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Removal of iron and manganese using biological roughing up flow filtration technology

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Abstract

The removal of iron and manganese from groundwater using biological treatment methods is almost unknown in Latin America. Biological systems used in Europe are based on the process of double rapid biofiltration during which dissolved oxygen and pH need to be strictly controlled in order to limit abiotic iron oxidation. The performance of roughing filter technology in a biological treatment process for the removal of iron and manganese, without the use of chemical agents and under natural pH conditions was studied. Two pilot plants, using two different natural groundwaters, were operated with the following treatment line: aeration, up flow roughing filtration and final filtration (either slow or rapid). Iron and manganese removal efficiencies were found to be between 85% and 95%. The high solid retention capability of the roughing filter means that it is possible to remove iron and manganese simultaneously by biotic and abiotic mechanisms. This system combines simple, low-cost operation and maintenance with high iron and manganese removal efficiencies, thus constituting a technology which is particularly suited to small waterworks.

Keywords: Groundwater; Iron; Manganese; Iron oxidizing bacteria; Manganese oxidizing bacteria; Roughing filtration

1. Introduction

Iron (Fe) and manganese (Mn) cause aesthetic, organoleptic and operating problems when they are present in groundwater. These metals consume chlorine in the disinfection process and promote biofouling and microbiological induced corrosion in water networks.

In groundwater, Fe and Mn are present as Fe(II) and Mn(II). The processes available for their removal are either physico-chemically or biologically based. The advantages of biological treatments compared with conventional physico-chemical treatments can be summarized as follows: no use of chemicals, higher filtration rates, the possibility of using direct filtration and lower operation and maintenance costs (Mouchet, 1992).

Fe and Mn removal by biological processes are based on different stages of biofiltration where beds are colonized by Fe–Mn oxidizing bacteria. In nature, iron oxidizing bacteria (IOB) and manganese oxidizing bacteria (MnOB) are widespread. They are prevalent in groundwater, swamps, ponds, in the hypolimnion of lakes, in sediments, soils, wells and water-distribution systems. In the latter they can cause significant clogging problems (Ghiorse, 1984). These bacteria which are present in raw water can multiply in sand filters under

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appropriate conditions and are able to oxidize divalent ions Fe(II), Mn(II) and precipitate them under their oxided forms Fe(III) and Mn(IV).

IOB and MnOB, studied since the late eighteenth century, have been recognized for their ability to deposit Fe hydroxide or Mn oxide in structures outside their cells. Many researchers have studied the physiology of these microorganisms and the mechanisms involved (Van Veen et al., 1978; Ghiorse, 1984; Hallbeck and Pedersen, 1991; Corstjens et al., 1992; Søgaard et al., 2000). However, many aspects of Fe and Mn deposition are still poorly understood.

The main groups of IOB are (Czekalla et al., 1985; Mouchet, 1992):

- stalked bacteria, e.g. *Gallionella* sp., which are chemolithotrophic and microaerophilic,
- sheathed bacteria, e.g. *Leptothrix* sp., *Sphaerotilus*, etc., which are facultative autotrophic-heterotrophic,
- unicelular bacteria, e.g. *Siderocapsa*, *Siderocystis*, etc., which are heterotrophic and more difficult to recognize by microscopic observation than the previous ones.

With the exception of the stalked bacteria (*Gallionella*), which oxidizes only Fe, MnOB include the major groups reported for the IOB. Some of the species of the genera *Leptothrix*, *Crenothrix*, *Hyphomicrobium*, *Siderocapsa*, *Siderocystis*, and *Metallogenium* can even oxidize Fe or Mn indifferently. Other bacteria oxidize only Mn, e.g. *Pseudomonas manganoxidans* (Mouchet, 1992).

The bacteria involved in biological Fe and Mn removal need different pH and redox potential (Eh) conditions for each metal, as is shown in Fig. 1, a Pourbaix diagram.

IOB may be completely aerobic or microaerophilic, depending on the pH, whereas MnOB require a fully aerobic environment (DO > 5 mg/l) to precipitate Mn (Mouchet, 1992; Gislette and Mouchet, 1997).

Nowadays biological processes to remove Fe and Mn are widely used in Europe, and there are some treatment plants in the United States and Canada (Mouchet, 1995; Gage and Williams, 2001) but they are almost unknown in Latin America (Pacini et al., 2003). In general, patented systems used for the removal of these two metals include: initial aeration followed by rapid filtration for Fe removal and secondary aeration, pH adjustment and secondary rapid filtration for Mn removal (Czekalla et al., 1985; Mouchet, 1992; Gislette and Mouchet, 1997). The above-mentioned systems need sophisticated devices to control DO, pH and Eh in order to limit abiotic Fe oxidation. Because of differences in

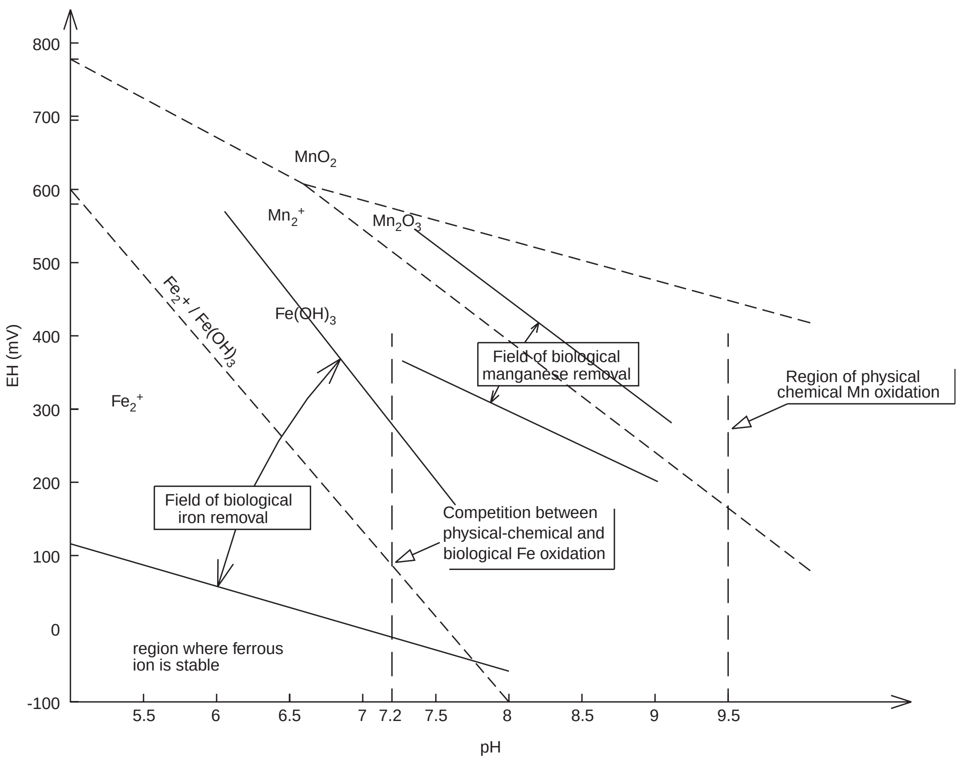

Fig. 1. Field of activity of Fe and Mn oxidizing bacteria in a pH-Eh diagram (Mouchet, 1992).