Removal of Iron and Manganese from Riverbed-filtrated Water using Manganese Sand

Nguyen Hoang Lan · Kyung-Hoon Moon* · Woo-Bum Lee**
Sung-Ug Kim** · Soo-Ho Park**,†

Faculty of Fisheries, University of Agriculture and Forestry Ho Chi Minh City
**K-water Institute*
***Department of Environmental System Engineering, Chonnam National University*

(Received 25, October 2016, Revised 14, November 2016, Accepted 28, November 2016)

망간사를 이용한 강변여과수의 철 및 망간 제거

Nguyen Hoang Lan · 문경훈* · 이우범** · 김성욱** · 박수호**,†

호치민 농업산림대학교 수산학부 · *한국수자원공사 · **전남대학교 환경시스템공학과

(2016년 10월 25일 접수, 2016년 11월 14일 수정, 2016년 11월 28일 채택)

Abstract

본 연구에서는 망간사를 이용하여 대해서 철 및 망간 제거 특성을 조사하였다. 대상시료는 철 및 망간의 함량이 10 mg/L, 2 mg/L가 되게 조제한 합성여과수와 A강에서 채수한 강변여과수를 사용하였다. 정적 및 동적 컬럼실험을 통해 최종 처리수가 한국의 음용수 수질 기준인 망간(Mn) 0.05 mg/L, 철(Fe) 0.3 mg/L를 만족하는지 여부를 검토하였다. 정적실험조건에서, 망간사의 철 및 망간의 제거 효율은 합성여과수 97.8%, 강변여과수 96.2%의 높은 제거효율을 나타내었으며, 철의 제거에 대해서는 합성여과수 99.5%, 강변여과수 98.9%의 제거율이 측정되었다. 동적컬럼실험결과, 합성여과수과 강변여과수 대해 망간사의 제거율은 매우 높게 나타났으며, 한국의 음용수 수질 기준을 만족하였다.

Keywords : 망간사, 철, 망간, RBW

1. Introduction

Generally, the quality of the groundwater in the natural is higher and better than the surface water, making the groundwater a better source for tap water. However, in Korea the surface water is a major source for drinking water because the amount of the groundwater is limited. But, the high level water purification process become a necessity due to the deterioration of surface water quality and the surface water pollution. Because of the high cost water treatment and public concerns for environment, the decision makers decided to use the riverbank-filtered water as an alternative to the surface water[1].

Drinking water originating from riverbank

†Corresponding author E-mail: abel@jnu.ac.kr

filtration provides considerable fractions of the overall drinking water production in several European countries (Netherlands 7%; Germany 16%; Hungary 40%; Finland 48%; France 50%; Switzerland 80%)[2-3]. At Korea, Changwon city is the first city started supplying domestic water treated through riverbank filtration in 2001[4].

But some problems may occur; after a long period of pumping and filtering, the water level fluctuations and the high concentration of some chemical such as iron and manganese can cause clogging in wells affecting the amount of water influx as well as its quality[1].

Until now several treatment methods for the removal of iron and manganese for the safe drinking water have been developed such as precipitation, chemical precipitation, ion exchange, oxidation-filtration, adsorption, and membrane process, etc[5]. These conventional methods are usually high capital cost, high operational cost, high energy consumption, complicated in large scale and low removal efficiency. Among effective methods for removing iron and manganese compounds, oxidation-filtration method and absorption are acceptable method.

In the present study, Manganese sands were used to remove iron and manganese from the riverbank-filtered water of river in Korea.

The aim of this study is first to remove iron, manganese from riverbank-filtered water to satisfy the Korean drinking water standards (iron ≤ 0.3 mg/L; manganese ≤ 0.05 mg/L). The second aim is to determine the potential and the effectiveness of Manganese sand in removing iron and manganese from the synthetic water and the riverbank-filtered water. The effects of contact time and adsorbent amount on the removal of iron(Fe) and manganese(Mn) have been reported.

2. Materials and methods

2.1. Materials

Materials that were used in this study were Manganese sand (Birm) which supplied by the Clark Corporation (USA). Solution of Fe (II) and Mn (II) were prepared from ferrous ammonium sulfate hexahydrate, $(NH_4)_2Fe(SO_4)_2{\cdot}6H_2O$ (Showa chemical, Japan) and Manganese Nitrate hexahydrate $Mn(NO_3)_2{\cdot}6H_2O$ (Kanto Chemical, Japan). For each experiment, the synthetic water sample containing mixed metals 10 mg/L Fe and 2 mg/L Mn was prepared based on riverbank-filtered water metal concentration. Riverbank-filtrated water was collected from river A.

2.2. Methods

2.2.1. Static experiment

The static experiment as performed in a wide variety of conditions including variation in sorbent dosages and sharking time. The prepared solutions were added into shaker flasks with different amounts of adsorbent and contact time. After contact time, the supernatant liquid of solution were withdrawn and the concentration of Fe ions and Mn ions were determined.

2.2.2. Dynamic experiment

Dynamic experiments were performed as follows: following Fig. 1, raw water flowed into the filtration column from the reservoir water at a filtration rate of 10 mL/min. After the filtration, the filtered water in the first 10 minutes was not kept to prevent some impurities affect to analysis result. About 300 mL of the effluent were measured total iron and total manganese concentrations.

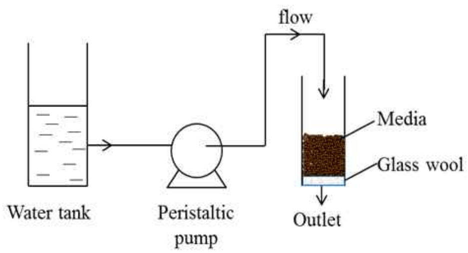

Fig. 1. Schematic diagram of filtration experimental set-up.

2.3. Analysis

During all experiments total iron and manganese values were measured following the "Standard Methods for the Examination of Water and Wastewater". The total manganese measurements were done with a DR/2500 Spectrophotometer (Hach Company, USA) by the method 8149, with range 0.007~0.7 mg/L. All spectrophotometer measurements of total iron were recorded using a Shimadzu Model UV-2450 Spectrophotometer (Shimadzu Corpor-ation, Japan) by the Korean standards method ES05410.1, and the limit iron concentration is 0.05 mg/L (accuracy: 75~125%).

3. Reuslts and discussion

3.1. Synthetic solution

To design the optimum treatment systems, a series of batch experiments was conducted by using a volume of Manganese sand (dosage: 4~60 g/L) and test synthetic solution at pH solution 4.5.

Fig. 2 show that Manganese sand was sufficient for removal of the two metals of Fe (10 mg/L) and Mn (2 mg/L) in synthetic solution to satisfy the Korean drinking standard. A further increase of Manganese sand dosage (4~60 g/L) would not have any significant effect on the removal of iron from the synthetic solution. However, followed by the increasing of Manganese sand dosage, the removal percentage of Mn was increased. It is suggested that, the optimum dosage for both iron and manganese removal is 20 g/L. Although the maximum removal efficiency was found as is 99.5% for iron and 97.8% for manganese at dosage of 60 g/L of sand.

The variations of iron and manganese removal percentage at different contact times with Manganese sand are represented in Fig. 3. The dosage of 40 g/L Manganese sand was added to 5 flasks of 150 mL synthetic water at pH 4.5. These flasks were oscillated during 5, 10, 15, 30, 60 and 120 min. The results show that the equilibrium removal was reached at 10 min for iron, and 30 min for manganese. The result, therefore, suggested that the optimum contact time for removal both iron and manganese is 30 min.

The results showed that Manganese sand has high removal efficiency for iron, which was not depend on the dosage or contact time. This result was consistent with the advantages of Manganese sand in removal of iron, previously reported by Chaturvedi and Dave[5]. However, the removal of manganese using Manganese sand was found to be depended on both the dosage and contact time. This can be explained by the cause the reaction rate of manganese oxidation is

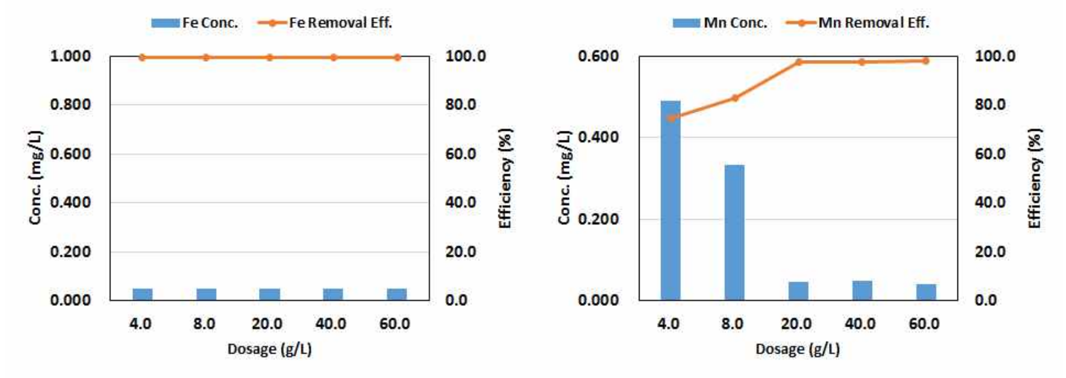

Fig. 2. The effect of dosage on removal efficiency of Fe and Mn from synthetic solution.

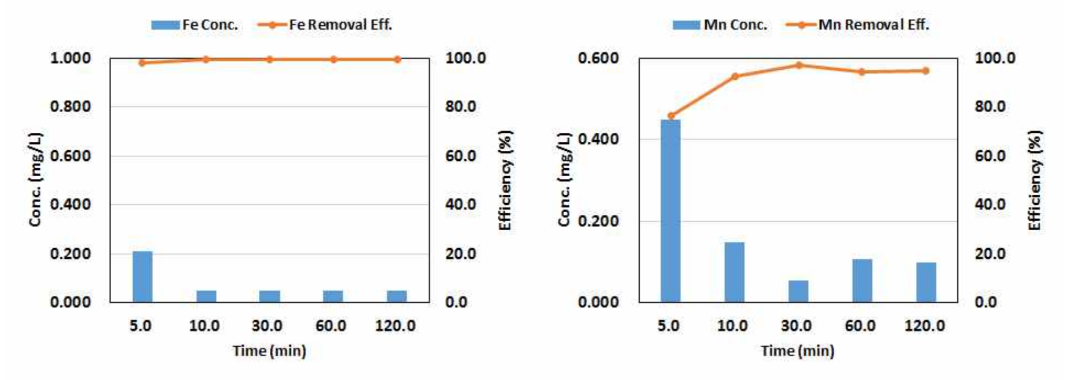

Fig. 3. The effect of contact time on removal efficiency of Fe and Mn from synthetic solution.

slower than iron oxidation, so that manganese oxidation is more difficult than iron oxidation [5].

3.2. Riverbank-filtered water

Similar to the experiment conditions for synthetic solution, the investigation for riverbank-filtered water was performed. To design the optimum treatment systems, a series of batch experiments were conducted with the volume of Manganese sand (dosage: 4~60 g/L) of test riverbank-filtered water a pH 6.28. The maximum removal efficiency of 98.9% for iron and 96.2% for manganese was obtained at dosage 60 g/L of Manganese sand(Fig. 4).

In the removal experiment for iron from synthetic solution (initial concentration: 10 g/L), the optimum of removal efficiency was obtained at dosage 4 g/L of Manganese sand. For the initial of riverbank-filtered water of 4.39 g/L, the optimum of removal efficiency was achieved at dosage 20 g/L of Manganese sand.

For removal manganese from synthetic solution, at the dosage 4 g/L of Manganese sand, the removal efficiency was 74.5%. On the other hand, at the same dosage of Manganese sand, the removing manganese from riverbank-filtered water was 85.5%. The reason for this result, perhaps by the pH of water, which is one of the most important

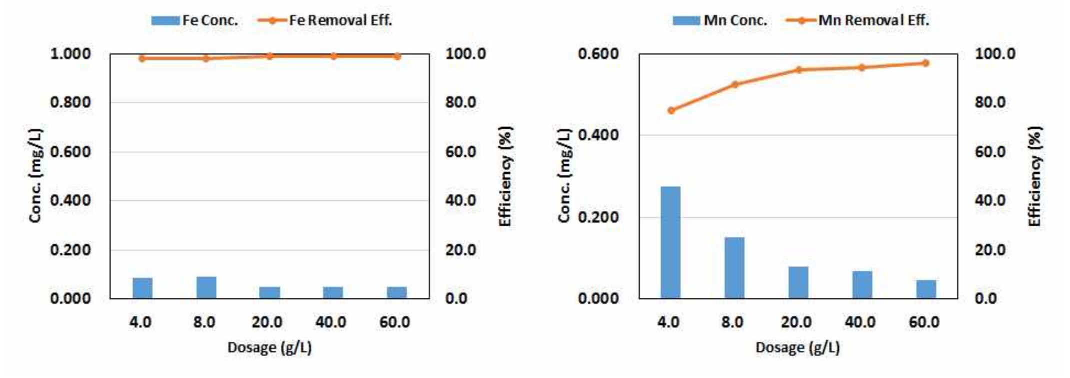

Fig. 4. The effect of dosage on removal efficiency of Fe and Mn from RBW.

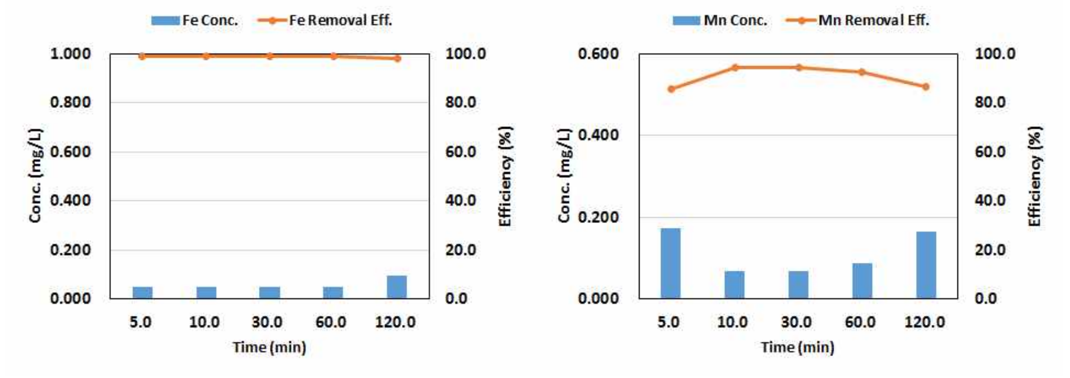

Fig. 5. The effect of contact time on removal efficiency of Fe and Mn from RBW.

factor influencing the oxidation process. Tiwari et al.[6] reported that Manganese coated sand was found to be effective in the removal of manganese ion from synthetic solution in the range pH 7~11. The removing for manganese was higher removal percen -tage when the pH was increased. It is wort noting that Lee et al.[7] reported that, the positive correlation between the removal efficiency of manganese ion and the pH of solution and increasing the pH from 5.0 to 8.0 causes a relatively sharp increase in the uptake of manganese ion.

The variations of iron and manganese removal percentage at different contact times with Manganese sand are represented in Fig. 4~Fig. 5. Dosage 40 g/L of Manganese sand was added to 5 flasks of 150 mL synthetic water at natural pH 6.28. The contact time was changed from 5~120 min (5, 10, 30, 60, 120 min), the difference of removal efficiency of iron were not significantly. However, the optimum of removal efficiency for manganese was achieved at 30 min.

The high sorbent dosage could cause the agglomeration of particles and a consequent reduction in inter-particle distance. They may have also produced a screening effect on the dense outer layer of the particles, which cover the binding sites from metals[8]. It could be one of the reason to explain the residual concentration iron and manganese at 120 min were higher than 30 min.

Phatai et al.[9] investigated the effect of removal Mn and Fe from synthetic ground water by using potassium permanganate at the contact time 0~70 min. They realized that the removal efficiency of iron was higher than manganese because it is easily oxidized in comparison to manganese. And, their results also reported that the removal concentration of iron was not changed by the contact time. But, the maximum removal concentration of manganese was achieved after only 15 min.

3.3. Dynamic column experiment

The obtained results of iron and manganese removal from synthetic solution and riverbank -filtered water(RBW) are presented in Table 1. The concentrations of iron and manganese in the effluent after filtration through the Manganese sand media were 0.05 mg/L, 0.028 mg/L and 0.161 mg/L, 0.021 mg/L for synthetic solution and riverbank-filtered water, respectively. It is noted that the two analyzed metals, iron and manganese were nearly completely removed from both of Synthetic solution and RBW.

4. Colclusions

This study was carried out to investigate the removal efficiency of iron and manganese from synthetic solution and riverbank-filtered water using manganese sand. The result showed high removal efficiency from both of laboratory synthetic solution and riverbank-filtered water. Manganese sand can be used as excellent alternative(s) and inexpensive materials to remove high amounts of iron and manganese in the RBW.

The results of static experiment showed that the removal efficiency of both iron and manganese was increased as the dosage and contact time increase The optimum removal efficiency for synthetic solution was achieved at the dosage of 20 g/L; contact time of 30 min respectively. The optimum dosage and contact time needed to remove Fe and Mn in riverbank-filtered water were found as 60 g/L and 30 min.

The dynamic column experiment for synthetic solution and riverbank-filtered water with flow rate(10 mL/min) was achieved the good result. The concentration of Fe and Mn in the filtrate is significant below the current Korean drinking standard (total Fe content below 0.3 mg/L and total Mn below 0.05 mg/L).

References

1. Lee, S. I., and Lee, S.(2008), Site suitability analysis filtration in the Han River, Korea. Proceedings of the IAHR-APD Congress, pp 236-239. Beijing: Tsinghua University Press.

Table 1. Results from dynamic column test (unit : mg/L)

Metals	Standard	Synthetic solution	RBW
Total manganese	0.05	0.028	0.021
Total iron	0.3	0.05	0.161

2. Tufenkji, N., Ryan, J.N., Elimelech, M. (2002), The promise of bank filtration. Environ. Sci, Technol. 3(21), pp 422a-428a.

3. Schmidt, C.K., Lange, F.T., Brauch, H., and Kuhn, W.(2003), Experiences with river -bank filtration and infiltration in Germany: DVGW Water Technology Center, 17 p.

4. Lee,S. I, Lee S. S,(2010), Development of site suitability analysis system for riverbank filtration, Water Science and Engineering, 3(1), pp 85-94

5. Chaturvedi, S., Dave, P.N.(2012), Removal of iron for safe drinking water, Desalination, 303, pp 1-11

6. Tiwari, D., Yu, M.R., Kim, M.N., Lee , S.M. , Kwon, O.H., Choi, K.M., Lim, G.J., Yang ,J.K.(2007), Potential application of manganese coated sand in the removal of Mn(II) from aqueous solutions. Water Science & Technology, 56(7), pp 153-160.

7. Lee, S. M., Diwakar, T., Choi, K. M, Yang, J. K., Chang, Y. Y., Lee, H. D.(2009), Removal of Mn (II) Aqueous solutions using Manganese-Coated sand samples. J. Chem. Eng., 54, pp 1823-1828.

8. Pons, M.P., Fuste, M. C.(1993), Uranium uptake by immobilized cells of Pseudomonas strain EPS 5028. Applied and Microbiology Biotechnology, 39, pp 661-665.

9. Phataia, P., Wittayakuna, J., Wen, H.C., Cybelle, M.F., Nurak, G., Chi, C.K.(2014), Removal of manganese (II) and iron(II) from synthetic groundwater using potassium permanganate. Desalination and Water Treatment, 52, pp 5942-5951.