Review Article **JPER (2018), 3:12**

Journal of Plant and Environmental Research
(ISSN: 2475-6385)

Assessment of Biological iron Removal from the Ground Water

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ABSTRACT

Iron can be removed from groundwater through the process of chemical oxidation followed by a rapid sand filtration. Different mechanisms (physicochemical and biological) contribute for the iron removal in filters but the dominant mechanism depends on physical and chemical characteristics of the water and which the process conditions applied. Now there are number of methods of biological iron removal which are reported to be much more efficient and cost effective than conventional physicochemical iron removal method. The mechanism of iron removal in filters could be solely biological the physicochemical iron removal mechanisms under certain specific conditions. The paper reviews that the theoretical background of biologically mediated iron removal, the advantages and limitations of the method and a few case studies. A literature review revealed that biological iron removal is not suitable when pH and oxygen concentrations are high and/or NH+4, H2S and Zn are present. Physico chemical removal mechanisms can achieve the same removal efficiency under the conditions that are reported to be favorable for biological iron removal. Biological iron removal is likely to be supplementary to conventional physico chemical iron removal.

Keywords: groundwater, filtration, iron removal, biological oxidation,

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How to cite this article:
Baby AbrarUnnisa Begum, Dr. N. Devanna, Dr. P. Ramesh Chandra, Razia Sultana. Assessment of Biological iron Removal from the Ground Water. Journal of Plant and Environmental Research, 2018,3:12

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Website: http://escipub.com/

Introduction

Water is the major sources of drinking water in the world. Iron is the fourth most abundant element and the second most abundant metal in the Earth’s crust. it is a common constituent of groundwater. There are is no health-based principle for the concentration of iron in drinking water. It is undesirable as it causes several aesthetic and operational problems including bad taste, discoloration, staining, and deposition in distribution systems leading to after growth and incidences of high turbidity. Based on taste and nuisance considerations, The (WHO) recommends that iron concentration in drinking water should be less than 0.3 mg/l The directive recommends that the iron in water supplies should be less than 0.2 mg/l. Several methods, namely oxidation – precipitation – filtration, lime softening, ion-exchange, sub-surface iron removal and membrane processes, have been employed for iron removal from groundwater. Stabilization with phosphate or silicates is applied as well to avoid the oxidation or precipitation of iron. Among the different techniques mentioned above, aeration or chemical oxidation followed by rapid sand filtration is most used.

✓ Oxidation- floc filtration:

In this process iron is first oxidized by oxygen or chemical oxidant, in which hydrolysis and agglomeration forms iron hydroxide flocs. Subsequently flocs are removed in rapid sand filters

✓ Adsorption oxidation (adsorptive filtration)

To make a new iron oxide layer the process involves the adsorption of iron (II) on the surface of the filter media and the presence of oxygen or other oxidant is used. The adsorption and oxidation of iron (II) is enhancing by the oxide layer and this process is facilitated. The pre-oxidation and oxidant concentration have to be limited to avoid oxidation-floc formation mechanism to occur

The adsorption – oxidation mechanism of iron removal has several advantages, e.g.:

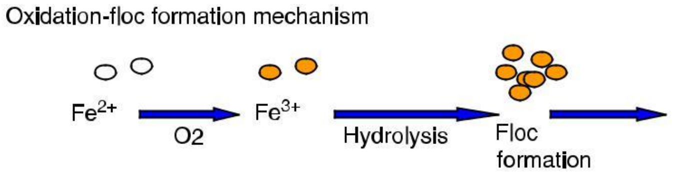
✓ it allows higher filtration rates and longer filter run lengths, since the specific volume of iron oxide adsorbed/-precipitated on the sand grains is much lower than that of iron hydroxide flocs,

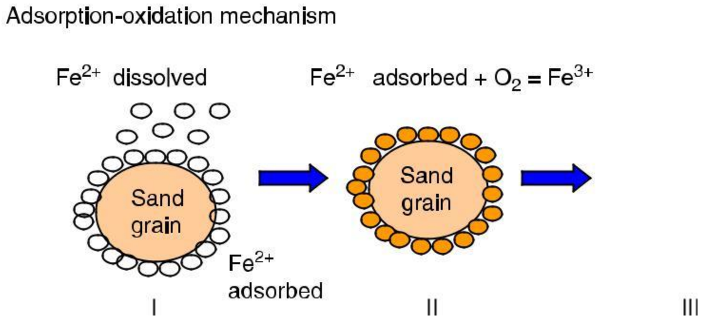
✓ Its high filtrate quality.

In Plants the conventional of iron removal plants both of these physico-chemical removal mechanisms occur simultaneously. The dominant mechanism under given conditions depends on the water quality and process 0063onditions applied; specifically, low oxygen concentration and a short pre-oxidation time in the supernatant of the filters reduces the role of the “oxidation – floc formation” mechanism and as a consequence the “adsorption – oxidation” mechanism will be dominant. At high pH values, the rate of oxidation of iron (II) is higher which is in favour of the “oxidation –flock formation” mechanism. This paper focuses on the role of the biological iron removal mechanism.

BIOLOGICAL IRON REMOVAL

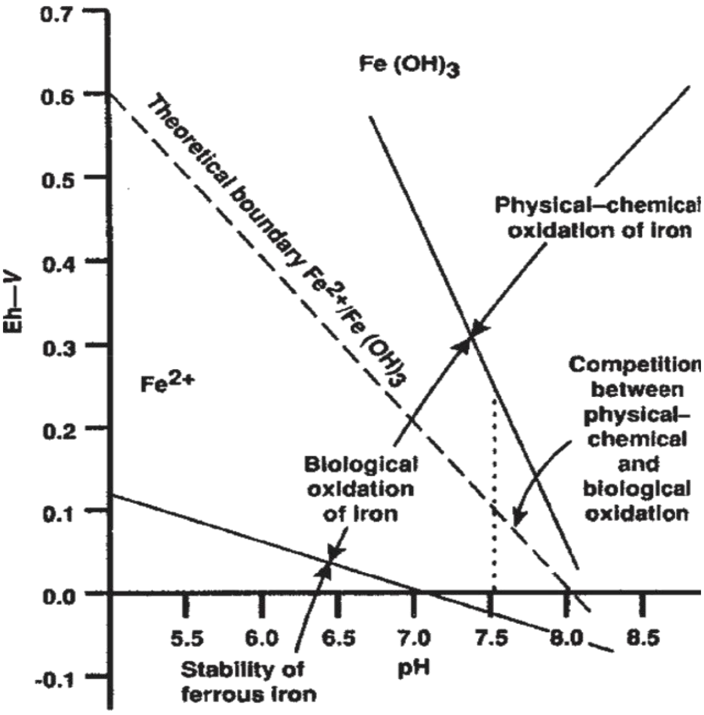
Biologically oxidation and removal of iron has reported in the sand filtration of groundwater





The Removal of Biological iron is attributed to the activity of microorganisms. These are reported to be a unique property of causing oxidation and precipitation of dissolved iron under pH and redox potential (Eh) conditions that are intermediate between those of natural groundwater and those required for conventional (physico–chemical) iron removal

The activity of presence of iron bacteria, which straddles theoretically the boundary between the fields of Fe^{2} þ stability and the formation of iron hydroxides as defined by thermodynamic analysis of the electrochemical equilibria (Figure 2). This is related to the fact that iron bacteria relying on iron(II) oxidation as a source of energy are gradient organisms, signifying that they are not likely to develop under strongly reducing or strongly oxidising conditions, but rather at the point where they have a source of both ferrous ions and air By aerating the raw water and increasing the dissolved oxygen concentration, the redox potential of raw water is increased in the pH–Eh range where biological iron oxidation is expected to take place predominantly



Mechanism and process conditions

The exothermic oxidation of iron(II) can be catalyzed by some bacteria due to the oxidation– reduction enzymes that they excrete trivalent iron rendered insoluble in hydroxide form is then stored in the mucilaginous secretions (sheaths, stalks, capsules, etc.) of these bacteria. The organisms responsible for this phenomenon belong to the genera Gallionella, Leptothrix, Crenothrix, Clonothrix, Siderocpasa, Sphaerotilus, Ferrobacillus and Sideromonas These iron-oxidising bacteria are widespread and are prevalent in groundwater, ponds, hypolimnion of lakes or impound-ments, sedimentary deposits and soil. Two mechanisms of bacterial oxidation have been

(i) intracellular oxidation by enzymatic action of auto-trophic bacteria (Gallionella and Leptothrix ochra-cea),

(ii) extracellular oxidation by the catalytic action of polymers excreted by iron bacteria (Gallionella, Leptothrix, Crenothrix, Clonothrix, Sphaerotilus and Siderocapsa).

In anaerobic groundwater, iron is mainly present in soluble forms of iron(II). Physicochemical removal processes require aeration of this water in order to sufficiently raise the redox potential of the water so that the dissolved iron(II) present will be converted into insoluble oxidized forms

The metabolic activities of iron bacteria are not fully understood but it is believed that the same oxidation of iron is carried out by some variation of the physical –chemical reaction

It is believed that the energy that is released by this reaction allows the bacteria to reduce and assimilate the carbon from CO_2, thereby synthesizing their own nutrients. However, oxidation of ferrous ions does not furnish much energy on a molar basis and about 600 mol of Fe^{2} þ is needed to assimilate 1 mol of carbon This implies that large amounts of iron have to be oxidized to satisfy the energy requirements for the growth of iron oxidising bacteria.

The metabolic pathway for the iron oxidation reactions, the biological process is catalytic in nature and causes a rapid oxidation. The red insoluble precipitates formed are all slightly hydrated iron oxides that, beneficially, are more compact forms than the precipitates formed when using physical – chemical processes.

This feature partially explains the greater iron retention capacity between backwashes of biological filters when compared to physical chemical treatment filters. It is likely that in these “physical– chemical filters” the oxidation – formation mechanism is dominant as the observed effect of a greater iron retention capacity can also be attributed to the adsorption – oxidation mechanism. Iron bacteria are generally robust and, because of the variety of species involved, one type or another is able to thrive under most environmental conditions. A pH of 6 – 8 is required for their activity. However, at a pH above 7.2, biological processes will compete with conventional (physi-cal– chemical) processes. The optimum temperature typi-cally ranges from 10 – 158C for Gallionella ferruginea and 20– 25 8C for the Sphaerotilus–Leptothrix group . The biological oxidation process is, however, inhib-ited in the presence of H_2S, chlorine, $NH^{þ}_4$ and some heavy metals .The water applied to the biological filter must contain 0.01 mg H_2S/l. Furthermore, it was reported that the iron removal rate decreased by 50% in the presence of a zinc concentration of 0.45 mg Zn/l and there was total inhibition of the treatment when the zinc concentration reached 1 mg Zn/l.

The biological iron removal process is not suitable for operation where there are rapid or large flow variations because the bacterial population needs to adjust over a period of time to the new conditions. Constant flow and loading provide the optimum operating conditions for biological iron removal plants. They added that the following criteria are normally required for biological iron removal to be effective

Dissolved oxygen	,	1 mg/l (, 10% saturation)
pH	5.5 –7.5	
Redox potential	.	100 mV
Iron(II)	0.1 –10 mg/l	
Iron (III)	Negligible	
Inhibitory materials (e.g. H_2S, $NH^{þ}_4$, Zn)	Negligible	

However, it is to be noted that, in the presence of oxygen, iron(II) is always partly oxidised in the supernatant and in the filter bed. So there will always be some iron(III) present when iron(II) is removed in the filter in the presence of oxygen.

Advantages and limitations of biological iron removal

The marked improvement in performance by converting conventional iron treatment plants to biological ones. The primary advantages associated with this process were reported to be high filtration rates (10 – 70 m/h), high retention capacity (1–5 kg Fe/m^2), and elimination of chemical reagents, flexibility of operation, and reduced capital and operating costs. The shift from physicochemical to biological precipitation of iron can increase the water treatment plant capacity substantially and reduce operation costs by up to 80%. However, high iron concentrations in the influent may cause breakthroughs, as the rate of absorption by the bacteria may not be high enough to match the supply rate.

The biological iron and manganese removal systems could have the following advantages:

- ✓ smaller plants because of higher applied filtration rates (sometimes in excess of 50 m/h versus 10 –15 m/h) or because aeration and filtration can take place simultaneously in the same vessel;
- ✓ longer filter runs because of iron retention in the filter due to the formation of more dense precipitates and the use of a more coarse media;
- ✓ denser backwash sludge that is easier to thicken and dewater;
- ✓ higher net productions due to less water being required for backwashing and being able to use raw water for the backwash;
- ✓ require no chemical addition;

- ✓ no deterioration of water quality over time;
- ✓ Lower capital and operating costs through the elimination of chemicals, less frequent backwashing, fewer components, etc.

The main disadvantage of this method is the long maturation time before full efficiency is achieved; perhaps 50 –60 days for a new filter and 5 days after a 2-month shutdown. The other shortcomings of this method include:

- ✓ not suitable for all types of groundwater;
- ✓ anaerobic conditions may develop in the filter bed, thus converting back iron(III) to iron(II), resulting in an elevated iron concentration in the filtrate;
- ✓ increased sludge production and backwash water with filter ageing;
- ✓ need for two filtration stages to remove iron and manganese as the required redox potential conditions for iron and manganese oxidising bacteria are very different;

Ineffective in the presence of ammonia ($NH^{þ}{}_4$) and inhibiting substances like H_2S and Zn

Result and DISCUSSION

It is still debated whether “near neutral pH bacteria” actually oxidize iron (II) and grow auto tropically or merely deposit iron in an oxidized form. Ehrlich (2002) stated that “microbes can promote iron oxidation, but this does not mean that the oxidation is always enzymatic. Because ferrous iron has a tendency to auto-oxidize (without bacteria or catalyst) in aerated solution at pH values above 5, it is difficult to demonstrate enzyme-catalyzed iron oxidation in near-neutral air-saturated solutions. At this time the most extensive evidence for enzyme-catalyzed iron oxidation in air-saturated solution by bacteria has been amassed at pH values below 5”.

In iron bacteria other than the acidophile species, autotrophy using ferrous iron as a source of energy has not been conclusively. The bacteria do, however, process iron intracellularly. Environments high in iron(II) will lead to elevated iron levels inside the cell. The cells have mechanisms to remove such unwanted ions. Therefore, oxidation of iron(II) may be purely to detoxify their intracellular environment rather than to create energy. The cell membrane and extracellular polymers do provide many sites for the adsorption of iron(II) ions. Once adsorbed the ions may undergo the oxidation reaction. This leads to the formation of the characteristic sheaths often cited as evidence for biological iron removal. It appears that bacteria can act as a pathway for iron(II) oxidation either via adsorption onto the cell membrane or via oxidation to detoxify the intracellular environment. It cannot be established if such mechanisms provide a significant removal capacity

The increased precipitation rate of iron in biological filters relative to physicochemical filters could be that precipitation of iron hydroxides takes place in contact with exoploymers of the bacterium Gallionella ferruginea. The exopolymers acts as a catalyst for the oxidation process of iron and prevent re-dissolution of iron hydroxides in spite of the oxic/anoxic conditions found in the biological filters. Furthermore the fact that the iron-precipitating bacterium Gallionella ferruginea is chemolithotropic with respect to the oxidation of iron(II) is not proven.

The reported increased efficiency and advantages of biological iron removal can also be achieved if the mode of operation of iron removal filters is switched from predomi-nantly floc filtration (oxidation – floc formation) to predo-minantly adsorptive filtration (adsorption – oxidation) The commercially available catalytic filter media BIRM (a federally registered trademark of Clack Corporation, USA) also claims similar advantages as that of biological iron removal reported by Therefore, it is still to be answered what is the clear advantage of using bacteria for iron removal in place of physicochemical processes, as iron bacteria may not be available in all groundwaters. In reality the boundary between physicochemical and biological iron removal is not well defined .It is also pointed out that the domain of effective biological iron removal is narrower than the field of existence of iron bacteria, as shown in Figure 1. Iron removal from anoxic groundwater by adsorption onto new or iron oxide coated filter media is possible in the pH–Eh range of iron bacteria which indicates that the process is not necessarily biological. In many iron removal plants and pilot studies, nearly complete removal of iron has been seen to occur immediately after the beginning of a filter run or test. The fact that iron was removed at the very beginning of the filtration process strongly suggests that this process is predominantly a physicochemical reaction. Furthermore, in the presence of oxygen iron(II) oxidation starts immediately (after the aeration step), implying that biological iron removal might be only supplementary to the conventional oxidation –floc formation method of iron removal. It has been reported that in some plants the removal efficiency has increased after the development of bio films or "coatings" on the surface of the filter media . This improved efficiency can also be explained by the increased adsorption of iron (II) onto

SUMMARY AND CONCLUSIONS

A review of the available literature on biological iron removal points to the following findings:

Iron in groundwater could be removed by biological oxidation under specific water quality and process conditions. It is not possible to employ the biological iron removal method for all groundwater, especially

When pH and oxygen concentrations are high and/or NH^{b}_{4}, H_2S and Zn are present.

Biological iron removal is very sensitive to process conditions (e.g. temperature, filtration rate, oxygen concentration) and will not be suitable when there is rapid or large variation in the flow and water quality.

Biological iron removal is not necessarily the sole iron removal mechanism in the filters. Physicochemical mech-anisms like oxidation – floc formation and adsorption – oxidation (adsorptive filtration) can achieve the same removal efficiency under the same conditions, so it is not clear which mechanism is dominant.

The presence of iron oxidising bacteria in iron removal filters is not unlikely to increase the efficiency of iron removal in filters. They could contribute by catalytically oxidising iron(II) to iron(III) if the rate of oxidation of iron(II) is very slow in water. This type of iron oxidation is only possible if the iron is entering the filter bed in iron(II) form. However, in the presence of oxygen iron(II) oxidation starts immediately (after the aeration step) in the supernatant and filter bed. Moreover the adsorption – oxidation mechanism will occur in the filter bed as well, implying that biological iron removal is likely to be supplementary to conventional physico-chemical iron removal.

REFERENCES

1. Badjo, Y. & Mouchet, P. 1989 Appropriate technologies – example of a large biological iron removal plant in Togo. Aqua 38(3), 197 –206.
2. Bourgine, F. P. et al. 1994 Biological processes at Saints Hill water treatment plant, Kent. J. IWEM, 8 August, 379– 392.
3. Bouwer, E. J. & Crowe, P. B. 1988 Biological process in drinking water treatment. J. AWWA 80(9), 82 –93.
4. Corstjens, P. 1993 Bacterial Oxidation of Iron and Manganese:
5. A Molecular-biological Approach. PhD Thesis, Rijsuniversitiet, Leiden, The Netherlands.
6. Czekalla, C., Mevius, W. & Hanert, H. 1985 Quantitative removal of iron and manganese by microorganisms in rapid sand filters (in situ investigations). Wat. Supply 3(1), 111– 123.
7. Degremont 1991 Water Treatment Handbook, 6th edn (1 and 2).
8. Degremont, France.
9. Official Journal of the European Communities. December 5 1998; Council Directive 98/83/EC on the quality of water intended for human consumption. L330/32 – L330/50.
10. Ehrlich, H. L. 2002 Geomicrobiology, 4th edn. Marcel Dekker, New York.
11. Frischherz, H., Zibuschka, F., Jung, H. & Zerobin, W. 1985 Biological elimination of iron and manganese. Wat. Supply 3(1), 125 –136.
12. Gage, B., O'Dowd, D. H. & Williams, P. 2001 Biological iron and manganese removal: pilot and full scale applications. Presented at the Ontario Water Works Association Conference, 3

May, 2001. See http://www.degremont.ca/en/biological.pdf

13. Hatva, T. 1988 Treatment of groundwater with slow sand filtration.
14. Wat. Sci. Technol. 20(3), 141 –147.
15. Hatva, T. 1989 Iron and Manganese in Groundwater in Finland: Occurrence in Glacifluvial Aquifers and Removal by Biofiltration. National Board of Waters and Environment, Helsinki, Finland.
16. Hedberg, T. & Wahlberg, T. A. 1998 Upgrading of waterworks with a new bio-oxidation process for removal of manganese and iron. Wat. Sci. Technol. 37(9), 121 –126.
17. Hughes, M. N. & Poole, R. K. 1989 Metals and Microorganisms.
18. Chapman and Hall, London.
19. Lerk, C. F. 1965 Enkele aspecten van de ontijzering van grondwater. PhD Dissertation Technical University Delft, The Netherlands (in Dutch).
20. Michalakos, G. D., Nieva, J. M., Vaynes, D. V. & Lybertos, G. 1997 Removal of iron from potable water using a trickling filter. Wat. Res. 31(5), 991–996.
21. Morris, T. & Siviter, C. L. 2001 Application of a biological iron removal process at Grove Water treatment works. J. CIWEM 15, 117 –121.