Effect of alum and lime on phosphorus leachability from sewage sludge

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Abstract

Wastewater treatment plants generate large amounts of solid wastes on a regular basis. These waste solids contain a large amount of organic matter, nutrients and heavy metal. Existing knowledge has focused on cost intensive options for disposal of these waste solids. For this reason, the ability to adopt these technological means has been limited to large scale wastewater treatment plants. Due to lack of viable technological means, small and medium sized wastewater treatment plants dispose of solid waste in an unplanned way causing harm to the environment. One of the disposal practices is land based application (e.g. fertilizer). However, the application poses concerns of contaminants from heavy metals and nutrients. Therefore, there appears to be a growing necessity for finding appropriate technology to address the concerns related to leachability in sewage sludge. Alum treatment has the potential to reduce the leachability in sewage sludge, but alum treatment can reduce the pH, so lime addition can control the pH for the sewage sludge. Previous studies conducted by the author showed that the alum and lime treatment can reduce the leachability of sewage sludge. However, the effect of alum and lime dosages was not investigated. The objective of this paper is to assess the effect of alum and lime treatment of waste solids for reduction of leachability in wastewater treatment residuals. Batch tests were conducted to evaluate the leachability of phosphorus. The sludge was treated with 10g/l, 20g/l and 30g/l of alum solutions and lime doses of 10g/l, 20g/l and 30g/l to evaluate the effect of lime dosage on the leachability. The results indicated that 20g/l of alum treatment seemed to be the most effective in reducing phosphorus leachability. However, the increase in lime dosage reduced the phosphorus leachability, with 30g/l of lime provided the least phosphorus leachability.

Keywords: leachability, batch tests, sewage sludge, land based applications and phosphorus.

WIT Transactions on Ecology and the Environment, Vol 145, © 2011 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/WRM110361

1 Introduction

Wastewater treatment plants generate solid wastes on a regular basis. These waste solids (sewage sludge) contain large amounts of organic matter, nutrients and heavy metal [1]. When disposed, these materials leach unwanted quantities of nutrients and heavy metals, causing deterioration of aquatic and ecosystem health [2]. Common disposal practices are often troubled with the toxic substances from the sludge that leach out in the surface water and groundwater causing pollution [3–6]. Phosphorus is a concern in leaching as it can accumulate in water bodies and cause deterioration of aquatic habitat. Existing knowledge have focused on cost intensive options for disposal of these waste solids. For this reason, the ability to adopt these technological means was limited to large scale wastewater treatment plants. One of the growing disposal practices are land based application (e.g. fertilizer). However, the application poses concerns of contaminants from heavy metals and nutrients.

Leaching of substances is the dynamic process of substance transport in a water medium. Heavy metals and phosphorus leaching from sewage sludge can be dangerous to ecological system and also to humans [7].

Retention or release in soil depends on the physical and chemical properties of the soil and the phosphorus. Sewage sludge treatment methods and phosphorus removal processes can influence the availability of phosphorus [8–10]. Previous studies revealed an effect on inorganic phosphorus in soils attached with aluminum [11, 12]. This is also indicative of reduced phosphorus leaching. Therefore, alum treatment of biologically treated sewage sludge can potentially reduce phosphorus leachability. Lime treatment of sewage sludge is also common. However, the effect of lime treatment on phosphorus leachability was not explored.

The objective of this paper is to assess the effect of alum and lime treatment of biologically treated sewage sludge for reduction of leachability. Laboratory based batch tests were conducted to observe the leachability of phosphorus.

2 Materials and methods

2.1 Materials

A bucket of untreated sewage sludge was collected from a local wastewater treatment plant. The treatment plant was an activated sludge based wastewater treatment plant. Alum and lime solutions of each 10g/L, 20g/L and 30g/L were used to treat the sludge. 500ml of the Alum solution and the pH was monitored. Then after, lime solutions of 50ml were added each time until a pH value of 7 was reached. The sludge sample was then dried in open air. Once dried, it has been used for subsequent experiments.

2.2 Experimental setup

Batch tests were conducted in a controlled environment in the lab to evaluate the used Erlenmeyer flask. For the batch test, five 250 ml Erlenmeyer flasks were used. Five flasks were provided with 0g/L, 2g/L, 4g/L, 6g/L and 8g/L of treated sludge respectively. The flasks were then placed on the shake table for one hour and a half (the shaker was set at 450 Hz). Phosphorus was tested after filtration of the leachate. After that the leachates was filtered into a separate storage bottle, and concentrated acid was used to make the PH of the water in the storage bottles around two. The storage bottles were then preserved at a temperature of 4 degrees Celsius to be used later for test of heavy metals.

2.3 Analytical methods

Phosphorus was measured using HACH spectrophotometer (DR5000). The ascorbic acid method was used based on standard methods. Temperature and pH was measured using standard pH probe. Turbidity was measured using HACH portable turibidimeter. Aluminum, chromium and copper were measured using HACH spectrophotometer (DR5000) based on standard available methods.

3 Results and discussions

3.1 Effect of lime treatment

Based on the experimental results, untreated sludge had a leachate concentration of up to 28.59 mg/L of phosphorus while Aluminum, chromium and copper concentrations were mostly low (<0.02mg/L) as shown in Table 1. However, with lime treatment (10g/L-30g/L), phosphorus concentration in the leachate was dropped to 0.936 mg/L as shown in Tables 2–4. It should be noted that phosphorus concentration dropped for all the sludge concentrations and the increase in lime concentration also reduced the phosphorus leaching.

Lime treatment however increased the aluminum concentration in the leachate. It may be due to availability of alum, not necessarily the availability of lime. With the increase of lime concentration, there was no significant change in the aluminum concentrations. However, the effect on chromium and copper was very insignificant.

Table 1: Leachate characteristics for untreated sludge.

Sludge	0g/L	2g/L	4g/L	6g/L	8g/L
pH	7.5	7.4	7.32	7.24	7.2
Temp.	25.4	25.8	25	25	25
Turbidity(NTU)	0.56	1.51	2.45	3.61	7.25
Al(mg/L)	0	0	0	0.012	0
Cr(mg/L)	0	0.017	0.009	0.015	0.01
Cu(mg/L)	0	0.01	0.01	0	0.01
P-PO4(mg/L)	0	7.99	12.29	28.59	28.19

Table 2: Leachate characteristics for sludge treated with 20g/L of alum and 10g/L of Lime

Sludge	0g/L	2g/L	4g/L	6g/L	8g/L
pH	7.83	7.73	7.75	7.5	7.75
Temp.	25	26	25	25	25
Turbidity(NTU)	0.15	8.19	26.5	34.7	48.8
Al(mg/L)	0	0.268	0.215	0.563	0.334
Cr(mg/L)	0	0.006	0	0.015	0
Cu(mg/L)	0	0	0.01	0.01	0
P-PO4(mg/L)	0	5.27	13.02	14.62	20.12

Table 3: Leachate characteristics for sludge treated with 20g/L of alum and 20g/L of Lime.

Sludge	0g/L	2g/L	4g/L	6g/L	8g/L
pH	7.78	7.88	8.23	7.95	7.96
Temp.	25	25	25	25	25
Turbidity(NTU)	0.32	4.54	17.7	16.7	37.4
Al(mg/L)	0	0.084	0.373	0.271	0.667
Cr(mg/L)	0	0.001	0	0.003	0
Cu(mg/L)	0	0	0	0	0.02
P-PO4(mg/L)	0	3.31	5.56	6.86	8.86

Table 4: Leachate characteristics for sludge treated with 20g/L of alum and 30g/L of Lime.

Sludge	0g/L	2g/L	4g/L	6g/L	8g/L
pH	7.6	7.98	8.32	8.39	8.25
Temp.	26	26.1	25	25	25
Turbidity(NTU)	0.3	2	12.8	31.6	34.3
Al(mg/L)	0	0.123	0.341	0.877	0.723
Cr(mg/L)	0	0.014	0.004	0.004	0
Cu(mg/L)	0	0	0.04	0.04	0.07
P-PO4(mg/L)	0	0.936	2.2	3.245	3.5

3.2 Effect of alum treatment

Experimental results indicated that alum treatment was able to reduce phosphorus leaching when treated at 10g/L and 20g/L of alum. However, at 30g/L of alum treatment the reduction in phosphorus leaching was not considerable. This indicates the effect of lime treatment to significant for reduction of phosphorus leachability more than alum treatment. However, with an increase in alum concentration during treatment increase the aluminum concentrations in the leachate. For chromium and copper, there was no significant effect observed.

Table 5: Leachate characteristics for sludge treated with 10g/L of alum and 20g/L of Lime.

Sludge	0g/L	2g/L	4g/L	6g/L	8g/L
pH	7.46	7.965	7.995	7.78	7.86
Temp.	25	25	25	25	25
Turbidity(NTU)	0.42	7.53	14.7	28.7	27.6
Al(mg/L)	0	0.155	0.373	0.2	0.644
Cr(mg/L)	0	0	0	0.03	0.022
Cu(mg/L)	0	0	0	0	0
P-PO4(mg/L)	0	2.81	2.96	8.76	9.81

Table 6: Table 6: Leachate characteristics for sludge treated with 30g/L of alum and 20g/L of Lime.

Sludge	0g/L	2g/L	4g/L	6g/L	8g/L
pH	7.57	7.74	7.77	7.81	7.67
Temp.	25	25	25	25	25
Turbidity(NTU)	0.3	4.17	13.9	22.4	41.2
Al(mg/L)	0	0.149	0.204	0.421	0.94
Cr(mg/L)	0	0.013	0	0.005	0
Cu(mg/L)	0	0	0	0	0
P-PO4(mg/L)	0	3.18	7.43	8.48	15.98

4 Conclusions

Alum and lime treatment of sewage sludge was able to reduce phosphorus leachability. However, lime treatment was more effective in reducing phosphorus leachability than alum treatment, and alum and lime treatment increased aluminum leachability from the sludge. The impact of other metals in the sludge was not significant. Future studies to evaluate the kinetic behavior would be able to evaluate the applicable treatment doses of alum and lime.

Acknowledgements

The author acknowledges the American University of Sharjah for providing the financial and institutional support to complete research work (FRG10-31). The author also acknowledges Kenan Jijakli and Ahmad Ghadban for their help in some of these experiments.

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