TREATMENT OPTIONS FOR REMOVAL OF SPECIFIC IMPURITIES FROM WATER

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Summary

Removal of excess concentrations of fluorides, iron and manganese from water before supply as drinking water is essential, as they result in health and economic complications. Removal of these specific impurities requires separate treatment steps, other than those for removal of conventional impurities such as floating and suspended matters, colloidal particles, dissolved organic matter, etc. Iron and manganese are

removed mainly by inducing oxidation of these impurities. Oxidation can be carried out either by adequate aeration or using chemical oxidants. Precipitates containing iron and manganese are removed by filtration or adsorption. Fluorides also can be removed by precipitation or coagulation and sedimentation methods using chemicals.

1. Introduction

Common water treatment processes such as flocculation, sedimentation, filtration and disinfection are employed to remove general impurities such as floating and suspended matters, colloidal particles, dissolved organic matter and destruction of disease-causing microorganisms (pathogens). In addition, there are some impurities such as iron, manganese and fluoride present in water, which do not directly affect the wholesomeness of water if present in smaller threshold levels. In fact, iron is an essential element required for humans for the formation of hemoglobin, which is essential in transporting oxygen from the lungs to tissue cells. For proper nutrition, human adults require 10 to 20 mg/L of iron intake per day, and deficiency of iron causes anemia in humans. However, when iron and manganese are present in excess, the water becomes unacceptable for drinking from an aesthetic point of view, and for other domestic and industrial uses from an economic point of view and hence have to be removed. Excessive amounts of fluoride in drinking water have been found to affect human health. In this article, some simple technologies to remove excessive iron, manganese and fluoride from water are described.

2. Iron (Fe) and Manganese (Mn) Removal

The problems of iron and manganese usually occur when the raw water source is groundwater, but can also be found in anaerobic surface waters and where industrial wastes are discharged. Markedly high levels of Fe and Mn in surface waters are found in anoxic hypolimnion of lakes and impoundments under eutrophication. Iron and manganese are natural constituents of soils and rocks. They are normally present in highly insoluble forms, but are brought into solution by anaerobic conditions or by the presence of carbon dioxide. Nuisance conditions can occur when the concentrations of iron and manganese exceed 0.3 mg/L and 0.1 mg/L respectively.

Iron exists in solution in the ferrous state, usually as ferrous bicarbonate. It can only remain in solution in the absence of oxygen, and generally when the pH is below 6.5. When such water is exposed to air, the soluble ferrous bicarbonate is oxidized to insoluble ferric hydroxide, making the water discolored, and will form a deposit.

Manganese occurs in a similar way to iron, and they may both be present at the same time. Deposits and discoloration due to manganese are black rather than rust-colored as for iron. The manganese deposits are of higher density and are less easily flushed out. Manganese oxidizes less readily than iron and therefore is more difficult to remove.

2.4. Problems of Fe and Mn in Water

Major problems associated with the presence of Fe and Mn in water include:

- objectionable bitter or metallic taste in water;
- objectionable reddish-brown or black color to water;
- interfering with plumbing fixtures by deposits;
- staining of clothes during laundering;
- supporting growth of microorganisms such as *clonothrix* and *crenothrix*, particularly when organic matter is present. these microorganisms may accentuate deposition problems and may produce sulfides, further exacerbating taste, odor and color problems;
- causing difficulty in water softening processes for industrial use, by clogging and coating the softening medium.

To prevent these difficulties, various regulatory agencies have put forward standards to control iron and manganese concentrations. For example, the United States Environmental Protection Agency (USEPA) has specified iron and manganese levels to be within 0.3 and 0.05 mg/L, respectively, in drinking water.

2.5. Treatment Processes for Fe and Mn Removal

In general, iron and manganese can be removed by oxidation. Organic substances found in surface waters and groundwaters can form soluble complexes with Fe and Mn, which may not be satisfactorily oxidized to an insoluble form, thus making the oxidation process ineffective. Use of strong oxidants may be required to treat such waters. The treatment adopted in the removal of different impurities will have a bearing on the choice of the method for iron removal.

In the case of surface water, due to the availability of oxygen, iron and manganese are found in oxidized form and can be removed relatively easily. In the case of ground water:

- Iron is usually accompanied by high amounts of free CO_2; removing only the iron and leaving the free CO_2 could cause corrosion of pipes and mains.
- Lime softening, if required for hardness removal, will also be effective for removing the iron and CO_2.
- If organics removal/bacterial disinfection is necessary, chlorination may be required, which will assist in the iron and manganese removal.

Groundwater generally is deprived of oxygen and so has a high content of reduced iron that can be removed by aeration or chemical oxidation. Of the technologies available for iron and manganese removal, the following ones have found widespread application in water supply:

- Aeration followed by sand filtration (or dual-media filtration), often complemented by a contact tank, settling, or flotation and the addition of chemicals. This is the commonly used method in developing countries.
- Chemical oxidation (without pre-aeration) followed by filtration method is used for water with high concentrations of iron (>5.0 mg/L).

- Filtration with a special medium that acts as an ion or electron exchanger, for example, manganese greensand, zeolites of volcanic origin (tectosilicates), sand that is naturally/artificially coated with manganese dioxide to simulate a natural greensand, or adsorption with activated carbon. These methods are useful for low to moderate concentrations of iron and manganese (about 0–5 mg/L).
- Magnesium oxide and diatomite pre-coat filtration (analogous to manganese removal by magnesium hydroxide).
- Conventional treatment combined with lime softening.
- Sodium silicate, phosphates, or polyphosphates as sequestering agents.
- Biological treatment methods. These methods are extensively used in European countries such as Holland and Germany, and is advantageous primarily when the water contains iron, manganese and ammonia at the same time.
- *In situ* treatment, in which oxygenated water is introduced into the aquifer by means of feed wells, thus creating a treatment area around the main well.

2.2.1. Aeration Filtration Method

If only iron is present in water, simple aeration followed by filtration will be effective. Aeration followed by sedimentation and rapid sand filtration is required when the amount of Fe is high or when Mn is present. Aeration assists in dissipation of free carbon dioxide, and oxidation and precipitation of iron. Free CO_2 should be reduced to less than 10 mg/L to remove corrosive properties.

Hydrogen sulfide, if present, should also be dissipated. The aeration process is based on the principle of oxidation of iron by oxygen from air, using different type of aerators. This process is applied to raw water with a maximum iron concentration of 5 mg/L, and with no other unfavorable characteristics (manganese, color, turbidity, humic acids); a low level of ammonia may be tolerated. The aeration process may take place:

- at atmospheric pressure for installations operated by gravity;
- under pressure in which compressed air is blown into oxidation towers with contact materials.

Aeration at atmospheric pressure often provides a cheap means of removing aggressive carbon dioxide, which otherwise requires expensive neutralization treatment. The advantage of the second type (compressed air) is that it can be operated at system delivery pressure without pumping.

According to the method used, the precipitate formed may contain larger or smaller proportions of ferrous carbonate, which, being more crystalline than ferric hydroxide, dictates the effective size of the filter media. Filters with homogenous layer of sand are suitable for the majority of cases, provided that the filtration rate, grain size, and depth of bed are carefully designed. Figure 1 shows a schematic diagram of an aeration filtration unit used for iron removal. High initial costs, and, unsuitability for higher levels of iron concentration and presence of other impurities, are some of the major disadvantages of the aeration-filtration method.

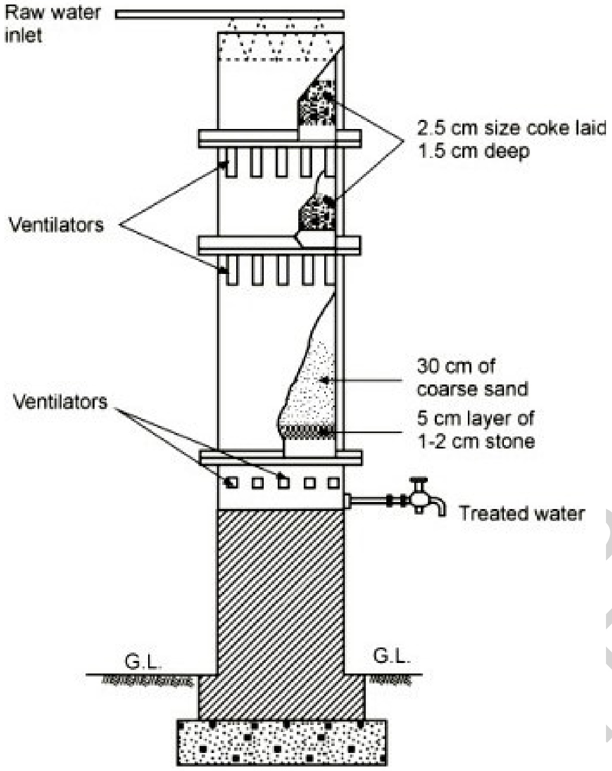

Figure 1. Aeration filtration method for Fe removal

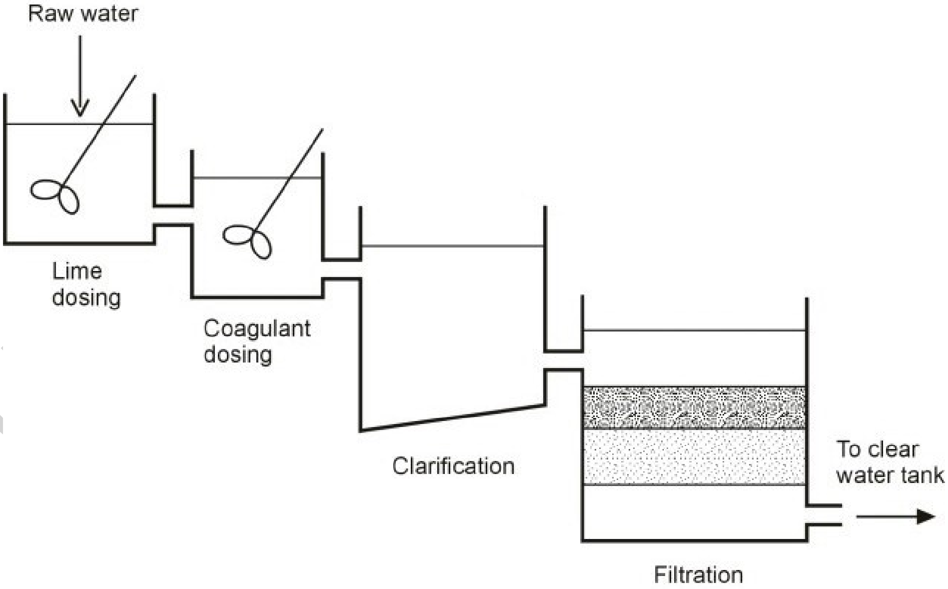

Figure 2. Iron removal plant for treatment of water with high iron content

High levels of iron in the raw water (>5–10 mg/L), results in large amounts of precipitate which subsequently clog the filters. Presence of color, turbidity, humic acids, and complex forming agents interfere with aeration, and hence removal of iron. By incorporating a clarification stage prior to filtration (Figure 2), the disadvantages can be overcome. Sludge blanket settlers are especially well suited for this purpose. An aeration stage must precede clarification if raw water is deprived of oxygen.

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Biographical Sketches

S. Vigneswaran is currently a Professor and a Head of Environmental Engineering Group in Faculty of Engineering, University of Technology, Sydney, Australia. He has been working on water and wastewater research since 1976. He has published over 175 technical papers and authored two books (both through CRC press, USA). He has established research links with the leading laboratories in France, Korea, Thailand and the USA. Also, he has been involved in number of consulting activities in this field in Australia, Indonesia, France, Korea and Thailand through various national and international agencies. Presently, Dr. Vigneswaran is coordinating the university key research strengths on “water and waste management in small communities”, one of the six key research centers funded by the university on competitive basis. His research in solid liquid separation processes in water and wastewater treatment namely filtration, adsorption is recognized internationally and widely referred.

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