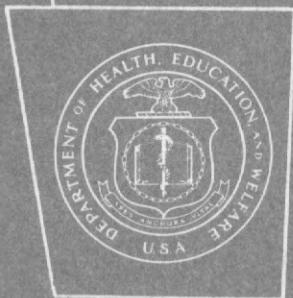


*Public Health Service*  
DRINKING WATER  
STANDARDS

1962



**U.S. DEPARTMENT OF  
HEALTH, EDUCATION, AND WELFARE**  
**Public Health Service**

# **Public Health Service**

## **Drinking Water Standards**

**Revised 1962**



**U.S. DEPARTMENT OF HEALTH, EDUCATION,  
AND WELFARE**  
**PUBLIC HEALTH SERVICE**  
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# THE PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS—1962

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,  
PUBLIC HEALTH SERVICE,  
*Washington 25, D.C., May 6, 1962.*

The Standards published herein have been promulgated as Public Health Regulations in the Federal Register. As such they became effective April 5, 1962, as the Standards to which drinking water and water supply systems used by carriers and others subject to Federal quarantine regulations must conform.

The Division of Environmental Engineering and Food Protection is responsible for the application of these Standards to all carrier water supplies.

These Standards supersede the Public Health Service Drinking Water Standards—1946, as amended in 1956. The new Standards were developed with the assistance of an Advisory Committee appointed by the Public Health Service to revise the Standards of 1946. The Committee in its deliberations took cognizance of man's changing environment and its effect on water supplies. Accordingly, new sections, such as one on radioactivity, have been added and substantive changes have been made elsewhere.

The new Standards are in a form believed useful in evaluating the quality and safety of water supplies generally and they are hereby recommended for such use.

LUTHER L. TERRY,  
*Surgeon General, Public Health Service.*

## ENDORSEMENT BY THE AMERICAN WATER WORKS ASSOCIATION

Acting on behalf of the Officers and Directors, the AWWA Executive Committee adopted a resolution endorsing the 1962 revision of the USPHS Drinking Water Standards as "minimum" standards for all public water supplies.

The resolution, which will be included with the published standards, read:

WHEREAS, the 1962 Drinking Water Standards of the U.S. Public Health Service, as prepared by the Advisory Committee on Revision of U.S. Public Health Service 1946 Drinking Water Standards and promulgated for use in the administration of interstate quarantine regulations, are intended to apply only to water used on common carriers engaged in interstate commerce;

WHEREAS, the 1962 Drinking Water Standards are to serve as minimum requirements to protect the health and promote the well-being of individuals and of communities;

WHEREAS, it is the desire of the American Water Works Association to support all efforts to promote health through safe water supplies and to recognize reasonable standards of quality for water furnished by public water supply systems; and,

WHEREAS, it is the hope of the American Water Works Association that its acceptance of the 1962 Drinking Water Standards will establish these standards as minimum criteria of quality for all public water supplies in the United States; now, therefore, be it

*Resolved* by the Officers and Directors of the American Water Works Association, that the 1962 Drinking Water Standards of the U.S. Public Health Service be accepted as minimum standards for all public water supplies.

## ADVISORY COMMITTEE REPORT

Domestic water supplies should protect the health and promote the well-being of individuals and the community. In this report on the revision of the 1946 edition of the Public Health Service Drinking Water Standards, the objective of the Committee is to recommend minimum requirements for reaching this goal.

The Public Health Service Drinking Water Standards were first adopted in 1914 to protect the health of the traveling public. The general and widespread use of these Standards since that time has led to a series of revisions which have been applicable to water supplies generally. The development of atomic energy and other technological advances requires that these Standards again be revised. To carry out this revision, the Chief Sanitary Engineer of the Public Health Service appointed the Advisory Committee. A Technical Subcommittee of Public Health Service Officers and a Toxicological Task Force were established to collect information and prepare suggestions for the consideration of the Advisory Committee.

In preparing this report on the revision of the Standards, the Committee established the following guidelines:

1. The proposed standards should be discussed widely and due cognizance should be given to International and other standards of water quality before a final report is submitted.
2. A new section on radioactivity should be added.
3. Greater attention should be given to the chemical substances being encountered increasingly in both variety and quantity in water sources.
4. In establishing limits for toxic substances, intake from food and air should be considered.
5. The rationale employed in determining the various limits should be included in an appendix.
6. The proposed format, with the exceptions noted above, should not differ greatly from the present Standards.
7. The Standards should be generally acceptable and should be applicable to all public water supplies in the United States, as well as those supplies used by carriers subject to the Public Health Service regulations.
8. The following two types of limits used in previous editions should be continued:
  - (a) Limits which, if exceeded, shall be grounds for rejection of the supply. Substances in this category may have adverse effects on health when present in concentrations above the limit.
  - (b) Limits which should not be exceeded whenever more suitable supplies are, or can be made, available at reasonable cost. Substances in this category, when present in concentrations above the limit, are either objectionable to an appreciable number of people or exceed the levels required by good water quality control practices.
9. These limits should apply to the water at the free-flowing outlet of the ultimate consumer.

This revision of the Drinking Water Standards includes, for the first time, limiting concentrations of radioactivity in water. The effects on large popula-

tion groups of chronic exposure to low levels of radioactivity are not yet well defined. The limits presented herein are an effort to derive conservative values from the best information now available and may be adjusted upward or downward as new and better data become available.

The Committee has taken cognizance of the growing problem of potentially harmful chemicals in sources of drinking water. Limits for several new chemicals have been added, including a gross limit for the concentration of some types of synthetic chemicals. It was not feasible, however, to include limits for all the many chemicals that have varying degrees of toxic potential. Consideration was given to the more common chlorinated hydrocarbon and organophosphate insecticides but the information available was not sufficient to establish specific limits for these chemicals. Moreover, the concentrations of these chemicals, where tested, have been below those which would constitute a known health hazard. The Committee believes that pollution of water supplies with such contaminants can become significant and urges that the problem be kept under closer surveillance. Further, the Committee recommends that regulatory actions be taken to minimize concentrations of such chemicals in drinking water.

In view of the accelerating pace of new developments affecting water quality, the Committee recommends that a mechanism be established for continual appraisal and appropriate revision of the Standards. It also recommends that the Public Health Service intensify its continuing studies toward the development of basic information on the relationship of the biological, chemical, physical, and radiological aspects of water quality to health.

The following pages contain the Drinking Water Standards recommended by the Committee, the membership of which is listed in appendix F.

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## PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS—1962

Standards promulgated by the Public Health Service, U.S. Department of Health, Education, and Welfare, Effective April 5, 1962, for potable water used by carriers subject to the Federal Quarantine Regulations

(Superseding Standards adopted Feb. 6, 1946)<sup>1</sup>

### 1. DEFINITION OF TERMS

The terms used in these Standards are as follows:

**1.1** *Adequate protection by natural means* involves one or more of the following processes of nature that produces water consistently meeting the requirements of these Standards: dilution, storage, sedimentation, sunlight, aeration, and the associated physical and biological processes which tend to accomplish natural purification in surface waters and, in the case of ground waters, the natural purification of water by infiltration through soil and percolation through underlying material and storage below the ground water table.

**1.2** *Adequate protection by treatment* means any one or any combination of the controlled processes of coagulation, sedimentation, absorption, filtration, disinfection, or other processes which produce a water consistently meeting the requirements of these Standards. This protection also includes processes which are appropriate to the source of supply; works which are of adequate capacity to meet maximum demands without creating health hazards, and which are located, designed, and constructed to eliminate or prevent pollution; and conscientious operation by well-trained and competent personnel whose qualifications are commensurate with the responsibilities of the position and acceptable to the Reporting Agency and the Certifying Authority.

**1.3** *Certifying Authority* means the Surgeon General of the U.S. Public Health Service or his duly authorized representatives. Reference to the Certifying Authority is applicable only for those water supplies to be certified for use on carriers subject to the Public Health Service Regulations—(42 CFR Part 72).

**1.4** The *coliform group* includes all organisms considered in the coliform group as set forth in *Standard Methods for the Examination of Water and Wastewater*, current edition, prepared and published

<sup>1</sup> Public Health Reports 61: 371-384, March 15, 1946.

jointly by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation.

1.5 *Health hazards* mean 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.

1.6 *Pollution*, as used in these Standards, means the presence of any foreign substance (organic, inorganic, radiological, or biological) in water which tends to degrade its quality so as to constitute a hazard or impair the usefulness of the water.

1.7 *Reporting Agencies* means the respective official State health agencies or their designated representatives.

1.8 *The standard sample* for the bacteriological test shall consist of:

1.81 For the bacteriological fermentation tube test, five (5) standard portions of either:

- (a) ten milliliters (10 ml)
- (b) one hundred milliliters (100 ml)

1.82 For the membrane filter technique, not less than fifty milliliters (50 ml).

1.9 *Water supply system* includes the works and auxiliaries for collection, treatment, storage, and distribution of the water from the sources of supply to the free-flowing outlet of the ultimate consumer.

## 2. SOURCE AND PROTECTION

2.1 The water supply should be obtained from the most desirable source which is feasible, and effort should be made to prevent or control pollution of the source. If the source is not adequately protected by natural means, the supply shall be adequately protected by treatment.

2.2 Frequent sanitary surveys shall be made of the water supply system to locate and identify health hazards which might exist in the system. The manner and frequency of making these surveys, and the rate at which discovered health hazards are to be removed, shall be in accordance with a program approved by the Reporting Agency and the Certifying Authority.

2.3 Approval of water supplies shall be dependent in part upon:

(a) Enforcement of rules and regulations to prevent development of health hazards;

(b) Adequate protection of the water quality throughout all parts of the system, as demonstrated by frequent surveys;

- (c) Proper operation of the water supply system under the responsible charge of personnel whose qualifications are acceptable to the Reporting Agency and the Certifying Authority;
- (d) Adequate capacity to meet peak demands without development of low pressures or other health hazards; and
- (e) Record of laboratory examinations showing consistent compliance with the water quality requirements of these Standards.

2.4 For the purpose of application of these Standards, responsibility for the conditions in the water supply system shall be considered to be held by:

- (a) The water purveyor from the source of supply to the connection to the customer's service piping; and
- (b) The owner of the property served and the municipal, county, or other authority having legal jurisdiction from the point of connection to the customer's service piping to the free-flowing outlet of the ultimate consumer.

### 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 I, 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 competence 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.

## DRINKING WATER STANDARDS, 1962

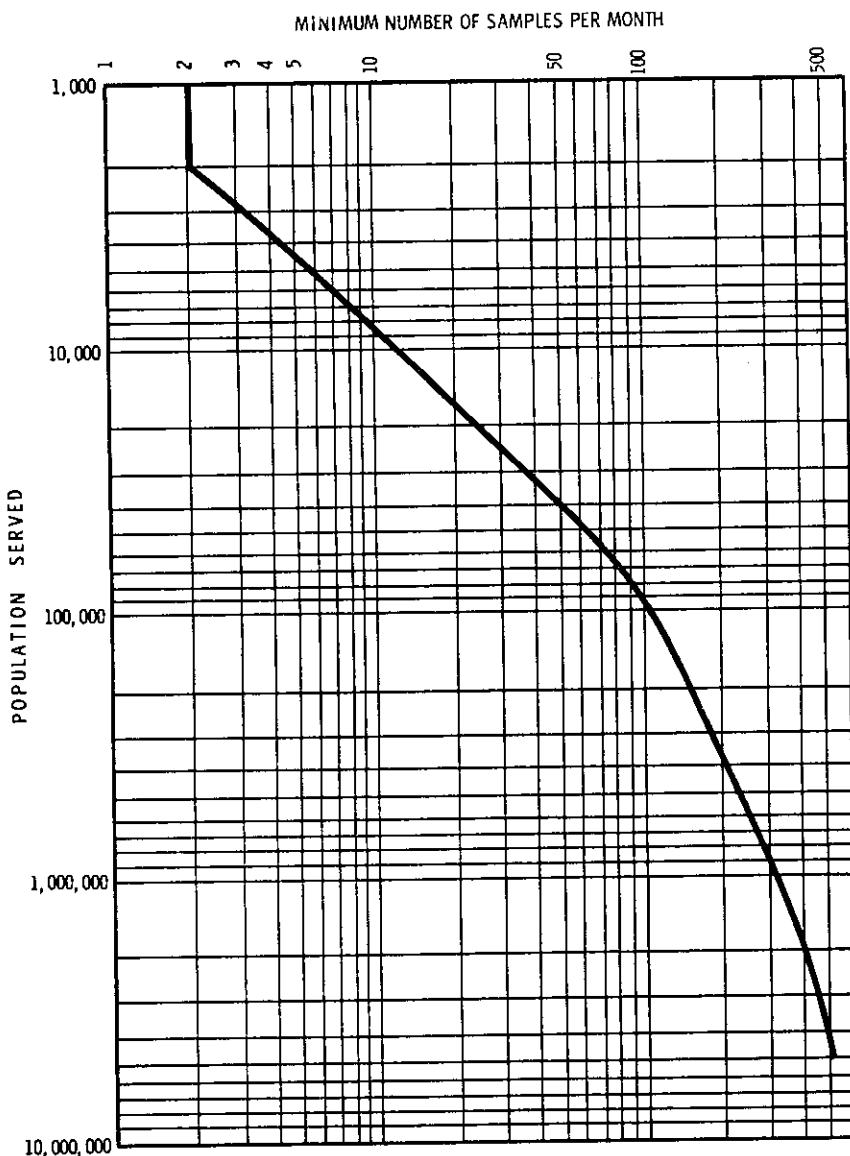


Figure 1

- (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 ml, 7/200 ml, 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

#### 5. CHEMICAL CHARACTERISTICS

##### 5.1 *Sampling.*

5.11 The frequency and manner of sampling shall be determined by the Reporting Agency and the Certifying Authority. Under normal circumstances, analyses for substances listed below need be made only semiannually. If, however, there is some presumption of unfitness because of the presence of undesirable elements, compounds, or materials, periodic determinations for the suspected toxicant or material, should be made more frequently and an exhaustive sanitary survey should be made to determine the source of the pollution. Where the concentration of a substance is not expected to increase in processing and distribution, available and acceptable source water analyses performed in accordance with standard methods may be used as evidence of compliance with these Standards.

5.12 Where experience, examination, and available evidence indicate that particular substances are consistently absent from a water supply or below levels of concern, semiannual examinations for those substances may be omitted when approved by the Reporting Agency and the Certifying Authority.

5.13 The burden of analysis may be reduced in many cases by using data from acceptable sources. Judgment concerning the quality of water supply and the need for performing specific local analyses may depend in part on information produced by such agencies as: (1) The U.S. Geological Survey, which determines chemical quality of surface and ground waters of the United States and publishes these data in "Water Supply Papers" and other reports, and (2) The U.S. Public Health Service which determines water quality related to pollution (or the absence of pollution) in the principal rivers of the Nation and publishes these data annually in "National Water Quality Network." Data on pollution of waters as measured by carbon chloroform extracts (CCE) may be found in the latter publication.

5.2 *Limits.*—Drinking water shall not contain impurities in concentrations which may be hazardous to the health of the consumers. It should not be excessively corrosive to the water supply system. Substances used in its treatment shall not remain in the water in concentrations greater than required by good practice. Substances which may have deleterious physiological effect, or for which physiological effects are not known, shall not be introduced into the system in a manner which would permit them to reach the consumer.

5.21 The following chemical substances should not be present in a water supply in excess of the listed concentrations where, in the judgment of the Reporting Agency and the Certifying Authority, other more suitable supplies are or can be made available.

Substance	Concentration in mg/l
Alkyl Benzene Sulfonate (ABS)-----	0.5
Arsenic (As)-----	0.01
Chloride (Cl)-----	250.
Copper (Cu)-----	1.
Carbon Chloroform Extract (CCE)-----	0.2
Cyanide (CN)-----	0.01
Fluoride (F)-----	(See 5.23)
Iron (Fe)-----	0.3
Manganese (Mn)-----	0.05
Nitrate <sup>1</sup> (No <sub>3</sub> )-----	45.
Phenols -----	0.001
Sulfate (SO <sub>4</sub> )-----	250.
Total Dissolved Solids-----	500.
Zinc (Zn)-----	5.

<sup>1</sup> In areas in which the nitrate content of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.

5.22 The presence of the following substances in excess of the concentrations listed shall constitute grounds for rejection of the supply:

Substance	Concentration in mg/l
Arsenic (As) -----	0.05
Barium (Ba) -----	1.0
Cadmium (Cd) -----	0.01
Chromium (Hexavalent) (Cr <sup>6+</sup> ) -----	0.05
Cyanide (CN) -----	0.2
Fluoride (F) -----	(See 5.23)
Lead (Pb) -----	0.05
Selenium (Se) -----	0.01
Silver (Ag) -----	0.05

5.23 *Fluoride*.—When fluoride is naturally present in drinking water, the concentration should not average more than the appropriate upper limit in Table I. Presence of fluoride in average concentrations greater than two times the optimum values in Table I shall constitute grounds for rejection of the supply.

Where fluoridation (supplementation of fluoride in drinking water) is practiced, the average fluoride concentration shall be kept within the upper and lower control limits in Table I.

TABLE 1.

Annual average of maximum daily air temperatures <sup>1</sup>	Recommended control limits— Fluoride concentrations in mg/l		
	Lower	Optimum	Upper
50.0-53.7-----	0.9	1.2	1.7
53.8-58.3-----	0.8	1.1	1.5
58.4-63.8-----	0.8	1.0	1.3
63.9-70.6-----	0.7	0.9	1.2
70.7-79.2-----	0.7	0.8	1.0
79.3-90.5-----	0.6	0.7	0.8

<sup>1</sup> Based on temperature data obtained for a minimum of five years.

In addition to the sampling required by paragraph 5.1 above, fluoridated and defluoridated supplies shall be sampled with sufficient frequency to determine that the desired fluoride concentration is maintained.

#### 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<sup>226</sup> or Sr<sup>90</sup> may vary considerably, quarterly samples composited over a period of three months are recommended. Samples for determina-

tion 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<sup>2</sup> 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  $\mu\mu\text{c}/\text{liter}$ , 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<sup>3</sup> of Strontium-90 and alpha emitters, the water supply is acceptable when the gross beta concentrations do not exceed 1,000  $\mu\mu\text{c}/\text{liter}$ . Gross beta concentrations in excess of 1,000  $\mu\mu\text{c}/\text{liter}$  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.

## 7. RECOMMENDED ANALYTICAL METHODS

7.1 Analytical methods to determine compliance with the requirements of these Standards shall be those specified in *Standard Methods for the Examination of Water and Wastewater*, Am. Pub. Health Assoc., current edition and those specified as follows.

<sup>2</sup>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  $\mu\mu\text{c}/\text{day}$  of Radium-226 and 200  $\mu\mu\text{c}/\text{day}$  of Strontium-90)."

<sup>3</sup>Absence is taken here to mean a negligibly small fraction of the above specific limits, where the limit for unidentified alpha emitters is taken as the listed limit for Radium-226.

7.2 Barium—*Methods for the Collection and Analysis of Water Samples, Water Supply Paper No. 1454, Rainwater, F. H. and Thatcher, L. L., U.S. Geological Survey, Washington, D.C.*

7.3 Carbon Chloroform Extract (CCE)—*Manual for Recovery and Identification of Organic Chemicals in Water, Middleton, F. M., Rosen, A. A., and Burtschell, R. H., Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio, Tentative Method for Carbon Chloroform Extract (CCE) in Water, J. Am. Water Works A. 54: 223-227, Feb. 1962.*

7.4 Radioactivity—*Laboratory Manual of Methodology, Radio-nuclide Analysis of Environmental Samples, Technical Report R59-6, Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio; and Methods of Radiochemical Analysis Technical Report No. 173, Report of the Joint WHO-FAO Committee, 1959, World Health Organization.*

7.5 Selenium—*Suggested Modified Method for Colorimetric Determination of Selenium in Natural Water, Magin, G. B., Thatcher, L. L. Rettig, S., and Levine, H., J. Am. Water Works Assoc. 52, 1199 (1960).*

7.6 Organisms of the coliform group—All of the details of techniques in the determination of bacteria of this group, including the selection and preparation of apparatus and media, the collection and handling of samples and the intervals and conditions of storage allowable between collection and examination of the water sample, shall be in accordance with *Standard Methods for the Examination of Water and Wastewater*, current edition, and the procedures shall be those specified therein for:

7.61 The Membrane Filter Technique, Standard Test, or

7.62 The Completed Test, or

7.63 The Confirmed Test, procedure with brilliant green lactose bile broth,<sup>4</sup> or

7.64 The Confirmed Test, procedure with Endo or eosin methylene blue agar plates.<sup>4</sup>

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<sup>4</sup>The Confirmed Test is allowed, provided the value of this test to determine the sanitary quality of the specific water supply being examined is established beyond reasonable doubt by comparisons with Completed Tests performed on the same water supply.

## **APPENDIX**

### **BACKGROUND USED IN DEVELOPING THE 1962 DRINKING WATER STANDARDS**

The Public Health Service Drinking Water Standards of 1962 have been predicated upon the best and latest information available at the time of their promulgation. The concepts and rationale included in this Appendix were used in making this revision and should enable those whose responsibility it is to interpret, apply, or enforce the Standards to do so with understanding, judgment, and discretion.

- A—Source and Protection**
- B—Microbiology**
- C—Physical Characteristics**
- D—Chemical Characteristics**
- E—Radioactivity**
- F—Membership of Advisory Committee.**
  - Technical Subcommittee, and Task Force  
on Toxicology**

#### **A—SOURCE AND PROTECTION OF SUPPLY**

Mounting pollution problems indicate the need for increased attention to the quality of source waters. Abatement and control of pollution of sources will significantly aid in producing drinking water which will be in full compliance with the provisions of these Standards and will be esthetically acceptable to the consumer.

Production of water supplies which poses no threat to the consumer's health depends upon continuous protection. Because of human frailties associated with this protection, priority should be given to selection of the purest source. Polluted sources should be used only when other sources are economically unavailable and then only when the provision of personnel, equipment, and operating procedures can be depended upon to purify and otherwise protect the drinking water supply continuously.

Well waters obtained from aquifers beneath impervious strata, and not connected with fragmented or cavernous rock, are usually considered sufficiently protected to preclude need for purification. How-

ever, ground waters are becoming polluted with increasing frequency and the resulting hazards require special surveillance. An illustration of such pollution is the presence of chemical pollutants originating either from sewage or industrial effluents. Surveillance of the safety of these water supplies should include chemical, physical, radiological, and biological examination.

Surface waters are subjected to increasing pollution and although some surface waters may be sufficiently protected to warrant their use as a supply without coagulation and filtration, they are becoming rare. Surface waters should never be used without being disinfected. Because of the increasing hazards of pollution, the use of surface waters without coagulation and filtration must be accompanied by intensive surveillance of the quality of the raw water and the disinfected supply in order to assure constant protection. This surveillance should include sanitary survey of the source and water handling, as well as biological, radiological, physical, and chemical examination of the supply.

The degree of treatment should be determined by the health hazards involved and the quality of the raw water. During times of unavoidable and excessive pollution of a source already in use, it may become necessary to provide extraordinary treatment (e.g., exceptionally strong disinfection,<sup>1</sup> improved coagulation, or special operation). If the pollution cannot be removed satisfactorily by treatment, use of the source should be discontinued until the pollution has been reduced or eliminated. When used, the source should be under continuous surveillance to assure adequacy of treatment in meeting the hazards of changing pollution conditions.

The adequacy of treatment should be judged, in part, upon a record of the quality of water produced by the treatment plant and the relation of this quality to the requirements of these Standards. Evaluation of adequacy of protection by treatment should also include frequent inspection of treatment works and their operation. Conscientious operation by well-trained, skillful, and competent operators is an essential part of protection by treatment. Operator competency is encouraged by a formal program leading to operator certification or licensing.

Delivery of a safe water supply depends upon the protection of the water in the distribution system as well as protection of the source and by treatment. Minimum protection in the distribution system should include programs which result in the *provision* of sufficient and safe materials and equipment to treat and distribute the water; *disinfection*

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<sup>1</sup> See reference to relationship of chlorine residual and contact time required to kill viruses, in section on Microbiology.

of water mains, storage facilities, and other equipment after each installation, repair, or other modification which may have subjected them to possible contamination; *prevention* of health hazards, such as cross-connections or loss of pressure because of overdraft in excess of the system's capacity; and *routine analysis* of water samples and frequent survey of the water supply system to evaluate the adequacy of protection. The fact that the minimum number of samples are taken and analyzed and found to comply with specific quality requirements of these Standards, is not sufficient evidence that protection has been adequate. The protection procedures and physical facilities must be reviewed along with the results of water quality analyses to evaluate the adequacy of the supply's protection. Knowledge of physical defects or of the existence of other health hazards in the water supply system is evidence of a deficiency in protection of the water supply. Even though water quality analyses have indicated that the quality requirements have been met, the deficiencies must be corrected before the supply can be considered safe.

## B—MICROBIOLOGY

### BACTERIOLOGICAL QUALITY

The bacteriological requirements for drinking water as specified by the 1946 Drinking Water Standards have been discussed extensively (1).<sup>1</sup>

#### Coliform Group

Of the two bacteriological examinations—(a) agar plate count for 24 hours at 35° C, and (b) quantitative estimation of the coliform group which have come to be recognized generally—the test for organisms of the coliform group is almost universally conceded to be the most significant. The plate count at 35° C or (20° C) incubation temperature is not required in the definition of a safe standard for potable waters but is useful as a routine quality control test in the various water treatment procedures and as a method for estimating the sanitary conditions of basins, filters, etc.

It does not seem advisable to repeat extensive discussions (1, 2, 3) of the principles involved in the quantitative interpretation of fermentation tests according to the "most probable number" concept in multiple portions of equal volume and in portions constituting a geometric series.

Discussions of the principles involved in the quantitative interpretation of membrane filter procedure results and as compared to the "most probable number" concept are available in the literature (4, 5, 6).

<sup>1</sup> Footnotes cited will be found at end of Microbiology Section.

## COLIFORM GROUP AND FECAL COLIFORM ORGANISMS AS INDICATORS OF POLLUTION IN DRINKING WATER<sup>2</sup>

The coliform group, as specified in U.S. Public Health Service Drinking Water Standards (1)<sup>3</sup> is defined in *Standard Methods* (2): "The coliform group includes all of the aerobic and facultative anaerobic, Gramnegative, nonspore-forming, rod-shaped bacilli which ferment lactose with gas formation within 48 hours at 35° C."

The coliform group includes organisms that differ in biochemical and serologic characteristics and in their natural sources and habitats. *Escherichia coli* is characteristically an inhabitant of human and animal intestines (3-6). *Aerobacter aerogenes* and *Aerobacter cloacae* are frequently found on various types of vegetation (7-9) and in materials used in joints and valves of pumps and in pipelines (10-11). The intermediate-aerogenes-cloacae (I.A.C.) subgroups may be found in fecal discharges but usually in smaller numbers than *Esch. coli*. *Aer. aerogenes* and intermediate types of organisms are commonly present in soil (12-14) and in waters polluted sometime in the past. Another subgroup comprises plant pathogens (15) and other organisms of indefinite taxonomy about whose habitat information is limited. All the subgroups may be found in sewage and in polluted waters. *Esch. coli* is therefore frequently referred to as "fecal coli"; the I.A.C. group as "nonfecal". It must be remembered, however, that these terms are only relative.

### Survival Times

Available information indicates that organisms of the I.A.C. group tend to survive longer in water than do fecal coliform organisms (16-18). The I.A.C. group also tends to be somewhat more resistant to chlorination than *Esch. coli* or the commonly occurring bacterial intestinal pathogens (19-22). Because of these and other reasons, the relative survival times of the coliform subgroups may be useful in distinguishing recent from less recent pollution. In waters recently contaminated with sewage, it is expected that fecal coliform organisms will be present in numbers greater than those of the I.A.C. subgroup. But in waters that have been contaminated for a considerable length of time or have been insufficiently chlorinated, organisms of the I.A.C. subgroup may be more numerous than fecal coliform organisms.

<sup>2</sup> This article, authored by Paul W. Kabler and Harold F. Clark, was published in J. Am. Water Works A. and is reprinted as a part of this appendix by permission of the AWWA.

<sup>3</sup> References cited in this article will be found at the end of the article.

### Differentiation of Organisms

Because various members of the coliform group normally grow in diverse natural habitats, attempts have been made to differentiate the population in polluted waters according to their original sources. In his pioneer work, MacConkey (23, 24) defined the aerogenes group in terms of certain fermentation characteristics, ability to produce indole, and reaction in the Voges-Proskauer test. Rogers, Clark, and Davis, (25) Clark and Lubs, (26) Koser, (27) and others contributed to the development of techniques and laboratory data that differentiated the coliform group on the basis of indole production, methyl red and Voges-Proskauer reactions, and citrate utilization (IMViC tests) into the *Esch. coli*, aerogenes, intermediate, and irregular subgroups. Hajna and Perry (28) and Vaughn, Levine, and Smith (29) further developed the Eijkman (30) test to distinguish organisms of fecal origin from those of nonfecal origin by increased temperature incubation. Clark and associates (31, 32) have reported additional data indicating the usefulness of such tests in sanitary investigations.

### Sanitary Significance

Information on the sanitary significance of the various types of coliform organisms is incomplete. In relation to untreated waters, however, the present position may be thus stated:

Fecal coliform organisms (*Esch. coli*) may be considered indicators of recent fecal pollution. No satisfactory method is currently available for differentiating fecal coliform organisms of human and animal origin. Therefore, it is necessary to consider all fecal coliform organisms as indicative of dangerous contamination.

In the absence of fecal coliform organisms, the presence of I.A.C. group organisms in untreated waters may be the result of relatively less recent fecal pollution, soil runoff water, or infrequently, fecal pollution containing only the I.A.C. group.

In general terms, the presence of fecal coliform organisms indicates recent and possibly dangerous pollution. The presence of I.A.C. organisms suggests less recent pollution or reveals the existence of defects in water treatment or distribution.

### Summary

The presence of any type of coliform organism in treated drinking water suggests either inadequate treatment or access of undesirable materials to the water after treatment. Although there are some differences between strain and subgroup organisms with regard to survival under natural conditions and resistance to chlorination, in

general all the coliform organisms exhibit survival and resistance patterns in the same order of magnitude. The presence of coliform organisms (as defined earlier) in treated water calls for definitive action for their elimination.

Insofar as bacterial pathogens are concerned, the coliform group is considered a reliable indicator of the adequacy of treatment. As an indicator of pollution in drinking water supply systems, and indirectly as an indication of protection provided, the coliform group is preferred to fecal coliform organisms (*Esch. coli*). Whether these considerations can be extended to include rickettsial and viral organisms has not been definitely determined.

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### Fecal Streptococci as Indicators of Pollution

Fecal streptococci appear to be characteristic of fecal pollution, being consistently present in both the feces of all warm-blooded animals and in the environment associated with animal discharges (7, 8, 9). They do not multiply in streams or surface waters to yield overgrowths as sometime occur with the coliform group. So far as is currently known, they are rare in soil or on vegetation not subject to continued fecal pollution (10). Therefore, the presence of fecal streptococci in a water indicates fecal pollution with the density equal to those originally present or reduced by natural purification processes.

By careful analysis of the streptococcal species present (11, 12, 13), the source of the fecal pollution can be estimated. For example: predominating strains of *Streptococcus fecalis* indicate human fecal pollution; *S. bovis* and *S. acidominimus* predominate in bovine excrement but are rarely present in human feces (about 0.4 percent of Streptococcus density); while in porcine excretal material, the species are about one-third *S. fecalis* (atypical types), one-third *S. bovis* and one-fourth *S. acidominimus*. Thus, it may be possible to separate human from other animal pollution and further studies of various animal excrement may permit further interpretations.

Improved methods and media are urgently needed for the analysis of streptococcal group. Investigations on the distribution of the various species of streptococci in nature should be diligently pursued. Azide Dextrose-EVA—(14, 15, 16, 17) multiple-tube procedure yields good results with the streptococci species present in humans but is relatively inefficient for the analysis of fecal streptococci present in other animals. The Slanetz MF (18) procedure yields a few more species. The KF streptococcus (19) medium and biochemical test procedures appear to offer promise of a more complete enumeration of fecal streptococci.

The streptococcus group in potable waters which are not chlorinated or which are in surface waters to be treated, appears to have certain advantages as indicator organisms in the interpretation of the type of pollution present. However, they do not appear to have any advantage over the coliform group in the examination of adequately chlorinated potable water.

### Enteric Viruses in Water

Enteric viruses (infectious hepatitis (20), poliomyelitis, Coxsackie, and ECHO) should be considered as waterborne infectious agents. Epidemiological evidence indicates that treated water from a public supply is not a frequent carrier of such organisms. Clarke and Chang (21) have recently reviewed both the published reports on outbreaks of infectious hepatitis and poliomyelitis and laboratory evidence on the resistance of various enteric viruses.

An estimated 20,000 to 40,000 cases of infectious hepatitis were reported in Delhi, India (1955-56) (22), attributable to treated municipal water supply. The outbreak was not accompanied by noticeable increase of typhoid fever and other intestinal diseases. This indicates that, in practice, the virus of infectious hepatitis is more resistant to chlorine (chloramine) than are vegetative bacteria. On the strength of epidemiological evidence, poliomyelitis outbreak in Edmonton, Canada (23) was attributed to the drinking (treated)

water supply. Kelly and Sanderson showed (1958) (24) that inactivation of enteric viruses (Polio virus I:MK 500 and Mahoney and Coxsackie B5) in water at pH 7, and 25° C requires a minimum free residual chlorine of 0.3 mg/l for at least 30 minutes. At higher pH levels or lower temperatures, either more chlorine or longer contact time is required. The same authors (1960) (25) showed that for the same viruses in water at 25° C and a pH of 7, a concentration of at least 9 mg/l combined residual chlorine is necessary to inactivate with a contact period of 30 minutes; of 6 mg/l with a 1-hour contact time; 0.5 mg/l with a contact period of more than 7 hours.

Sabin found  $10^6$  TcD<sub>50</sub> of polio virus per gram of feces in human stools. Neefe *et al.* estimated there were  $10^4$  to  $10^8$  infectious doses of infectious hepatitis virus per gram of feces from human cases. Other estimations of viral content in feces have been in the same order of magnitude or less. Human feces normally contain  $10^6$  to  $10^{10}$  coliform bacteria per gram. An estimated mean value is  $10^8$  coliforms per gram. Because nearly all feces contain coliform organisms and only a relatively small portion (2 to 20 percent) contribute pathogenic virus (26, 27, 28), domestic sewage normally contains approximately 10,000 times as many coliforms as virus. Virus populations in sewage and polluted waters are subject to die-aways due to aging, adsorption, and sedimentation, dilution, and various undetermined causes. It is likely, therefore, that the virus content of polluted surface waters, wells, etc., is quite low when judged on the basis of the coliform-virus ratio. This relatively low virus content may account for the apparent paucity of virus infections attributed to such sources. The possibility of waterborne epidemics remains, and the efficacy of various water treatment processes including high free chlorine dosages and increased contact times should be further investigated.

Virology techniques have not yet been developed to a point where virus enumerations can be recommended as a routine procedure in microbiological examination of drinking water. Development of methodologies to permit such examination is currently under investigation but may require extended periods of study before perfection. The objectives of a research program under which several laboratories could cooperate should include the accumulation of sufficient data and the development of methodologies on which to base standards. In the interim, control laboratories having access to facilities for virus isolation and identification should be encouraged to utilize the best available procedures for evaluating the occurrence of enteroviruses in treated waters.

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## C—PHYSICAL CHARACTERISTICS

Turbidity, color, and odor requirements are easily attained during general use by properly designed and operated treatment plants and distribution systems. Failure to meet these requirements is an indication of either inadequate treatment facilities or improper operation of the system. Supplies used without treatment should also meet these requirements. It should not be implied that these turbidity limits represent acceptable effluent standards for water treatment plants. Such plants should routinely produce water with a turbidity of less than one unit.

Although these tests do not directly measure the safety of the water, they are related to consumer acceptance of the water. The levels of 5 units of turbidity, 15 units of color, and a threshold odor number of 3 are levels at which these characteristics become objectionable to a considerable number of people. Experience has shown that under such circumstances, many people turn to alternate supplies which may be less safe.

## D—CHEMICAL CHARACTERISTICS

### INTRODUCTION

In its report, the Advisory Committee defined guidelines which were used in developing the standards. The following pages present de-

tailed data and the reasoning used in reaching the various chemical limits.

In general, "grounds for rejection" limits are based on the fact that the substances enumerated represent hazards to the health of man. In arriving at specific limits, the total environmental exposure of man to a stated specific toxicant has been considered. The Committee has attempted to set limits at the lowest practical level in order to minimize the amount of a toxicant contributed by water, particularly when other sources such as milk, food, or air are known to represent the major exposure of man.

The limits, which should not be exceeded when more suitable water supplies can be made available, are based on factors which render a supply less desirable for use. These considerations relate to materials which impart objectionable taste and odor to water, render it economically or aesthetically inferior, or are toxic to fish or plants. In one instance (Carbon Chloroform Extract), the limit is expected also to have utility as a generalized procedure for limiting toxic exposure to organic chemicals.

The Drinking Water Standards are regarded as a standard of quality which is generally attainable by good water quality control practices. Poor practice is an inherent health hazard. It has been the policy of the Committee to set limits which are not so low as to be impracticable nor so high as to encourage pollution of water.

No attempt has been made to prescribe specific limits for every toxic or undesirable contaminant which might enter a public water supply. While the Committee is fully cognizant of the need for continued attention to chemical contaminants of water, the Standards are limited to recognized need. Standards for innumerable substances would require an impossible burden of analytical examination.

#### ALKYL BENZENE SULFONATE (Anionic Surfactant)

The surfactant is a synthetic organic chemical having high residual affinity at one end of its molecule and low residual affinity at the other. Its vigorous surface activity justifies not only its name but its use as a principal ingredient of modern household detergents. Surfactants may be divided into two broad chemical classifications, ionic and non-ionic. Ionic types may be either anionic (-) or cationic (+). Alkyl benzene sulfonate is a typical anionic surfactant.

Contamination of drinking water supplies with surfactants results from their disposal, as household and industrial wastes, into sources of raw water. Such contamination is appearing in supplies from both surface and ground waters. Other potential sources of human intake

of surfactants are inadequately rinsed cooking and household utensils and dinnerware and food.

More than 75 percent of the surfactants in household detergents are of the anionic type. Alkyl aryl sulfonates account for almost three-quarters of these, the remainder being mostly alkyl sulfates. Next in extent of such use are the nonionics, the cationics making up only a small percentage (1). Hence, the anionic group comprises the specific materials of this type most apt to be present in raw water supplies if any at all are present (2). The principal agent in this anionic group is the sodium salt of the sulfonation product of dodecylbenzene, an alkyl aryl sulfonate, termed alkyl benzene sulfonate or simply ABS (3). It is largely for this reason that the degree of detergent contamination is established currently in terms of the concentration of alkyl benzene sulfonate (ABS), for which quantitative determination can be made by practical and reasonably satisfactory laboratory procedures.

In general, commercial ABS is produced by condensing polypropylene (typically the tetrapolymer) with benzene, followed by a distillation cut to yield a reproducible product. ABS is thus a controlled mixture of isomers and homologues of dodecylbenzene, which upon sulfonation may be represented by the following typical structure:



Concentrations of anionic surfactants found in drinking waters have ranged from 0 to 2.6 mg/l in well water supplies and from 0 to 5 mg/l in river water supplies. In one instance, a municipal water supply contained 5 mg/l when a period of drought necessitated use of an impounded, highly purified sewage treatment plant effluent as a raw water supply (4).

In a study (5) made for the purpose, 10 percent of those using water containing less than 1 mg/l anionic sulfonated detergents complained of an off-taste, whereas all those using water containing 1.5 mg/l complained of an off-taste. Frothing was also a common complaint occurring most frequently at concentrations of 1 mg/l and above. The off-taste has been described as oily, fishy, or perfume-like (5). ABS itself is essentially odorless. The odor and taste characteristics are likely to rise from the degradation of products of other wastes rather than from ABS. The concentration of ABS in municipal sewage is of the order of 10 mg/l. Thus waters containing ABS are likely to be at least 10 percent of sewage origin for each mg ABS/l present.

From the basic toxicologic point of view, there are two reports which are especially pertinent to the present consideration.

1. The Toxicologic Subcommittee of the Food Protection Committee of the Food and Nutrition Board, National Research Council, published a comprehensive report in 1956 (6) bearing on the question of surfactants in food. Reviewing extensively the acute and chronic toxicity studies which have been reported on these chemicals, they found that there appears to be little specific relationship of toxicity to surface activity (reduction of interfacial tension). In conclusion, it was stated that:

- (a) There are no toxic effects common to all surfactants.
- (b) Surface activity *per se* is not a measure of toxicity.
- (c) The safety of each surfactant used in food must be determined separately.

The report pointed out that surfactants may occur fortuitously in some foods in amounts of a few parts per million and that: "It appears probably that the interfacial tension existing in the digestive tract of a healthy human is so low that it will not be further lowered by the small amounts of synthetic surfactants which may be present in food."

2. In a report on an investigation dealing with the chronic and subacute toxicity for rats of several surface-active agents, among which was sodium alkyl aryl sulfonate, Fitzhugh and Nelson (7) declared that: "The toxic effects of the surface-active agents studied in the experiments were produced by irritation of the gastrointestinal tract (10,000 ppm or more in the diet). To an extent which depended on the concentration of the surface-active agents in the diet, this irritation prevented proper nutrition. In severe cases of irritation, death resulted.

It is recommended that alkyl benzene sulfonate (ABS) in drinking water be limited to 0.5 mg/1, inasmuch as higher concentrations may cause the water to exhibit undesirable taste and foaming. Concentrations of ABS above 0.5 mg/1 are also indicative of questionably undesirable levels of other sewage pollution.

An ABS concentration of 0.5 mg/1 in drinking water, in terms of a daily adult human intake of 2 liters, would give a safety factor of the order of 15,000, calculated on the results of subacute (6) and 2-year (8) tests on rats fed diets containing ABS. In these rat studies, it was found that levels of ABS in the diet of 0.5 percent and below produced no discernible physiological, biochemical, or pathological deviations from normal.

Human experience (6 subjects) with oral doses of purified ABS of 100 mg (equivalent to 2 liters of water containing 50 mg ABS/1) daily for 4 months led to no significant evidence of intolerance (9).

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## ARSENIC

The widespread use of inorganic arsenic in insecticides and its presence in animal foods, tobacco, and other sources, make it necessary to set a limit on the concentration of arsenic in drinking water.

Normal human blood contains approximately 0.064 mg of arsenic per 100 ml, whereas urine may contain from trace amounts up to 5 mg per day. Arsenic is found in many foods in varying amounts, occurring naturally in some foods and introduced in others as in pork and turkey and appears in poultry feeds or as a pesticide spray. Shellfish and crustaceans may contain up to 170 ppm (1), but it is suspected that assimilation of arsenic from this source is limited. Vegetables and fruits (and wine) may contain varying small amounts. The tolerance for arsenic on sprayed fruits and vegetables set by the Food and Drug Administration is 3.5 ppm (2). Neither trivalent nor pentavalent arsenic is known to be an essential or beneficial element, and the body is not known to be dependent on a daily intake.

The toxicity of arsenic is well-known and the ingestion of as little as 100 mg usually results in severe poisoning. Chronic poisoning from arsenic may be insidious and pernicious. A considerable proportion is retained at low intake levels. A single dose may require ten days for

complete disappearance and this slow excretion is in part the basis for its cumulative effects (3, 4).

Both trivalent and pentavalent arsenic are easily absorbed from the gastrointestinal tract and lung, and become distributed throughout the body tissues and fluids. The toxicity of the pentavalent form is believed to be due to its reduction to the trivalent state. Inorganic arsenicals are potent inhibitors of the intracellular SH enzymes involved in cellular oxidations. The concentration of arsenic in kidney, liver, and the walls of the intestine can lead to serious consequences (4).

Recent evidence supports the view that arsenic may be carcinogenic. Industrial workers in a plant manufacturing arsenic powder were exposed to arsenic dust and showed a higher incidence of skin and lung cancer than other occupational groups (5, 6, 7). Ulceration of the nasal septum appears to be a common finding among workers exposed to inorganic arsenic. The incidence of skin cancer has also been reported to be unusually high in areas of England where arsenic was present in drinking water at a level of 12 mg/1 (8).

Arsenic concentrations of from 2 to 4 mg/1 are reported not to interfere with the self-purification of streams (9), nor have arsenic concentrations of 3 to 14 mg/1 been harmful to mayfly nymphs and 10 to 20 mg/1 to dragon and damsel flies (10). Bass have tolerated 6 mg/1 for 232 hours (11). A concentration of 15 mg/1 proved toxic to crappies and blue gills (11), and 20 mg/1 (as sodium arsenite) proved harmful to minnows after 36 hours exposure (12).

The U.S. Public Health Service Drinking Water Standards for 1946 established an arsenic limit of 0.05 mg/1. In light of our present knowledge concerning the potential health hazard from the ingestion of inorganic arsenic, the concentration of arsenic in drinking water should not exceed 0.01 mg/1 and concentrations in excess of 0.05 mg/1 are grounds for rejection of the supply.

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### BARIUM

Reference to a limiting concentration for barium in the Public Health Service Drinking Water Standards of 1946 is confined to "salts of barium . . . shall not be added for water-treatment purposes." No reference to barium is made in the International Drinking Water Standards of 1958. Barium occurs naturally in some mineral springs as the carbonate salt.

Barium is recognized as a general muscle stimulant, including especially the heart muscle (1). The fatal dose for man is considered to be from 0.8-0.9 g as the chloride (550-600 mg Ba). Most fatalities have occurred from mistaken use of barium salts incorporated in rat poison. Barium is capable of causing nerve block (2) and in small or moderate doses produces transient increase in blood pressure by vasoconstriction (3). Aspirated barium sulfate has been reported to result in granuloma of the lung (4) and other sites in man (5). Thus, evidence exists for high acute toxicity of ingested soluble barium salts, and for chronic irreversible changes in tissues resulting from the actual deposition of insoluble forms of barium in sufficient amounts at a localized site. On the other hand, the recent literature reports no accumulation of barium in bone, muscle, or kidney from experimentally administered barium salts in animals (6). Most of the administered dose appeared in the liver with far lesser amounts in the lungs and spleen. This substantiates the prior finding of no measurable amounts of barium in bones or soft tissues of man (7). Later, more accurate analysis of human bone (British) showed 7 ug Ba/g ashed sample (8), but no increase in bone barium occurred from birth to death. Small amounts of barium have been shown to go to the skeleton of animals when tracer amounts of barium-140 were used (9), but no determinations

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