

Iron Criteria and Implementation For Iowa Surface Waters

Update: Effective November 11, 2020, a dissolved iron criterion of 1 mg/L applies, in place of the total iron criterion of 1 mg/L.

Summary

It is recommended DNR apply a total iron concentration of 1 mg/l (replacing the current 0.16 mg/l) as the criterion for protecting aquatic life uses when establishing water quality-based NPDES permit limits for iron. For wasteload allocation calculations, the iron criterion of 1 mg/l would be applied at the end of Zone of Initial Dilution for both designated and general use waters. Valid site specific acute toxicity data for iron may be used in lieu of the 1 mg/l iron concentration when it is available.

I. Background

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 clay soils where it is usually a major constituent. The dissolved iron concentration in Iowa's groundwater can range from less than 1 mg/l up to 20 mg/l (USGS Groundwater Monitoring Data).

The ferrous, or bivalent (Fe^{++}), and the ferric, or trivalent (Fe^{+++}) ions, 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 groundwater or mines when these are pumped or drained. For practical purposes, the ferric (Fe^{+++}) form is insoluble.

Iron is an objectionable constituent in water supplies for either domestic or industrial use. Iron can affect the taste of beverages and can stain laundered clothes and plumbing fixtures. The EPA red book (1976) recommended a criterion of 0.3 mg/l for domestic water supply uses for iron.

At certain concentrations, iron can also be toxic to aquatic life. The EPA red book (1976) recommended a criterion of 1.0 mg/l for freshwater aquatic life protection.

II. Current Iron Criteria and Implementation

No numerical criteria have been adopted in Iowa's Water Quality Standards (IAC 567–61.3(3), Table 1) for iron. However, there are 29 facilities with water quality-based numerical iron discharge limits. The current water quality-based iron limits are derived from the implementation of general criterion (61.3(2)“d”), which states that waters must be free from of any substance that is **acutely** toxic to human, animal or plant life. The implementation of the general criterion (61.3(2)“d”) for iron considers the use of the ½ 96-hour LC50 value of 0.16 mg/l iron for mayflies, stoneflies, and caddisflies (Warnick and Bell, 1969). The current iron limit is expressed as total iron concentration.

III. Issues with the Current Iron Limit

There are no EPA established national 304(a) acute or chronic criteria for iron. Furthermore, toxicity studies of iron on aquatic life are rare. The current water quality-based iron limits in Iowa NPDES permits were based on a lab study over 30 years ago, which did not record at what pH level that the study was done. The bioavailable form of iron is ferrous iron, which only exists at low pH levels. The pH level in a natural stream is usually around 8. At this pH and available dissolved oxygen conditions, the ferrous iron is oxidized rapidly to ferric ion that is insoluble in water. This may be the reason that as noted in EPA red book, data obtained under laboratory conditions suggest a greater toxicity for iron than that obtained in natural ecosystems. That appears to be the reason that EPA recommended an iron criterion of 1 mg/l even though the lab study data noted in the Red Book showed a much lower LC50 value for mayflies, stoneflies and caddisflies.

As shown in Table 1 of Appendix A, for the states surveyed, only New York applies an iron criterion of 0.3 mg/l (total)

that is below the EPA recommended 1 mg/l. However, New York is in the process of replacing 0.3 mg/l with 1 mg/l of total iron criterion. Most states adopted the EPA recommended iron criterion of 1 mg/l (total iron) as the chronic criterion even though EPA red book did not identify whether it is acute or chronic. Since most Iowa permitted facilities with iron limits have difficulties to comply with the current iron criterion of 0.16 mg/l, DNR allows the facilities the opportunity to survey the receiving stream. If the survey data shows that only less sensitive species are present in the stream, a more relaxed iron criterion may apply. The problem with this approach is that literature iron toxicity data are only available for Carp, Pike and trout species. 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). A newer study by A. Gerhardt (1995) demonstrated that iron concentration below 40 mg/l had no severe effect of the survival of the mayflies within 30 days. In addition, EPA itself agrees that the iron criterion needs updating; the Agency is currently working with EPRI (Electric Power Research Institute) to update the criterion for iron. EPRI's current work to update the ambient water quality criterion for iron is in the final stages. Depending on how EPA and individual states decide to implement EPRI's recommendations, the allowable limit on iron discharges in some circumstances may double from 1 mg/l to 2 mg/l. Based on the issues facing Iowa's current water quality-based iron limits, the current iron criterion needs to be revised.

IV. The Recommended Iron Criteria and Implementation Procedure

A. The Recommended Iron Criteria

Based on field observations principally, a criterion of 1 mg/l iron for freshwater aquatic life is believed to be adequately protective (US EPA, 1976). Also, the site specific toxicity test data for TDS that DNR has received (Appendix A, Table 2) indicates that an iron concentration of 1.4 mg/l does not cause acute toxicity for fathead minnows and ceriodaphnia. It is recommended DNR adopt iron concentration of 1 mg/l as the basis for establishing NPDES permit limits for iron.

B. Wasteload Allocation Implementation Procedure for Iron

Even though dissolved iron is bioavailable and more toxic to aquatic life, particulate iron, when suspended in water, may be detrimental to fishes and other aquatic life. Particulate iron can settle to form flocculants materials that cover stream bottoms thereby destroying bottom-dwelling invertebrates, plants, or incubating fish eggs. Thus, the iron criterion of 1 mg/l is applied as total iron.

EPA red book does not indicate whether the recommended criterion of 1 mg/l is an acute or a chronic value. Since the iron criterion is associated with the implementation of the general criterion that applies to all waters of the state, to prevent discoloration (or aesthetically objectionable conditions) of the stream, and to control or minimize the allowed area of above 1 mg/l of iron concentration in the receiving waterbody, the iron criterion will be applied as an acute criterion (that is, LC₀ - lethal concentration 0% of tested species died) and is applied at the Zone of Initial Dilution for designated waters as well as general use waters.

If a valid site specific acute whole effluent toxicity test demonstrates that the LC₀ or the Non-Observed-Adverse-Effect Concentration (NOAEC) for iron is higher than 1 mg/l, the site specific data may be used to establish the final limits for iron.

References

- Brandt, HH. 1948. Intensified injurious effects on fish, especially the increased toxic effect produced by a combination of sewage poisons. Beitr. Wass. Abwass. Fischerei-chemi. 15.
- Doudoroff, P and M Katz. 1953. Critical review of literature on the toxicity of industrial wastes and their components to fish. II. The metals, as salts. Sew. Ind. Wastes, 25:802.
- Gerhardt, A. 1995. Joint and Single toxicity of Cd and Fe related to metal uptake in the mayfly *Leptophlebia marginata* (L.) (Insecta). Hydrobiologia, 306:229-240.
- USEPA, July 1976. Quality Criteria for Water. Washington, D.C. 20460.
- Warnick, SL and HL Bell. 1969. The acute toxicity of some heavy metals to different species of aquatic insects. Jour. Water Poll. Cont. Fed. 41(2):280.

Appendix A: Table 1 & 2

Table 1. Aquatic Life Criteria for Iron¹ For Other States

States	Acute Criteria	Chronic Criteria	Comments
Oregon	--	1.0	
Nebraska	--	1.0	24-hour average
Missouri	--	1.0	No indication as acute or chronic
Pennsylvania	--	1.5	30-day average as total recoverable
West Virginia	--	1.5 (Warmwater) 0.5 (Trout streams)	
Kansas	--	Narrative criteria	The permittee shall take measures to reduce the iron content of the discharge so no discoloration and/or iron deposition occurs on adjacent landowners' property and/or within the receiving stream.
North Carolina		1.0	No indication as acute or chronic
New York	--	0.3	In the process replacing 0.3 mg/l by 1 mg/l
Michigan	--	1 to 2 (total)	
		0.5 (dissolved)	

¹The iron criteria are measured in total unless indicated otherwise

Table 2. Summary of Whole Effluent Toxicity (WET) Tests on Iron in Iowa

Facility	Iron Concentration at Which Acute Test Passed* (mg/l)	Comments
Voyager Ethanol (Emmetsburg)	0.4	Actual effluent
Golden Grain Energy (Mason City)	0.7	1/2 48-hour LC50, cook up sample
Ajinomoto Heartland Inc (Eddyville)	1.4	
PLCP, L.P. (Steamboat Rock)	0.02	Cook up sample, iron is filtered out before Reverse Osmosis (RO)
Iowa Falls Ethanol	0	Cook up sample, iron is filtered out before RO
City of Grinnell	0.15	
Des Moines County Sanitary Landfill	0.58	
West Liberty	0.09	
Holiday Inn Lagoon (Amana Nordstrom)	0.24	
Sparboe Renaissance, LLC	0.32	

*It is the highest iron concentration tested.