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QUALITY CRITERIA FOR WATER



U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C. 20460

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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OFFICE OF WATER AND
HAZARDOUS MATERIALS

To the Reader:

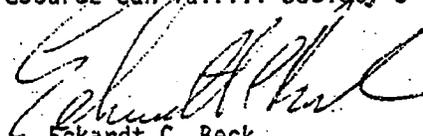
Thousands of fine scientists throughout the country have contributed directly or indirectly to this publication on "Quality Criteria for Water." This volume represents a stock-taking effort on the part of this Agency to identify as precisely as possible at this time, on a national scale, the various water constituents that combine to form the concept of "Quality Criteria for Water". This process of definition will continue far into the future because research related to water quality is a never-ending evolutionary process, and the water environment is so complex that man's efforts to define it will never attain finite precision.

Water quality criteria do not have direct regulatory use, but they form the basis for judgment in several Environmental Protection Agency and State programs that are associated with water quality considerations. The criteria presented in this publication should not be used as absolute values for water quality. As it is stated in the chapter on "The Philosophy of Quality Criteria" there is variability in the natural quality of water and certain organisms become adapted to that quality, which may be considered extreme in other areas. These criteria represent scientific judgments based upon literature and research about the concentration-effect relationship to a particular water quality constituent upon a particular aquatic species within the limits of experimental investigation. They should be used with considered judgment and with an understanding of their development. The judgment associated with their use should include the natural quality of water under consideration, the kinds of organisms that it contains, the association of those species to the particular species described in this volume upon which criteria values have been placed, and the local hydrologic conditions.

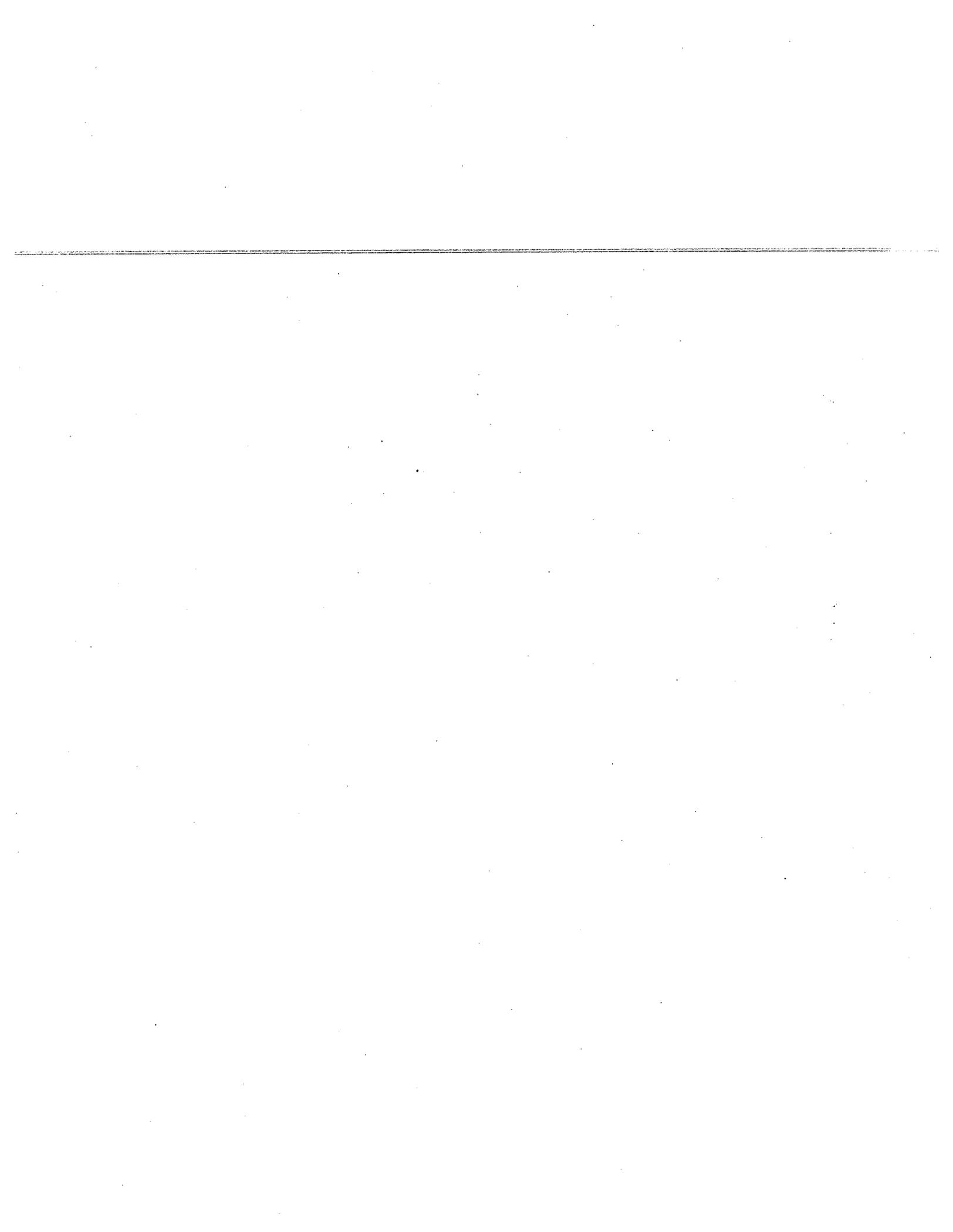
It must be emphasized that national criteria can never be developed to meet the individual needs of each of the Nation's waterways--the natural variability within the aquatic ecosystem can never

be identified with a single numerical value. Water quality criteria will change in the future as our knowledge and perception of the intricacies of water improve. There is no question but that criteria for some constituents will change within a period of only two years based upon research now in progress. That is a mark of continuing progressive research effort, as well as a mark of a better understanding by man of the environment that he inhabits.

This, then, is the challenge for the future: to expand upon our present baseline of knowledge of the cause-effect relationships of water constituents to aquatic life and of the antagonistic and synergistic reactions among many quality constituents in water; and to mold such future knowledge into realistic, environmentally protective criteria to insure that the water resource can fulfill society's needs.



Eckardt C. Beck
Deputy Assistant Administrator
for Water Planning and Standards



IRON

CRITERIA:

0.3 mg/l for domestic water supplies (welfare).

1.0 mg/l for freshwater aquatic life.

INTRODUCTION:

Iron is the fourth most abundant, by weight, of the elements that make up the earth's crust. Common in many rocks it is an important component of many soils, especially the clay soils where usually it is a major constituent. Iron in water may be present in varying quantities dependent upon the geology of the area and other chemical components of the waterway.

Iron is an essential trace element required by both plants and animals. In some waters it may be a limiting factor for the growth of algae and other plants; especially this is true in some marl lakes where it is precipitated by the highly alkaline conditions. It is a vital oxygen transport mechanism in the blood of all vertebrate and some invertebrate animals.

The ferrous, or bivalent (Fe^{++}), and the ferric, or trivalent (Fe^{+++}) irons, are the primary forms of concern in the aquatic environment, although other forms may be in organic and inorganic wastewater streams. The ferrous (Fe^{++}) form can persist in waters void of dissolved oxygen and originates usually from groundwaters or mines when these are pumped or drained. For practical purposes the ferric (Fe^{+++}) form is insoluble. Iron can exist in natural organometallic or humic compounds and colloidal forms. Black or brown swamp waters may contain iron concentrations of several mg/l in the presence or absence of dissolved oxygen, but this iron form has little effect on aquatic

life because it is complexed or relatively inactive chemically or physiologically.

In stratified lakes with anaerobic hypolimnia, soluble ferrous iron occurs in the deep, anaerobic waters. During the autumnal or vernal overturns and with aeration of these lakes, it is oxidized rapidly to the ferric ion that precipitates to the bottom sediments as a hydroxide, $\text{Fe}(\text{OH})_3$, or with other anions. If hydrogen sulfide (H_2S) is present in anaerobic bottom waters or muds, ferrous sulfide (FeS) may be formed. Ferrous sulfide is a black compound and results in the production of black mineral muds.

Prime iron pollution sources are industrial wastes, mine drainage waters, and iron-bearing groundwaters. In the presence of dissolved oxygen, iron in water from mine drainage is precipitated as a hydroxide, $\text{Fe}(\text{OH})_3$. These yellowish or ochre precipitates produce "yellow boy" deposits found in many streams draining coal mining regions of Appalachia. Occasionally ferric oxide (Fe_2O_3) is precipitated forming red waters. Both of these precipitates form as gels or flocs that may be detrimental, when suspended in water, to fishes and other aquatic life. They can settle to form flocculant materials that cover stream bottoms thereby destroying bottom-dwelling invertebrates, plants or incubating fish eggs. With time these flocs can consolidate to form cement-like materials, thus consolidating bottom gravels into pavement-like areas that are unsuitable as spawning sites for nest building fishes; particularly this is detrimental to trout and salmon populations whose eggs are protected in the interstices of gravel and incubated with oxygen-bearing waters passing through the gravel.

RATIONALE :

Iron is an objectionable constituent in water supplies for either domestic or industrial use. Iron appreciably affects the taste of beverages (Riddick, et al., 1958) and can stain laundered clothes and plumbing fixtures. A study by the Public Health Service (Cohen, et al., 1960) indicates that the taste of iron may be detected readily at 1.8 mg/l in spring water and at 3.4 mg/l in distilled water.

The daily nutritional requirement for iron is 1 to 2 mg, but intake of larger quantities is required as a result of poor absorption. Diets contain 7 to 35 mg per day and average 16 mg (Sollman, 1957). The iron criterion in water is to prevent objectionable tastes or laundry staining (0.3-mg/l) constitutes only a small fraction of the iron normally consumed and is of aesthetic rather than toxicological significance.

Warnick and Bell (1969) obtained 96-hour LC₅₀ values of 0.32 mg/l iron for mayflies, stoneflies, and caddisflies; all are important fish food organisms. Brandt (1948) found iron toxic to carp, Cyprinus carpio, at concentrations of 0.9 mg/l when the pH of the water was 5.5. Pike, Esox lucius, and trout (species not known) died at iron concentrations of 1 to 2 mg/l (Doudoroff and Katz, 1953). In an iron polluted Colorado stream, neither trout nor other fish were found until the waters were diluted or the iron had precipitated to effect a concentration of less than 1.0 mg/l even though other water quality constituents measured were suitable for the presence of trout (FWPCA, 1967).

Ferric hydroxide flocs have been observed to coat the gills of white perch, Roccus americanus; minnows and silversides, Menidia sp. (Olsen, et al.,

1941). The smothering effects of settled iron precipitates may be particularly detrimental to fish eggs and bottom-dwelling fish food organisms. Iron deposits in the Brule River, Michigan and Wisconsin were found to have a residual long-term adverse effect on fish food organisms even after the pumping of iron-bearing waters from deep shaft iron mines had ceased (West, et al., 1963). Settling iron flocs have also been reported to trap and carry diatoms downward in waters (Olsen, et al., 1941).

Ellis (1937) found that in 69 of 75 study sites with good fish fauna, the iron concentration was less than 10.0 mg/l. The European Inland Fisheries Advisory Commission (1964) recommended that iron concentrations not exceed 1.0 mg/l in waters to be managed for aquatic life.

Based on field observations principally, a criterion of 1 mg/l iron for freshwater aquatic life is believed to be adequately protective.

As noted, data obtained under laboratory conditions suggest a greater toxicity for iron than that obtained in natural ecosystems. Ambient natural waters will vary with respect to alkalinity, pH, hardness, temperature and the presence of ligands which change the valence state and solubility, and therefore the toxicity of the metal.

The effects of iron on marine life have not been investigated adequately to determine a water quality criterion. Dissolved iron readily precipitates in alkaline sea waters. Fears have been expressed that these settled iron flocs may have adverse effects on important benthic commercial mussels and other shellfish resources.

Iron has not been reported to have a direct effect on the recreational uses of water other than its effects on aquatic life. Suspended iron precipitates may interfere with swimming and be aesthetically objectionable. Deposits of yellow ochre or reddish iron oxides can be aesthetically objectionable.

Iron at exceedingly high concentrations has been reported to be toxic to livestock and interfere with the metabolism of phosphorus (NAS, 1974).

Dietary supplements of phosphorus can be used to overcome this metabolic deficiency (McKee and Wolf, 1963). In aerated soils, iron in irrigation waters is not toxic. Precipitated iron may complex phosphorus and molybdenum making them less available as plant nutrients. In alkaline soils, iron may be so insoluble as to be deficient as a trace element and result in chlorosis, an objectionable plant nutrient deficiency disease. Rhoades (1971) reported a reduction in the quality of tobacco because of precipitated iron oxides on the leaves when the crop was spray irrigated with water containing 5 mg/l of soluble iron.

For some industries, iron concentrations in process waters lower than that prescribed above for public water supplies are required or desirable. Examples include high pressure boiler feed waters; scouring, bleaching, and dyeing of textiles; certain types of paper production; some chemicals; some food processing; and leather finishing industries.

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of the Menominee and Brule rivers, Michigan-Wisconsin. U.S. Dept.
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Sanitary Engineering Center, Cincinnati, Ohio.

LEAD

CRITERIA:

50 ug/l for domestic water supply (health);

0.01 times the 96-hour LC_{50} value, using the receiving or comparable water as the diluent and soluble lead measurements (non-filtrable lead using an 0.45 micron filter), for sensitive freshwater resident species.

INTRODUCTION:

In addition to their natural occurrence, lead and its compounds may enter and contaminate the global environment at any stage during mining, smelting, processing, and use. The annual increase in lead consumption in the U. S. during the 10-year period from 1962-1971 averaged 2.9 percent, largely due to increased demands for electrochemical batteries and gasoline additives (Ryan, 1971). In 1971 the total U. S. lead consumption was 1,431,514 short tons, of which 42 percent came from recycled lead (Ryan, 1971). Of the 1971 U. S. lead consumption, approximately 25 percent was as metallic lead or lead alloy (Ryan, 1971; NAS, 1972). Non-industrial sources that may contribute to the possibility of ingestion of lead by man include the indoor use of lead-bearing paints and plaster, improperly glazed earthenware, lead fumes on ashes produced in burning lead battery casings, and exhaust from internal combustion engines.

Most lead salts are of low solubility. Lead exists in nature mainly as lead sulfide (galena); other common natural forms are lead carbonate (cerussite), lead sulfate (anglesite), and lead chlorophosphate (pyromorphite). Stable complexes result also from the interaction of