PASSIVE TREATMENT OF MINE WATER USING ROUGHING FILTERS AS A PRE-TREATMENT OPTION

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ABSTRACT

Roughing filters can be considered as a major passive 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 in Delmas. The design and sizing of the pilot plant was guided by Wegelin design criteria. Gravel was used as a control medium as one of the most commonly used roughing filter media. In order to improve the performance of roughing filters, this process was modified by applying locally available material like charcoal as the filter media. The pilot plant was monitored for a continuous 60days from commissioning till the end of the project. The filter (locally available charcoal) was successfully used in removing suspended solids, heavy metals such as magnesium and increasing the pH. This results of 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 was attributed that charcoal has a slightly higher specific surface area and porosity that is higher than that of gravel. This enhanced sedimentation and absorption, better than the gravel.

Keywords: Roughing filters, Sedimentation, Absorption, Mine water.

1. 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 & 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 such activity. In fact, according to the Environmental Mining Council of British Columbia (2001), water has been called "mining's most common casualty".

There is a growing awareness worldwide of the environmental legacy of mining activities that have been undertaken with little concern for the environment (EMCBC, 2001). Mining by its nature consumes, diverts and can seriously pollute water resources (Miller, 1999) Changes in laws, technologies and attitudes have begun to address some of the most immediate threats posed by coal development, but there are still many areas of coal mining practices and regulations that need to be addressed both in South Africa and on a worldwide scale (Younger, 2001). While there have been improvements in coal mining methods, practices and technologies in recent years, significant environmental risks, such as environmental degradation, soil, air and water pollution, still remain (EMCBC, 2001).

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 us by current and future generations. This falls in line with the principal of sustainable development (IIED, 2002). There is, therefore, a need to ensure that the best pollution prevention strategies are employed, especially in case where the environmental risks can be managed. The effect of mining on the environment includes the release of many chemical contaminants into water resources turning them into acidic which is referred as Acid Mine Drainage. AMD is widely accepted to be responsible for negative environmental and socio-economic impacts. AMD is characterized by low pH, high salinity levels, elevated concentrations of sulphate, iron, aluminum and manganese, raised levels of toxic heavy metals such as cadmium, cobalt, AMD is not only associated with surface and groundwater pollution, but is also responsible for the degradation of soil quality, aquatic habitats and for allowing heavy metals to seep into the environment (Adler, 2007). Systems devised to treat such minewaters can be described as either active or passive. Active treatment is the use of conventional minewater treatment unit processes, which is pre-treatment steps of chemical coagulation, rapid mixing and flocculation, followed by floc removal via sedimentation or flotation. Active system is quite demanding in chemical use, energy input and mechanical parts as well as skilled manpower that are often unavailable, especially in rural areas of developing countries such as South Africa. Passive treatment involves the developing of a self-operating system that can treat the effluent without constant human intervention (IIED, 2002). The basis for passive treatment is to let nature purify itself over time (Younger, 2001). An example would be passing the water through linked ponds (Barton & Karathansis, 1999) or an artificial wetland in which organic matter, bacterial, and algae work together to filter, adsorb, absorb, 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 & 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 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.

2. METHODS

In this study, Horizontal roughing filters 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 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 with only one compartment were constructed. One compartment was selected to perform the function of the removal of magnesium. 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 comparing it with other potential filter media available locally such as charcoal. The filter medium was placed in different filters that consist of a chamber. The compartment was filled up of medium sizes of 15mm – 5mm decreasing in size in the direction of flow. The filter bed was provided with an under drain system, to allow cleaning of the filters after a certain period. A constant filtration rate of 1m/h was used.

Standard methods were adopted and in the analysis of the selected performance monitoring parameters. In this study, pH, magnesium, and suspended solids were used as performance monitoring parameters. The filter inlet and outlet values of these parameters were monitored to access the removal efficiency of the roughing filters at the set field operating conditions. The system was monitored on a daily basis due to the development of excessive filter resistance and to prevent algal growth in the filter.

Design concept.

The conceptual filter theory for evaluating the efficiency of HRF is still based on the filtration theory described by Weglin (1996). When a particle in the water passes through gravel, there is a chance for the particle to escape 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 or 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 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 & 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,

$$Ce= C_0*E_1* E2* E3* E4^{*}. ....En \quad (3)$$

C_0 = Concentration of the HRF influent,

Ce = Concentration of the HRF effluent

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

The basic expression for the above relationship is expressed by,

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

Where:

λ = Coefficient of filtration

L = Length of the filter.

The Filter efficiency is given by,

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

$$Ce = Co* E \quad (6)$$

E_i = Filter efficiency for (i−1, 2, 3 . . . n) compartments.

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

3. 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 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 in the guidelines. Table 1 shows the water quality standard set by DWAF.

Table 1. Water quality standard for South Africa

Variables	**Units**	**DWAF water target.**
Magnesium	mg/l	
Iron	mg/l	0-1.0
pH		6-9
Suspended Solids	mg/l	0-25

Water quality standard for industrial use (DWAF, 1996)

The in and out parameters were benchmark against the DWAF guidelines. The removal of the mentioned parameters in the inlet and outlet are detailed in Tables 2, 3, 4. The comparison of the effluent to DWAF guidelines as indicated in Table 1.And later it was used to compare the standard set by Department of Water Affairs and forestry. The overall function of the pilot plant in reducing metal such as magnesium, suspended solids and pH value is accepted.

Table2. Magnesium reduction in the inlet and outlet of the gravel and charcoal filters respectively.

days	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

In terms of individual performances, it was observed that in general charcoal performed better than gravel. This observation is related to the higher specific surface area and porosity of charcoal which is slightly higher than that of gravel. This resulted in enhanced sedimentation compared to gravel. In terms of the general performance of the HRF, the observations made based on Tables 2, 3, 4, was that the filter did not perform better at the developing stage but later it starts performing better.

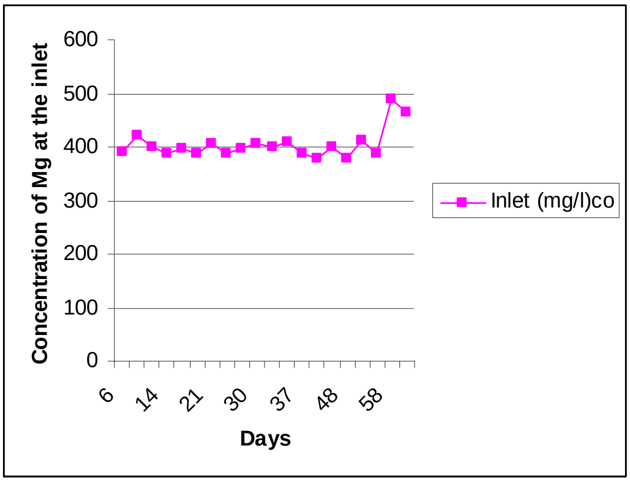

Figure 1. shows the concentration of Mg at the inlet.

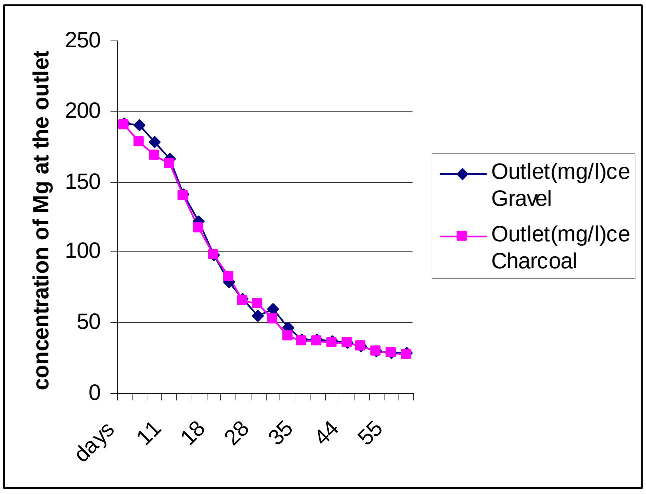

Figure 2 shows the concentration of Mg at the outlet.

Table 3. Suspended Solids reduction in the inlet and outlet of the gravel and charcoal filters respectively.

days	Inlet (mg/l)c_o	Outlet(mg/l)c_e Gravel	Outlet(mg/l)c_e Charcoal
6	184.22	42.32	40.34
9	178.42	41.11	42.09
11	164.82	39.14	39.87
14	172.71	35.82	34.84
16	176.60	32.89	31.76
18	168.11	31.13	30.45
21	154.18	29.15	29.23
24	172.17	29.14	29.13
28	194.87	26.34	24.11
30	198.72	24.65	24.16
33	184.18	23.12	22.15
35	199.14	22.76	22.00
37	174.17	21.43	21.65
40	188.33	20.87	20.88
44	192.38	18.32	18.18
48	198.85	17.87	16.86
50	186.44	16.85	15.87
55	191.00	15.87	14.98
58	172.72	14.90	14.78
60	198.64	14.10	13.33

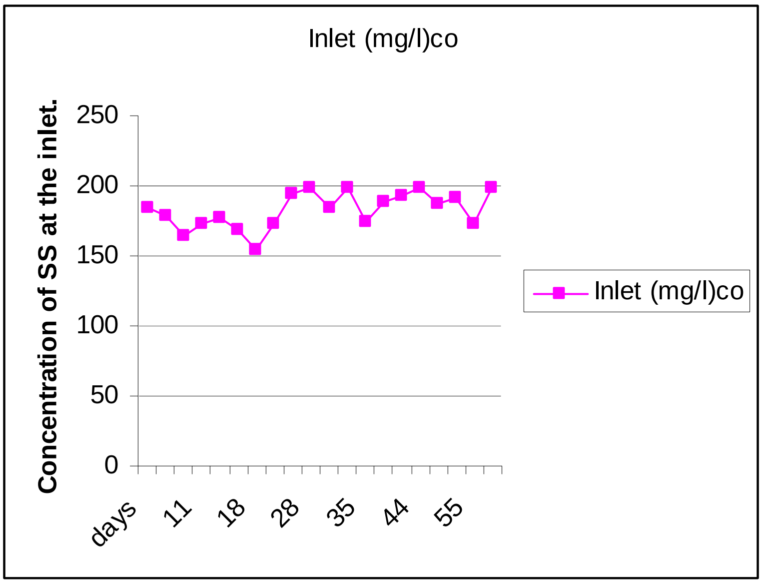

Figure 3. Concentration of SS at the inlet.

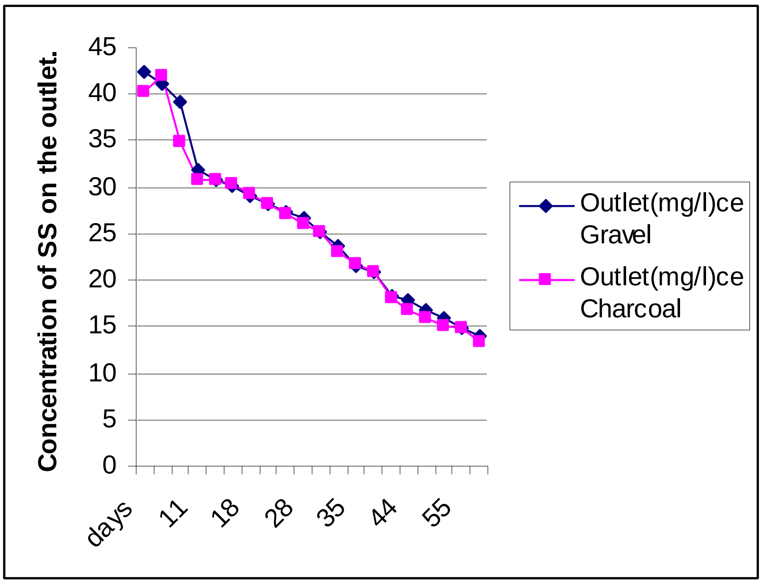

Figure 4 Concentration of SS at the outlet.

Table 4. pH value of the raw water compared to the inlet and outlet of the charcoal and gravel filters respectively.

days	Inlet (mg/l)c_o	Outlet(mg/l)c_e Gravel	Outlet(mg/l)c_e Charcoal
6	5.57	6.88	6.89
9	5.64	6.97	6.99
11	6.01	7.01	7.08
14	5.56	6.86	7.03
16	5.98	6.89	6.88
18	6.21	6.98	7.00
21	5.87	7.02	7.04
24	5.99	7.03	7.01
28	5.43	7.00	7.01
30	5.22	6.88	7.01
33	5.76	6.85	6.99
35	5.87	6.76	6.93
37	6.11	6.88	7.00
40	5.99	7.09	7.02
44	5.48	7.03	7.03
48	5.64	6.97	7.01
50	5.76	6.96	6.94
55	5.41	6.90	7.01
58	5.30	6.89	6.97
60	5.65	6.99	7.01

4. CONCLUSION

The following were concluded based on the results

- Charcoal performed better than gravel in the removal of magnesium respectively
- pH increase was the same in both system and
- The removal of SS in both systems was 55%
- Charcoal as a locally available material was successfully used as a replacement for gravel which is an advantage as it is locally available.
- Roughing filtration as a system can be successfully used as an efficient passive mine water pretreatment to provide water compatible with industrial use.

5. RECOMMENDATION

It is recommended that further studies must 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 0.75m/h is suggested for gaining removal efficiencies in the filters.

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