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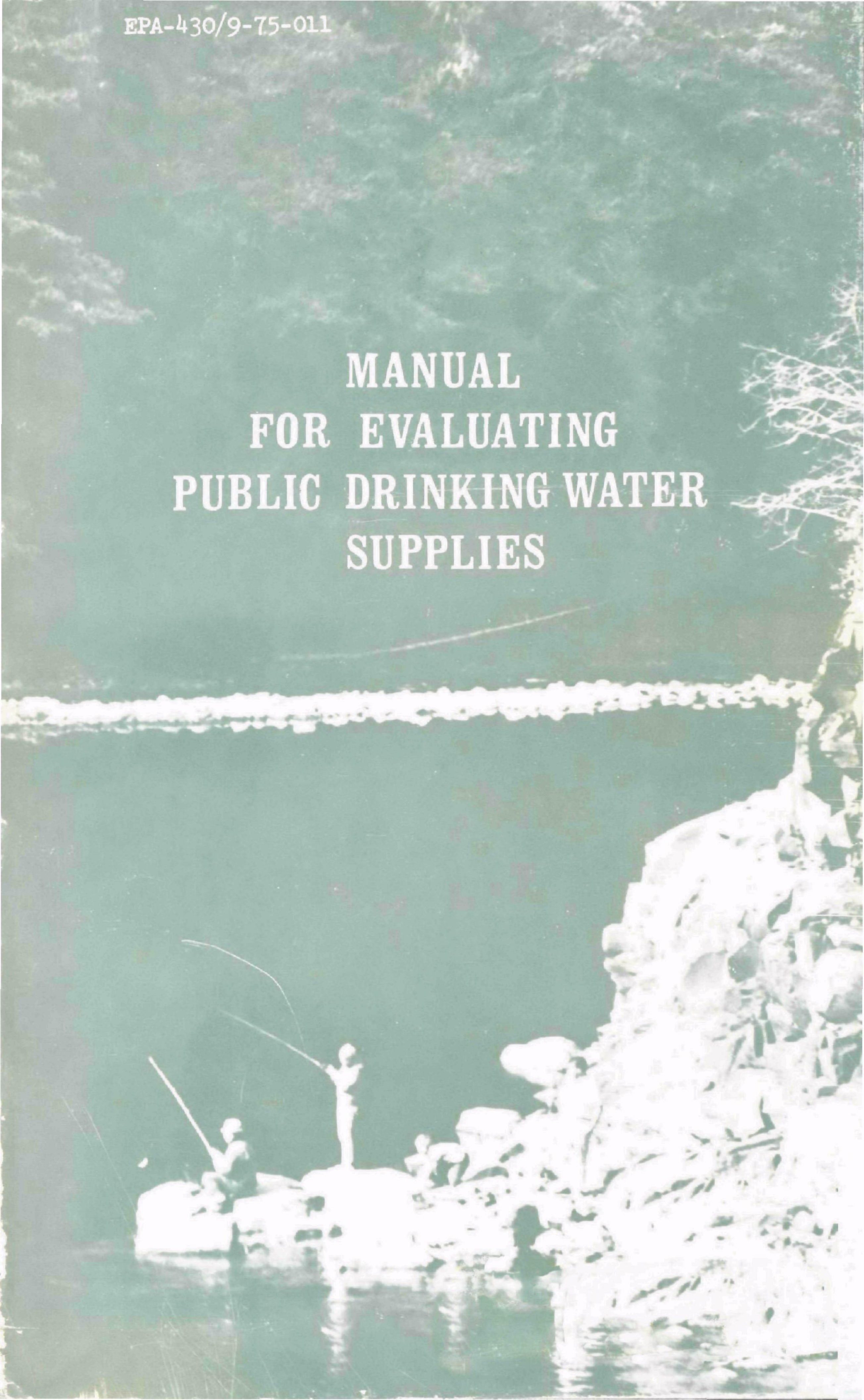
MANUAL FOR EVALUATING PUBLIC DRINKING WATER SUPPLIES



MANUAL
FOR EVALUATING
PUBLIC DRINKING WATER SUPPLIES

A Manual of Practice

U. S. ENVIRONMENTAL PROTECTION AGENCY
Office of Water and Hazardous Materials
Water Supply Division

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PREFACE

Today much attention is being focused on water supply as an aspect of man's environment that can be either (a) a natural resource of great benefit to him or (b) a vehicle by which disease organisms or toxic chemicals can be distributed widely. The public has no way of directly protecting its own water supply. Constant vigilance by health and waterworks officials is necessary for continued safe water production and distribution. These professionals must exercise this vigilance by regular evaluation of existing public water supplies and thorough study of proposed installations.

The Manual for Evaluating Public Drinking Water Supplies is designed to provide guidance to health and waterworks officials in determining whether a public drinking water supply satisfies modern health requirements. It replaces the Manual of Recommended Water Sanitation Practice, which for many years has been a reference document widely used by the health and waterworks professions.

The Manual for Evaluating Public Drinking Water Supplies has been prepared by the Water Hygiene Division of the Office of Water Programs, Environmental Protection Agency. Particular credit for assistance in its preparation is extended to members of the Advisory Committee on Use of the Public Health Service Drinking Water Standards and to the EPA Regional Office personnel responsible for the water hygiene program. It is hoped that this manual will be found useful by all whose duty it is to ensure safe drinking water for the American people.

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INTRODUCTION

Since 1914, Federal, state, and local health authorities and waterworks officials have used the Public Health Service Drinking Water Standards, in its original and revised forms, as the standards for healthful public drinking water supplies. An appendix in the 1942 revision sets forth guidelines for evaluating a public water supply. This appendix, which was published separately in 1946 as the Manual of Recommended Water Sanitation Practice, has now been revised and updated to reflect important changes about organic chemicals and radiochemicals and to include more details of sanitary requirements for water source protection and treatment. It is published here as the Manual for Evaluating Public Drinking Water Supplies.

The evaluation of a public drinking water supply appraises the origin, treatment, distribution, and storage of water, and the bacteriological, physical, chemical, and radiochemical qualities of the water as it flows from the tap. This Manual recommends procedures for surveying and evaluating a water supply and describes the elements of water treatment generally necessary to ensure the production of water that continuously meets the requirements of the Public Health Service Drinking Water Standards.

Adherence to the recommendations contained in this Manual is not a requirement for approval of any public drinking water supply, nor is it intended that these recommendations supplant design criteria adopted by state or local regulatory bodies. This Manual is intended to serve as a guide to those whose task it is to evaluate public water supply systems and deals primarily with health hazards attendant on the production of a potable public water supply.

Factors such as the complexity of the system being evaluated, the nature of the raw water source, and the competence of personnel engaged in operating the supply require professional judgment to successfully apply the Manual's recommendations.

The Manual supplements the Public Health Service Drinking Water Standards with particular emphasis on those items related to "Source and Protection." The construction criteria pertain to those features of a plant that are essential to the continued production of a safe water supply.

Part I
THE SANITARY SURVEY AND WATER TREATMENT REQUIREMENTS

A. THE SANITARY SURVEY

1. Basic Principle

Section 2.2 of the Public Health Service Drinking Water Standards 1962 (PHS Drinking Water Standards)[1] provides that ''Frequent sanitary surveys shall be made of the water supply system to locate and identify health hazards which might exist in the system.''

2. Public Water Supplies - General Evaluation

In the PHS Drinking Water Standards, a water supply system is defined to include ''the works and auxiliaries for collection, treatment, storage, and distribution of the water from the source of supply to the free-flowing outlet of the ultimate consumer.'' Sanitary protection is concerned with all those parts of a water system that come within this definition. The responsibility of the water purveyor for conditions in the water supply system generally ends at the connection to the consumer's piping, and responsibility for the consumer's system rests with the owner of the premises and with municipal, county, or other legally constituted authorities.

Proper evaluation of a water supply requires a careful study of the source and of the practices and protection applied to the supply. Although no precise outline of such a study can be given here, all studies should include, as a minimum, a compilation and evaluation of the following basic data:

(a) a field and office sanitary survey of the water and its environment from source to the consumer's tap;

(b) a description of the water system's physical features including adequacy of supply, treatment processes and equipment, storage facilities, and delivery capabilities (sketches are invaluable);

(c) an analysis of 12-month bacterial records and current chemical records on water from the source, the treatment plant, and the distribution system;

(d) an analysis of operating records showing present capacity, water demands, production to meet demands, and anticipated future demands;

(e) a review of management and operation methods and of the training, experience, and capabilities of personnel;

(f) a review of treatment plant and supporting laboratory equipment and procedures, including the qualifications of the laboratory personnel;

(g) an examination of state and local regulations and plumbing codes; and

(h) a summary and analysis of all facts pertinent to all water-system-related health hazards that were observed during a field survey.

Health hazards are defined in the PHS Drinking Water Standards as "any conditions, devices, or practices in the water supply system and its operation which create, or may create, a danger to the health and well-being of the water consumer. An example of a health hazard is a structural defect in the water supply system, whether of location, design, or construction, which may regularly or occasionally prevent satisfactory purification of the water supply or cause it to be polluted from extraneous sources." Detection of such health hazards requires a careful survey of the entire water supply system. The complexity of this task varies from the relatively simple investigation of a single well supply and limited distribution system to the involved survey of a supply that includes complete treatment facilities and complex distribution systems.

3. The Survey Engineer

A qualified person should make the sanitary survey of a water supply; his competence determines the reliability of the data collected. Although the qualifications constituting competence cannot be precisely defined, he should have a technical education in basic sanitary sciences and engineering and a broad knowledge of sanitary features and physical facts concerning potable water supplies and their sources. The essential features of water purification plants and systems, including their operation and methods of laboratory control, must also be understood by the investigator.

4. The Survey Report

The basic survey objective is to collect sufficient information to determine conclusively the capability of a water supply to continuously provide water that meets the PHS Drinking Water Standards. An engineering assessment of the adequacy of the source, the treatment plants, and the distribution system to meet normal and peak demands and to maintain adequate pressures should be included. Existing supplies should be surveyed frequently enough to control health hazards and maintain good sanitary quality, and the survey report of each public water supply system should be reviewed annually and updated when necessary.

A brief, general description of the physical features of the water supply from source to tap, employing maps and sketches where appropriate, should include:

(a) the name and owner of the supply;
(b) a description of sources and catchment areas;
(c) a description of the storage available before and after treatment; and
(d) a description of the system including date of installation of the main works and a record of major extensions or alterations made since the last survey.

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B. WATER TREATMENT REQUIREMENTS

1. General Requirements

The water quality requirements of the PHS Drinking Water Standards are minimum requirements, and good quality water should have physical and chemical characteristics considerably better than the limiting values established in the PHS Drinking Water Standards (Sections 4.2, 5.1, 5.2, 6.1, and 6.2). For example, water with turbidity of 5 units and a color of 15 units may be acceptable, but in a coagulated, filtered water such values could indicate serious malfunctioning of the purification process. (The PHS Drinking Water Standards are being revised currently, and will contain a recommendation that the turbidity standard be reduced to 1 turbidity unit. This and other revisions of the Drinking Water Standards, proposed at the time of this printing, are shown on the following pages.) Similarly, increased concentrations of copper and iron could indicate a corrosiveness that would be objectionable to consumers, even though the concentrations of the metals did not exceed recommended limits. In well water an increase in chlorides over the normal amount found in ground waters in the area may be the first indication of pollution.

The type of treatment required depends on the characteristics of the watershed, the raw water quality, and the desired finished water quality. If pollution of the source water is increasing, plant facilities, which were adequate for treatment of a nonpolluted water, may become inadequate. The production of water that is free from pathogenic organisms, aesthetically satisfactory to the senses, and reasonably acceptable chemically becomes increasingly difficult when the raw water has a high and varying chlorine demand, contains large numbers of coliform bacteria, or contains high concentrations of dissolved solids, toxic substances, or taste and odor producing substances.

When evaluating the ability of a water supply system to constantly produce a safe and satisfactory water, these factors should be considered:

(a) the quality of water produced at times of unusual stress, such as during heavy run-offs, periods of drought, or periods of excessive demand as shown in the records;

(b) the quality of the raw and finished waters, as determined by laboratory data and sanitary surveys, and any trends in improvement or deterioration;

(c) the purification processes, including the facilities used to apply disinfectants at various locations in the treatment process, and their capacities compared with the capacities considered necessary to meet maximum anticipated requirements;

(d) the treatment processes used and their reliability in changing raw water characteristics to produce a finished water that continuously meets the PHS Drinking Water Standards;

(e) the minimum residual chlorine concentration in the plant effluent water, when chlorine is used, together with the time that this or greater chlorine levels were maintained;

(f) the qualifications of the operators and laboratory personnel, as indicated by appropriate training, or certification, or both; and

(g) the laboratory facilities and analytical procedures, frequency and extent of their use, and application of the data to operational control.

2. Extent of Treatment

The Public Health Service recommends that all municipal water supplies, whether they be ground water or surface water, receive treatment by disinfection regardless of the quality of the water. The benefits from the added protection provided by disinfection far outweigh the increased cost and the added maintenance incurred by the water utility. When coliform density is used as one criterion for judging treatment requirements, raw waters can be divided into three groups: clean, clear, and polluted waters. The coliform densities of the raw waters can be expressed in terms of the most probable number (MPN) from the multiple-tube fermentation technique, or actual coliform counts determined by the membrane filter (MF) technique.

The requirements are given for three groups of water: those usable without treatment, those needing disinfection only, and those needing complete treatment. The quality requirements listed below are the recommended Technical Review Committee Tentative Standards, that are proposed as revisions to the current PHS Drinking Water Standards. They differ from the current PHS Standards in that some standards have been added, some have been deleted, and others modified.

Group I. Requirements for Water Usable Without Treatment[1]

A. Bacteriological Quality: The coliform standard remains the same as the PHS Drinking Water Standards, 1962, plus the inclusion of a standard plate count limit of 500 organisms per ml.

B. Physical Quality: should meet the following standards.

Color	15
Turbidity	1 turbidity unit
Taste and odor	2 threshold odor number

[1]Recommended Technical Review Committee Tentative Standards.

C. Chemical Quality: chemical concentrations should not exceed the following:

Substance	Maximum Allowable Limits concentration - mg/liter
Arsenic (As)	0.1
Barium (Ba)	1
Cadmium (Cd)	0.010
Chloride (Cl)	250
Chromium (Cr)	0.05
Copper (Cu)	1
Cyanide (CN)	0.2
Fluoride (F)[a]	
50.0-53.7°F	1.8
53.8-58.3	1.7
58.4-63.8	1.5
63.9-70.6	1.4
70.7-79.2	1.2
79.3-90.5	1.1
Foaming Agents as Methylene Blue Active Substances	0.5
Iron (Fe)	0.3
Lead (Pb)	0.05
Manganese (Mn)	0.05
Mercury (Hg)	0.005
Nitrate Nitrogen	10
Organics - Carbon Absorbable	
CCE	0.3
CAE	1.5
Selenium (Se)	0.01
Silver (Ag)	0.05
Sodium (Na)	270
Sulfate (SO_4)	250
Zinc (Zn)	5

[a]Annual average of maximum daily air temperature.

Substances not included in the above table that may have deleterious physiological effect or that may be excessively corrosive to the water supply system should not be permitted in the raw water supply.

D. Radioactivity: should comply with the following certification limits:

ALPHA ACTIVITY

Gross Alpha Activity - 1 pCi/l, or Radium 226 - 1 pCi/l when the gross activity is greater than 1 pCi/l but less than 10 pCi/l.

BETA ACTIVITY

Gross Beta Activity - 10pCi/l, or Strontium 90 - 10 pCi/l when gross beta activity, after the Potassium 40 activity has been subtracted, is greater than 10 pCi/l but less than 100 pCi/l.

The recommended technical task force tentative standards provide for provisional arrangements to be made by further community surveillance of radioactivity to modify the above listed certification limits.

E. Pesticides: should not exceed the following limits:

Pesticide	Maximum permissible concentration, mg/l
Aldrin	0.01
Aldrin and Dieldrin	0.01
Dieldrin	0.01
Chlordane	0.01
DDT	0.1
Endrin	0.003
Heptachlor	0.02
Heptachlor epoxide	0.02
Heptachlor and Heptachlor epoxide	0.02
Lindane	0.1
Methoxychlor	0.5
Organophosphate and carbamate insecticides[a]	0.1
Toxaphene	0.1
2,4-D	1
2,4,5-T	0.005
2,4,5-TP	0.2

[a]Expressed in terms of parathion equivalent cholinesterase inhibition.

Group II. Requirements for Water Needing Disinfection Only

A. Physical, Chemical, Radioactivity, and Pesticide Requirements: the requirements as shown for untreated raw ground water (Groups I.B, I.C, I.D, and I.E) should be met. If the water does not consistently meet all these requirements, consideration should be given to providing additional treatment during periodic decreases in quality that result from high turbidity, tastes, etc.

B. Bacteriological Quality:

1. Fecal Coliform Density: If fecal coliform density is measured, the total coliform density discussed below may be exceeded, but fecal coliform density should not, in any case, exceed 20 per 100 milliliters as measured by a monthly arithmetic mean. When the fecal coliform vs. total coliform criterion is used for Group II water, the fecal coliform count should never exceed the 20 per 100 milliliters monthly arithmetic mean. This fecal coliform standard only applies when it is being measured on a regular basis.

2. Total Coliform Density: Less than 100 per 100 milliliters as measured by a monthly arithmetic mean.

Group III. Requirements for Water Needing Treatment by Complete Conventional Means Including Coagulation, Sedimentation, Rapid Granular Filtration, and Disinfection (Pre and Post)

A. Bacteriological Quality:

1. Fecal Coliform Density: If fecal coliform density is measured, the total coliform density discussed below may be exceeded, but fecal coliform should not exceed 2,000 per 100 milliliters as measured by a monthly geometric mean.

2. Total Coliform Density: Less than 20,000 per 100 milliliters as measured by a monthly geometric mean.

The same rationale applies here as in the Group II waters concerning the use of the fecal coliform vs. total coliform criterion. In no case should the fecal coliform count exceed the 2,000 per 100 milliliters monthly geometric mean.

The arithmetic mean is used with the Group II waters because the bacteriological data from these waters will be of lesser magnitude than that from the Group III waters; this difference in magnitude between the monthly means of the Group II and Group III waters is best reflected by the arithmetic and geometric means, respectively.

These bacteriological limits may possibly be exceeded if treatment (in addition to coagulation, sedimentation, rapid granular filtration, and disinfection) is provided and is shown to be doing a satisfactory job of providing health protection.

B. Physical Quality: Elements of color, odor, and turbidity contribute significantly to the treatability and potability of the water.

1. Color: A limit of 75 color units should not be exceeded. This limit applies only to nonindustrial sources; industrial concentrations of color should be handled on a case-by-case basis and should not exceed levels that are treatable by complete conventional means.

2. Odor: A limit of 5 threshold numbers should not be exceeded.

3. Turbidity: The limits for turbidity are variable. Factors of nature, size, and electrical charge for the different particles causing turbidity require a variable limit. Turbidity should remain within a range that is readily treatable by complete con-

ventional means. It should not overload the water treatment works, and it should not change rapidly either in nature or in concentration when such rapid shifts would upset normal treatment operations.

C. Chemical Quality: Since there is little reduction in chemical constituents with complete conventional treatment, raw water should meet the limits given for Group I.C.

D. Radioactivity: Should comply with Certification Limits given in Group I.D.

E. Pesticides: Should comply with requirements for pesticides as shown for untreated raw ground water in Group I.E.

Infectious material, the increasing diversity of chemical pollutants found in Group III raw waters, and the many different situations encountered in regional and local problems make it impractical to prescribe a limited selection of facilities and processes that can effectively handle all problems presented by raw water and its sources. Future improvements in treatment technology cannot be reasonably assisted or regulated by requiring the fixed process steps considered good for today's technology. Table 1 describes some factors that increase the difficulty in securing disinfection, e.g., adequate disinfection with halogens depends on temperature, pH, contact time, and concentration of disinfectant.

Types of disinfection other than chlorination must be demonstrated to function effectively in all compositions of water likely to be encountered from the source used. If a distribution system is of any considerable length, the disinfection method should provide a residual protection that can be easily measured.

Table 1. CONDITIONS CREATING DIFFICULTIES AT THE WATER PLANT AND IN THE WATER MAINS

Bacterial and biological conditions	Chemical conditions	Physical and operational conditions
Increasing numbers of coliforms	Ammonia nitrogen	Low temperature
Biological pollution, i.e., algal or fungal metabolic products that effect chlorine demand	Toxic materials or taste and odor requiring removal	Extended distribution systems
Filter clogging organisms that effect chlorine demand	Color or organic dispersing agents (anticoagulants), lignin compounds	Highly variable water quality
	Chlorine demand	Rapid variation in flow and turbidity of surface water resource
	Iron and manganese	Tidal effects
	High organic content	
	High or organic content	
	High or fluctuating pH	

Where water sources show continuing quality deterioration or the quality of water available is not adequate for future demand, the water purveyor should be examining alternate or auxiliary sources of supply and should have positive plans to procure adequate facilities and sources.

Part II

RECOMMENDED SANITARY REQUIREMENTS FOR WATER SOURCE PROTECTION AND TREATMENT

A. GROUND WATER SUPPLIES (Refer to Part I. B.2, Group I)

Adequate, natural protection of ground water involves purification of water by infiltration into the soil, by percolation through underlying material, and by storage below the ground water table.

Ground water, when available in sufficient quantity, is often a preferred source of water supply. Such water can be expected to be clear, cool, colorless, and quite uniform in character. Underground supplies are generally of better bacterial quality and contain much less organic material than surface water but may be more highly mineralized.

1. Geologic Factors for Source Protection

When water seeps downward through overlying material to the water table, particles held in suspension, including microorganisms, may be removed. The extent of removal depends on the depth and character of the overlying material. The bacterial quality of the water also generally improves during storage in the aquifer because time and storage conditions are usually unfavorable for bacterial multiplication or survival. Of course, the clarity of ground water does not guarantee safe drinking water, and only adequate disinfection can guarantee the absence of pathogenic organisms. An important, naturally protected water supply is available where sufficient artesian water is present.

2. Distances from Sources of Contamination

All ground water withdrawal points should be located a ''safe'' distance from sources of pollution. Sources of pollution include septic tanks and other individual or semipublic sewage disposal facilities, sewers and sewage treatment plants, industrial waste discharges, land drainage, farm animals, fertilizers, and pesticides. Where water resources are severely limited, ground water aquifers subject to contamination may be used for water supply if adequate treatment is provided.

After the decision has been made to develop a water supply in an area, the direction of water movement during proposed withdrawal conditions and the ''safe'' distance from potential pollution sources should determine the withdrawal point. A ''safe'' distance is the distance that ensures no contamination will be drawn or will flow to the withdrawal point when conditions of pollution sources, withdrawal, and water table levels are the most adverse.

Because many factors affect the determination of ''safe'' distances between ground water supplies and sources of pollution, it is impractical to set fixed distances. Where insufficient information is available to determine the ''safe'' distance, the distance should be the maximum that economics, land ownership, geology, and topography will permit. If possible, a well site should be located at an elevation higher than that of any potential source of contamination. It should be noted that the direction of ground water flow does not always follow the slope of the land surface.

3. Wells

All wells must be properly sealed against surface water contamination (Figure 1). Ground water can be contaminated by surface water entering through the top of the well or by surface water or water from contaminated aquifers, through

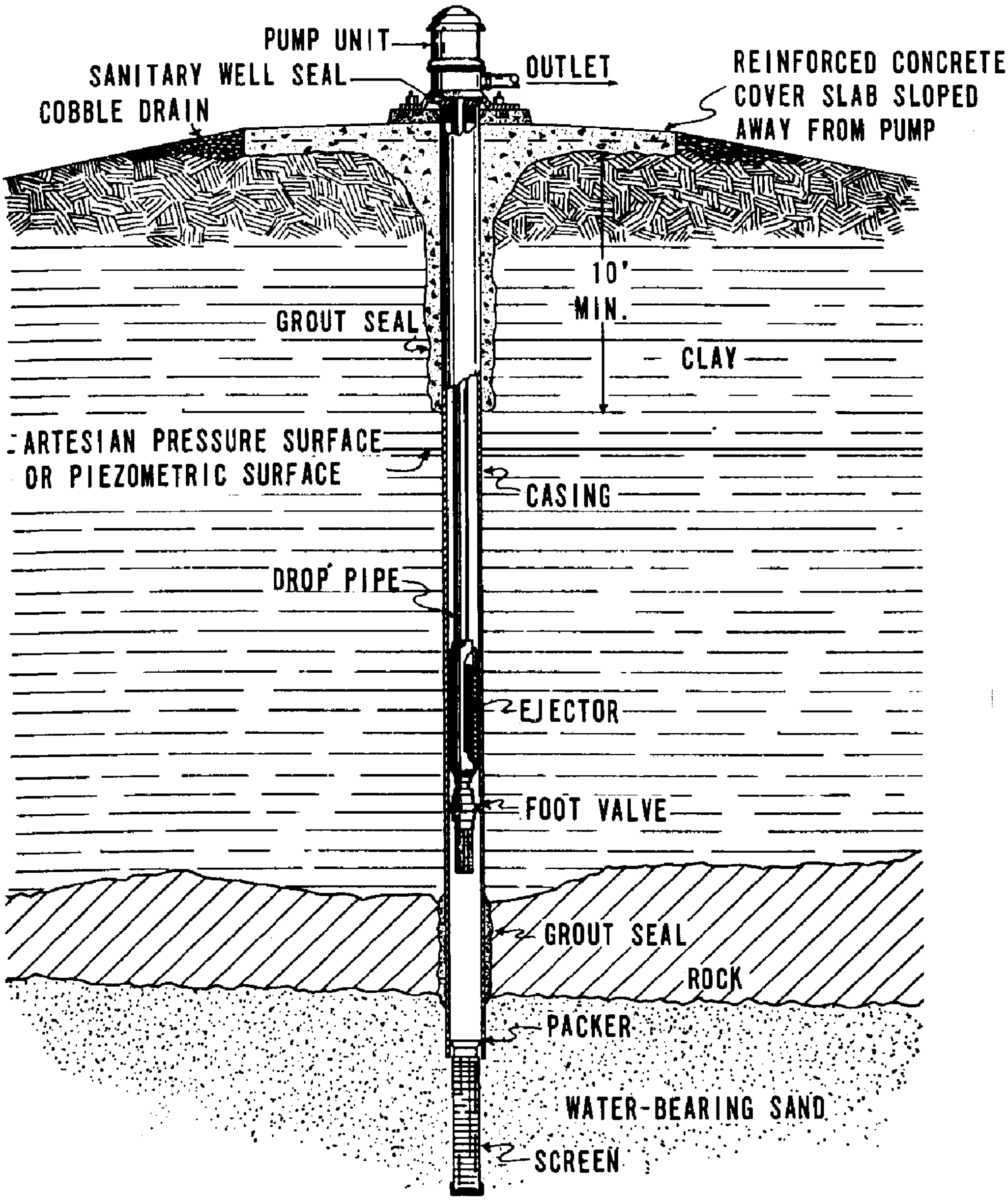

Figure 1. Drilled well showing sanitary protective features.

which the well passes, that flow down outside of the well casing to the intake point.

When shallow ground water is developed, pathogenic organisms may penetrate the water table. Fluctuations of the water table caused by periods of heavy precipitation may at times bring the water table into contact with contaminated zones near the surface. Wells that extend only a short distance into shallow water tables are more likely to be contaminated than wells that penetrate more deeply. The construction of wells with watertight casings surrounded by cement grout protects against surface contamination being drawn to or reaching the casing wall. The depth of grout necessary depends on the individual characteristics of the of the area involved. When a sanitary survey is made of an existing or proposed well site, nearby sewage disposal facilities, caves, sink holes, abandoned borings used for surface drainage or sewage disposal, and improperly sealed wells should be located, mapped, and evaluated as to possible hazard. Investigation should be made for fissures or faults in the stratum overlying the aquifer.

The following specifications for sanitary protection are particularly applicable to wells producing water that is not treated or that receives disinfection only. (See also American Water Works Association [AWWA] Specification A100.[2])

a. Exclusion of Surface Water from Site. The top of the well must be so constructed that no foreign matter or surface water can enter the well. The well site should be properly drained and adequately protected against flooding. Surface drainage should be diverted away from the well.

b. Earth Formations Above Water-Bearing Stratum. Recharge formations above the tapped aquifer should provide sufficient filtration to prevent contamination from sources of pollution.

c. Distance to Source of Contamination. The horizontal distance from a well to a source of contamination should be as great as practical.

d. Depth of Casing and Curbings. Well casings should extend into and be sealed to the impermeable stratum immediately above the aquifer.

e. Construction and Use of Casing and Curbing. For drilled wells, the space between casing and well hole should be filled with cement grout to a sufficient depth below grade to prevent surface pollution. Aquifers containing water of undesirable quality should be sealed off from the well casing. The casing must extend 6 inches or more above the surface of the well house floor or collar. Casings should not be used as suction pipes.

f. Gravel-Packed Wells. The top level of the gravel packing should be at least 50 feet below ground surface. The remaining space above the gravel level should be filled with impervious puddled clay or cement grout. Gravel fill pipes must be securely capped and sealed.

g. Well Seals or Covers. A watertight seal or cover must be provided at the top of the casing.

h. Well Vents. Vents necessary to maintain atmospheric pressure in the casing should be screened (#24 mesh), with the return bend facing downward, and terminate at least 18 inches above the floor level or above the maximum flood level, whichever is higher.

i. Well Pits. Well pits should be used only where there is adequate protection to prevent flooding.

j. Construction and Installation of Pumps. The connection between the top of the well casing and the power unit must be watertight. The openings for pump suction lines, water level measurement lines, power cables, and lubrication lines must be tightly sealed. Where pump suction lines are outside well casings, the suction lines should be positively protected from environmental hazards. Submersible pumps are considered safe.

k. Pump Houses. Pump houses should be adequately drained and protected against flooding.

l. Disinfection and Other Unit Processes. All treatment processes should be accomplished in accordance with provisions contained in other sections of this Manual.

4. Springs

Water appears at the ground surface from springs of two types, gravity and artesian. Gravity springs occur when the aquifer in which water is percolating laterally comes to the surface because of a sharp drop in surface elevation below the normal ground water table or when obstructions to flow result in an overflow at the surface. Artesian springs are formed when faults in impermeable strata permit artesian water to escape from confinement. Artesian springs discharge from artesian aquifers at pressure higher than the discharge elevation and are usually freer from environmental hazards than are gravity springs. The nature of the strata underlying porous strata should be known, and the possibility should be considered that water may enter the aquifer through sink-holes or other large openings. The slope of the water table should be ascertained. The quality of water derived from springs should be protected from surface contamination even if processed as a surface water. The following requirements should be met:

a. Structure. Springs should be housed in permanent buildings or structures with watertight walls. For surface springs, the walls should extend into the aquifer.

b. Drainage. Direct surface drainage should be diverted away from the spring.

c. Fencing. The entire area within 100 feet of the spring should be fenced to prevent trespass of livestock and unauthorized persons. Any portion of surface drainage diversion ditches lying above the spring should be within the fenced area.

d. Disinfection and Other Unit Processes. Disinfection and other unit processes should be accomplished in accordance with provisions contained in other sections of this Manual.

5. Infiltration Galleries

An infiltration gallery is essentially a horizontal well that collects water along its entire length. Such galleries are usually laid in the alluvium near a body of surface water but are sometimes constructed beneath the surface water. Infiltration galleries are subject to the same sanitary hazards as shallow wells but have greater exposure to pollution because of their horizontal position. The following precautions should be taken to protect against contamination:

a. Soil Filtration. To ensure adequate removal of suspended matter and bacteria, each infiltration gallery should be constructed and located to provide the collected water the maximum filtration through soil and sand.

b. Protection from Contamination. With the exception of service facilities, the surface area above and within a minimum of 100 feet or a ''safe'' distance of each gallery should be void of buildings and dwellings and should be protected by a fence to prevent trespass of livestock and unauthorized persons.

c. Disinfection and Other Unit Processes. Disinfection and other unit processes should be accomplished according to provisions contained in other sections of this Manual.

B. SURFACE WATER USED WITHOUT FILTRATION (Refer to Part I.B.2, Group II)

1. General

It is increasingly difficult, because of recreational use of streams, lakes, and watersheds, and urban and industrial development, for unfiltered surface water supplies to meet the requirements of the PHS Drinking Water Standards. With suitable catchment areas, adequate storage in impound-

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ing reservoirs, strict control of pollution sources on the catchment and storage areas, and effective disinfection, unfiltered water can quite often meet the bacteriological requirements. Most unfiltered supplies, however, are unable to consistently produce suitably clear and colorless water, usually because of the influence of seasonal changes in human activity and weather.

Special emphasis must be placed on prevention of pollution of watersheds, or reservoir inspection and policing procedures, and on disinfection. Terminal reservoirs[a] and Class A upstream reservoirs[b] should never be used for recreation. Upstream reservoirs are classed as follows:[3]

Class A: Water derived from an uninhabited or sparsely inhabited area, at or near the point of rainfall or snow melt; collected in a storage reservoir, clean and clear enough to be distributed to the consumers with disinfection only. (See Figure 2 for illustration.)

Class B: Water impounded from an area not heavily inhabited and allowed to flow from storage in a natural stream to the point of withdrawal and requiring treatment in varying degree in addition to disinfection.

Class C: Water which has flowed in a natural stream before storage for a considerable distance, having received polluting materials from municipalities, industries, or agricultural areas; confined in a reservoir primarily for purposes of storage until such time as low stream flow makes the stored water necessary for the use of the downstream city; and later allowed to flow from the reservoir to the tributary water works in an open stream accessible to the public; and requiring complete treatment.

[a]Terminal Reservoirs: areas providing end storage of water prior to treatment.

[b]Upstream Reservoirs: reservoirs providing storage of untreated water at various points in the watershed to provide or supplement the supply at the terminal reservoir.

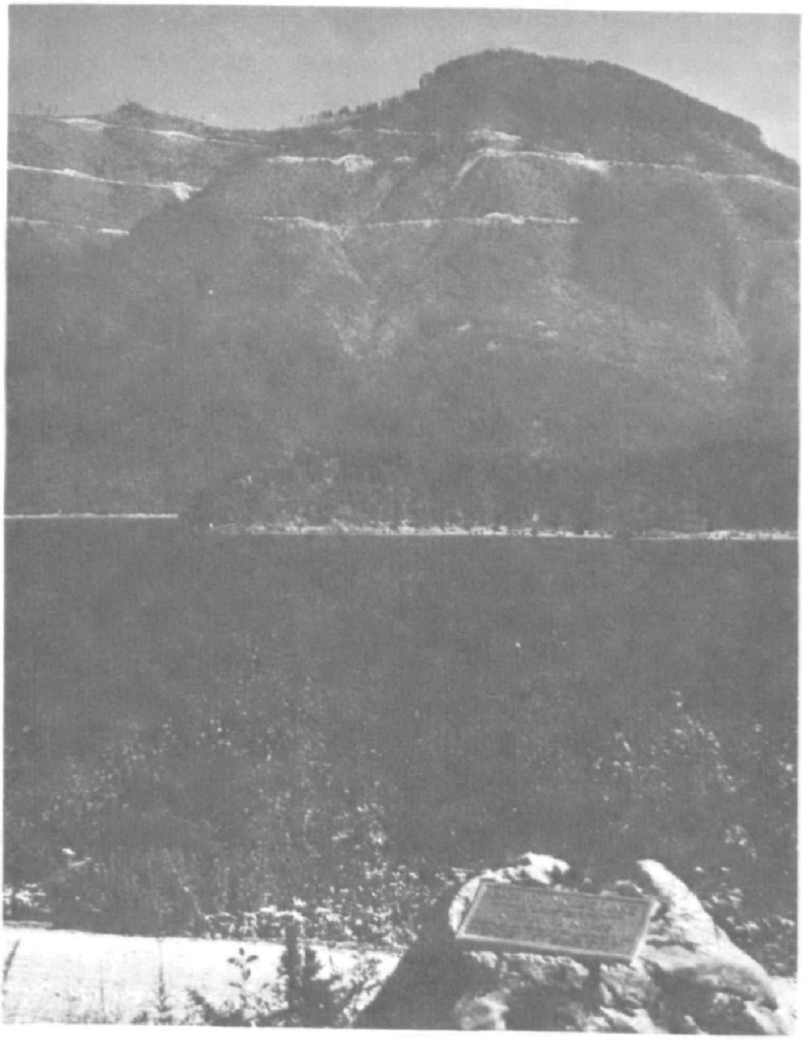

Figure 2. Chester Morse Reservoir, Cedar River Watershed, near Seattle, Washington.

Multipurpose reservoirs are those constructed for purposes in addition to the supply of domestic water. The water purveyor does not have complete control over the reservoir, and the water requires the same complete treatment as Class C water.

When the watershed cannot be owned completely or nearly completely by the water purveyor, ownership of marginal land around the reservoirs is recommended and ownership of the land for a considerable area around the supply intake is mandatory.

Although the beneficial effects of storage are considerable, they cannot approach those obtained from chemical treatment and filtration. Such treatment should be considered when the pollution loading, expressed as the average monthly concentration of total coliforms, approaches 100 per 100 milliliters.

2. Special Precautions to be Taken

Some precautions that must be taken with unfiltered surface sources are:

(a) The character of the watershed area should be such that heavy rainfall does not excessively increase the turbidity in the storage reservoir. The area of swampland should be small, and the water draining therefrom should have a minor effect on the color of the impounded water. Excessive turbidity exceeds 5 units, and excessive color exceeds 15 units.

(b) Because the ideal of 100 percent ownership or control of the watershed of a surface supply cannot usually be obtained, one protective measure is a strong program for pollution control and abatement. The entire watershed area should be surveyed periodically to detect existing or potentially dangerous sources of pollution. If polluting emissions can not be eliminated, they must be treated. A permit to discharge waste should be given to those who treat wastes adequately, as determined by health authorities, or the water purveyor, or both, with the understanding that such permits may be revoked and all emissions prohibited, if necessary to protect the water supply.

(c) The population density of the watershed should be determined yearly to forecast the future need for more extensive treatment. This should include assessment of possible pollution from industrial, agricultural, or recreational sources.

(d) When permission is given for limited recreational use of upstream reservoirs, permission should be only by permit and under proper supervision and should be revokable. Sufficient laboratory testing should be conducted to evaluate the effect of such use.

(e) Where disinfection is the only treatment, exceptional precautions should be exercised to ensure the effectiveness and reliability of this treatment. (See Part I. B.2) If the flow of water to the supply system is variable, the chlorinators should be of the proportional feed type, and standby units should always be available.

C. SURFACE WATERS USED WITH CHEMICAL TREATMENT, FILTRATION, AND DISINFECTION (Refer to Part I.B.2, Group III)

1. General Requirements

Most surface waters require chemical treatment, coagulation, sedimentation, filtration, and disinfection to make them suitable for use as public water supplies. A combination of treatment methods will, if properly carried out, convert a moderately polluted water into a safe drinking water. Filtration systems such as diatomite, slow sand, and certain patented processes may also be used under certain conditions. The limitations of each treatment process must not be exceeded.

In general, the design and construction (see Figure 3) of water treatment plants vary with local circumstances. Each plant should be designed and constructed to deal with the characteristics of the water being treated in accordance with state standards and generally accepted good prac-

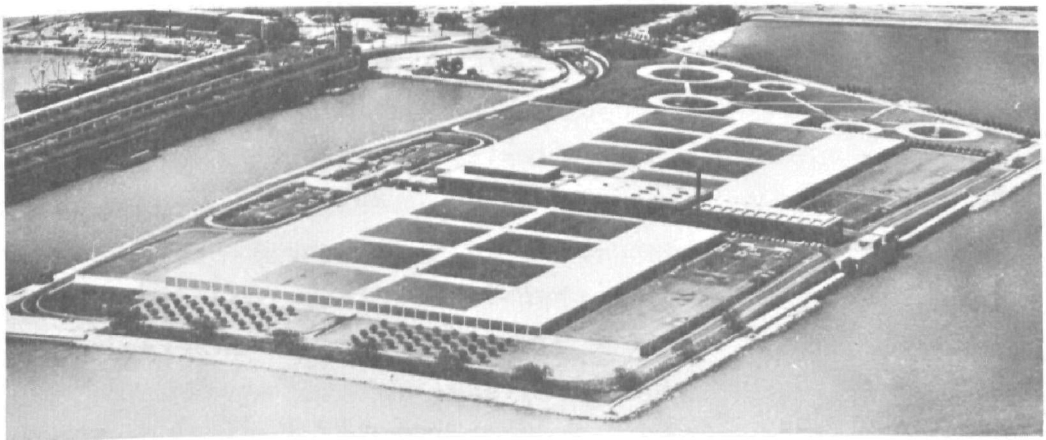

Figure 3. Central District Filtration Plant, Chicago, Illinois.

tice. The following recommendations are intended only as a general guide to good practice and should be interpreted somewhat broadly in the light of specific raw water characteristics and other conditions that may be involved. Older plants may be expected to produce safe, palatable, economically useful water if modifications and improvements have made the treatment facilities adequate and if they are properly maintained and operated.

2. Plant Intake

The purpose of the plant intake is to withdraw continuously adequate quantities of the best available grade of raw water. When selecting the intake location, the stream or lake bottom character, currents, and potential sources of pollution must be considered. To provide for the variability of environmental influences, the intake structure should be designed and built to permit raw water withdrawal at various levels, or locations, or both. The intake capacity, including pumping facilities, should provide sufficient raw water for the treatment plant at all times. The quantity of finished water in storage provides a buffer and is a factor in determining the necessary intake capacity. This intake capacity generally equals the average rate of demand on the maximum day. Dual facilities should be provided for mechanical equipment. Pump priming must not create a cross connection between the finished and raw water supplies.

Intake facilities should also be constructed to ensure continuous raw water flow despite floods, icing, plugging with debris or sand, high winds, power failure, damage by boats, or any other occurrences; be inaccessible to trespass; contain adequate toilet facilities, located and installed to prevent chance contamination of the raw water supply; and contain an immediate warning system for the treatment plant operator in case of failure of automatic or semiautomatic pumping stations.

3. Plant Delivery Capacity

The delivery capacity of a treatment plant, including finished water storage should exceed the maximum anticipated demand for a reasonable time period. A sufficient time margin should be allowed for future expansion as the community grows. Water systems that are experiencing demands approaching, equalling, or greater than this delivery capacity and that are not progressing with construction plans or the acquisition of auxiliary supplies to meet these demands cannot be considered satisfactory. A capacity of sufficient margin is one that can reasonably be expected to meet all demands 5 years in the future.

4. Plant Location

The treatment plant should be located so that no conduit, basin, or other structure containing or conducting water in the process of treatment can possibly be affected by leakage from any sewer, drain, or other source of contamination. The site should be drained so that no surface water can enter into wells, basins, filter tanks, or other process units.

Protection against floods may be provided by locating the plant on high ground above flood levels or by constructing levees. The adequacy of flood protection would depend on the flood heights to be expected, the structural soundness of the protective works, the availability of adequate auxiliary power, and the availability of pumping equipment to assure the continuous removal of interior drainage under emergency conditions. Facilities must be provided to remove filter wash water, plant wastes, and sanitary wastes during floods. All drainage and sewer lines for the plant facilities must be designed and constructed to prevent backflow from submerged outlets.

5. Presettling Reservoirs

Presettling reservoirs are those removing turbidity by plain sedimentation, supplemented in special cases by the addition of coagulants, chlorine, or both. Not included are the relatively small, so-called grit reservoirs commonly used in the Mississippi Valley for removing coarse silt and sand.

If presettling reservoirs are used, they should be located above the influence of flood waters and should have sufficient capacity to remove sand, silt, and clay with an efficiency that will prevent overloading of subsequent treatment facilities. The reservoir shape, inlet and outlet design, and location should minimize potential short circuiting.

Provision should be made for rapid, convenient removal of sludge from the reservoirs and for duplicate reservoirs, a bypass with special treatment, adequate storage, or some other means to avoid interruption of service during cleaning periods. Where highly polluted waters of variable quality are involved, coagulation at the inlet and prechlorination at the inlet or the outlet of the reservoirs should be provided.

6. Coagulation and Sedimentation Basins

Coagulation and sedimentation properly prepare the water for filtration. Coagulation and flocculation, which precede sedimentation, are generally accomplished by rapid distribution of the coagulating agent followed by gentle agitation to promote flocculation.

Sedimentation basins should be sized and arranged to ensure the settling of the floc developed and the delivery of relatively clear water to the filters. Basins should be of sufficient number and hydraulic flexibility to ensure the continuous operation of the treatment plant. Provisions should be made for satisfactory removal of sludge. The critical displacement velocity of the floc must not be exceeded by water flowing through the sedimentation basins. The flow over discharge weirs should be less than 20,000 gallons per day per foot of weir to prevent surges.

7. Chemical Feeding

Treatment plants should be provided with modern devices for accurately measuring and adding to the water each chemical used for coagulation or other purposes, with at least one reserve unit for all chemical feed equipment, whether of a dry feed or solution feed type. This chemical feed equipment should have continuous recording devices and alarm devices to ensure continuity of treatment and should be capable of ready adjustment to variations in the flow of water being treated. Where flows vary considerably throughout a 24-hour period, the chemical feed adjustment should be automatic. Sufficient chemicals should be stored to prevent shortages caused by any unforeseeable interruption of chemical supply. An up-to-date inventory of chemical stock should be kept, and the oldest chemicals in stock should be used first. The minimum chemical inventory should be a 30-day supply; this required inventory will vary from month to month because of varied raw water quality and varied demands.

8. Slow Sand Filters

Properly designed and operated slow sand filters are suitable for the treatment of certain types of relatively clear water. Preferably they should be covered, and they should be operated at rates (normally about 4 million gallons per acre per day) consistent with the continuous production of water meeting the PHS Drinking Water Standards. Care should be taken to avoid any sudden increases in the filtration rate of slow sand filters. The filter area should consist of several independent units so that the quality and quantity of water required at times of maximum draft can be supplied when some units are out of service for cleaning (normally done every 20 to 60 days) or repair work. To provide for more efficient filtration by the slow sand filters and particularly to remove turbidity, the raw water is sometimes given pretreatment consisting of simple sedimentation, coagulation and sedimentation, preliminary rapid filtration with or without coagulation and sedimentation, or microstraining. Filtration rates for slow sand filters may be appreciably increased (by a factor of 2 or 3) over normally acceptable rates if enough preliminary treatment is provided.

9. Rapid Granular Filters

Rapid granular filters should preferably be of the open, gravity type to permit ready and continuous inspection. The depth, effective size, and uniformity coefficient of the media should meet the requirements of adequate yield and filter efficiency. The rate of filtration should be consistent with the production of a water that meets or exceeds the requirements of the PHS Drinking Water Standards.

In general, rapid granular filters should be designed and operated to maintain high efficiency in particulate removal and to keep the filtering medium free of mud balls, cracks, and other hindrances to efficient filtration. The total available filter area should be divided into several independent units so that maximum demands occurring during cleaning or repair of individual units can be met. Rapid granular filters are operated at 1.5 to 3.0 gallons per square foot per minute and are usually cleaned every 12 to 40 hours. Cleaning is normally done when sufficient head loss has been established to put the bed and its underdrainage system under partial vacuum or when there seems to be danger of a breakthrough. This partial vacuum should not be allowed to become large enough to cause air binding or shrinkage cracks to occur; backwashing should be done before evidence of a breakthrough is seen.

Rapid granular filters operated at rates higher than those mentioned above can still produce high quality water depending on the incoming water quality, the efficiency of the treatment units preceding the filters, the capabilities of the filters, and the degree of quality control exercised.

10. Alternate Forms of Treatment

Other treatment processes may be used either as an added degree of treatment or to replace one of the aforementioned units (sections 5 through 9 above). The more common processes are diatomaceous earth filters, filter beds with more than one type of media, and high rate filters. Use of these and other alternate forms of treatment will depend on incoming water quality and volume, economic feasibility, performance of the other units of the treatment process, and degree of quality control exercised.

11. Finished Water Storage Reservoirs

All finished water reservoirs should be covered. If such reservoirs are located below adjacent structures or below ground elevation, adequate protection against leakage of nonpotable or drainage water from such higher elevations should be provided. If practical, such reservoirs should be situated above the ground water table and should have no common wall with any other plant units containing water in a prior stage of treatment.

12. Cross-Connections, Open Connections, and Partition Walls in a Water Treatment Plant

No cross-connection should exist between any conduit carrying filtered or postchlorinated water and another conduit carrying nonpotable water, or water in any prior stage of treatment.

No conduit or basin containing finished water should have a common division wall with another conduit or basin containing nonpotable water. Vertical double division walls, where separated sufficiently to permit ready access for inspection, are permissible where the division walls are monolithic in construction and are properly keyed into their footings or are cast monolithically with the footings.

Filter-to-waste conduits should not be directly connected to any drainage conduit if backflow can occur.

No conduit carrying nonpotable or partially treated water, no center-passage type conduits, and no conduits having double separation walls should be located directly above any conduit or basin containing finished water.

13. Drains

All drainage conduits should be watertight against leakage. Where drains discharge into bodies of water serving as raw water supplies, the discharge points should be located so that no drain water can, under any circumstances, be carried to the plant intake, or to any other water intake located in the vicinity of the plant. No sanitary sewer or process wastes sewer should be permitted to discharge waste water into the raw water supply in the vicinity of any treatment plant intake; nor should any drain carrying contaminated surface water be permitted to be so discharged. ''In the vicinity of'' means any discharge point from which the waste water may adversely affect the raw water supply, and should be evaluated in terms of flow conditions for the raw water supply and for the waste water.

14. Finished Water Pumping Stations

For sanitary protection, the precautions given below should be taken:

(a) Pumping stations should be protected against interruption of operation because of floods. Similarly, protection against fire should be provided, and plans should be established for operation under all natural or man-made disaster situations.

(b) The required number, types, and capacities of pumps depend on the conditions peculiar to the system involved. The pumps should be able to meet existing load conditions with ample reserve. In addition, sufficient standby capacity should be available to meet maximum demands when the largest pumping unit is out of service. All pumps should be maintained in good condition and periodically operated and checked for proper performance. The suction pipes should be examined frequently to determine that they are watertight.

(c) Proper plumbing and proper location of sewer lines protect clear wells from pollution. Pump priming, if required, should be accomplished with potable water.

(d) Both design and operation should minimize any conditions that might lead to negative pressures in the distribution system. This includes providing surge suppressors, closing and opening valves slowly, and avoiding unnecessary starting and stopping of pumps.

D. DISINFECTION

1. Chlorination

a. Chlorination Equipment. Chlorination equipment should be selected, installed, and operated to achieve continuous and effective disinfection under all possible conditions, with enough stand-by units to ensure uninterrupted operation. The capacity of the regular chlorination equipment, stand-by equipment excluded, should exceed the highest anticipated dosage. The determination of this maximum dosage (and normal dosages) should be made with the guidance and approval of the appropriate health agency. The characteristics of the water to be treated, conditions of water use, and type of chlorination provided, i.e., free or combined chlorine residual, should be considered. Frequent operation of stand-by units to ensure reliability can be accomplished by rotating the stand-by assignment from unit to unit on a monthly basis. Adding the plumbing necessary for feeding chlorine from any prechlorination, postchlorination, or stand-by equipment to any chlorination point in the treatment process provides flexibility to the chlorine feeding facilities. A complete stock of spare parts and tools should be maintained for emergency replacements or repairs, and preventive maintenance (scheduled inspection and repair before breakdown) should be practiced. Chlorination equipment should be capable of satisfactory operation under every probable hydraulic condition.

Manual control of the chlorine dosage is permissible if the rate of flow is relatively constant and an attendant is always on duty to promptly make the necessary adjustments in dosage. Automatic proportioning of the chlorine dosage to the chlorine demand of the water is particularly desirable where the quality of the water is subject to change without warning. If the instantaneous flow rate varies more than 25 percent above or below the daily average, the chlorine dosage to the flow of water being treated should be automatically proportioned. If the water being chlorinated is pumped by manually controlled pumps, manual adjustment of the chlorine dosage is permissible, provided there is assurance that chlorine dosage will be changed to compensate for changes in the pumping rates. Whether manual or automatic chlorinators are used, the operator should frequently check both the chlorinators and the chlorine residuals.

A reliable and uninterrupted supply of potable water, under proper pressure and free from coarse, suspended matter, should be available to ensure the continuous operation of solution-free chlorinators. Hydraulically or electrically-driven pumping equipment used for maintaining pressure should be provided with alternate sources of power to ensure continuous operation.

Scales for measuring the quantity of chlorine used in a given time period provide information needed for a chlorine inventory and for a check on the dosage rates. Such scales, preferably of the recording type, should be rugged, easily read, and sufficiently accurate and sensitive to measure chlorine withdrawal with suitable precision. A visual or audible pressure drop warning device installed on the feed lines gives supplementary protection against interruption of supply.

A sufficient number of cylinders or containers of chlorine should be connected to the chlorinator in use through a manifold header to maintain adequate operating pressures throughout any unattended periods. A sufficient reserve supply of chlorine should be connected at all times to assure continuous chlorination of the water, even when cylinders or containers are being changed. Minimum chlorine inventory should be sufficient for the plant to satisfy a maximum 30-day demand. If chlorinators are remote from the chlorine supply, dual feed lines should be provided and should be installed along different routes.

If simple chlorination is the only treatment, frequent residual chlorine determinations should be made. In the absence of full time treatment, supervision consisting of frequent manual determinations or residual chlorine recorders with alarms should be used. Such alarms must be placed where frequent servicing is convenient and where they will be easily heard. Daily service and calibration of these recorders and alarms should be under the supervision of skilled personnel.

The water plant should have sufficient chlorination capacity to provide free residual chlorination.

Chlorination enclosures should be adequately ventilated to permit exhaust by gravity or mechanical means from the lowest point of the enclosure. The chlorinator installation and the handling and storage of chlorine containers should conform to safety requirements recommended by the Chlorine Institute.[a]

[a] The Chlorine Institute, Inc., 342 Madison Avenue, New York, New York 10017

b. Hypochlorite Solutions. Solutions of calcium or sodium hypochlorite should be prepared in a mixing tank, diluted, and allowed to settle before the clear supernatant liquid is withdrawn to the solution storage tank and subsequently to the hypochlorinator.

The strength of the clear supernatant hypochlorite solution should be checked frequently by laboratory test and appropriate adjustment should be made in either its strength, by dilution, or in the rate of feed to provide proper chlorine application. Batches of calcium hypochlorite solution should not be stored for more than 5 days, unless the solution is properly alkalinized with sodium carbonate. If hard water is used to make the hypochlorite solution, the addition of sodium hexametaphosphate will stabilize the solution and will aid in preventing the fouling and clogging of equipment.

c. Control of Chlorination. Chlorine should be continuously applied to the water being treated in a manner that ensures rapid and thorough dispersion of the chlorine throughout the water.

The proper dosage of chlorine should be determined by regular and frequent free chlorine residual tests, both at the plant and at various points in the distribution system. In general, a minimum free chlorine residual of 0.1 milligram per liter at distant points in the distribution system helps maintain a system free from bacterial growths. If chloramines are used, the desirable residual is 1.0 to 2.0 milligrams per liter at distant points in the distribution system. The residual chlorine carried in the finished water leaving the treatment plant should be regulated accordingly. At times of threatened or actual outbreaks of waterborne disease, such as during floods, the residual chlorine should be maintained at a minimum of 1.0 milligram per liter for free chlorine and 6.0 milligrams per liter for chloramine in all parts of the distribution system despite resulting tastes, odors, or both in the delivered water. Where a short contact time exists to the first consumer's service line or where waters of high pH are to be treated, residuals should be increased.

Routine sampling points should be established at the treatment plant and at several representative points in the water distribution system. Samples from these distribution points should be tested for chlorine residuals on the same scheduled basis as for bacteria, and the residuals should be recorded as free chlorine and combined chlorine on the bacteriological report form. Any abnormal decrease in the normal free or combined chlorine at any point in the distribution system should be checked, and if the abnormality persists, a thorough investigation of that portion of the system should be made.

The frequency at which chlorine residual tests should be made is related to the contact period. If the contact time is short (less than 15 minutes), frequent tests are needed, often at less than hourly intervals. If the contact time is long (several hours), tests of the plant effluent should be made at least once in each 8-hour period of operation, and at least daily at regular sampling points on the distribution system.

Special care should be taken to maintain a detailed, accurate daily record of chlorination practice and chlorine residuals.

Such a record should include:

(a) rate of flow and volume of water treated per unit time, (continuous record);

(b) gross weight of chlorine cylinders or containers in use and the weight at the end of a selected time period (24 hours or less) (continuous record);

(c) the pounds of chlorine used in a selected time period (24 hours or less);

(d) the gallons of water treated in a selected time period (24 hours or less);

(e) the applied dose for the selected time period;

(f) chlorinator control settings; and

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(g) time and location of sampling, and the type and results of residual chlorine tests.

Unless bacteriological or other tests indicate a need for maintaining a higher minimum concentration of residual chlorine, a minimum of at least 0.4 milligram of free chlorine per liter should be maintained in the treated water for an actual contact period of at least 30 minutes before delivery to the first consumer. If chloramine (combined chlorine) treatment is used for disinfection, the residual chlorine concentration as indicated by the orthotolidine method should be at least 2.0 milligrams per liter after at least 3 hours of contact before delivery to the first consumer. When required, the state health department should direct that the minimum concentration of residual chlorine and the minimum retention period for the chlorinated water should be increased.

Efficient disinfection of a water supply with chlorine depends on the type of chlorine residual and the factors of contact time, temperature, pH, and the presence of suspended material (nature and amount). Free chlorine, a more effective bactericide than combined chlorine, kills bacteria and viruses in less time or in the same time at lower concentrations than combined chlorine. Information on the bactericidal and viricidal effect of free chlorine is given in Table 2 and Figure 4. Note that most laboratory studies have been performed under ideal conditions with water free from suspended matter (other than organisms) and free from chlorine demand. Practical plant operation requires higher chlorine residuals or longer contact times than those indicated by laboratory tests. Free chlorine and combined chlorine are most effective at low pH values (Figures 5 and 6) and at higher temperatures (Figure 5).

The relationship between the chlorine added and the type of chlorine residual obtained (a chlorine residual curve) is illustrated in Figure 7. A chlorine residual curve plots data obtained from a specific test conducted under established conditions. These test results may vary considerably

Table 2. GERMICIDAL EFFICIENCY OF FREE CHLORINE IN WATER[a]

Microorganism	Temp., deg. cent.	Final pH	Free Cl, mg/liter	Destruction, %/no. o of min.
Salmonella typhosa suspended in DFW[b]	20-25	7.0	.06	> 99.99/5
(Butterfield et al.)	20-25	8.5	.06	> 99.99/5
Escherichia coli suspended in DFW	20-25	7.0	.04	> 99.99/5
	20-25	8.5	.07	> 99.99/5
Aerobacter aerogenes suspended in DFW	20-25	7.0	.05	> 99.99/5
Shigella dysenteriae suspended in DFW	20-25	7.0	.05	> 99.99/5
Feces-borne infectious hepatitis virus in distilled water (Neefe et al.)	Room	6.7-6.8	.04	c
Purified Coxsackie A2 in DFW	3-6	6.8-7.1	1.9-2.2	99.6/4
(Clarke and Kabler)	3-6	8.8-9.0	7.4-8.3	99.6/5
	27-29	6.9-7.1	.16-.18	99.6/4
	27-29	8.8-9.0	.92-1.0	99.6/3
Purified poliovirus I (Mahoney) in DFW	0	7.0	.53	99.6/4 1/2
(Weldenkopf)	0	8.5	5.0	99.6/3
Purified poliovirus I (Mahoney) in DFW	25-28	7.0	.21-.30	99.9/3
(Kelly and Sanderson)	25-28	9.0	.21-.30	99.9/8
Purified poliovirus III (Saukett) in DFW	25-28	7.0	.11-.20	99.9/2
(Kelly and Sanderson)	25-28	9.0	.11-.20	99.9/16
Purified Coxsackie B5 in DFW	25-28	7.0	.21-.30	99.9/1
(Kelly and Sanderson)	25-28	9.0	.21-.30	99.9/8
Purified adenovirus 3 in DFW	25	6.9-7.1	.20	99.8/8-16 secs.
(Clarke et al.)	25	8.8-9.0	.20	99.8/40-50 secs.

[a]From "Pathogenic Bacteria and Viruses in Water Supplies." P. W. Kabler, S. L. Chang, N. A. Clarke, and H. F. Clark. In: Proc. 5th Sanit. Eng. Conf., Urbana, Ill., Jan. 29-30, 1963. Univ. Ill. Eng. Exp. Sta. Cir. No. 81. Univ. Bull. 61(22):72-78.

[b]Demand-free water.

[c]Thirty-minutes contact time protected all of 12 volunteers.

with changes in temperature, contact time, and pH. The breakpoint shown in Figure 7 determines the amount of chlorine that will react with ammonia, organic nitrogen compounds, and/or other substances to form combined chlorine before free chlorine will be present. Any increase in the amount of chlorine applied past the breakpoint results in a corresponding increase in the free chlorine residual.

Treatment to obtain a free chlorine residual means the addition of chlorine beyond the breakpoint. In actual practice, the character of the water, including its pH, temperature, and analysis, may vary over relatively short periods of time to cause variations in the breakpoint. Not all waters show a typical breakpoint.

2. Other Methods of Disinfection

Disinfection methods other than chlorination, which have been advocated or introduced from time to time, include

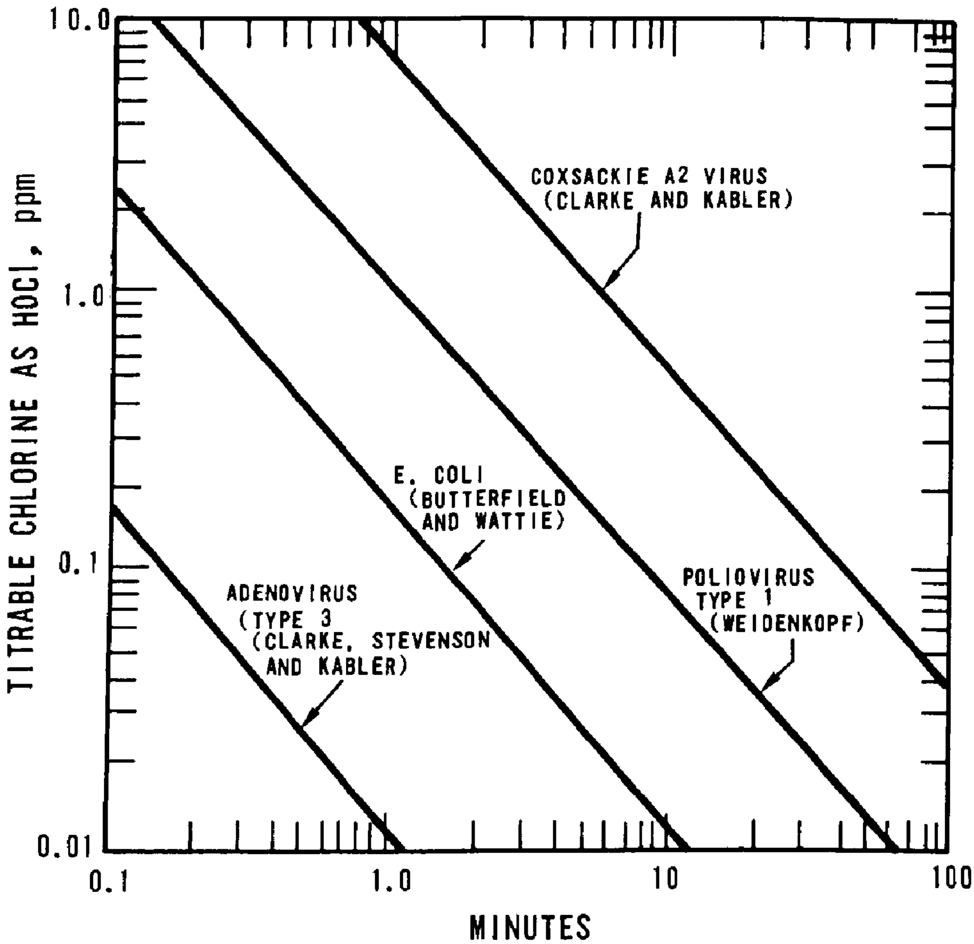

Figure 4. Concentration-time relationship for 99 percent destruction of Escherichia coli and several viruses by HOCl at 0 to 6°C.

the use of ionic silver, ozone, bromine, iodine, and ultraviolet light. For the most part, recommended use has been limited to individual or semipublic water supplies or swimming pools. Any system of disinfection other than chlorination should be approved by the proper health agency before the method in question is applied to public water supplies.

All methods of disinfection (including chlorination) should satisfy the following criteria:

(a) The disinfectant must contact all particles of the water treated;

(b) The disinfectant must be effective despite any possible change in the conditions of treatment or in the characteristics of the water being treated, i.e., color,

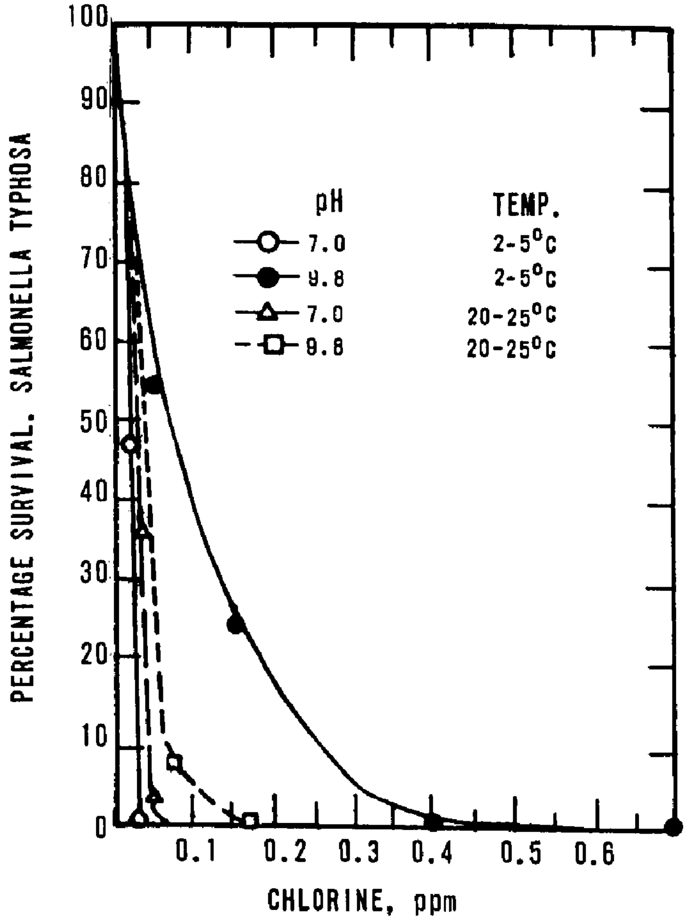

Figure 5. pH-temperature relationship in chlorine disinfection.

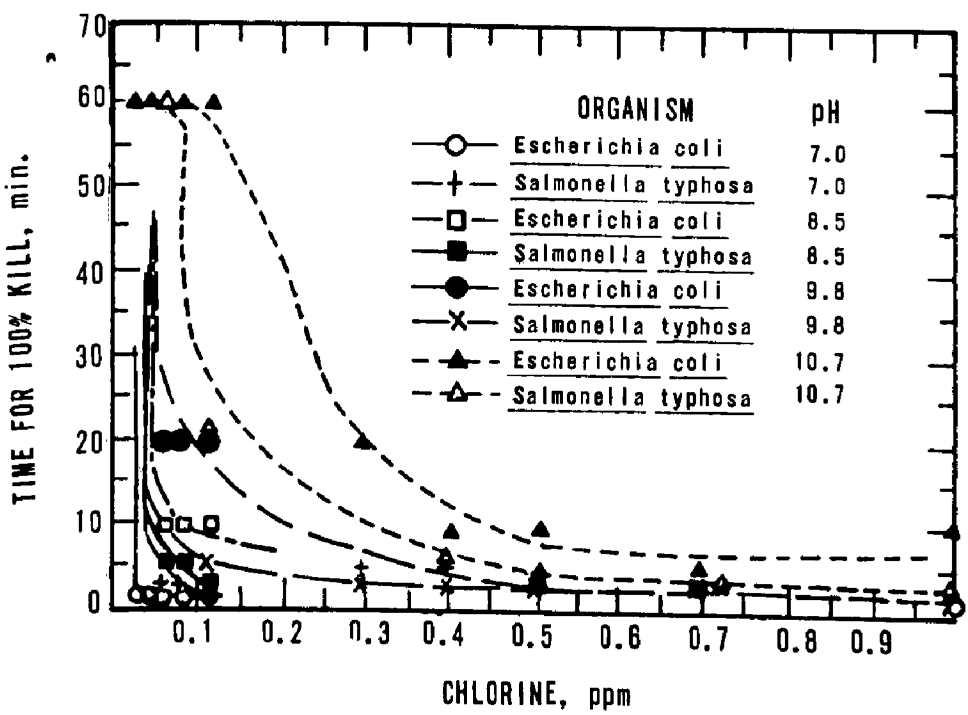

Figure 6. Residual requirement for 100 percent kill.

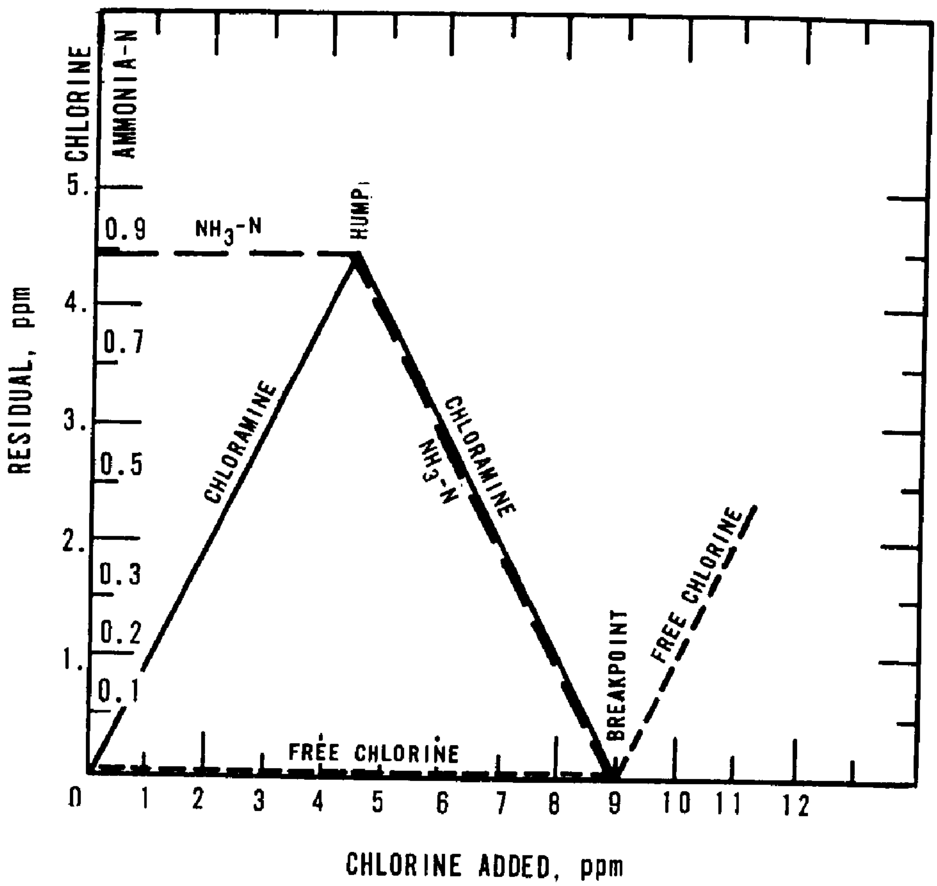

Figure 7. Chlorine residual curve.

turbidity, pH, total dissolved solids, temperature, or other factors;

(c) The disinfectant must not be toxic to people using the water supply;

(d) The disinfectant must have a residual action sufficient to protect the distribution system from bacterial growths;

(e) The disinfectant can be readily measured in water in the concentrations expected to be effective for disinfection;

(f) The disinfectant (bactericidal and viricidal effectiveness) will destroy virtually all microorganisms, and

(g) The disinfection system is practical.

E. FLUORIDATION

The Public Health Service recommends an optimum level of fluoridation for all public water supplies. PHS Drinking Water Standards state ''Fluoride in drinking water will prevent dental caries. When the concentration is optimum, no ill effects will result and caries rates will be 60-65 percent below the rates in communities using water supplies with little or no fluoride.''

Fluoridation operations in public water supplies should be checked very carefully in the course of a sanitary survey. Accurate and complete records should be kept at the plant, and all responsible personnel should be competent to operate the fluoridation equipment, with strict attention paid to the operation of the dosing equipment. Dry chemical feeders can be clogged by lumps formed in the holding bin, and hydrofluosilicic acid feed equipment can be corroded because of the active nature of the chemical. Fluoride dosing devices should be checked frequently by the operators to assure accurate dosing. All dosing devices, whether they are single-set constant flow dispensers or dispensers paced to the flow of water through the plant, should be checked to see that they perform reliably. The loss of as little as 0.3 milligram of fluoride per liter that might result from inaccurate dosing will noticeably reduce the dental health benefits. In some cases, there is an appreciable amount of natural fluoride in the water and normally used amounts of fluoride compound do not have to be used to bring the water up to the optimum level. The optimum level of fluoride ion may be determined for each location by consulting Table 3. Local health departments occasionally set seasonal levels in which the dosage varies according to the month of the year. The amount of control by the local health agency should be noted in the sanitary survey, and the existence of some office to handle the complaints received is often beneficial.

Table 3. FLUORIDE LEVEL DETERMINATION

Annual average of maximum daily air temperatures[a]	Fluoride ion concentration		
	Minimum	Optimum	Maximum
50.0 - 53.7°F	0.9	1.2	1.7
53.8 - 58.3°F	0.8	1.1	1.5
58.4 - 63.8°F	0.8	1.0	1.3
63.9 - 70.6°F	0.7	0.9	1.2
70.7 - 79.2°F	0.7	0.8	1.0
79.3 - 90.5°F	0.6	0.7	0.8

[a]Based on temperature data obtained for a minimum of 5 years.

The treatment plant records of the fluoridation operation should include:

(a) amount of water treated in each 24-hour period;

(b) amount of fluoride compound used;

(c) amount of fluoride ion used;[a]

(d) theoretical dosage in milligrams of fluoride ion per liter in the water treated;

(e) setting on the dosing machine;

(f) amount of fluoride compound on hand; and

(g) fluoride ion concentration as measured by analytical means.

F. OPERATION CONTROL

1. Supervision

Every water treatment plant producing water for public, domestic use should be under the full-time control of a technically trained and state certified supervisor. For certain types of small plants, part-time trained supervision may be permissible; in such cases, the supervisor

[a]The fluoride compound will vary in purity (e.g., NaF = 98 percent pure, and of this 98 percent only a certain percentage of the compound is available fluoride). Sodium fluoride (98 percent pure) contains 44.4 percent available fluoride.

should be on call for any emergency and should inspect the plant at least twice each week.

2. Laboratory Tests and Control

All water quality tests should be made in accordance with the current edition of Standard Methods for the Examination of Water and Waste Water.[4] The schedule of laboratory tests followed in controlling the operation of a water treatment plant will vary with the volume and character of the water being treated.

For the conventional plant treating lightly polluted water, the scheduled laboratory tests should be sufficient to assure conformance with the bacteriological, physical, and chemical requirements of the PHS Drinking Water Standards. Such tests should include: turbidity, color, alkalinity, temperature, pH, hardness, residual chlorine, and examinations for coliform bacteria by both presumptive and confirmed tests or by membrane filter. Completed tests should be conducted to verify positive results of confirmed tests. Special tests, such as for residual alum, iron, manganese, taste, odor, or other undesirable constituents in the final effluent, may be necessary. Where prechlorination is used in addition to postchlorination, tests for residual chlorine should be made at each major stage of treatment.

Personnel in the average water plant laboratory are not expected to make tests for all the trace elements and chemicals listed in the PHS Drinking Water Standards (e.g., ABS, arsenic, CCE, cyanide, etc.). Such tests should be made, however, by qualified laboratories at sufficient intervals to ensure that the waters reaching the consumer meet the provisions of the PHS Drinking Water Standards.

Although the frequency of tests, particularly for turbidity and coliform organisms, depends on the character and variability of the quality of the water treated, at least one test should be conducted every 24 hours, on each day of the week. Since the turbidity and residual chlorine in finished water concentrations are valuable indices of the effectiveness of treatment processes, these tests should be made often, sometimes at hourly intervals, when the character of the raw or partly treated water is changing rapidly. Where possible, recording turbidimeters and chlorine residual recorders should be used.

An important element in judging the efficiency of plant operation is the general appearance of the plant and its surroundings. A neat, well-kept plant with attractive grounds is an indication of good operation, although this criterion is not infallible. Neatness in the appearance of a plant can not offset insufficient supervision and operator training. The following items are important in the evaluation of the general efficiency of operation and maintenance control:

(a) training and experience of the supervisory and operating staff;

(b) adequacy of operation records;

(c) adequacy of laboratory control;

(d) suitability of plant design and construction for adequate treatment of available raw water; and

(e) capacity of the plant and finished water storage in relation to average and maximum demands.

G. SUMMARY

Part I.B.2, Groups I, II, and III, provides guidance on the relationship between pollution loadings and extent of treatment required. Each purification plant should be operated to handle adequately any loading placed upon it. The extent of this loading will be determined by the climate; the character of the supply's watershed, including its size, vegetation, and topography; the characteristics and volume of sewage and other wastes entering the raw water source.

For an evaluation of a plant's operating effectiveness, information must be available on raw water characteristics:

turbidity, color, alkalinity, hardness, iron, bacterial quality, and average and ranges of variations in quality, especially after heavy rainfall or at times of high runoff, as well as the finished water's characteristics.

Complete records should be maintained and should include equipment, maintenance, and operating data. Data such as the rated capacity of raw and finished water pumps; character, types, number, and reliability of pumps, and other equipment including standby units; average and maximum daily delivery; and maintenance records are important to an adequate evaluation of plant adequacy.

Part III

RECOMMENDED SANITARY REQUIREMENTS FOR WATER DISTRIBUTION SYSTEMS

A. WATER DISTRIBUTION SYSTEM

A number of principles of protection required by good sanitary engineering practice are:

1. General Protection Principles

(a) A water distribution system should be designed and constructed to provide, at all times, an adequate supply of water, at ample pressure, in all parts of the system.

(b) The safety and palatability of potable water should not be degraded in any manner while flowing through the distribution system.

(c) The system should be provided with sufficient bypass and blow-off valves to make necessary repairs without undue interruption of service over any appreciable area. Blow-off connections to sewers or sewer manholes should be prohibited.

(d) Open finished water reservoirs should not be permitted. If there are such reservoirs, chlorine residuals should be maintained into the distribution system. Where this is not practical, booster chlorination facilities should be provided at the reservoir site and ample contact time must be provided to ensure complete disinfection before distribution to the first consumer.

(e) Physical cross-connections should not be permitted that allow unsafe water to enter the distribution system.

(f) The system should not permit excessive leakage (greater than 10 percent).

(g) Special precautions should be taken to prevent possible damage to submarine lines.

(h) The distribution system should be maintained to prevent contamination of any part of the system during necessary repairs, replacements, or extensions of mains. When pressure in any part of the distribution system becomes abnormally low, provisions should be made to notify consumers in the area of necessary protective health precautions.

(i) The frequency of bacteriological sample collection should be in accord with the requirements of the PHS Drinking Water Standards. Samples should be collected at representative points on the distribution system, and the proper location of these representative points should be routinely evaluated.

2. Protection for Pipe System

(a) The pipe system and its appurtenances should be designed to maintain an adequate positive water pressure throughout the system.

(b) Materials used for caulking should not be capable of supporting growth of pathogenic bacteria and should be free from oil, tar, or greasy substances. Joint packing materials should meet the latest AWWA specification.

(c) Corrective water treatment should be practiced where lime deposits in the mains tend to reduce the effective size and capacity of the pipes. To prevent and destroy biological deposits, heavy chlorination may be effective.

(d) The pipe layout should be designed for future additions and connections to provide circulation where deadends are necessary in the growth stage of the pipe system.

(e) The corrosive effects of finished water on nonferrous metal pipe used for water-service lines should be considered, together with possible toxicological effects upon consumers resulting from solution of the metals.

(f) Only nontoxic plastic pipe shall be used, where plastic pipe is acceptable.

(g) Sanitary precautions should be taken in laying new water pipes.

- Insofar as possible, pipes should not be laid in water or where they can be flooded with water or sewage in the laying process.
- Leakage should be determined by hydrostatic pressure tests.
- New mains and repaired main sections should be disinfected by the latest AWWA procedure before being placed in or returned to service.
- Underground drains from fire hydrants and valve chambers should not be connected directly to sewers or storm drains.
- The absence of pollution should be demonstrated by bacteriological examination before new lines and appurtenances are placed in service.
- Water pipes should be laid at an elevation above that of nearby sewers, with water pipe joints preferably no closer than 10 feet from the sewer pipe center line. Where this is not possible, extra durable and corrosion-resistant water and sewer pipe should be specified and special care should be taken to ensure proper installation, with durable water-tight tested joints.
- Where water pipes cross sewer lines, the water pipes must be laid above the sewer pipes.

3. Storage Protection

(a) Storage reservoirs and elevated tanks should be operated and maintained to ensure the highest sanitary quality of the water.

(b) Storage reservoirs should be located above probable ground water levels. Surface runoff and underground drainage should be away from the structure. Provisions should be included to guard against the sanitary hazards related to location; ground water levels, movements, and quality;

character of soil; possibility of sewage pollution; and overtopping by floods. Sites in ravines or low areas subject to periodic flooding should be avoided. Any sewer located within 50 feet of a storage reservoir with a below-ground level floor should be considered carefully. Such sewers should be constructed of extra heavy or service-weight mechanical-joint cast-iron pipe with tested, water-tight joints. No sewer should be located less than 10 feet from the reservoir.

(c) All storage reservoirs should be protected against flood waters or high water levels in any stream, lake, or other body of water. The reservoir should be placed above the high water level, and the structure and appurtenances should be watertight.

(d) The ground surface above the reservoir should be graded to drain surface water away from the reservoir and to prevent pooling of surface water within the vicinity. Walls or fencing should surround open reservoirs and public access should be prohibited.

(e) Any overflow, blow-off, or clean-out pipe from a storage reservoir should discharge freely into an open basin from a point not less than three diameters of the discharge pipe above the top or spill line of the open basin. All overflow, blow-off, or clean-out pipes should be turned downward to prevent entrance of rain and should be screened with removable 24-mesh screen to prevent the entrance of birds, insects, rodents, and contaminating materials. If the discharge pipes are likely to be submerged by surface or flood water, a watertight blind flange should be provided to attach to the pipe opening to prevent contaminated water backflowing into the reservoir. If the reservoir must be emptied when the normal outlet is submerged by surface or flood waters, pumps with outlets above the flood water should be used for emptying.

(f) All inlet and outlet pipes of storage reservoirs should be properly supported and constructed to minimize the effects of settling, and wall castings should be provided with suitable collars to ensure watertight connections.

(g) A suitable and substantial cover should be provided for any reservoir, elevated tank, or other structure used for finished water storage. Covers should be watertight, made of permanent material, and constructed to drain freely and to prevent contamination from entering the stored water. The surface of a storage reservoir cover should not be used for any purpose that may result in contamination of the stored water.

(h) Manholes and manhole frames used on covered storage reservoirs and elevated tanks should be fitted with raised, watertight walls projecting at least 6 inches above the level of the surrounding surface. Manholes used for ground level reservoirs in heavy snowfall areas should be elevated 24 to 36 inches. Each manhole frame should be closed with a solid watertight cover, preferably with edges projecting downward at least 2 inches around the outside of the frame. The manhole covers should be provided with a sturdy locking device and should be kept locked when not in use.

(i) Any vents or openings for water-level control gauges or other purposes that project through covers on storage reservoirs and elevated tanks should be constructed to prevent the entrance of dust, rain, snow, birds, insects, or other contaminants.

(j) Reservoirs and elevated tanks on the distribution system should be disinfected before being put into service or after extensive repairs or cleaning have been completed. Steel tanks[5] and ground level water reservoirs[6] should be disinfected in accord with AWWA standards.

4. Interconnections, Backflow Connections, Cross and Open Connections

a. Cross-Connection. A cross-connection is any physical connection or arrangement between two otherwise separate piping systems, one of which contains potable water, and the other, water of unknown or questionable safety, or

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steam, gases, or chemicals, whereby there may be a flow from one system to the other. No physical cross-connection should be permitted between public or private water distribution systems containing potable water and any other system containing water of questionable quality or containing contaminating or polluting substances.[7]

b. Open Connection. An open connection is a piping arrangement that provides an air gap between two water supply systems. The arrangement may become a cross-connection or interconnection by the insertion of a length of pipe into the air gap. Open connections may be permissible under the regulation and supervision of the appropriate health agencies.

c. Backflow Connection. A backflow connection is any arrangement whereby water or other liquids, mixtures, or substances can flow into the distribution pipes of a potable water supply from any source or sources other than its intended source. Backsiphonage is one type of backflow. House or industrial toilet or sink fixtures that contain or may contain fluids that may be siphoned into the water system should be classed as backflow connections and should be prohibited.

d. Interconnection. An interconnection is a physical connection between two potable water supply systems. Interconnection may be allowed when the sources of supply involved are approved by the appropriate health agencies.

B. WATER DISTRIBUTION SYSTEM HAZARDS

Many failures to meet the bacteriological requirements of the PHS Drinking Water Standards are directly related to the use of poor operating and maintenance procedures for distribution systems or to the presence of sanitary defects in the system. Some causes that contribute to poor bacteriological quality are:

(a) insufficient treatment at the point of production;

(b) cross-connections;

(c) improperly protected distribution system storage;

(d) inadequate main disinfection;

(e) unsatisfactory main construction, including improper joint-packing;

(f) close proximity of sewer and water mains;

(g) improperly constructed, maintained, or located blow-off, vacuum, and air relief valves; and

(h) negative pressures in the distribution system.

The distribution system of a water supply presents many opportunities to impair water quality. The time of detention within the system's mains may be quite long, and many potential inlets for polluting materials, such as services, blow-off and relief valves, and cross-connections, usually exist. Any list of protective measures must include proper procedures for the laying, flushing, and disinfecting of new or repaired mains; maintenance of chlorine residuals when a main is returned to service; and adequate separation of water and sewer lines. Blow-off and relief valves can adversely affect water quality if improperly constructed or installed, or if located in sumps subject to flooding or in other places subject to inundation by wastes or poor quality water.

The system should be designed to supply adequate quantities of water under ample pressure and should be operated to prevent, as far as possible, conditions leading to the occurrence of negative pressure. Steps to prevent negative pressure should include minimizing planned shutdowns, providing adequate supply capacity, correcting under-sized conditions, and properly selecting and locating booster pumps to prevent the occurrence of a negative head in piping subject to suction. Continuity of service and maintenance of adequate pressure throughout a public water supply system are essential to prevent back-siphonage.

Contaminated secondary water sources, where cross-connected to a community system, can seriously degrade the water in the system. Many water-borne disease outbreaks have resulted from such connections. Cross-connection hazards may be divided into those resulting from the interconnection of a nonpotable water supply with a potable supply, and those resulting from backflow caused by the development of negative pressure in the water distribution systems of premises having internal piping defects. Negative pressure can develop from such causes as main breaks, inadequate supply pressure, undersized mains, unusual water demands, and shutdowns for maintenance or repair. On the consumer's premises, backflow can also be caused by back pressure from cross-connections to boilers, elevated storage tanks, hydro-pneumatic systems, pumps, circulating systems, and auxiliary water supply systems. To deal with these problems, an active cross-connection control and elimination program and an aggressive program of reducing, to a minimum, the frequency of occurrence of negative pressure in the system should be established.

Stored, treated water in the distribution system may be contaminated by substances that fall into uncovered finished water storage tanks or reservoirs, by wind-blown material entering vents, and by ground or surface water seepage. Open storage is subject to pollution from gulls, ducks, and other birds; animals, such as rodents; wind-blown contaminants; human activities such as bathing, fishing, and deliberate contamination; and many other sources. The best method to prevent deterioration of the quality of water stored in tanks and reservoirs is to provide water-tight storage facilities that are constructed with roofs to afford protection against surface runoff. In the absence of such cover, disinfection of all water fed to the system from storage is essential and tends to offset, but does not prevent, the ill effects from this introduced contamination.

REFERENCES

1. Public Health Service drinking water standards. PHS Publ. No. 956. 1962. 61 pp.
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APPENDIX

EXCERPTS FROM THE UNITED STATES PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS[a]

3. Bacteriological Quality

3.1 *Sampling*

3.11 Compliance with the bacteriological requirements of these Standards shall be based on examinations of samples collected at representative points throughout the distribution system. The frequency of sampling and the location of sampling points shall be established jointly by the Reporting Agency and the Certifying Authority after investigation by either agency, or both, of the source, method of treatment, and protection of the water concerned.

3.12 The minimum number of samples to be collected from the distribution system and examined each month should be in accordance with the number on the graph in Figure A1, for the population served by the system. For the purpose of uniformity and simplicity in application, the number determined from the graph should be in accordance with the following: for a population of 25,000 and under—to the nearest 1; 25,001 to 100,000—to the nearest 5; and over 100,000—to the nearest 10.

3.13 In determining the number of samples examined monthly, the following samples may be included, provided all results are assembled and available for inspection and the laboratory methods and technical compe-

[a]Public Health Service drinking water standards. PHS Publ. No. 956. 1962. 61 pp.

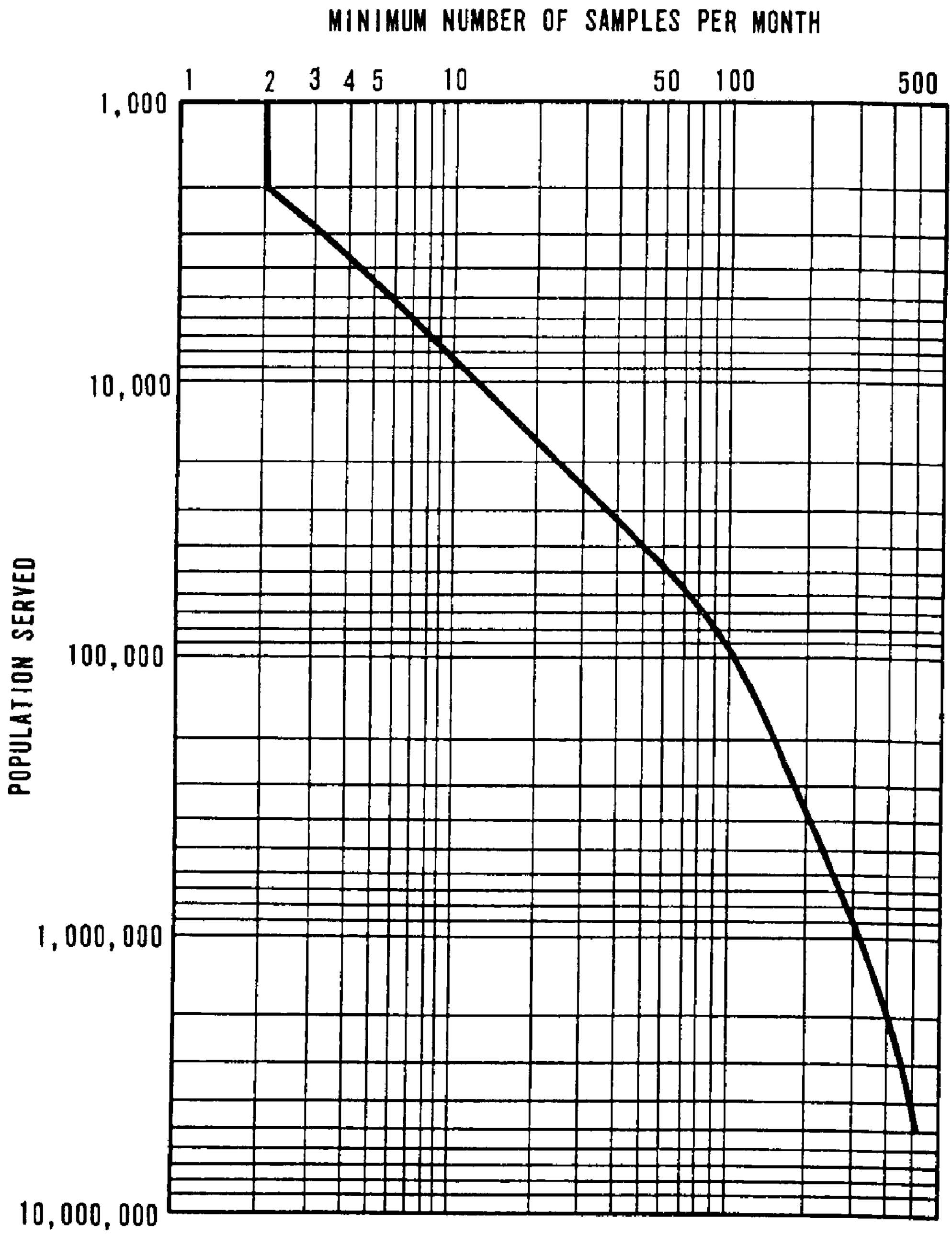

Figure A1. Recommended minimum monthly samples per population served by water supply.

tence of the laboratory personnel are approved by the Reporting Agency and the Certifying Authority:

(a) Samples examined by the Reporting Agency.

(b) Samples examined by local government laboratories.

(c) Samples examined by the water works authority.

(*d*) Samples examined by commercial laboratories.

3.14 The laboratories in which these examinations are made and the methods used in making them shall be subject to inspection at any time by the designated representatives of the Certifying Authority and the Reporting Agency. Compliance with the specified procedures and the results obtained shall be used as a basis for certification of the supply.

3.15 Daily samples collected following a bacteriologically unsatisfactory sample as provided in sections 3.21, 3.22, and 3.23 shall be considered as special samples and shall not be included in the total number of samples examined. Neither shall such special samples be used as a basis for prohibiting the supply, provided that: (1) When waters of unknown quality are being examined, simultaneous tests are made on multiple portions of a geometric series to determine a definitive coliform content; (2) Immediate and active efforts are made to locate the cause of pollution; (3) Immediate action is taken to eliminate the cause; and (4) Samples taken following such remedial action are satisfactory.

3.2 *Limits.*—The presence of organisms of the coliform group as indicated by samples examined shall not exceed the following limits:

3.21 When 10 ml standard portions are examined, not more than 10 percent in any month shall show the presence of the coliform group. The presence of the coliform group in three or more 10 ml portions of a standard sample shall not be allowable if this occurs:

(*a*) In two consecutive samples;

(*b*) In more than one sample per month when less than 20 are examined per month; or

(*c*) In more than 5 percent of the samples when 20 or more are examined per month.

When organisms of the coliform group occur in 3 or more of the 10 ml portions of a single standard sample, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

3.22 When 100 ml standard portions are examined, not more than 60 percent in any month shall show the presence of the coliform group. The presence of the coliform group in all five of the 100 ml portions of a standard sample shall not be allowable if this occurs:

(a) In two consecutive samples;

(b) In more than one sample per month when less than five are examined per month; or

(c) In more than 20 percent of the samples when five or more are examined per month.

When organisms of the coliform group occur in all five of the 100 ml portions of a single standard sample, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

3.23 When the membrane filter technique is used, the arithmetic mean coliform density of all standard samples examined per month shall not exceed one per 100 ml. Coliform colonies per standard sample shall not exceed 3/50 ml, 4/100, 7/200, or 13/500 ml in:

(a) Two consecutive samples;

(b) More than one standard sample when less than 20 are examined per month; or

(c) More than five percent of the standard samples when 20 or more are examined per month.

When coliform colonies in a single standard sample exceed the above values, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

4. PHYSICAL CHARACTERISTICS

4.1 *Sampling.*—The frequency and manner of sampling shall be determined by the Reporting Agency and the Certifying Authority. Under normal circumstances samples should be collected one or more times per week from representative points in the distribution system and examined for turbidity, color, threshold odor, and taste.

4.2 *Limits.*—Drinking water should contain no impurity which would cause offense to the sense of sight, taste, or smell. Under general use, the following limits should not be exceeded:

Turbidity	5 units
Color	15 units
Threshold Odor Number	3

6. RADIOACTIVITY

6.1 *Sampling.*

6.11 The frequency of sampling and analysis for radioactivity shall be determined by the Reporting Agency and the Certifying Authority after consideration of the likelihood of significant amounts being present. Where concentrations of Ra^{226} or Sr^{90} may vary considerably, quarterly samples composited over a period of three months are recommended. Samples for determination of gross activity should be taken and analyzed more frequently.

6.12 As indicated in paragraph 5.1, data from acceptable sources may be used to indicate compliance with these requirements.

6.2 *Limits.*

6.21 The effects of human radiation exposure are viewed as harmful and any unnecessary exposure to ionizing radiation should be avoided. Approval of water supplies containing radioactive materials shall be based upon the judgment that the radioactivity intake from such water supplies when added to that from all other sources is not likely to result in an intake greater than the radiation protection guidance[a] recommended by the Federal Radiation Council and approved by the President. Water supplies shall be approved without further consideration of other sources of radioactivity intake of Radium-226 and Strontium-90 when the water contains these substances in amounts not exceeding 3 and 10 $\mu\mu c$/liter, respectively. When these concentrations are exceeded, a water supply shall be approved by the certifying authority if surveillance of total intakes of radioactivity from all sources indicates that such intakes are within the limits recommended by the Federal Radiation Council for control action.

6.22 In the known absence[b] of Strontium-90 and alpha emitters, the water supply is acceptable when the gross beta concentrations do not exceed 1,000 $\mu\mu c$/liter. Gross beta concentrations in excess of 1,000 $\mu\mu c$/liter shall be grounds for rejection of supply except when more complete analyses indicates that concentrations of nuclides are not likely to cause exposures greater than the Radiation Protection Guides as approved by the President on recommendation of the Federal Radiation Council.

[a]The Federal Radiation Council, in its Memorandum for the President, Sept. 13, 1961, recommended that "Routine control of useful applications of radiation and atomic energy should be such that expected average exposures of suitable samples of an exposed population group will not exceed the upper value of Range II (20 $\mu\mu c$/day of Radium-226 and 200 $\mu\mu c$/day of Strontium-90)."

[b]Absence is taken here to mean a negligibly small fraction of the above sepcific limits, where the limit for unidentified alpha emitters is taken as the listed limit for Radium-226.

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