Comparison of MgO and $MgCO_3$ in the treatment of Acid Mine Drainage

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***Abstract*—** The discharge of raw or partially treated acid mine drainage poses a great burden on the freshwater resources in South Africa. This not only increases the treatment cost, but also introduces a wide range of chemical and microbial contaminants to the water. There have been lots of investments made in AMD treatment in South Africa and many techniques have been explored, however, the environment is still threatened by the discharge of untreated or partially treated mine water into water sources as the innovations are restricted in usage due to poor execution, mistakes and lack of understanding of their use. They are expensive, utilizes dangerous chemicals, causes degradation of the environment and production of more wastes. It is, therefore, important to find a new approach in treating AMD that would not be harmful to the environment. This study seeks to compare the two magnesium sources ($MgCO_3$ and MgO) for the treatment of AMD. Batch AMD treatment experiments were carried out in glass beakers with a volume of 500 mL, the optimum dosage of 6g was added to the AMD and mixed with over-head stirrer. The pH was monitored and measured using a pH meter. Analysis of aqueous solution was done using IC and ICP-OES. The results indicated that although $MgCo_3$ and MgO can neutralize AMD, MgO met most of the water quality guidelines but further refining will be required.

***Keywords*—** *Acid Mine Drainage, Treatment, MgO, $MgCO_3$*

I. Introduction

Acid Mine Drainage remains the largest risk confronted by the mining industry due to the degree of its impacts, it undermines water resources, human wellbeing, and the environment [1][2][3]. The Western Basin on the West Rand basin in Gauteng Province generates enormous quantities of AMD. The amounts of ~60 ML/d, containing sulphate (SO_4) concentrations of ~4.5 to 5 g/L and ferrous iron (Fe^{2+}) concentrations of up to ~1.5 g/L [4][5]. Coal basins in Mpumalanga may have up to ±18 g/L of sulphate and ± 6 g/L of Fe-species [2]. Acid mine drainage results when pyrite (FeS_2), a common constituent of many mineral deposits in SA (both coal and gold) comes into contact with oxygenated water and atmospheric air, undergoes oxidation to produce H_2SO_4. This leads to the discharge of a seepage that is acidic, and rich in sulfate and metal species into the environment. These minerals may be entrenched in the mined rock or crushed rock deposited on waste heaps (tailings) [6]. Fig 1 shows the AMD seepage from tailings and pumps at Grootvlei Mine.

Fig 1: AMD seepage from tailings (A) and Pumps at the Grootvlei Mine (B)

The main constituents found in acid mine drainage are H^+, SO_4^{2-}, and Fe (II). [7] further highlighted that Al (III) and Mn (II), As, Cu, Ni, Zn, Co and Cr and alkaline earth metals such as Mg and Ca are found in AMD. The formation of AMD can be described by the following chemical equation [3][4].

$$4FeS_2 + 15O_2 + 14H_2O \xrightarrow{\text{bacteria}} 4Fe(OH)_3 + 8SO_4^{2-} + 16H^+ \quad (1)$$

The high acidity of AMD causes adverse effects on aquatic ecosystems due to the declining quality of water in the environment, and it reduces the buffering capability of water [8]-[10]. AMD can be recognized by a yellowish or orange deposit in stream channels from the precipitation of ferric (Fe^{3+}) hydroxide and oxy-hydroxide and oxy-hydrosulphates [9]. There has been lots of investments made in AMD treatment in South Africa, however, the environment is still threatened by the discharge of untreated or partially treated mine water into water sources [11]-[15]. The current technologies are ineffective poor execution, mistakes, and lack of understanding of their use, they are expensive, utilizes dangerous chemicals, causes degradation of the environment and the production of more wastes [3][16]. This calls for a new approach to treating AMD that would not be harmful to the environment [10].

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II. METHOD

A. Sampling

AMD samples were collected from a disused mine shaft discharging point. High-density polyethylene (HDPE) bottles were used for sample collection.

B. Characterization of aqueous samples

The pH, EC and Temp were monitored and measured using Hanna model HI9828 probe. The analysis of aqueous samples was done using ICP-OES for metal cations, while anions were analysed using IC. Three replicate measurements were made on each sample and results are reported as mean of the three samples.

C. Batch Experiments

Experiments were carried out in glass beakers with a volume of 500 mL. Field AMD samples were treated at established optimized conditions to assess the effectiveness of the two Mg sources in neutralizing AMD. Optimum dosage of 6g of magnesite and 6g magnesium oxide were added to the AMD and the mixtures were agitated with the overhead stirrer. The rapid mixing of 225 rpm and slow mixing of 50 rpm were used. The solution was left to settle for 60 minutes.

III. RESULTS AND DISCUSSION

After contacting AMD with calcined cryptocrystalline magnesite, and magnesium oxide the levels of Fe, Al, Mn and other heavy metals were reduced from an aqueous solution except for sulphate which was slightly removed.

A. Percentage removal

The amount of Al, SO_4^{2-}, Mn and Fe (II), removed from AMD was estimated by the use of Equation (2), i.e.:

$$\%\ Removal = \frac{(C_0 - C_e)}{C_0} \times 100 \qquad (2)$$

where C_0 is the initial Al, SO_4^{2-}, Mn and Fe (II) concentration and C_e is the equilibrium concentration of Al, SO_4^{2-}, Mn and Fe (II). The outcomes for metal removal and neutralization efficacy as a function of MgO and/or $MgCO_3$ dosage are presented in Fig 2.

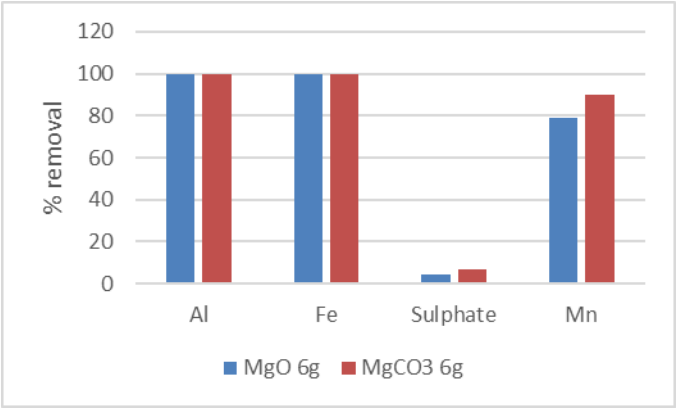

Fig 2: Percentage removal of Al, SO_4^{2-}, Mn and Fe (II) concentration using MgO and $MgCO_3$

The experimental results showed that there was an increase in pH with the addition of both MgO and $MgCO_3$. The initial conditions: pH < 2, 3453 mg/L Fe,399 mg/L Al, 78 mg/L Mn, 11346 mg/L SO_4^{2-} were significantly reduced, except for sulphate which only a small percentage was removed. A pH of 7.13 for magnesite and 7.67 for magnesium oxide were obtained respectively.

B. Chemical composition of raw and treated AMD

After contacting $MgCO_3$, the levels of Fe, Al and other heavy metals were reduced from an aqueous solution except for sulphate which was slightly removed and NO_2 and NH4 which were increased. The results correspond well with the results obtained by [5], $MgCO_3$ can be used in the pre-liminary stages of AMD treatment. There has been a significant increase in NH4 from interacting AMD with magnesium oxide, and slight decrease in sulphate. Table 1 depicts the results of AMD before and after treatment.

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TABLE I: CHEMICAL COMPOSITION OF RAW AND TREATED AMD

Parameters	Unit / S	SANS 241	Raw AMD	Magnesite $MgCO_3$	MgO
Aluminium	µg/L Al	300	398,46	0,07	0,09
Ammonia	mg/l NH4	1.5	14,62	15,78	166,88
Arsenic	µg/L As	10	2,25	ND	ND
Barium	µg/L Ba	700	0,48	0,05	0,01
Cadmium	µg/L Cd	3	0,16	ND	ND
Calcium	mg/l C	-	478,36	586,74	316,66
Chloride	mg/l Cl	300	22,97	28,93	26,4
Chromium	µg/L Cr	50	0,02	ND	ND
Copper	µg/L Cu	2000	0,49	0,14	ND
Fluoride	mg/l F	1.5	12,11	2,57	1,4
Iron	µg/L Fe	2000	3453,69	0,79	0,78
Lead	µg/L Pb	10	0,55	0.45	0,43
Manganese	µg/L Mn	400	77,49	8,02	16,24
Nickel	µg/L Ni	70	1,77	0,02	0,1
Nitrate Nitrogen	mg/l N	11	0,66	21,76	1,77
Nitrite Nitrogen	mg/l N	0.9	N.D	0.00	0,2
pH	pH	5 - 9,5	2.31	7.13	7.67
Strontium	µg/L Sr	<40	0,52	1,83	0,49
Sodium	mg/l Na	<200	44,46	44,73	41,45
Phosphate	mg/l PO4		N.D	0.00	0.00
Sulphate	mg/l SO4	<500	11346,156	10515,12667	10918,8
Zinc as Zn	µg/L Zn	<5	6,55	0,19	0,1

IV. CONCLUSION

Acid mine drainage treatment using $MgCO_3$ and MgO has provided promising results at laboratory-scale. Contact of AMD with these substances led to an increase in pH, from pH<3 to pH above 7 and large decreases in major metal concentrations. Removal of Al, Fe, Mn and other metals, and the minor reduction in SO_4^{2-} was achieved. Optimum dosage of 6g added to AMD with 2 mins of rapid mixing and 15 mins of slow mixing. MgO treated AMD resulted in water that met most of the water quality guidelines requirements as compared to the $MgCO_3$ and other alkali materials such as lime. There is a need however, to further "polish" treated AMD to lower the residual concentration of sulphate, and ammonia even though major cations were removed from AMD.

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