colleges and universities have used similar manuals as texts in formal classes (often taught by operators). In areas where colleges are not available or are unable to offer classes in the operation of water treatment plants, operators and utility agencies can join together to offer their own courses using the manual.

Cities or utility agencies can use the manual in several types of on-the-job training programs. In one type of program, a manual is purchased for each operator. A senior operator or a group of operators are designated as instruc-

tors. These operators help answer questions when the persons in the training program have questions or need assistance. The instructors grade the objective tests at the end of each chapter, record scores and notify California State University, Sacramento, of the scores when a person successfully completes this program. This approach eliminates any waiting while papers are being graded and returned by CSUS.

This manual was prepared to help operators operate and maintain their water treatment plants. Please feel free to use the manual in the manner which best fits your training needs and the needs of other operators. We will be happy to work with you to assist you in developing your training program. Please feel free to contact

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INSTRUCTIONS TO PARTICIPANTS IN HOME-STUDY COURSE

Procedures for reading the lessons and answering the questions are contained in this section.

To progress steadily through this program, you should establish a regular study schedule. For example, many operators in the past have set aside two hours during two evenings a week for study.

The study material is contained in two volumes divided into 23 chapters. Some chapters are longer and more difficult than others. For this reason, many of the chapters are divided into two or more lessons. The time required to complete a lesson will depend on your background and experience. Some people might require an hour to complete a lesson and some might require three hours; but that is perfectly all right. **THE IMPORTANT THING IS THAT YOU UNDERSTAND THE MATERIAL IN THE LESSON!**

Each lesson is arranged for you to read a short section, write the answers to the questions at the end of the section, check your answers against suggested answers; and then **YOU** decide if you understand the material sufficiently to continue or whether you should read the section again. You will find that this procedure is slower than reading a normal textbook, but you will remember much more when you have finished the lesson.

At the end of each chapter, you will find an "objective test." Mark your answers on the special answer sheet provided for each chapter. Some discussion and review questions are provided following each lesson in the later chapters. These

questions review the important points you have covered in the lesson.

The objective test at the end of each lesson contains true or false, multiple-choice, fill-in-the-blank, or match-the-answers types of questions. The purposes of this exam are to review the chapter and to give experience in taking different types of exams. **MAIL TO THE PROGRAM DIRECTOR ONLY YOUR ANSWERS TO OBJECTIVE TESTS ON THE PROVIDED ANSWER SHEETS.**

After you have completed the last objective test, you will find a final examination. This exam is provided for you to review how well you remember the material. You may wish to review the entire manual before you take the final exam. Some of the questions are essay-type questions which are used by some states for higher-level certification examinations. After you have completed the final examination, grade your own paper and determine the areas in which you might need additional review before your next certification or civil service examination.

You are your own teacher in this program. You could merely look up the suggested answers from the answer sheet or copy them from someone else, but you would not understand the material. Consequently, you would not be able to apply the material to the operation of your plant nor recall it during an examination for certification or a civil service position.

YOU WILL GET OUT OF THIS PROGRAM WHAT YOU PUT INTO IT.



SUMMARY OF PROCEDURE

A. OPERATOR (YOU)

1. Read what you are expected to learn in each chapter (the chapter objectives).
2. Read sections in the lesson.
3. Write your answers to questions at the end of each section in your notebook. You should write the answers to the questions just as you would if these were questions on a test.
4. Check your answers with the suggested answers.
5. Decide whether to reread the section or to continue with the next section.
6. Write your answers to the discussion and review questions at the end of each lesson in your notebook.
7. Mark your answers to the objective test on the answer sheet provided by the Project Director or by your instructor.

8. Mail material to Project Director. (Send *ONLY* your completed answer sheet.)

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Water Treatment Plant Operation
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B. PROJECT DIRECTOR

1. Mails answer sheet for each chapter to operator.
2. Corrects tests, answers any questions, and returns results to operators.

C. ORDER OF WORKING LESSONS

To complete this program you will have to work all of the lessons. You may proceed in numerical order, or you may wish to work some lessons sooner.

SAFETY IS A VERY IMPORTANT TOPIC. Everyone working in a water treatment plant must always be safety conscious. Operators daily encounter situations and equipment that can cause a serious disabling injury or illness if the operator is not aware of the potential danger and does not exercise adequate precautions. For these reasons you may decide to work on the chapter on "Safety" early in your studies. In each chapter, **SAFE PROCEDURES ARE ALWAYS STRESSED.** See Chapter 20, "Safety," Volume II, for details.



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COURSE OUTLINE

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COURSE OUTLINE

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CHAPTER 1

THE WATER TREATMENT PLANT OPERATOR

by

Ken Kerri

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OBJECTIVES

Chapter 1. THE WATER TREATMENT PLANT OPERATOR

At the beginning of each chapter in this manual you will find a list of *OBJECTIVES*. The purpose of this list is to stress those topics in the chapter that are most important. Contained in the list will be items you need to know and skills you must develop to operate, maintain, repair and manage a water treatment plant as efficiently and as safely as possible.

Following completion of Chapter 1, you should be able to:

1. Explain the type of work done by water treatment plant operators,
2. Describe where to look for jobs in this profession, and
3. Describe how you can learn to do the jobs performed by water treatment plant operators.



CHAPTER 1. THE WATER TREATMENT PLANT OPERATOR

Chapter 1 is prepared especially for new operators or people interested in becoming water treatment plant operators. If you are an experienced water treatment plant operator, you may find some new viewpoints in this chapter.

1.0 NEED FOR WATER TREATMENT PLANT OPERATORS

People need safe water to drink. Many sources of water are not directly suitable for drinking purposes without treatment because of pollution and contamination by man and nature. Before modern society and the intensive use of available water resources, sun, wind, filtration through soil, and time purified water. Today water treatment plants are built to provide us with safe drinking water. Thus, nature is given an assist by a team consisting of designers, builders, and treatment plant operators. Designers and builders occupy the scene for only a short time, but operators go on forever. Water treatment plant personnel operate, maintain, repair and manage water treatment plants. These operators have the responsibility of producing safe and pleasant drinking water from their plants. Cities and towns need qualified, capable, and dedicated operators to do these jobs.



The need for *RESPONSIBLE* water treatment plant operators cannot be over stressed. You, as a water treatment plant operator, have the responsibility for the health and well being of the community you serve. Yes, you are responsible for the drinking water of your community and anytime you fail to do your job, you could be responsible for an outbreak of a water-borne disease which could even result in death. As an operator, you do not want the knowledge that you were negligent in your duty and, as a result, were responsible for the death of a fellow human being.

QUESTIONS

Below are some questions for you to answer. You should have a notebook in which you can write the answers to the questions. By writing down the answers to the questions, you are helping yourself learn and retain the information. After you have answered all the questions, compare your answers with those given in the Suggested Answer section on page 11. Reread any sections you do not understand and then proceed to the next section. You are your own teacher in this training program, and *YOU* should decide when you understand the material and are ready to continue with new material.

- 1.0A Why is there a need for water treatment plant operators?
- 1.0B Why do many sources of water need treatment?
- 1.0C Why must water treatment plant operators be responsible persons?

1.1 WHAT IS A WATER TREATMENT PLANT?

1.10 Conventional Surface Water Treatment Plant

The purpose of a water treatment plant is to produce safe and pleasant drinking water. This water must be free of disease-causing organisms and toxic substances. Also, the water should not have a disagreeable taste, odor or appearance.

A water treatment plant takes raw water from a source such as a stream or lake and passes the water through a series of treatment processes. The raw water flows through tanks or basins where chemicals are added and mixed with it. Then the water slowly flows through larger tanks which allow the heavier suspended solids to settle out. Any remaining solids are removed by filtration and the water is disinfected. The size of a water treatment plant as well as the number and specific types of processes it uses will depend on several factors: (1) the impurities in the raw water, (2) water quality (purity) standards, (3) the demand for water by the population being served, (4) fire protection, and (5) cost considerations.

To describe a water treatment plant, we will follow a drop of water as it passes through a typical or conventional surface water treatment plant. Most surface waters receive this type of treatment. Figure 1.1 shows a flow diagram of water treatment plant processes and the purpose or function of each process. Figure 1.2 illustrates the flow pattern through a water treatment plant. In this figure both the plan (top view) and the profile (side view) are provided to help you visualize the appearance of a water treatment plant.

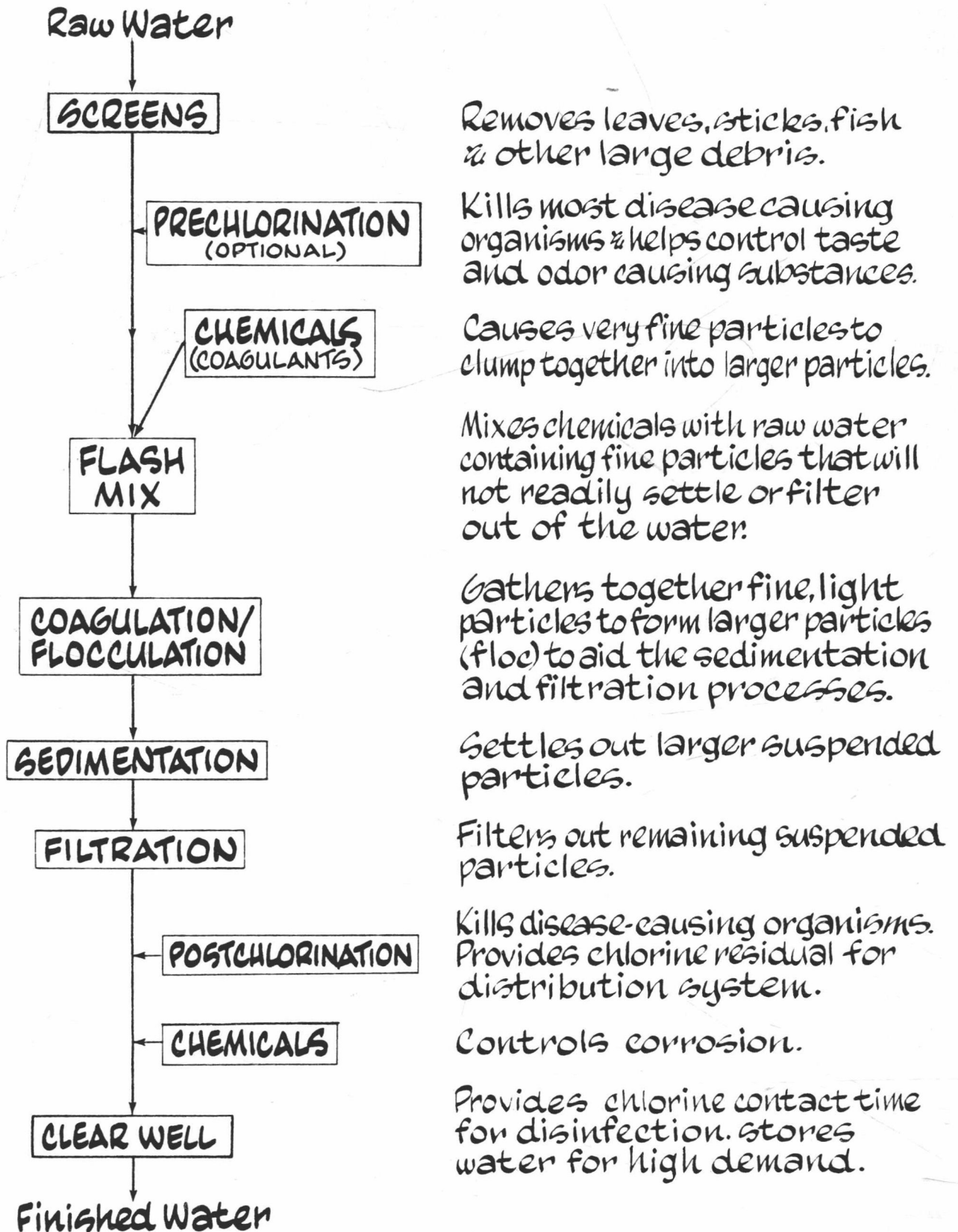
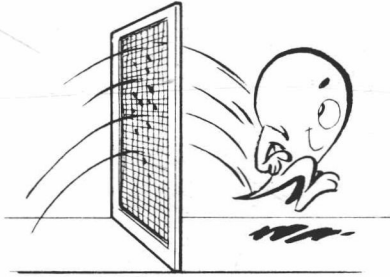
TREATMENT PROCESSPURPOSE

Fig. 1.1 Flow diagram of conventional surface water treatment plant processes

6 Water Treatment

Raw water usually enters a water treatment plant through some type of intake structure. The main purpose of the intake structure is to draw in water while preventing leaves and other debris from clogging or damaging pumps, pipes and other pieces of equipment in the treatment plant. Various types of screens are often found in intake structures or in the suction line to raw water pumps.



Chlorination at the beginning of a water treatment plant (prechlorination) can help control tastes and odors and also prevent the growth of algae and slimes in other treatment processes. Chlorine is added to water to kill pathogenic (disease-causing) organisms. Also, the use of prechlorination often reduces chlorine requirements for postchlorination. Some waters should not be prechlorinated because

they contain substances which will react with chlorine and form cancer-causing compounds (trihalomethanes).

Coagulant chemicals such as alum are added to help remove light, fine particles and other materials suspended in the water. Coagulants cause these very fine particles to clump together into larger particles. A flash mixer is used to thoroughly mix the coagulating chemicals with the water being treated. Flocculation is the name of the treatment process where paddles gently mix the water. The clumps of particles formed by coagulation come together and form larger and larger floc particles. These larger floc particles are easier to remove by sedimentation and filtration.

Sedimentation is an operation in which the water being treated flows very slowly through a large tank or basin. During this time the heavier floc particles gradually settle out of the water being treated. The flocs and settled solids that reach the bottom of the basin form a sludge that must be removed and either discharged to a sewer or disposed of in a landfill after drying beds. Treated water leaves the sedimentation basin by flowing over weirs (a flow control device) at the outlet end of the basin.

After sedimentation, the water passes through some type of filter to remove the remaining suspended impurities and flocs. The filter may be made of sand, anthracite coal or some other type of granular material or a combination of these materials.

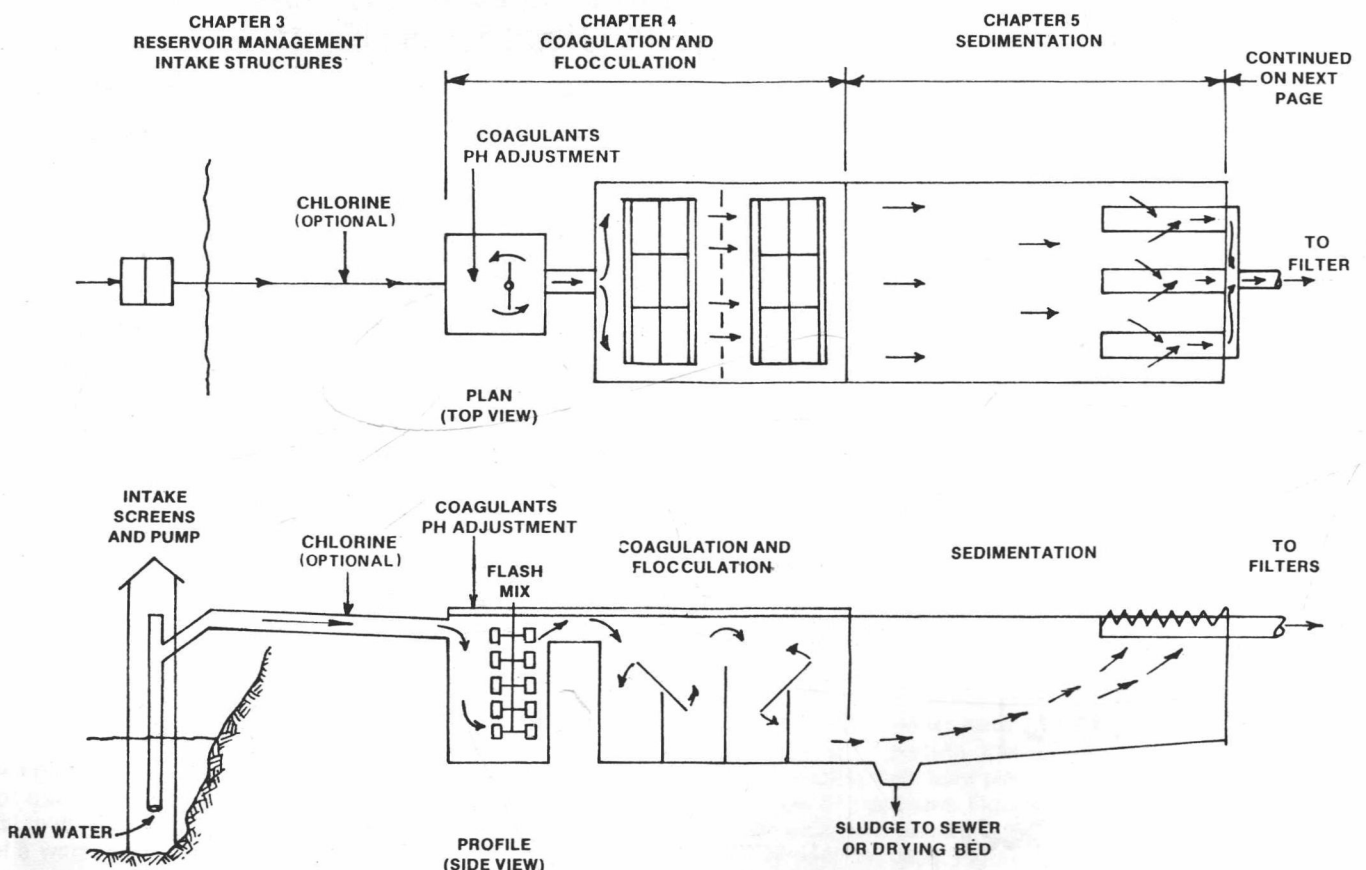


Fig. 1.2 Flow pattern through a conventional surface water treatment plant

After filtration the water is usually disinfected by some type of chlorination process. The purpose of disinfection is to kill the remaining disease-causing organisms in the water.

If the treated water is corrosive (capable of deteriorating metal pipe), chemicals should be added to reduce the corrosivity of the water or to prevent scale (rust) formation.

Treated water is stored in a large tank or basin (clear well) until it is pumped into the distribution system for use or to service storage during low demand periods for later use during periods of high demand. Storage also provides chlorine contact time for disinfection.

1.11 Softening

Some water treatment plants include processes for softening water. Waters are softened to remove excess hardness caused by calcium and magnesium. Extra soap is needed to clean or wash with hard water. Also hard waters will cause scale to develop in water heaters, pipes, and fittings.

1.12 Iron and Manganese Control

Iron and manganese are undesirable because they will cause undesirable color in water and also stain clothes and plumbing fixtures. Iron and manganese also can promote the growth of iron bacteria which can cause tastes and

odors. Flow diagrams and treatment processes for removing hardness and also iron and manganese will be discussed in Volume II of this manual.

All of the chapters in Volume I of this manual deal with the processes shown in Figures 1.1 and 1.2. As you go through this manual, feel free to return to these figures so you will understand the location and purposes of these processes and how they relate to each other. **REMEMBER** that if the quality of the raw water changes, or any process fails to do its intended job, all of the downstream processes will be affected.

QUESTIONS

Write your answers in a notebook and then compare your answers with those on page 11.

- 1.1A What is the purpose of a water treatment plant?
- 1.1B Why do intake structures at water treatment plants have screens?
- 1.1C How is the sludge disposed of after it is removed from a sedimentation basin?
- 1.1D Why is excessive hardness removed from drinking water?

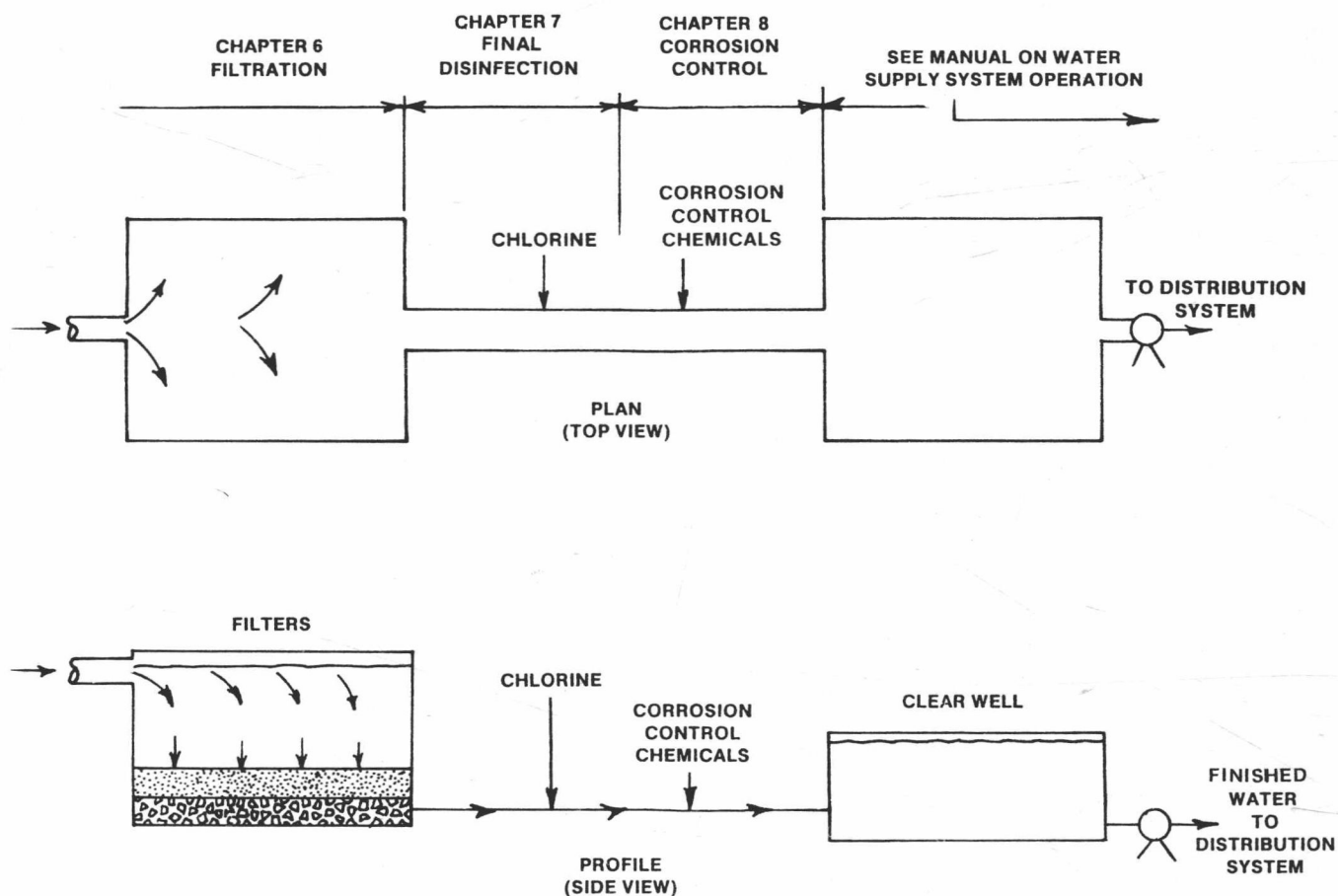


Fig. 1.2 Flow pattern through a conventional surface water treatment plant (continued)

8 Water Treatment

1.2 WHAT DOES A WATER TREATMENT PLANT OPERATOR DO?

1.20 Operation and Maintenance

Simply described, water treatment plant operators keep a treatment plant operating to produce a safe, pleasant, and adequate supply of water. They monitor the raw water entering the plant and keep an eye on the water as it flows through all of the various treatment processes. Flows into the plant are adjusted according to conditions of the raw water and system demands for water. Equipment and facilities are maintained and repaired as necessary to keep the water flowing and the plant working today and into the future. Typical duties performed by water treatment plant operators are summarized in Table 1.1

To start at the beginning, let's assume that the need for a new or improved water treatment plant has been recognized by the community. The community has voted to issue the necessary bonds to finance the project, and the consulting engineers have been requested to submit plans and specifications. In the best interests of the community and the consulting engineer, you should be present (or at least available) during both the design and construction periods in order to be completely familiar with the entire plant layout, including the piping, equipment, and machinery and their intended operation. This will provide you with the opportunity to relate your plant drawings to actual facilities. At this time you should gather together all the data and literature for the equipment in order to prepare a regular maintenance schedule. You and the engineer should discuss how the water treatment plant should best be run and the means of operation the designer had in mind when the plant was designed.

If the plant is an old one that is being remodeled, you may be in a position to offer excellent advice to the consulting engineer. Your experience provides valuable technical knowledge concerning the characteristics of the raw water and the limitations of the present facilities. Together with the consultant, you can be a member of an expert team able to advise your water utility.

1.21 Supervision and Administration

In addition to operation and maintenance duties for your water treatment plant, you may also be responsible for supervision of personnel. Chief operators frequently have the responsibility of training new operators and should encourage all operators to strive for higher levels of certification.

As a plant administrator, you may be in charge of record-keeping. In this case, you will be responsible for operating and maintaining the facilities as efficiently as possible, keeping in mind that the primary objective is to produce safe and pleasant drinking water from your plant. Without adequate, reliable records of the important phases of operation and maintenance, the effectiveness of your operation will not be properly documented (recorded). Also, accurate records are required by regulating agencies in accordance with the Interim Primary Drinking Water Regulations of the Safe Drinking Water Act.

Records are an excellent operating tool. Reference to past records can be quite helpful in adjusting treatment processes for various changes in raw water.

You may also be the budget administrator. Here you will be in the best position to give advice on budget requirements, management problems, and future planning. You should be aware of the necessity for additional expenditures, including funds for plant maintenance and enlargement, equipment replacement, laboratory requirements, and personnel needs. You should recognize and define such needs in sufficient time to inform the proper officials to enable them to accomplish early planning and budgeting.

1.22 Public Relations

As an operator, you are in the field of public relations and must be able to explain the purpose and operation of your water treatment plant to visitors, civic organizations, school classes, representatives of the news media, and even to city council members or directors of your district. A well-guided tour for officials of regulatory agencies or other operators may provide these people with sufficient understanding of

Table 1.1 TYPICAL DUTIES OF A WATER TREATMENT PLANT OPERATOR

1. Start up, shut down and make periodic operating checks of plant equipment, such as pumping systems, chemical feeders, auxiliary equipment (compressors), measuring and control systems.
2. Perform routine preventive maintenance, such as lubrication, operating adjustments, cleaning and painting equipment.
3. Load and unload chemicals, such as chlorine cylinders, bulk liquids, powdered chemicals and bagged chemicals using chemical-handling equipment such as fork lifts, hoists, and by hand.
4. Perform minor corrective maintenance on plant mechanical equipment, for example, chemical feed pumps and small units.
5. Maintain plant records, including operating logs, daily diaries, chemical inventories and data logging duties.
6. Monitor the status of plant operating guidelines, such as flows, pressures, chemical feeds, levels, and water quality indicators by reference to measuring systems.
7. Collect representative water samples and perform laboratory tests on samples for turbidity, color, odor, coliforms, chlorine residual, and other tests as required.
8. Order chemicals, repair parts and tools.
9. Estimate and justify budget needs for equipment and supplies.
10. Conduct safety inspections, follow safety rules for plant operations, and also develop and conduct tail-gate safety meetings.
11. Discuss water quality with the public, conduct tours of your plant (especially school children), and participate in your employer's public relations program.
12. Communicate effectively with other operators and supervisors on the technical level expected for your position.
13. Make arithmetic calculations to determine chemical feed rates, flow quantities, detention and contact times, and hydraulic loadings as required for plant operations.