IOE Graduate Conference
[Placeholder for Publication Information]

The Process of Manganese Deduction Using Katalox Light, Birm and ISR from Bore Well Water

Chandan Kumar Sah [a], Iswar Man Amatya [b]

[a, b] *Department of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
Corresponding Email: [a] kecsahchandan@gmail.com, [b] iswar@ioe.edu.np

Abstract

Poorer quality and depletion of groundwater is a main problem in landloked country Nepal. The Overelevated level of groundwater contaminants like Manganese is a major problem. This paper expresses the deduction of Manganese through relative analysis of Combined Media Filtration (CMF) to gravity rapid sand filtration (RSF) at three flow rates.The Katalox Light,Gravel, Iron Specific Resin (ISR), sand and Burgess Iron Removal Method (BIRM) are commonly used filter media for CMF and RSF respectively. CMF is stimulant physical surface adsorption of high removal capacity of Manganese purification process through oxidation with precipitation following filtration with extreme pH.Two alike columns of filter filled with Katalox 1.24 mm, ISR 0.56 mm, BIRM 1.23 mm and sand 0.57 mm were implemented at three discharges viz., 0.018, 0.020 and 0.022 l/s at Bhaktapur,Changunarayan in Manohara Besi Khanepani Aayojana and wide study was performed.. For raw Mn concentration up to of 0.750 mg/l, the exit Mn was found to be 0.030, 0.041 and 0.044 mg/l in CMF and 0.542, 0.561 and 0.572 mg/l in RSF at 0.018, 0.020 and 0.022 lps respectively. The average Manganese removed at 0.018, 0.020 and 0.022 lps were developed to be 95.000, 93.363, and 92.920 % in CMF and 10.500, 9.507, and 8.850 % in RSF of overall raw Mn concentration respectively. The overall removal of Mn was more effective at low flow discharge of 0.018 l/s. CMF and RSF media filter were cleaned with cleaning rate of 24 m/h with daily 10-15 minutes and 36 m/h within 3 days at 1.5 hours in each filter runs simultaneously. Finnally the study was concluded that at gravity flow the CMF media could serve as a good media for deduction of Mn at gravity flow.

Keywords

Bore Well Water, Manganese,Iron Specific Resin(ISR), Katalox Light(KL), Burgess Iron Removal Method(BIRM)

1. Introduction

1.1 Background

Manganese is found commonly in groundwater along with iron and is generally it hasnot been considered to be a health aspects. However, a number of muddless are associated if manganese level is too much, such as creating bad smell and a water look, staining on your laundry and plumbing related eqipments, distribution system deposition, and interference with the process of disinfection [12]. In surface and sub-surface sources, Manganese is sometimes found in varying concentrations. Soluble Manganese concentration yield 0.05 mg/l of soluble manganese [8] or the NDWQS limits maximum concentration 0.2ppm of Manganese [1] with the most Manganese oxide species precipitates out. However, if the manganese concentration exceeds 1.0 mg/l the reservoir hypolimnions soluble Manganese may exceed within the reduced environment. The high levels of manganese in water results aesthetic issues, fixture discoloration and nerves problems, neurobehavioral effects, because the neurological effects (e.g., tremor, gait disorders). For reducing the problem associated with the manganese, different countries asses the contaminant level. North America have assed the Manganese contaminant level as 0.05mg/l. [5, 8]. The Manganese is freely available in nature of different food sources and the basic element for the humans and different living animals. The foremost different states of Manganese for existance are Mn^{2+}, Mn^{4+} and Mn^{7+}. The Manganese occurs in different surface and sub-surface sources particularly in anaerobic low oxidation states which is the major sources of drinking water. There are various studies of Manganese relating factors but doesnot achieve a adverse effect on these parameters on drinking water. Manganese (Mn) is an essential element in virtually all living organisms where it can fulfill two different functions: acting as an enzyme cofactor and a metal with catalytic activity in biological clusters. [6]. The different study based on quantitative risk assessment on Manganese was studied during a few animals based on the basal diet wasn't provided. This maked a strong interest of studying kinetics of Manganese removal and comparison of overall removal efficiency of Manganese in various flow rates in Combined Media Filtration (CMF) to Rapid Sand Filtration (RSF).

1.2 Research Objectives

The focus of this study is to measure of Manganese deduction using CMF of KL, BIRM and ISR as advanced filter media to rapid sand media sand in RSF to get rid of Manganese guiding as water quality while maintaining the same operating under and environmental conditions of raw water. Specific objectives of the study can be pointed as in accordance with:

- To find out the removal efficiency of Manganese by Combined Media Filtration (CMF) and Rapid Sand Filtration (RSF) system.
- To check depthwise variation of Manganese in Combined Media Filtration (CMF) system.
- To check manganese removal to the the effect of discharge.

2. Literature Review

2.1 Solubility of Manganese

The Mn^{2+}, Mn^{3+}, Mn^{4+}, Mn^{6+}, and Mn^{7+} oxidation states can exist in an aqueous environment .The usual forms found in natural water are Mn^{2+} and Mn^{4+} oxidation states. The Mn^{7+} is strong oxidizing agaent used in water treatment to reduce reduced manganese. The stoichiometric formula MnO_2(s), is the representation of precipitated oxidized manganese from water, known as manganese dioxide.[6]. For a pH below 9 in aqueous solutions, Mn^{2+} is stable as its oxidation property is low. At the pH range of 6 to 9 MnO_2 is stable in natural water. The oxidation of Mn^{2+} results Mn oxides coated as discrete particles on soil. In absence of reducing agents, the unstable form of Mn is Mn^{3+} which reduced to Mn^{2+} through disproportionation reaction in the but at strong complexing agents, Mn^{3+} occurs in soluble form .At the pH range 3 to 10, the solubility of manganese(IV) oxide MnO_2 is very low . The redox reactions between Mn^{2+}, Mn^{3+}, Mn^{4+} and pH of groundwaters and surface waters controls the concentration of dissolved Mn [2, 10].

2.2 Katalox Light

Katalox Light, the German media has been engineered with a unique MnO_2 coating technique on ZEOSORB,providing on best filtration performance less than 3 microns particles with respect to other granular filter media, higher filtration surface, lightweight, and more service life. Over elevated Manganese, concentration can lead to health problems, staining or discolored water in the distribution systems. For removal of dissolved manganese, a strong catalyst such as Katalox light to handle pH and an oxidant such as oxides, Chlorine, or Hydrogen peroxide are required . Manganese with higher pH values and a greater concentration of oxidant precipitate out faster [13].

Table 1: Chemical cinfiguration of Katalox Light

Compounds	Typical Values	Specifications
ZEOSORB(Naturally mined)	85%	>85%
Manganese dioxide	10%	>9.5%
Hydrated lime	5%	<5%

Katalox Light, a German media product, is newly advanced media used for filtration. Its constitution in compare to contemporary filter media, like BIRM, sand, Manganese Greensand, Greensand Plus, etc, simply makes it exceptionally good. Watch Katalox Light systems offer an advance technology available in the water treatment industry with advanced catalytic filtration [13].

2.3 Burgess Iron Removal Method (BRIM)

Birm is produced through the activation of manganese salts to saturation on a sand of aluminum silicates . Following the manganese ions are oxidized in the solid form with potassium permanganate . To ensure the functionality of the oxidant birm is necessary the presence of dissolved oxygen (DO) in the water to be treated and the alkalinity should be greater than twice the combined concentration of sulphates and chlorides. In-ground waters the dissolved iron is combined with an excess of free carbon dioxide to form the ferrous bicarbonate state which is not filterable. In between the soluble iron compounds and dissolved oxygen (D.O.), BIRM acts as an insoluble catalyst that enhances the oxidation reaction of ferrous to ferric and finally ferric hydroxide precipitates and filtered out easily [7, 3].

2.4 Iron Specific Resin (ISR)

It has manganese dioxide which acts as a catalytic moiety and promotes iron oxidation. Basically, manganese dioxide attracts iron and oxygen, where ISR oxidizes the dissolved iron and in-ground waters the dissolved iron is combined with an excess of free carbon dioxide to form the ferrous bicarbonate state which is not filterable and does not get consumed. In the reaction, manganese dioxide is reduced to manganese oxide and ferric hydroxide is precipitated. During the backwash, scouring action has occurred on the surface of the material, converting it to MnO_2, which is further oxidize the iron. The regeneration of the manganese dioxide by simple back washing. The regeneration of the resin are done with no chemicals[4].

2.5 Rapid Sand Filter

The Rapid Sand Filter (RSF) water treatment equipment differs from the Slow Sand Filter water treatment equipment in a variety of ways, the most important of which are the much greater water treatment filtration rate and the ability to clean automatically using back washing. The mechanism of particle removal also differs. Rapid sand Water treatment filter does not use biological filtration and depends primarily on mechanical straining, sedimentation, impaction, interception, adhesion and physical adsorption. In Rapid sand water filter the complete filtration cycle (filtration and back washing) occurs sequentially. It is a purely physical treatment process[11]. However, without adequate pre-treatment and final disinfection, RSF never provide safe drinking water. In these types of filters, the raw water is usually fed to the filters only after it has been treated through sedimentation (Kansakar, 2015). RSF provide removal of relatively large suspended particles rapidly and efficiently. Biological filtration isn't used by RSF. Later on, with the development RSF, other material has also been used as filter media [9].

3. Materials and Methods

3.1 Importance Area

Figure 1: Importance Area (Duwakot)

Several pieces of literature have been studied regarding the placement of filter media, determination of Manganese and the way how the study of removal of Manganese have been selected were found to be quite similar. The site area is at Manohara-Besi Water Supply Committee located at Bhaktapur,Changunarayan in Manohara Besi Khanepani Aayojana and lies within 27º 42' 29.97" N latitude and 85º 24' 39.29" E longitude. shown in Figure 1.The importance of the experiment was conducted by using fiber glass of two filter columns arranged with CMF and RSF media. The gradual adaption of real Mn water on both the filtration system CMF and RSF was studied.

3.2 Experimental Setup

The reactor was made of using a fiber glass of (11x 11 x 290) cm^3 of internal dimension. Gravel 63.5 cm, KL of 96.52 cm, BRIM of 38.1 cm and ISR of 5.1 cm media used in CMF whereas 60 cm gravel and 60 cm sand media used in RSF flow reactor. The deep boring water was served by pumping through submersible pump . The schematic flow diagram is showed in Figure 2. The oxidation along with precipitation and filtration mechanisms followed as the raw water passed in both the filtration media. There are naturally varrying the concentration of Mn as per site condition.

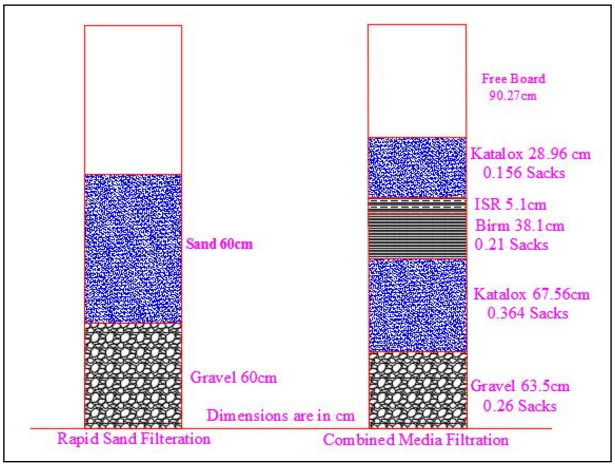

Figure 2: Arrangement of CMF and RSF media

3.3 Kinetics of Manganese Removal in Filtration

The main theme for the process of Manganese reduction in the CMF and RSF system. Particulate Mn can be removed by a range of appropriate particle separation processes. Truly dissolved Mn is almost entirely in the reduced Mn(II).As Katalox Light contains large surface negetively charged of the Gamma-MnO_4 which is used to attract all the hydrogen Ion's H^+ towards the surface of the KL media and Manganese sulfate is formed which is soluble compound as the pH decreases when the CO_2 enters the ground water. Similarly, the intermediate product MnS break out into Mn^{2+} as in the equilibrium at a high pH. Hence, when the pH value is seems to higher with respect to 10.5 or 11, the MnS field is replaced by the $Mn(OH)_2$, and sulfur gas leave. At lastly if the pH is greater than 10, MnS is very important.

Different flow rates of water were operated and the kinetics of Manganese removal were observed. Particular raw Mn concentration was checked at of 0.018, 0.020 and 0.022 lps to solve out Mn reduction in the CMF and RSF system. Based on Mn concentration of raw and outlet from both the filters, the efficiency of both the filters are calculated.

3.4 Analytical Methods

The Manganese test were performed through Persulfate and Spectrophotometry method at absorbance of 525 nm for sample analysis.

4. Results and Discussions

At first discharge Q=0.018 l/s in CMF and RSF, the average concentration of Manganese in raw water, outlet of CMF, and RSF were 0.606, 0.030, and 0.542 mg/l respectively. While in second discharge Q=0.020 l/s in CMF and RSF, the average concentration of Manganese in raw water, outlet of CMF, and RSF were 0.619, 0.041, and 0.561 mg/l respectively. Whereas in third discharge Q=0.022 l/s in CMF and RSF, the average concentration of Manganese in raw water, outlet of CMF and RSF were 0.628, 0.044, and 0.572 mg/l respectively as shown in Figure 3.

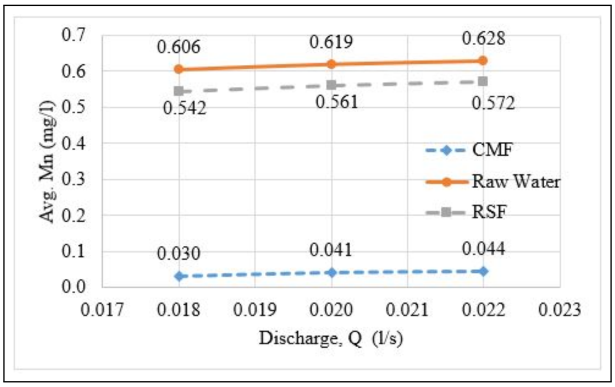

Figure 3: Concentration of Mn at different discharge

In the different discharge conducting in both the CMF and RSF filter media, The outlet of Mn through RSF was above 0.2 mg/l and CMF was below 0.2 mg/l as acceptable limit [1]. The difference was observed in the of Manganese in CMF and RSF. However,CMF produces better quality of Manganese free water than RSF. The Mn removal by RSF wasnot seen good [1].

The overall Manganese reduction efficiency at 0.018, 0.020 and 0.022 l/s in CMF and RSF were 95.00 and 10.50, 93.36 and 9.51, and 92.92% and 8.85% respectively as shown in Figure 4. However, based on removal criteria, CMF system produces better effluent quality if water than that of RSF system media. Besides of this, the CMF media play vital role in reduction of Mn as shown in Figure 4 as 0.2 mg/l lower limit [1].

At discharge Q=0.018 l/s in CMF, the average concentration of Manganese in raw water (0 cm),150, 170, 190, 210 and outlet of CMF (270 cm) was 0.606, 0.306, 0.236, 0.145, 0.088 and 0.030 mg/l respectively shown in Figure 5. Similarly, at discharge Q=0.020 l/s in CMF, the average concentration of Manganese in raw water (0 cm),150, 170, 190, 210 and outlet of

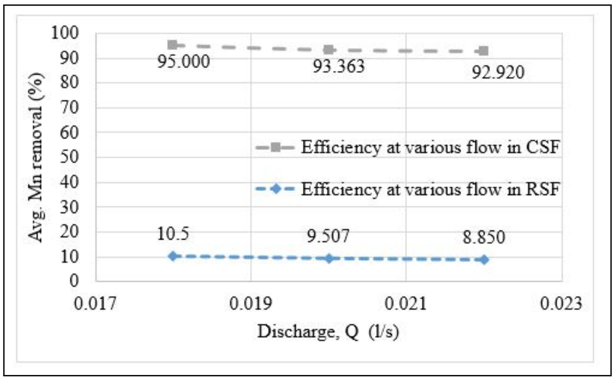

Figure 4: Average Mn Removal efficiency at various discharge

CMF (270 cm) was 0.619, 0.341, 0.259, 0.166, 0.100 and 0.041 mg/l respectively ,and lastly, at discharge Q=0.022 l/s in CMF, the average concentration of Manganese in raw water (0 cm),150, 170, 190, 210 and outlet of CMF (270 cm) was 0.628, 0.356, 0.283, 0.200, 0.117 ,and 0.044 mg/l respectively as shown in Figure 5. In the different discharges, Manganese produced by CMF at different depth was decreased slowly below 0.2 mg/l as lower limit [1] as the depth of the port was increased but in sand filter Mn concentration wasn't decreased to standard limit as shown in Figure 5.

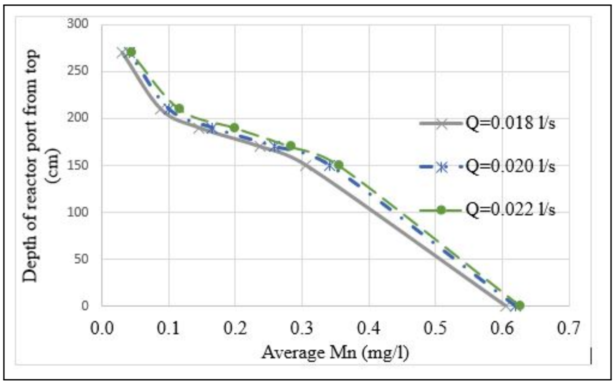

Figure 5: Average Mn with increase in depth of port from top

The difference was observed in the concentration of Manganese in CMF and RSF. However,CMF filter outlet effluent was effectfull than RSF filter outlet. The Mn removal by RSF was seen good which is not safe consumption and fruitful.

5. Conclusions

The experiment of the research was performed comparative study of two CMF and RSF filter, using filtration media of Katalox light, BIRM and ISR in one model and sand in another model. Inspite of this, it can be say that Mn operation in CMF filter media is far better than RSF filter media. Finally, it is found that actual observed effectiveness of Manganese removal mainly depends upon the dissolved minerals of underground water. The maximum Mn removal efficiency in the CMF and RSF system is obtained as 95.000, 93.363 and 92.920% in CMF and 10.500, 9.507 and 8.850% in RSF at discharge of: 0.018, 0.020 and 0.022 l/s respectively, as per guidelines of NDWQS, the operation of CMF filter media is most acceptable than RSF. In blank condition, certain part of Manganese concentration also removes in RSF which influence the removal of remaining residual concentration of Manganese from CMF. So from the above experiment we can say that CMF filter media is acceptable filtration system throughout the world for Mn containing water.

6. Recommendations

Following tasks are recommended for further studies.

- The water temperature and dissolved oxygen (DO) content affects the filtration process. Therefore, it is recommended to perform tests at different water temperature and dissolved oxygen (DO) content.
- The effect of head loss and porosity development of CMF and RSF could be studied.
- It is recommended to use capping media to increase effectiveness of CMF.
- It is recommended to perform pH analysis through the CMF in detail.

Acknowledgments

The authors acknowledge Kathmandu Valley Water Supply Management Board (KVWSMB) for providing space for the laboratory and Rural Water Supply and Sanitation Fund Development Board (RWSSFDB) through Lucent Drop Nepal for making availability of media. The authors are also grateful for the support from the Masters in Environmental Engineering Program, Pulchowk Campus, IOE, TU, Nepal.

References

[1] J Aryal, B Gautam, and N Sapkota. Drinking water quality assessment. *Journal of Nepal Health Research Council*, 2012.

[2] R Buamah, B Petrusevski, and JC Schippers. Adsorptive removal of manganese (ii) from the aqueous phase using iron oxide coated sand. *Journal of Water Supply: Research and Technology—AQUA*, 57(1):1–11, 2008.

[3] Clack Corporation. Manganese and Iron Removal Media. https://www.lenntech.com/Data-sheets/Birm-Clack-L.pdf/. [Online].

[4] Chemical Industry Digest. Indion-ISR (Iron Specific Resin) Promising Technology for Removal of Dissolved Iron from Ground Water. http://www.ionxchng.com/kms/techpaper/indion_isr.pdf, 2004. [Online; accessed December-2004].

[5] KA Emmanuel and A Veerabhadra Rao. Comparative study on adsorption of mn (ii) from aqueous solutions on various activated carbons. *e-Journal of Chemistry*, 6(3):693–704, 2009.

[6] Robert W Hungate. *Adsorption kinetics for the removal of soluble manganese by oxide-coated filter media*. PhD thesis, Virginia Tech, 1988.

[7] Acuro organics limited. Iron Removal Media. https://www.chemicals99.com/iron-removal-media.html, 2021. [Online; accessed 12-June-2021].

[8] World Health Organization. *Guidelines for drinking-water quality*. World Health Organization, 1993.

[9] BC Punmia, Ashok Kr Jain, and Arun Kr Jain. *Water supply engineering*. Firewall Media, 1995.

[10] C Venot, L Figueroa, RA Brennan, TR Wildeman, D Reisman, and M Sieczkowski. Comparing chitin and organic substrates on the national tunnel waters in blackhawk, colorado for manganese removal. *Proceedings America Society of Mining and Reclamation*, pages 1352–1366, 2008.

[11] Jan Teun Visscher. Slow sand filtration: Design, operation, and maintenance. *Journal-American Water Works Association*, 82(6):67–71, 1990.

[12] Timothy Vogel et al. *Assessing Design and Funding Methods of Water Infrastructure for Saskatchewan First Nations*. PhD thesis, University of Saskatchewan, 2019.

[13] Watch Water. Katalox Light Advanced Filtration Media. https://www.watchwater.de/documents/. [Online].