Screening of substrates for the removal of heavy metals from acid mine drainage (AMD)

A. Shweta Singh*, B. Saswati Chakraborty
Department of Civil Engineering, Indian Institute of Technology Guwahati, Assam, India
** e-mail: shwetasingh@iitg.ac.in*

Introduction

Acid mine drainage (AMD, also referred as acid rock drainage) generated from various active as well abandoned mines pose a serious environmental concern and remains a very challenging industrial wastewater. Owing to its physio-chemical characteristics such as low pH (in case of net acidic AMD), less organic matter (< 10 mg/L) and higher sulfate concentration (1000 – 3000 mg/L) deteriorates the quality of nearby surface streams when disposed of untreated. Low pH (< 3) is the most problematic issue related to AMD generation, as many heavy metals tend to leach out from rocks and remain in the solubilized state, which further adds heavy metal contamination (Colmer et al. 1950). The conventional treatment practiced is the addition of lime to raise the pH and simultaneously precipitating metals out, which is expensive and disposal of hazardous metal-laden sludge is still questionable. Therefore, the utilization of active/passive biological treatment (such as sulfidogenic bioreactors, anaerobic wetlands) has gained attention lately.

In the present study, various waste derived substrates such as cow manure (organic), bamboo chips (cellulosic) and alum sludge (drinking water treatment sludge) were explored for the treatment of AMD. AMD characteristics were similar to the one generated in North-eastern coalfield Ltd (NEC, a subsidiary of Coal India Ltd) in Assam. Metal sorption capacity of different substrates was evaluated at various dosages of batch studies. Thus, the main objective of the study is to identify the potential substrate material based on its pH raising ability and metal removal capacity, which could be applied in bio-remediation of constructed wetlands.

Materials and Methods

The AMD was directly collected from various coalmines of North-eastern coalfield (Makum) and seasonally characterized. For batch studies the synthetic AMD was prepared in the laboratory by dissolving known amount of metal sulfate salts in deionized (MilliQ) water, similar to the pollutant concentration of studied coalmines. Bamboo chips were obtained from the local farm units outside IIT Guwahati campus while cow dung was collected from local dairy farms in Amingaon. Alum sludge was procured from the drinking water treatment plant of IIT Guwahati.

Batch studies were carried out with different substrate materials to evaluate its applicability in treating AMD. The metal removal efficiency as well as change in pH were observed under different substrate dose (varying from 0 to 200 g/L). Synthetic AMD had composition of Fe (100 mg/L), Mn (2 mg/L), Al (25 mg/L), Zn (5 mg/L), Co (1 mg/L), Ni (1 mg/L) and Cr (1 mg/L), the pH of AMD was kept 2.50 ± 0.50 (adjusted using 1M H_2SO_4). All batch sorption experiments were performed in 250 mL Erlenmeyer flasks, where the desired dose of the substrate was added in known AMD volume and agitated (120 rpm) at room temperature (27 ± 5°C) for a given contact time period of 24 hours in a horizontal mechanical shaker. Samples were filtered at the end of the agitation period and filtrates were analysed for the change in pH and residual metal concentration. pH was first measured using pH meter (Systronics, India) and then filtrates were preserved by acidifying with HNO_3 to bring the pH < 2 and later analysed for residual metal concentration using Flame Atomic Absorption Spectroscopy (SpectrAA 55B, Varian). The batch experiments were carried out in duplicates. The metal removal efficiency (R, %) was calculated using the following equation (1) :

$$\text{Metal removal (R, \%)} = \{(C_i - C_e)/C_i\} * 100 \tag{1}$$

where C_i and C_e are the initial and final metal ion concentrations, respectively.

Results and Concluding Remarks

The metal precipitation as well as binding of metal ions with the surface of media, depends on the pH of the solution. pH of the solution increased with the increase in the dose for all the selected substrates (Figure 1). An increase in pH up to 5, 7.42 and 7.3 was achieved at highest dose of 200 g/L with alum sludge, cow manure and bamboo chips, respectively. Cow manure was found to be most effective in raising the pH, as reported in earlier literatures (Choudhary and Sheoran 2012). This could be attributed to buffering from bicarbonates and organic acids in manure as well as due to the dissolution of the surface-bound hydroxyl ion from substrate materials (Song et al. 2012). Removal of metals ions increased with simultaneous increase in substrate dose due to the decrease in H^+ on the surface, which results in the less repulsion with metal ions (Table 1). Higher metal sorption affinity was maximum for Cr followed by Co, Ni, Zn and Fe, and least in Al and Mn, this trend was in accordance with the increase in affinity for higher electronegative metal as described earlier (Kim 2014).

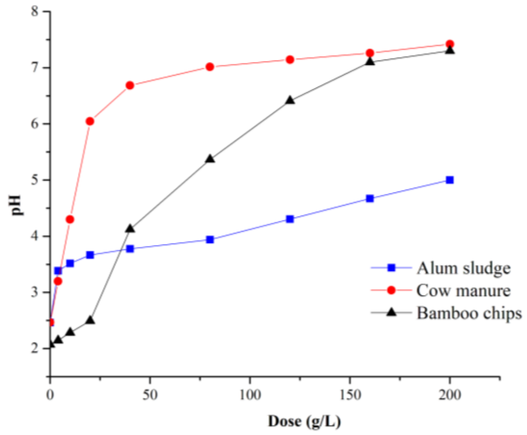

Figure 1. pH Vs substrate dose (g/L).

Table 1. Metal removal efficiency (%) of different substrates under varying dosage.

Substrate	Dose (g/L)	Metal removal (R, %) Fe	Mn	Zn	Al	Co	Ni	Cr
Alum sludge	0	2.633	2.406	0.245	0.689	0.621	2.875	1.970
	25	7.782	34.89	45.34	10.31	72.87	90.51	100.0
	50	22.19	51.59	82.11	16.06	85.89	94.15	100.0
	100	53.39	64.66	91.48	22.35	92.23	98.97	100.0
Cow manure	0	1.847	5.179	2.956	3.519	0.463	1.164	11.85
	25	100.0	30.79	100.0	46.74	91.42	100.0	100.0
	50	100.0	67.91	100.0	50.32	92.06	100.0	100.0
	100	100.0	77.25	100.0	57.17	93.13	100.0	100.0
Bamboo chips	0	1.016	2.534	5.106	0.711	6.562	2.351	5.156
	25	10.94	13.21	35.59	19.68	36.33	25.62	14.46
	50	34.47	43.76	71.29	51.68	47.21	34.61	65.57
	100	49.70	62.57	83.66	63.68	62.85	51.58	72.21

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