Forest Service Manual-Handbook
National Headquarters - Washington Office
Washington, DC

Forest Service Handbook 7409.11 – Sanitary Engineering and Public Health Handbook

Chapter 20 - Drinking Water Quality

Amendment: 7409.11-2004-1

Effective date: September 01, 2004

Duration: This amendment is effective until superseded or removed.

Superseded Directive: 20--1 thru 29.3; Amendment 13

Approved by: Fred L. Norbury, Associate Deputy Chief

Date approved: August 19, 2004

Responsible Staff:

Explanation of changes: Following is an explanation of the changes throughout the directive by section.

Posting Instructions: Amendments are numbered consecutively by Handbook number and calendar year. Post by document; remove the entire document and replace it with this amendment. Retain this transmittal as the first page(s) of this document. The last amendment to this Handbook was No. 13.

20: Updates the chapter in its entirety, incorporates requirements of current regulations and engineering standards. Makes additional style, nomenclature, and format changes throughout.

Table of Contents

20.1 - Authority

1. National Primary Drinking Water Regulations, Environmental Protection Agency, 40 CFR part 141.

2. National Secondary Drinking Water Regulations, Environmental Protection Agency, 40 CFR part 143.

20.2 - Objectives

The purpose of this chapter is to provide guidance and instructions for evaluating the quality of water sources to determine their initial and ongoing suitability for human consumption. The minimum objective of quality control procedures is to maintain the quality of water resources at such a level that they can be utilized directly or with minimal upgrades.

20.6 - References

1. Standard Methods for the Examination of Water and Wastewater; American Public Health Association, American Water Works Association, and Water Environment Federation.

2. Manual of Small Public Water Supply Systems, Environmental Protection Agency, Office of Water, May 1991. EPA 570/9-91-003.

3. National Recommended Water Quality Criteria. Environmental Protection Agency, Office of Water, April 1999. EPA 822-Z-99-001.

4. Handbook of Drinking Water Quality: Standards and Controls. De Zuane, Van Nostrand Reinhold (NY) 1990.

5. Guidelines for Drinking-Water Quality. World Health Organization, 1984.

21 - Water Quality Standards

Water quality is the characteristic nature of a water source expressed in physical, chemical, biological, microbiological, and radiological parameters. The determination of suitability of a water source for drinking water is based upon the criteria and standards of quality, which may be self-imposed or regulated by environmental protection and public health agencies. The standards by which drinking water quality is judged for public water systems are those established by the Environmental Protection Agency and State agencies. The Federal regulations setting the Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) are found in 40 CFR parts 141 and 143. An MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse health effect would occur. An MCL is the maximum permissible level of a contaminant in water which is delivered to users of a public water system. These Federal regulations cover contaminants affecting public health and safety in the Primary Drinking Water Regulations (40 CFR part 141) and aesthetic qualities in the Secondary Drinking Water Regulations (40 CFR part 143). In addition to these regulations, most States publish their own standards, which must be at least as stringent as Federal regulations.

Since these regulations reflect the most current criteria for health and acceptance of drinking water, they should be used for assessment of nonpublic water systems, as well.

Additionally, the Environmental Protection Agency (EPA) and the States have established water quality standards for other beneficial uses of surface and groundwater and discharges into such. These standards help ensure that water resources are not degraded and that the designated uses of the waters are maintained. These are discussed in “National Recommended Water Quality Criteria” (EPA, April 1999) (sec. 20.6).

Comprehensive documentation on the various water quality parameters can be found in most of the references listed in section 20.6. A particularly useful discussion is in the "Manual of Small Public Water Supply Systems."

22 - Drinking Water Quality Requirements

Requirements for drinking water quality ensure that the supplied water is safe for human consumption and that the water resource is protected from future contamination. The watersheds for surface sources, and the wellhead for groundwater sources, are those surface and subsurface areas through which contaminants are likely to pass and eventually reach the drinking water source. All land management, agricultural, industrial, and waste management practices in these areas can affect water quality. When developing a source for drinking water, a watershed or wellhead sanitary survey would include inspection and evaluation of practices, such as pesticide and fertilizer application, use of road salt, storm water discharges, use of septic tanks and industrial sump use. Recent Federal regulations, such as the Wellhead Protection Program and the Watershed Control Program governed by the surface water treatment rule (40 CFR parts 9,141, and 142) encourage development of management plans that address contamination source controls and land management practices.

Water from all surface sources and some ground water sources will require some sort of treatment, including disinfection and possibly filtration, to meet standards for human consumption.

In the selection of a drinking water source or the upgrading of an existing system, an engineering economic analysis should be performed to determine the quality of the source selected versus the degree of treatment to be applied. A drinking water supply is best drawn from the highest quality source available.

23 - Water Quality Evaluation

Water quality is dynamic, and its changing parameters require continual evaluation in light of these dynamics and the continuing unfolding of new water contaminants and new assessment methods. When a water source is considered as a potential drinking water source, it needs to be evaluated for safety, aesthetics, and potential required treatments to make it an acceptable source. Once developed into a water system, it needs to be evaluated for the effectiveness of any treatment, the quality of the delivered water, and the overall integrity of the system.

Water quality must be evaluated in compliance with the many Federal and State regulations which require ongoing monitoring of source water and of treatment processes. For example, the surface water treatment rule mandates daily or continuous disinfectant residual and turbidity monitoring, and the total coliform rule (40 CFR part 141) mandates monthly coliform sampling for public water systems.

23.1 - Water Quality Examination

1. Drinking water examination includes characterization of:

    a. The source water,

    b. The treated water, and

    c. The delivered water.

2. Delivered water is typically that coming from taps or faucets, but can be extended to hauled water brought into fire camps. Contaminants may occur or even be created at any point in the production/treatment/delivery train in a water system. For example, trihalomethanes are formed during chlorination, and lead may be introduced from service or residential water lines. It is, therefore, important to examine each part of the water system.

3. Examination of water involves:

    a. Surveys of the conditions under which the water exists, is treated and delivered,

    b. Observations and examinations of certain characteristics of the drinking water in the field, and

    c. Sampling and off-site analysis for various parameters.

4. A sanitary survey of a water supply system is a field survey of all the conditions, devices and practices in the water system that pose, or could pose, a threat to the integrity of the system. Sanitary surveys should be conducted with sufficient frequency to be useful in interpreting trends or sudden significant changes in the quality of drinking water, as determined by physical, microbiological and chemical monitoring. At a minimum, sanitary surveys should be conducted at the frequency specified by Federal or State regulations.

5. Observations and examinations of drinking water in the field fall into two groups:

    a. Observation of gross quantities, such as water weeds, algae, and other macroscopic organisms.

    b. Examination of physical properties that change rapidly during transportation, and storage and chemical properties that require continual monitoring. Examples of this latter group include temperature, turbidity, and chlorine residual.

6. Sampling and off-site analysis is the most common type of examination performed on Forest Service water systems. The examination of drinking water in the laboratory is concerned with the analysis of samples collected in the field, in treatment plants, from sampling points in the distribution system, or from natural bodies of water. Knowledge of the sampling conditions and the conditions under which the water was found is essential to the interpretation of laboratory analyses. Samples represent a single point in time. Certain groups of tests performed on a single sample, such as those for nitrogen in its various forms, may give some information on recent trends in pollution of the water. Multiple samplings and analyses are needed to delineate the profile of the water, either in terms of the variation of its quality factors in time, or in terms of the progressive changes that take place as water is collected, stored, treated, and distributed.

7. Collection and analysis methods are mandated by Federal and State regulations for public water systems and also should be used for nonpublic systems. Both certified operators for sample collection and certified laboratories for sample analysis are required in most States for sampling of public water systems. This certification promotes standardized methods to be used for sample collection, handling, and analysis.

Sample collection guidelines are given in "Standard Methods for the Examination of Water and Wastewater." Analytical methods are prescribed in references such as "Standard Methods for the Examination of Water and Wastewater" and "Methods for Chemical Analysis of Water and Wastes" (sec. 20.6).

The selection of parameters for analysis should be based upon the reason for sampling. Most monitoring is prescribed by regulation (40 CFR part 141, subpart C) and direction in FSM 7410 and FSM 7420, either in the development of a source, or as part of the system operations. Monitoring plans for nonpublic systems should parallel those required for public water systems.

24 - Water Quality Sampling

24.1 - Sampling for Physical and Chemical Examination of Natural and Treated Waters

The material in sections 24.11 - 24.13 is intended for the physical and chemical examination of natural and treated waters in the absence of gross pollution. Such waters include surface water, ground water, and treated water. Refer to "Standard Methods for the Examination of Water and Wastewater" for additional details (sec. 20.6).

24.11 - Quantity of Sample

Verify the necessary sample quantity with the laboratory. A 2-liter sample should suffice for most physical and chemical analyses. Certain special determinations may require larger samples. Do not use the same sample for chemical, bacteriologic, and microscopic examinations, because the methods of collection and handling can vary.

24.12 - Time Interval Between Collection and Analysis

In general, the shorter the elapsed time between sample collection and analysis, the more reliable the analytical results. For certain constituents and physical values, immediate analysis in the

field is required to obtain dependable results, since composition of the sample may change before it arrives at the laboratory.

It is impossible to state exactly how much time may elapse between collection of a sample and its analysis. This depends upon the character of the sample, the particular analyses to be made, and the conditions of storage. For specific time interval requirements between collection and analysis, contact the laboratory directly.

The time elapsed between collection and analysis should be recorded on the laboratory report. Contact the laboratory to verify the proper preservation techniques for the analyses planned. The laboratory report should state which, if any, chemical preservative was added.

Temperature can change very quickly; pH may change significantly in a matter of minutes; dissolved gases may be lost (oxygen, carbon dioxide, hydrogen sulfide, chlorine) or gained (oxygen, carbon dioxide). For these reasons, determination of temperature, pH, dissolved gases, and alkalinity should always be completed in the field.

Other transformations can also occur after sample collection. For example, iron and manganese form readily soluble compounds in their lower (reduced) valence states and relatively insoluble compounds in their higher (oxidized) valance states; therefore, these captions may precipitate out, or they may dissolve out of a sediment, depending upon the redox potential of the sample. Microbiological activity may cause changes in the nitrate-nitrite-ammonia balance, decreases in phenols and in Biochemical Oxygen Demand (BOD), or reduction of sulfate to sulfide. Residual chlorine can be converted to chloride. Sulfide, sulfite, ferrous iron, iodide, and cyanide may be lost through oxidation. Color, odor, and turbidity may increase, decrease, or change in quality. Sodium, silica, and boron may be leached out of the glass container. Hexavalent chromium may be reduced to the trivalent state. This list is not all-inclusive. It is not practical to prescribe absolute rules for the prevention of all possible changes. To a large degree, the dependability of water analyses must rest upon the experience and good judgment of the analyst.

24.13 - Representative Samples

Time and trouble can be saved by contacting the laboratory (sec. 25) in advance to obtain information on the recommended technique for collecting samples.

The general directions in this section do not provide enough information for collecting samples in which dissolved gases are to be determined. Specific instructions can be found in "Standard Methods for the Examination of Water and Wastewater" (sec. 20.6).

Take care to obtain a sample that is truly representative of existing conditions. Handle the sample so it does not deteriorate or become contaminated before it reaches the laboratory. If the sample container does not contain a preservative or dechlorinating agent (verify with laboratory), rinse the sample bottle two or three times with the water to be collected before filling. Representative samples of some supplies can only be obtained by making composites of samples which were collected over a period of time, or at many different sampling points. Sometimes it is better to analyze numerous separate samples, instead of one composite, so as not to obscure maximal and minima.

Ensure that analyses are representative of the actual composition of the water sample. Important factors affecting the results are the presence of turbidity, the method chosen for its removal, and the physical and chemical changes brought about by storage or aeration. Each sample showing turbidity must be treated individually with regard to the substances to be determined, the amount and nature of the turbidity present, and other conditions which may influence the results.

Make a record of every sample collected, and identify every bottle by attaching a label. Record enough data to permit positive identification of the sample at a later date. Include the name of the sample collector, the date, hour, exact location, the water temperature, and any data which may be needed in the future for correlation, such as weather conditions, water level, stream flow, or the like. Fix sampling points by detailed descriptions, by maps, or with the aid of stakes, buoys, or landmarks to permit other persons to locate them without reliance upon memory or personal guidance.

1. Piping Systems. Before samples are collected from distribution systems, flush the lines long enough to ensure a representative sample of the supply. Take into account the diameter and length of the pipe to be flushed and the velocity of flow.

2. Wells. Collect samples from wells only after the well has been pumped long enough to ensure that the sample will represent the groundwater which feeds the well. Sometimes it will be necessary to pump at a specified rate to achieve a characteristic drawdown, if this determines the zones from which the well is supplied. It may be desirable to record the pumping rate and the drawdown as part of the sample record.

3. Open Waters. When samples are collected from a river or stream, their characteristics may vary with depth, stream flow, distance from shore and from one shore to the other. If equipment is available, take an integrated sample from top to bottom in the middle of the stream so that the sample is a composite of the flow. If only a grab sample can be collected, take it from the middle of the stream and at middepth.

Lakes and reservoirs are subject to considerable variations from normal causes, such as seasonal stratification, rainfall, runoff, and wind. The choice of location, depth, and frequency of sampling will depend upon local conditions and upon the purpose of the investigation.

24.2 - Sampling for Bacteriological Examination of Drinking Water

Sections 24.21 through 24.23 describe procedures to be used in making bacteriologic examinations of samples of water to determine sanitary quality and suitability for human consumption. The material is excerpted from "Standard Methods for the Examination of Water and Wastewater" (sec. 20.6). The methods are intended to indicate the degree of contamination of the water with wastes from human or animal sources. These are the best currently available techniques, but the limitations must be understood.

24.21 - Sampling for Coliform Organisms

Tests for detection and enumeration of indicator organisms, rather than pathogens, are used. The coliform group of bacteria is the principal indicator of the suitability of water for domestic use. Cultural reactions and characteristics of this group of bacteria have been studied extensively.

Coliform group densities indicate the degree of pollution, and thus the sanitary quality, of a water sample. The multiple tube fermentation test, the membrane filter technique, and Colilert test are standard methods used for detecting coliform bacteria in raw water sources. For finished drinking water, the Colisure and Presence-Absence methods may also be used. Verify acceptable test methods with the governing regulatory agency.

The results of the coliform test by the multiple-tube fermentation procedure are usually reported as a most probable number (MPN) index. This is merely an index of the number of coliform bacteria which, more probably than any other number, would give the results shown by the laboratory examination. It is not an actual enumeration of the coliform bacteria. Direct plating methods, such as the membrane filter procedure, permit a direct count of coliform colonies. In both procedures, coliform density is reported conventionally as the MPN or membrane filter count per 100 milliliters. Either procedure permits appraising the sanitary quality of the water and the effectiveness of treatment.

1. <u>Sample Techniques</u>. Proper sampling techniques include a consideration of:

    a. The use of sample bottles,

    b. Washing and sterilization of sample containers, etc.,

    c. Collection procedures, including sample size, identification, and dechlorination, and

    d. Preservation and storage.

2 <u>Sample Bottles</u>. Sample bottles should be obtained from the testing laboratory, if possible. Sample bottles for bacteriologic examination must be made of glass or other material resistant to the solvent action of water, and must be capable of being sterilized. Additionally, bottles must:

    a. Hold a sufficient volume of sample for all the required tests,

    b. Permit proper washing,

    c. Maintain the samples uncontaminated until the examinations are completed, and

    d. Be wide-mouthed.

Bottles made of nontoxic plastic (such as polypropylene) have been found to be satisfactory as sample containers, and are often preferable to glass because they eliminate the possibility of breakage during shipment. Although plastic bottles can be sterilized, they should not be used for

repetitive sampling. Some types may be autoclaved once or twice at 121 degrees Celsius for 10 minutes, but only a few do not distort and leak when autoclaved repeatedly.

Metal or plastic screw-cap closures may be used on sample bottles provided that no volatile compounds are produced upon sterilization, and that they are equipped with liners that do not produce toxic or bacteriostatic compounds upon sterilization.

3. Washing and Sterilization. Field personnel should use collection bottles that have been prepared (washed and sterilized) by the testing laboratory.

4. Sample Collection Procedures.

a. Containers. Samples for bacteriologic examination must be collected in bottles that have been cleansed and rinsed with great care, given a final rinse with distilled water, and sterilized. Therefore, it is advisable to use sampling containers prepared by the laboratory.

b. Dechlorinating Agents. A dechlorinating agent, such as sodium thiosulfate, should be added to bottles intended for the collection of water containing residual chlorine. The dechlorinating agent neutralizes residual chlorine and thereby halts its bactericidal action. The bacteriologic examination will then be more indicative of the true bacterial content of the water at the time of sampling. If sampling of chlorinated water is planned, it is advisable to have the dechlorinating agent added by the laboratory prior to shipment of sample bottles to the field.

c. Chelating Agents. Water samples which may have high levels of metals should be collected in sample bottles containing a chelating agent that will reduce metal toxicity. This is particularly significant when such samples are in transit for 4 hours or more. Ethylene diaminetetraacetic acid (EDTA) is a common chelating agent. It is advisable to have the chelating agent added by the laboratory prior to shipment of sample bottles to the field.

d. Sampling Procedures. When sampling from a distribution system tap, it is preferable to utilize a tap with a plain end and no attachments. However, if a tap with attachments must be used, remove aerators, splash guards, etc. prior to sampling. Avoid sampling from mixing faucets. Avoid sampling from leaking taps that allow water to flow over the outside of the tap. Utilize an indoor tap, if possible. If tap cleanliness is questionable, apply a solution of sodium hypochlorite (200 mg/l NaOCl, or about one teaspoon bleach to one quart of water) to the tap before sampling.

Open the tap fully and flush for two to three minutes, or as required to clear the service line. When sampling from a hand pump, pump water for five minutes before sampling. Reduce water flow so the stream is about the size of your little finger. This permits filling the bottle without splashing. Keep the sample bottle closed until it is to be filled. Remove cap from the bottle without touching the inside of the cap or neck of the bottle. Keep the cap in your hand. Fill the bottle without rinsing, leaving

about 2.5 cm or 1 inch air space so the laboratory can thoroughly mix the sample. Replace cap immediately.

In collecting samples directly from a river, stream, lake, reservoir, spring, or shallow well, the objective is to obtain a sample representative of the water that will be the source of supply to consumers. Therefore, it is undesirable to take samples too near the bank or too far from the point of drawoff, or at a depth above or below the point of drawoff.

If the sample is to be taken from a well equipped with a mechanical pump, the sample should be collected from a tap on the discharge pipe. If there is no pumping machinery, a sample can be collected directly from the well by means of a sterilized bottle fitted with a weight at the base; in this case, care should be taken to avoid contaminating samples by any surface scum.

e. Sample Size and Identification. Verify the required sample size with the testing laboratory. The volume of a sample should be sufficient to carry out all the tests required, preferably not less than 100 ml of water for samples intended for bacteriologic examination.

All samples should be accompanied by complete and accurate identifying and descriptive data. Such data must include the Forest, District, site name, type of sample (see FSH 7409.11, sec. 91.21), time and date of sample, and name of person collecting the sample. Failure to record this information on the sample may result in a refusal to test the sample by the laboratory.

5. Sample Preservation and Storage. The bacteriological examination of a water sample should be started as soon as possible after collection to avoid unpredictable changes.

Since samples usually cannot be processed within 1 hour after collection, the use of iced coolers for storage of water samples during transport to the laboratory is recommended. Samples should be kept below 10 degrees Celsius during transport to the laboratory.

Since these requirements are seldom realistic in the case of an individual drinking water sample sent to the laboratory by mail service, the time elapsing between collection and examination should in no case exceed 30 hours, or the maximum number of hours set by the State. Samples delivered to the laboratory with more than 30 hours elapsed time since collection may still be analyzed, but the laboratory may report the results as unreliable. Where refrigeration of individual water samples sent by mail is not possible, the use of a thermos-type insulated sample bottle that can be sterilized is recommended as an option. The time and temperature of storage of all samples should be recorded and should be considered in the interpretation of data.

24.22 - Heterotrophic Plate Counts

Heterotrophic plate count (HPC) measures a broad group of bacteria including coliform, non-coliform, pathogenic, and non-pathogenic bacteria. The HPC provides a general measure of the bacteriological quality of water in the distribution system, and can be an early sign of excessive

biofilm growth on pipe walls, well casings, and reservoirs. An HPC result greater than 500/ml indicates generally poor bacteriological water quality.

The HPC analysis should be used in conjunction with routine coliform testing. A high HPC may result in false negatives for coliform due to suppression of laboratory growth of coliform bacteria, even though they may be present in the water distribution system.

24.23 - Routine Sampling and Sanitary Surveys

Bacteriologic examinations should be made on samples collected at representative points throughout the distribution system. Written sampling plans are required for public water systems. Sample sites should be rotated throughout the distribution system to demonstrate bacteriological quality throughout the distribution system and to ensure that localized contamination does not occur through cross-connections, breaks in distribution lines, or reduction in positive pressure. It is important to examine repetitive samples from a designated point, as well as samples from a number of widely distributed sampling points.

Results of routine bacteriologic samples of water cannot be regarded as complete or final information concerning water quality. Bacteriologic results should be considered in light of information available concerning sanitary conditions surrounding the source of any particular sample. Precise evaluation of the quality of a water supply can only be made when laboratory results are interpreted in light of such sanitary survey data.

25 - Laboratory Coordination/Analysis

All States that maintain Environmental Protection Agency (EPA) primacy requirements for public water systems under the Safe Drinking Water Act (42 U.S.C. 300f et seq.) are required to maintain a laboratory approval and certification program. This includes identification and publication of all laboratories certified to be capable of performing analytical measurements of all contaminants specified in the Primary Drinking Water regulations (40 CFR part 141). All Forest Service facilities which fall under the jurisdiction of the act must use these certified laboratories or certified personnel for the analysis of physical, chemical, and bacteriological contaminants in drinking water systems. Forest Service laboratories may be certified by the States, if such facilities meet State certification requirements.

Certification is meant to ensure the productions of accurate results with repeatability of primary importance are:

1. Training and experience of both supervisory and operating staff.

2. Adequacy of operation records.

3. Adequacy of laboratory quality assurance/quality control program.

State certification is not the only necessary criterion for receiving Forest Service samples. Quantity and quality of services rendered and their timeliness are also important considerations.

State lists of certified laboratories are updated frequently. Therefore, prior to procuring analytical services from a particular laboratory, it is advisable to contact the State laboratory certification officer to determine the certification status of that specific laboratory.

Once a laboratory is chosen, it is advisable to contact that laboratory directly to receive information concerning specific sampling requirements, to make provisions for obtaining sampling and shipping containers, to procure their instructions for the proper collection and preservation of samples, and to set up distribution of test results.