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AFFORDABLE WATER SUPPLY AND SANITATION



## Biological iron and manganese removal

*Dr Mohd Azraai Kassim, Department of Environmental Engineering, UTM, Malaysia.*

IRON AND MANGANESE in objectionable concentrations are present in many water supply sources. Alone or in combination with the other, they may cause serious impairment of water quality. They are natural constituents of the earth's crust and found in both surface and groundwater, but predominant in the latter. The concentrations of these elements in groundwater are influenced by the geological structure of the soil and rocks formation, the hydrological conditions of the area, the physical and chemical make-up of the surrounding rocks and soil, and the presence of microorganisms. The last two are the most important dictating factors (Kothari, N., 1988). Iron and manganese exist in soil as insoluble forms of ferric oxide ( $\text{Fe}^{3+}$ ) and manganese dioxide ( $\text{Mn}^{4+}$ ), and they do not dissolve in water containing oxygen. When water percolates through soil, it is deprived of oxygen because the soil contains organic materials and aerobic organisms. In the absence of oxygen, iron and manganese would be reduced into soluble  $\text{Fe}^{2+}$  and  $\text{Mn}^{2+}$  states. Their presence has long been a serious problem in planning the water sources, determining the method of treatment and maintenance of the water supply system (ASCE & AWAA, 1990). This is evident in water treatment works with raw water source extracted from aquifers. Elevated levels of iron and manganese in drinking water will not pose health hazards apart from undesirability due to precipitation which stains clothes and utensils, corrosion of cast-iron and steel pipelines which produces "red-water" (Sawyer & McCarty, 1967). They may also impart a metallic, bitter, astringent or medical taste to water.

Kota Bharu, located on the north-east coast of Peninsular Malaysia, extracts water from the aquifer for supply. Water is extracted from five main wellfields. There were a total of 48 wells in 1992 and 16.54 MGD of water was extracted in 1987. Tanjung Mas, one of the wellfields, faces the worst problem with iron and manganese because of the depth of the aquifer.

The treatment systems consist of aeration (cascading), flocculation, sedimentation, filtration (pressure filter) and chlorination before dissemination. Analysis of samples showed that the treatment systems did not produce potable water complying to the standards (WHO International 1958) of 0.3 mg/l and 0.1 mg/l for iron and manganese respectively. The results were; with respect to iron, 1.8 - 12.0 mg/l for raw water and 0.06 - 6.00 mg/l after treatment and with respect to manganese, 0.01 - 0.15 mg/l for raw water and 0.01 - 0.10 mg/l for treated water (Ghazali, H., 1993).

Although numerous methods have been used to remove both metals from drinking water sources, they can be broadly categorised as either physical-chemical processes or biological processes. Following the successful experiences of biological iron and manganese removal in countries like France and Finland (Seppanen, H.T., 1992), the biological method has been chosen for this study. This paper discusses results of study to develop a simple treatment method for removing iron and manganese using biological reactor system.

### Objectives of study

Kassim & Hamid (1993) reported that removal of iron after biological reactor seeded with iron bacteria showed a consistent decrease. Low flow rates gave better removal than higher flow rates.

The primary objective of this study is to find a biological iron and manganese removal system which is applicable to small units.

The specific objectives are to study the removal efficiencies at various flow rates and types of medium suitable for use in the biological reactor.

### Methodology of study

The apparatus was set up as shown in Figure 1. The treatment consisted of 3 parts i.e. aeration, biological reactor and sand filtration. The effluent from each part of the treatment was collected after 4 hours for analysis. The parameters analysed were conductivity and temperature using the conductivity/TDS meter (HACH), dissolved oxygen using DO meter (Orion 820) and pH using Horiba Model D-12E. Iron and manganese were analysed using DR 3000 spectrophotometer. The flow rates were varied, and for each flow rate the experiment was repeated for 6 consecutive days. To simulate water condition as in the field,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  and  $\text{MnCl}_2$  were added to tap water to give concentrations of approximately 10 mg/l and 1.0 mg/l of iron and manganese respectively.

Iron bacteria was isolated by using Isolation Medium and inoculated onto the surfaces of the medium in the biological reactor. The bacteria was isolated in a medium prepared by using the basic ingredients in 1.5% agar. The type and strain of bacteria were determined by staining preparation & fixation, and negative staining. During the study, manganese bacteria failed to be isolated due to lack of ingredients for its culture.

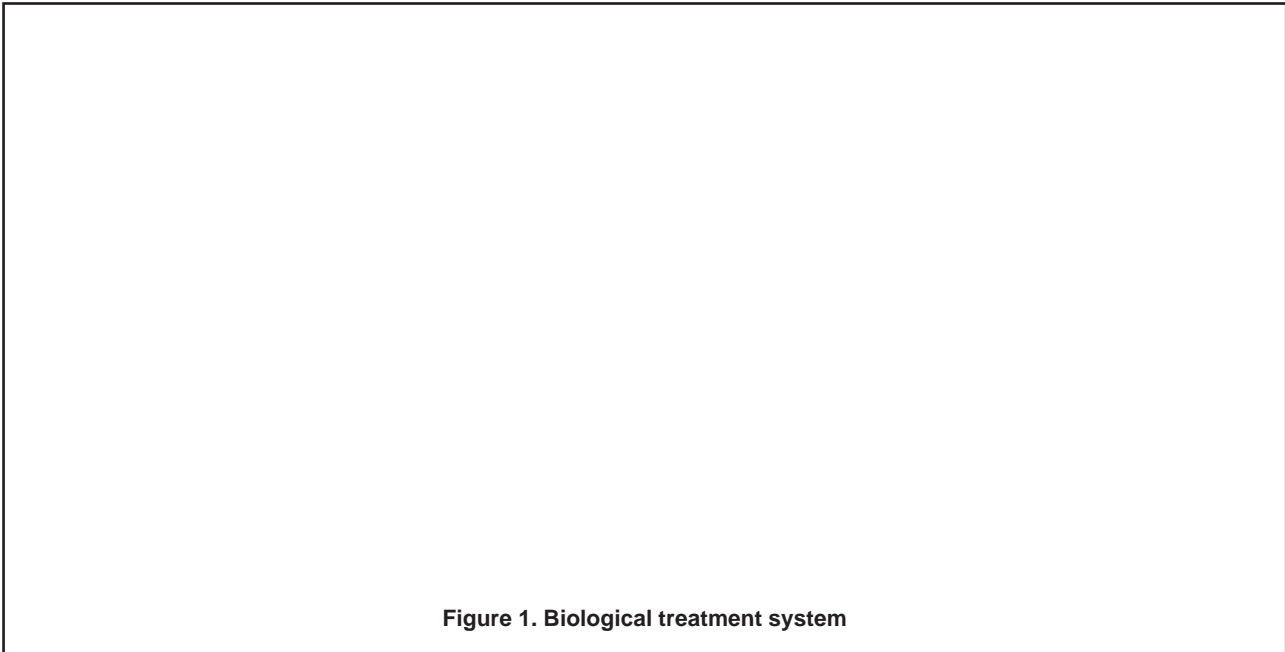


Figure 1. Biological treatment system

In the first phase of the experiment, cascade aeration was used. After aeration, the water passed through the biological reactor with granite medium followed by sand filter 115 mm thick. The flow rates were varied from 150 to 200, 250, 300 and 350 l/day.

The next phase of the experiment was by using cascade aeration followed by biological reactor with limestone medium. Then the water passed through sand filter 160 mm thick. The flow rates were varied from 150 to 200, 300, 350 and 400 l/day. Aziz, H.A. (1993) reported that in their batch scale studies, limestone gave 95 % removal of manganese.

The final phase of the experiment was done by aeration by cascading together with bubbling. Air at a rate of 850 ml/min was pumped through air-stone placed 25 mm from the bottom of the aeration tank forming bubbles. After aeration the water passed through the biological reactor with limestone medium followed by sand filter 160 mm thick. The flow rates were varied from 150 to 200, 300, 350 and 400 l/day.

### Results and discussion

The performance of the biological reactor with regards to iron and manganese is given in Table 1 and graphs in Figure 2 & 3. The removal of iron was higher in the case of limestone preceeded with bubbling (55.56 - 97.18 % at various flow rates) compared to limestone without bubbling (74.96 - 92.70 % at various flow rates). The biological reactor with granite medium showed the least removal (52.33 - 93.23 % at various flow rates).

The flow rates influenced the removal. For all three sets of experiment, the highest removal was at flow rate of 200 l/day. The biological reactor with limestone preceeded with bubbling showed a small decline from the peak with increased Q. This was followed by the biological reactor with limestone without bubbling. The biological reactor with granite showed a sharp decline with increasing Q. All three observations indicated that the removal declined with increase in Q.

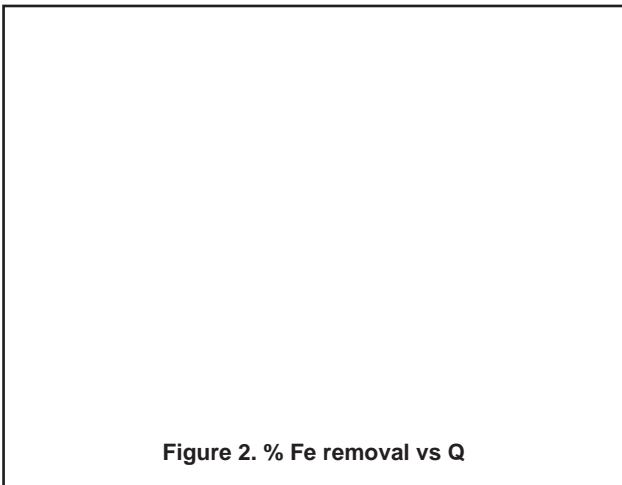


Figure 2. % Fe removal vs Q

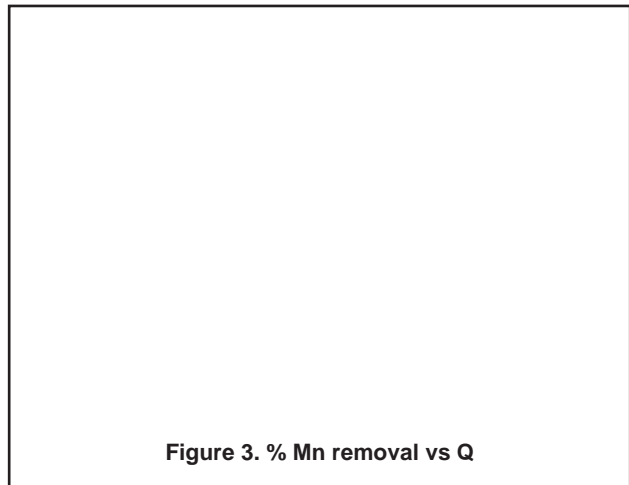


Figure 3. % Mn removal vs Q

**Table 1: % Fe and Mn Removal by Biological Reactor**

Medium (l/day)	Flow rate (Fe mg/l)	Influent (Fe mg/l)	Effluent (Fe)	% Removal Removal(Fe)*	% Overall (Mn mg/l)	Influent (Mn mg/l)	Effluent (Mn)	% Removal Removal(Mn)*	% Overall
Granite	150	9.00	3.33	63.00	86.05	0.80	0.60	25.00	50.00
	200	16.25	1.10	93.23	92.02	0.66	0.70	-	39.76
	250	9.57	0.75	92.16	94.19	0.78	0.66	15.39	49.26
	300	4.00	1.40	65.00	89.57	0.80	0.80	-	70.00
	350	9.23	4.40	52.33	91.36	0.83	0.60	23.00	48.72
Limestone	150	5.57	1.25	77.55	97.33	0.50	0.30	40.00	66.67
	200	8.63	0.63	92.70	98.73	0.70	0.50	28.57	42.86
	300	6.70	0.65	90.30	97.93	0.60	0.60	-	42.86
	350	7.60	1.08	85.78	94.17	1.00	0.40	60.00	71.42
	400	6.71	1.68	74.96	92.83	0.60	0.50	16.67	57.14
Limestone & Bubbling	150	9.00	4.00	55.56	99.73	0.50	0.30	40.00	98.33
	200	8.88	0.25	97.18	98.05	0.70	0.50	28.57	57.14
	300	9.28	0.48	94.82	99.73	0.80	0.70	12.5	50.00
	350	6.65	0.28	95.79	99.41	0.90	0.70	22.22	54.55
	400	6.38	0.75	88.25	99.36	0.70	0.70	-	50.00

(\*) whole treatment

The removal of manganese for all three sets of experiment was low. The graph in Figure 3 shows that the removal was not consistent and fluctuated with increasing Q. For granite the removal was between 15.00 - 25.00 %, limestone 16.67 - 60.00 % and limestone with bubbling 12.5 - 40.00 % at various flowrates. Manganese bacteria was not seeded in the biological reactor and this could be the probable reason why the removal was low.

### Conclusion

The biological reactor with limestone medium seeded with iron bacteria is an efficient method for removing iron in water. Added aeration by bubbling for pretreatment would enhance the removal. The optimum flow rate to achieve a good removal is 200 l/day.

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