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Full Length Research Paper

Magnesium and iron removal in mine water using roughing filters

Onyeka Nkwonta

Department of Civil Engineering, Mangosuthu University of Technology, P. O. Box 12363, Jacobs 4026, Durban, South Africa. E-mail: IfeanyiO@tut.ac.za. Tel: +2712 382 4434. Fax: +27865452543.

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Roughing filters can be considered as a major pre-treatment process for mine water, since they efficiently separate fine solids particles over prolonged periods without addition of chemicals. A pilot plant was designed at delcoal. The design and sizing of the pilot plant was guided by wegelin design criteria. Gravel was used as a control medium since it is one of the most commonly used roughing filter media and because it was used in developing these criteria. In order to improve the performance of the roughing filters, the process has been modified by applying local available material such as charcoal as an alternative filter media. The pilot plant was monitored for a continuous 60 days from commissioning till the end of the project. The overall function of the filter in removing parameters such as iron and magnesium is accepted using charcoal. The achieved results in this study showed that, roughing filters may be considered as an efficient pretreatment process for mine water. It was also observed that in general, charcoal performed better than gravel. This observation could have resulted from the reason that charcoal has a slightly higher specific surface area and porosity, respectively to enhance sedimentation and other filtration processes like absorption, compared to gravel.

Key words: Roughing filters, sedimentation, absorption, mine water.

INTRODUCTION

Water is essential to life on our planet (Miller, 1999). This fundamental resource is of such importance because no living organism can survive without water, (Kupchella and Hyland, 1993). Therefore, there is a demand for clean, unpolluted water in substantial supply. As a result, a prerequisite of sustainable development therefore, must be obtained, to ensure uncontaminated streams, rivers, lakes and oceans (IIED, 2002). Increasingly, human activities threaten the water sources on which we all depend. Coal mining is one of such activity. In fact, according to the Environmental Mining Council of British Columbia (2001), water has been called “mining’s most common casualty”. According to the Environmental Mining Council of British Columbia (2001), for the sake of current and future generations, there is a need to safeguard the purity and quantity of water against irresponsible mineral development. Such irresponsible mineral development can result in a reduction of the quality of water, through increased pollution and sedimentation loads, leading to a reduced quantity of water being available for use by current and future generations.

This falls in line with the principle of sustainable development (IIED, 2002; Younger, 2001). An example would be passing the water through linked ponds (Barton and Karathansis, 1999) or an artificial wetland in which organic matter, bacterial, and algae work together to filter, adsorb, and precipitate out the heavy metal ions, and reduce the acidity (IIED, 2002). In addition, the ponds may be lined with limestone, which is able to neutralize the acidity levels of the water (Barton and Karathansis, 1999). Passive treatment of mine water uses physical and biological processes to decrease metal concentrations and neutralize acidity, compared to conventional chemical treatment. Passive methods generally require more land area, but use less costly reagents, and require less operational attention and maintenance. This scenario calls for appropriate technologies that utilize locally available materials, skills and other resources in accessing quality, effective and less costly treatment

Abbreviations: HRF, Horizontal roughing filters; **DWAF,** Department of Water Affairs and Forestry; **TWQR,** target water quality range.

system like roughing filters. Roughing filters can be considered as a major pretreatment process for mine water, since they efficiently separate fine solid particles over prolonged periods without addition of chemicals. Roughing filters are simple, efficient and cheap mine water pre-treatment technology compared to the conventional system. This is in terms of technical labour requirement, daily operation, maintenance costs and treatment efficiency and effectiveness. Roughing filters are primarily used to separate fine solids from the water that are only partly or not retained at all by stilling basin or sedimentation tanks. Roughing filters mainly acts as physical filters and reduce the solid mass. However, the large filter surface area available for sedimentation and relatively small filtration rates also supports absorption as well as chemical and biological processes. Therefore, besides solid matter separation, roughing filters also partly improve the bacteriological water quality and, to a minor extent, change some other water quality parameters such as colour or amount of dissolved organic matter (Wegelin, 1996). Roughing filters are classified as deep-bed filters, whereby proper filter design promotes particle removal throughout the depth of the filter bed, maximising the capacity of the filter to store removed solids. Particle removal efficiency in roughing filters is dependent on filter design, particulate, and water quality parameters (Boller, 1993; Collins, 1994; Wegelin, 1986).

MATERIALS AND METHODS

In this study, horizontal roughing filters (HRF) were selected as the pretreatment filters. Horizontal roughing filters perform better than other treatment filters, like Vertical roughing filters (Boller, 1993). Horizontal roughing filters also have the advantage of simplicity in design, cleaning, and operation. To conduct this study, a pilot plant was constructed at delcoal. To enable a comparative study, two horizontal roughing filters that consist of only one compartment were constructed. One compartment was selected due to the overall function of the filter, which is to check the parameters such as magnesium and iron only. The design and sizing of the pilot plant was guided by the wegelin design criteria (Wegelin, 1986). This study aimed at verifying these criteria based on gravel as a filter medium and other local available possible filter media, namely charcoal, which can serve as an alternative where gravel is not available. The filter medium was placed in different filters that consist of a chamber. The compartment was filled up of medium sizes of 15 to 5 mm, decreasing in size in the direction of flow. The filter bed was provided with under drain system, so that, it will allow cleaning of the filters after a certain period. A constant filtration rate of 1 m/h was used. Standard methods was adopted and analysis of the selected performance monitoring parameters. In this study, metals such as magnesium and iron were used as performance monitoring parameters. The filter inlet and outlet values of these parameters were monitored with the aim of analyzing the removal efficiency of the roughing filters at the set field operating conditions. Monitoring was done on a daily basis due to development of excessive filter resistance and to prevent algal growth in the filter.

Design concept

Now the conceptual filter theory for evaluating the efficiency of the filter in case of HRF is still based on the filtration theory described by Weglin (1996). When a particle in the water passes through a gravel bed filled up with gravel, there is a chance to escape the particle either on the left side or on the right side or a chance to settle at the surface of the gravel. Hence the probability of chance of the success of removal and the failure is 1/3 and 2/3. According to Fick's law, the filter efficiency can be expressed by the filter coefficient or,

$$\frac{dc}{dx} = -\lambda c \qquad (1)$$

Where, c = Solid concentration, x = filter depth, λ = filter coefficient or coefficient of proportionality. From the above equation, it can be stated that, the removal of the suspended particles is proportional to the concentration of the particles present in the water. The total length of the filter can be described as the number of parallel plates and act as a multistage reactor so that the performance of the HRF can be ascertained on the basis of the results obtained from the small filter cells. The total suspended solid concentration after a length of Δx of the filter cell can be expressed.

$$c_{outlet} = \Sigma^{C}{}_{inlet} e^{-\lambda i \Delta x} \qquad (2)$$

Where: λ_i = Filter efficiency of each filter cell, Δx = length of experimental filter cell; c_{inlet} and c_{outlet} = concentration of particles in the inlet and outlet of the filter.

It is to be stated that, after evaluating the filter depth (length) and the filter coefficient and the suspended solids concentration, the performance efficiency of the filter can be predicted. According to Wegelin (1996), the effluent quantity for the n number of compartments is given by,

$Ce = C_0{}^*E_1{}^*\ E2^*\ E3^*\ E4^*.\ \ldots\ \ldots En$

C_0 = Concentration of the HRF influent,

Ce = Concentration of the HRF effluent

$E_1, E_2, E_3, E_4. \ldots \ldots E_n$ = Filtration efficiency for the each compartment (1, 2, 3, respectively).

(3)

The basic expression for the above relationship is expressed by:

$$Ce = Coe^{-\lambda L} \qquad (4)$$

Where, λ = Coefficient of filtration, L = length of the filter. The filter efficiency is given by.

$$E = Ce/C_0 = e^{-\lambda L} \qquad (5)$$

$$Ce = Co^* E \qquad (6)$$

Where, E_i = filter efficiency for (i–1, 2, 3 . . . n) compartments.

The description of the theory above showed that, the solid removal by filtration can be described by exponential equation.

RESULTS AND DISCUSSION

The term "water quality" was coined with reference to the quality of water required for human use: "good quality" water is "pure" and unpolluted and suitable for drinking as

Table 1. Water quality standard for South Africa.

Variable	Unit	DWAF water target
Magnesium	mg/l	
Iron	mg/l	0 -1.0
pH		6 - 9

Water quality standard for industrial use (DWAF, 1996).

Table 2. Magnesium reduction in the inlet and outlet.

Day	Inlet (mg/l)c_o	Outlet (mg/l)c_e Gravel	Outlet (mg/l)c_e Charcoal
6	389.45	191.90	190.1
9	420.78	189.78	178
11	398.98	178.09	169.09
14	387	165.87	163.09
16	396.88	141.23	139.78
18	388.83	121.67	117.63
21	406.06	98.09	98.11
24	387.98	78.38	82.12
28	397.05	66.78	65.45
30	406.11	54.78	63.09
33	399.01	59.66	52.34
35	409.87	46.09	41.07
37	388.79	38.10	37.34
40	378.09	37.78	37.01
44	398.76	37.09	36.07
48	378.62	36.09	36.08
50	412.89	33.71	33.07
55	389	30.08	30.09
58	487.98	29.11	29.02
60	464.22	28.14	28.05

well as for agricultural and industrial purposes. It is critically important to acknowledge however, that this is entirely a human perspective since each species thrives optimally in water with particular combinations of physical and chemical attributes. One of the goals of the Department of Water Affairs and Forestry (DWAF) is to maintain quality range of the quality of South Africa's water resources such that, water quality remains within the desired water quality range for a particular industrial process category; this includes pretreatment.

The DWAF encourages all stakeholders concerned with the quality of South Africa's water resources to join forces and aim to maintain water quality within the desired water quality range, where and whenever possible (DWAF, 1996). For this reason, the desired water quality range in the South African water quality guidelines is referred to as the target water quality range (TWQR). It is included, and highlighted as such, in the water quality criteria provided for each of the constituents dealt with the guidelines. Table 1 shows the water quality guideline set by DWAF. In order to monitor the quality of outlet water, parameters such as magnesium and iron are being compared between the inlet and outlet water and later was compared with the standard set by DWAF. The removal of the mentioned parameters in the inlet and outlet are shown in Tables 2 and 3; also the reduction in magnesium and iron are shown in Figures 1, 2, 3 and 4. The overall function of the pilot plant in reducing metals such as magnesium and iron is accepted.

In terms of individual performances, it was observed that, in general, charcoal performed better than gravel. This observation could have resulted from the reason that, charcoal has a slightly higher specific surface area and porosity, respectively to enhance the sedimentation and other filtration processes compared to gravel. In terms of the general performance of the horizontal roughing filters (HRF), the following observations were made based on Tables 1, 2, and 3 that, the roughing filter did not perform better at the developing stage but later performed better.

Table 3. Iron reduction in the inlet and outlet.

Days	Inlet (mg/l)c_o	Outlet (mg/l)c_e Gravel	Outlet (mg/l)c_e Charcoal
6	14.82	1.89	1.92
9	13.87	1.82	0.85
11	15.65	1.79	1.72
14	14.78	1.67	1.67
16	15.63	1.55	1.53
18	14.66	1.49	1.45
21	13.98	1.46	1.45
24	14.95	1.43	1.43
28	13.87	1.37	1.33
30	14.63	1.35	1.32
33	15.67	1.28	1.30
35	14.88	1.21	1.19
37	14.76	1.16	1.15
40	14.59	1.12	1.10
44	15.02	1.09	1.09
48	14.56	1.06	1.05
50	15.06	0.89	0.92
55	14.78	0.83	0.81
58	14.98	0.80	0.76
60	15.01	0.75	0.72

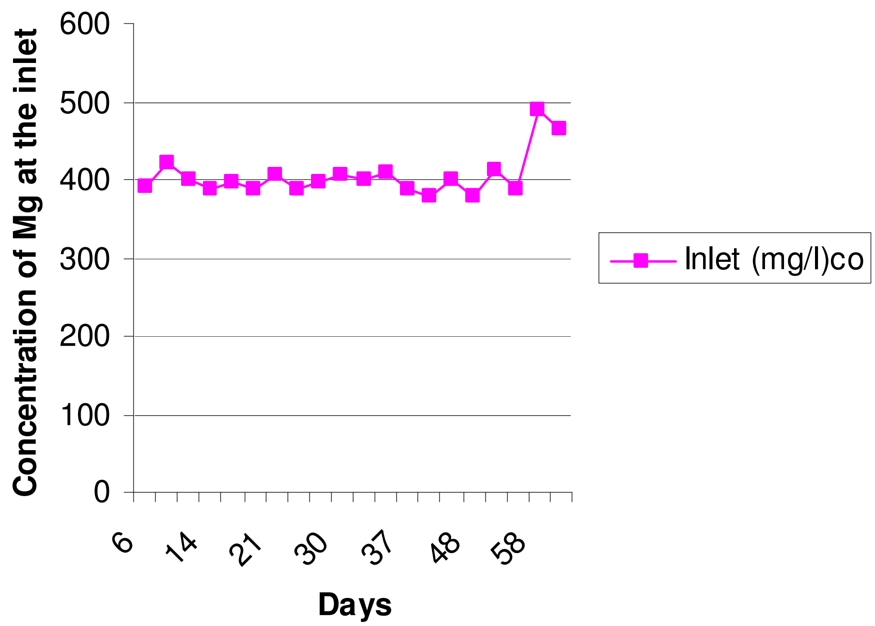

Figure 1. Shows the concentration of Mg at the inlet.

Conclusion

It was indicated that, roughing filter can perform under wegelin design criteria. It was shown that charcoal performed better than gravel in general removal efficiency with regards to the parameter that was put to test; and it could serve as an alternative where gravel is not available. This observation could have resulted from the reason that, charcoal has a slightly higher specific surface area and porosity respectively, to enhance the

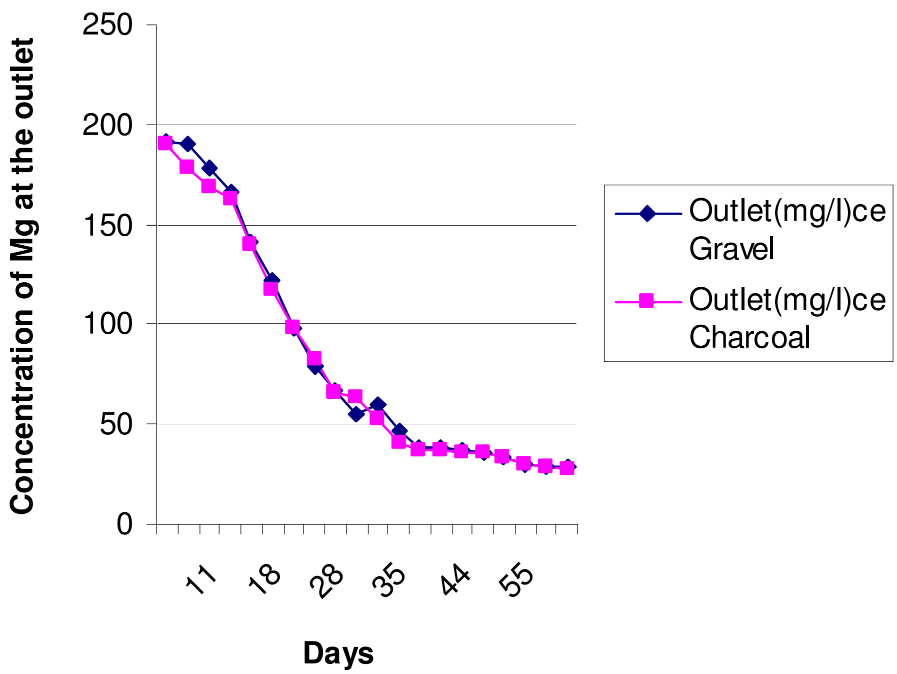

Figure 2. Shows the concentration of Mg at the outlet.

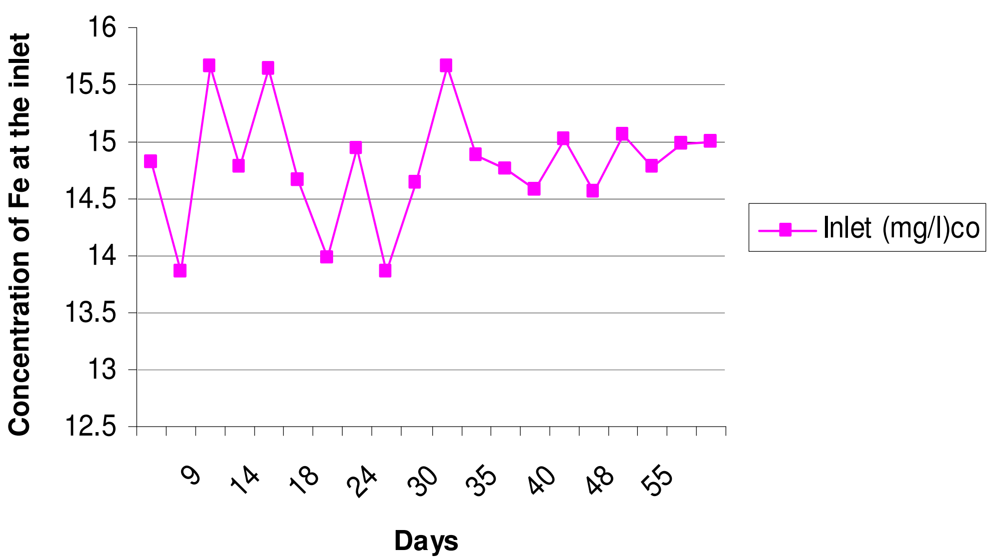

Figure 3. Shows the concentration of Fe at the inlet.

sedimentation and other filtration processes compared to gravel. The achieved result in the study showed that, roughing filtration may be considered as an efficient pretreatment process in mine water treatment. Due to time constraints, the durability test of the alternative filter material; charcoal, was not prioritised to be within the scope of this study. However, within the operating ranges and the study period, the media remained stable. It is recommended that, further studies be carried out to investigate the longevity, stability and possible rejuvenation of the material given that they are agricultural by-products stabilized by carbonation. Furthermore, lowering the filtration rate to 0.75 m/h is suggested for gaining removal efficiencies in the filters.

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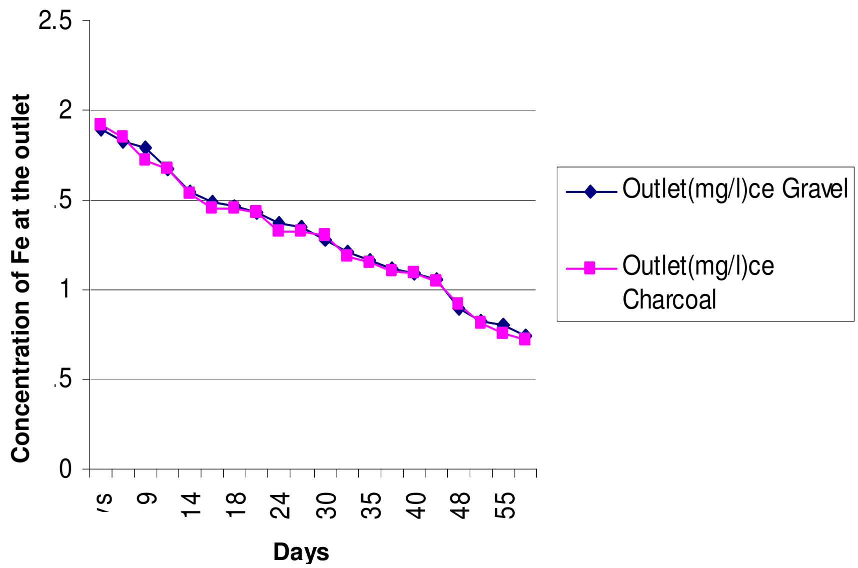

Figure 4. Shows the concentration of Fe at the outlet.

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