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Iron removal using an aerated granular filter

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Abstract

Laboratory scale experiments concerning iron removal from artificial raw water by an artificial filter using anthracite as filter media were conducted. The major findings were that iron oxidation and removal by an aerated filter is mainly a catalytic chemical reaction rather than a biological reaction. Further, iron removal does not perform effectively without aeration. Iron removal was very effective when the pH was weakly acidity. Iron oxide attached to the surface of the media is identified as ferrihydrite, which catalyzes the oxidation of iron as shown by Mössbauer spectra analysis.

Keywords: Iron removal; Anthracite; Iron oxidation; Catalytic chemical reaction; X-ray diffraction; Mössbauer; Ferrihydrite

1. Introduction

Iron in drinking water and water supplies causes problems, such as giving reddish colour and odour. In general, iron exists in soluble from as ferrous iron and is converted to insoluble ferric iron before removal is achieved. There are several methods for removal of iron used in water purification processes. In this study, iron removal by aerated filter [1] under different conditions of filtration velocity, aeration volume, pH and temperature was investigated. The crystalline structure of iron oxide attached to the filter media was analyzed using X-ray diffraction method and Mössbauer spectra analysis.

2. Materials and methods

Fig. 1 shows the experimental set up. The laboratory scale reactor is a circular column of height of about 114 cm filled with anthracite media size varying from 3.36 to 4.00 mm. Raw water containing ferrous iron (pH 7.0–8.5) was fed to the column from the top of the reactor. Sodium hydrosulphite was added to remove the residual chlorine in the raw water. Air was supplied through an aerator located at about 100 mm from the bottom column. The water level was controlled by head loss. Sampling ports were located at 10–20 cm intervals and water samples were taken from the centre of the cross-section through a stainless steel tube of 3 mm inner diameter. Alkalinity, pH, dissolved oxygen, total iron and ferrous iron were monitored. X-ray analysis and Mössbauer spectra analysis were conducted to investigate the crystalline structure of solids attached on the surface of the anthracite media.

3. Results and discussion

3.1. Iron oxidation in weak-alkalinity

Raw water controlled at pH 7.0–8.5 was fed to the column at a constant rate until the filter was clogged. Fig. 2 shows a sample result of the experiments. In this study, ferrous iron was completely converted to ferric iron, but total iron in the effluent remained at the level of 1.0–1.5 mg l^{-1}. Total iron removal rate profiles were parallel to ferrous iron concentrations, and this is observed under conditions of filtration velocity 100–200 m d^{-1} and aeration rate between 91.5 and 366 m d^{-1}.

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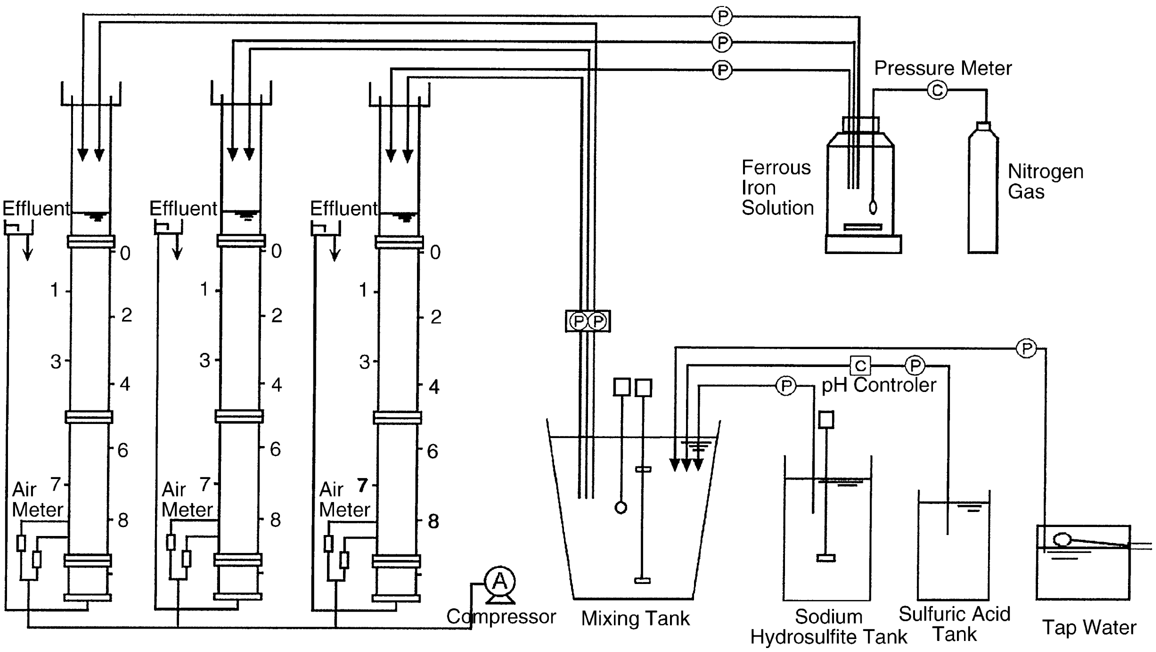

Fig. 1. Experiment set up.

3.2. Oxidation velocity of ferrous iron

Logarithmic plots of ferrous iron concentration versus distance from the top of the filtration layer are linear. As a result, the relationship between ferrous iron concentration and retention time is described as follows:

$$\ln\left(\frac{F_{\mathrm{I}}}{F_0}\right) = -\mu' \cdot z \tag{1}$$

The following equation is proposed:

$$\frac{\mathrm{d}F_{\mathrm{I}}}{\mathrm{d}z} = -\mu' \cdot F_{\mathrm{I}} \tag{2}$$

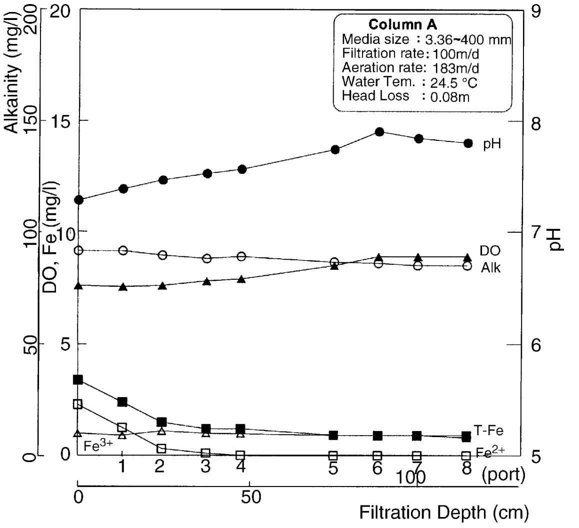

Fig. 2. Iron oxidation in weak-alkalinity.

The relationship between retention time and ferrous iron oxidation rate is described as follows:

$$\frac{\mathrm{d}F_{\mathrm{I}}}{\mathrm{d}t} = -\mu' \cdot v \cdot F_{\mathrm{I}} = -\mu \cdot F_{\mathrm{I}} \tag{3}$$

where F_{I} is the ferrous iron concentration (mg l^{-1}); F_0 the initial ferrous iron concentration (mg l^{-1}); z the distance from the top of the filtration layer (m); μ' the ferrous iron oxidation coefficient (m^{-1}); μ the ferrous iron oxidation rate coefficient (h^{-1}); t the void space retention time (h); v is the filtration rate (m h^{-1}).

The value of ferrous iron oxidation coefficient μ' is given as the slope of the line, and ferrous iron oxidation rate coefficient μ is calculated using the value.

3.3. Removal rate of total iron

As described above, total iron remained in the effluent to some extent at higher pH. F_{f} indicates the total iron concentration in the effluent, and F the total iron concentration at each sampling point. A straight line was obtained by plotting the difference between F_{f} and F and the retention time in the filter on semi-logarithmic graph. This relation ship may be written as follows:

$$\ln\left(\frac{F - F_{\mathrm{f}}}{F_0 - F_{\mathrm{f}}}\right) = -\lambda' \cdot z \tag{4}$$

this equation is rewritten as follow:

$$\frac{\mathrm{d}F}{\mathrm{d}t} = -\lambda' \cdot v \cdot (F - F_{\mathrm{f}}) = -\lambda \cdot (F - F_{\mathrm{f}}) \tag{5}$$