Groundwater Treatment: Iron and Manganese Removal by Biological Filtration

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Abstract: At present, one of the most important challenges for the world is to provide access to safe and clean water for the entire population. Lack of water can have a negative impact on human health. Therefore, finding ways to solve this problem is of utmost importance. Fe and Mn are abundant in the Earth's crust making it one of the most common pollutants for groundwater. This paper focuses on the biological filtration method that uses bacteria to remove Fe and Mn from groundwater. It also covers the groundwater characteristics, Fe and Mn pollution sources and the way it affects human health. The main objective of this work is to present the biological filtration method as a simple, low-cost operation and maintenance with Fe and Mn removal efficiencies between 85% to 95%. In this manner, a suitable technology for small waterworks is achieved, which is particularly suited for people in rural areas or small cities.

Index Terms— Bacteria, biological filtration, Fe and Mn, groundwater, water treatment

I. Introduction

According to the NAE Grand Challenges for Engineering 2017 booklet, access to clean water for the entire population is a serious challenge for today's world. In developing countries, such as Argentina, there are places where people can access only groundwater due to several reasons such as the lack of infrastructure to connect to a water network, the distance from a fresh water source for cities and towns, or the lack of investments from the governments for water treatment. Although groundwater may be a solution, it is usually contaminated not only by naturally occurring poisonous pollutants but also by human-caused contamination.

As a result of these natural or anthropogenic pollution sources, groundwater is often contaminated with iron (Fe) and manganese (Mn) ions. Above specific levels, Fe and Mn dissolved in water can have an unfavorable impact on both the environment and humans [1]. Therefore, engineers have been developing different treatments to remove these chemicals.

At present, there are two types of processes for their removal, namely, the traditional physico-chemically based or the biologically based process. The former is a method that relies on the chemical theory of contact oxidation of Fe and Mn and uses strong oxidants that are overly expensive [2]. Instead, the latter is a biological filtration method which only uses bacteria to remove Fe and Mn from groundwater. Thus, the biological treatment has multiple advantages over conventional treatment, as it is mentioned later.

The aim of this paper is to analyze the biological filtration method to remove Fe and Mg from groundwater. In order to achieve this aim, the first section of this paper describes groundwater and the way it affects human health if it is contaminated with Fe and Mn. The second section introduces the characteristics of the biological filtering method describing the stages and materials used in the treatment. To conclude, the advantages and disadvantages over traditional methods of Fe and Mn removal will be presented.

II. Iron and Manganese in Groundwater

A. Groundwater Characteristics

Water found underground is known as groundwater and it is stored in aquifers, which are geologic formations of gravel, sand, sandstone, and rocks (Fig. 1). Groundwater can be

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The present manuscript is part of the research activities in the Inglés II lesson at Universidad Tecnológica Nacional, Facultad Regional Paraná. Students are asked to research into a topic so as to shed light on a topic of their interest within the National Academy of Engineering's Grand Challenges or the United Nations' Sustainable Development Goals frameworks. If sources have not been well paraphrased or credited, it might be due to students' developing intercultural communicative competence rather than a conscious intention to plagiarize a text. Should the reader have any questions regarding this work, please contact Graciela Yugdar Tófalo, Senior Lecturer, at gyugdar@frp.utn.edu.ar

brought to the surface naturally or can be extracted by pumps from wells drilled in the aquifer. “In areas where the material above the aquifer is permeable, pollutants can readily sink into groundwater supplies”, and it will no longer be safe to drink if gets polluted [4].

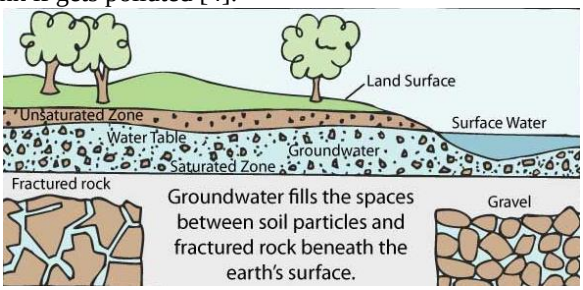

Fig. 1. Groundwater [4]

Two of the most common contaminants found in water are Fe and Mn and they can come from various natural and anthropogenic sources. Fe and Mn ions in water resources are caused by industrial wastewater, including sources from mining, pesticides, organic chemicals, rubber and plastics, lumber and wood products, metal processing, tanneries, and pharmaceuticals. Also, domestic sewage, waste from livestock and farms, runoffs from farms and towns, silt from earthworks, leachate from rubbish dumps, litter from riverside squatters and mining waste [1].

In addition, as groundwater moves through rocks and subsurface soil, it can dissolve minerals containing Fe and Mn and store them in solution. This is a natural source of Fe and Mn contamination [1].

Iron and Manganese in groundwater are found dissolved in the form of divalent ions -Fe (II) and Mn (II) (Iron Oxide and Manganese Oxide respectively) [3]. When exposed to air, Fe and Mn react forming dark precipitates and water becomes dull and brown-red colored, which is problematic for consumption (Fig. 2) [1].

Fig 2. Water contaminated with Fe and Mn

B. Effects of High Concentrations of Iron and Manganese in Human Health

Fe and Mn are two toxic environmental pollutants easily found in the lithosphere. These pollutants can lead to significant impacts on human health through people drinking that contaminated groundwater [5].

Although Fe is an important mineral for the human body and the consumption between 0.4 - 1.0 mg Fe/kg body weight per day of Fe does not cause discomfort in a healthy person, exceeding those limits can cause several health problems. These minor to severe health issues include anorexia, diarrhea, diphasic shock, metabolic acidosis, vascular congestion of the gastrointestinal tract, brain, spleen and thymus, and death. On the other hand, concentrations of Mn over 0.05 mg/L affect the central nervous system and can cause lung, liver, and vascular disturbances, including a decrease in blood pressure, and brain damage [1].

In Argentina, current regulations establish the recommended limits of Fe and Mn in water. Those limits are 0.10 mg / l and 0.05 mg / l respectively for Fe and Mn [3].

III. BIOLOGICAL FILTRATION

A. Characteristics of the Method

The traditional methods used to remove Fe and Mn ions from groundwater can be both physical and chemical methods. These methods can be ultrafiltration, coagulation-flocculation, activated carbon, among others. These processes add other chemical compounds to water to increase the Fe and Mn removal performance. This implies additional operating costs as well as the generation of polluting chemical sludge [1].

The removal of Fe and Mn by biological filtration is based on contact oxidation of iron and manganese oxidizing bacteria [5]. These bacteria are widespread in nature and are known as Iron Oxidizing Bacteria (IOB) and Manganese Oxidizing Bacteria (MnOB). Some of them can oxidize Fe and others only Mn, but those used in this method can oxidize both Fe and Mn indifferently and belong to the species of the genera *Leptothrix*, *Crenothrix*, *Hyphomicrobium*, *Siderocapsa*, *Siderocystis*, and *Metallogenium* [3].

The method consists of three defined stages. The first one is the aeration of the raw water using a trickling filter. Secondly, the water passes through an up flow roughing filter and finally the process ends with a rapid sand filtration (Fig.3). The process can be carried out at natural pH and Eh (Oxidation/Reduction Potential), without using special devices to control DO (dissolved oxygen).

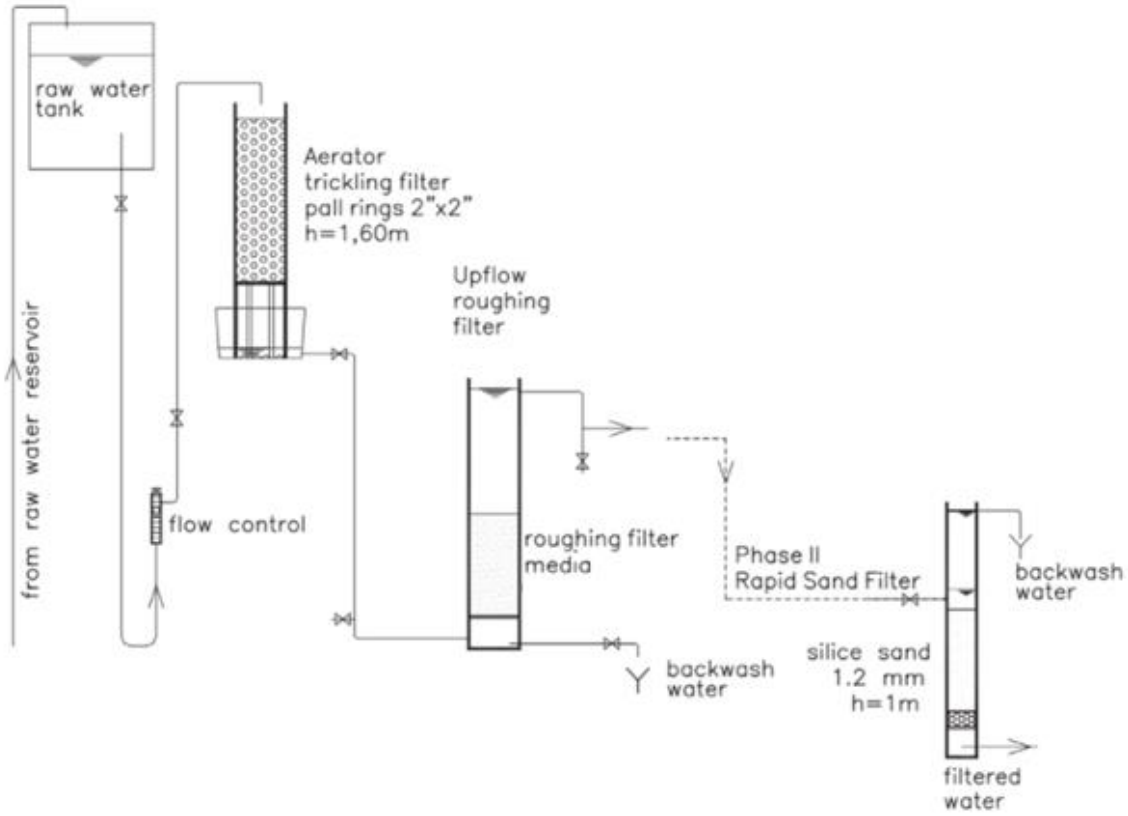

Fig 2. Biological filtration plant [3]

In the sand filters the bacteria can multiply themselves and therefore oxidize Fe (II) and Mn (II) ions and precipitate them under their oxidized forms Fe (III) and Mn (IV). As Fe and Mn are precipitated, they are captured by the different filters, resulting in suitable water for human consumption at the end of the process [3].

B. Advantages of Biological Filtration

The biofiltration method has advantages over traditional methods as it is a viable and economical alternative since qualified personnel are not required for the operation and maintenance of biological filtration treatment plants. This method does not use chemicals to remove Fe and Mn at any stage. Instead, it uses Fe and Mn oxidizing bacteria, that also makes it an economical alternative.

As well as this, the biofiltration technology presented provides a more compact treatment plant and smaller space requirements; thus, it is particularly suited to small waterworks. This provides the possibility that biofiltration plants can be used to treat drinking groundwater supplies in small and rural communities [1].

In addition to such benefits, this method not only functions under natural conditions and without using any chemical agents, but also the Fe and Mn removal efficiency levels are between 85% and 95%. This efficiency is obtained in large part using up-flow rough filtration in the treatment line, where a very high metal removal efficiency is obtained, since it simultaneously removes Fe and Mn in one step. Another advantage is that the biofiltration does not require any sophisticated control of pH, Eh, and DO [3].

C. Disadvantages of Biological Filtration

Despite being an efficient and economical alternative to traditional methods, the biofiltration method has a few disadvantages. The most important disadvantage is that it requires a large space to purify significant quantities of water than the traditional methods. Therefore, this method demands large quantities of filter media.

Additionally, this method can be considered slower than the conventional treatments since the filtration runs are long, coming to last 30 days in the rapid sand filter. Finally, this method demands manual labor to clean the filtering tanks which stops the purification process for a considerable amount of time [1], [3].

IV. CONCLUSION

Although the treatment of groundwater for the removal of iron and manganese by biological filtration hasn't proven to be faster than the chemical method, the enormous advantages of this process cannot be ignored. The method of iron and manganese precipitation by bacteria is a very effective and environmentally friendly method.

In this article the biological filtration method to remove Fe and Mn from groundwater have been presented. As shown, Fe and Mn are two common pollutants in groundwater since they come from diverse sources. These chemicals have a negative impact on the human health when they are consumed through water, so their removal is necessary.

The biological filtration is an alternative method that has multiple advantages, not only that function without the

addition of chemicals, but also that is a simple process that not requires sophisticated control and operator skills. These advantages make this method the best option for the purification of groundwater in rural areas.

There are still disadvantages when trying to bring this method to plants that process large volumes of water per day. However, it is quite possible that, in the future, using new technologies and filtering techniques, the disadvantages of this process can be solved.

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