Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 7 (11): 1547-1550, 2007
ISSN 1812-5654
© 2007 Asian Network for Scientific Information

Vermiculite Clay Mineral Barrier Treatment System for Chrome Tannery Effluent

R.M. Jayabalakrishnan and S. Mahimai Raja
Department of Environmental Science,
Tamil Nadu Agricultural University, Coimbatore-641 003, India

Abstract: An attempt has been made to assess vermiculite, a phyllosilicate mineral group with high cation exchange capacity, as an alternative for activated carbon. In this investigation, the adsorption potential of raw vermiculite grade 2 was evaluated using vermiculite clay mineral barrier system for reducing pollutant loads in specially designed treatment system, where the important parameters like flow rate, effluent loading rate required were optimized. The VCMB treatment system has reduced the Cr in the outlet end soil layer by 66.1% than the inlet end soil layer. The build up of Cr in the middle vermiculite was 6.1 times more than the inlet end soil which could be attributed to its adsorption and retention properties. With reference to Na, the vermiculite treatment layer retained 12.7 times more than the top surface soil and 4.29 times as that of the inlet end soil layer. These results confirm that for the removal of Cr, salts and Na from chrome tannery effluent, the VCMB treatment system could be viable option. But in case of sulphate, it was found that its accumulation was the highest in the inlet end soil layer and was 4.24 times lower in the middle vermiculite layer which could be due to the lower anion exchange capacity of vermiculite compared with soil layer.

Key words: Vermiculite, treatment system, tannery effluent, mustard crop

INTRODUCTION

Water pollution is a world wide phenomenon and is one of the most serious problems confronting mankind today. With the rapid growth of industries in India, pollution has increased tremendously. Economic growth by industrialization through aims at more jobs, more food and more consumer goods has some other adverse effects which may pollute the environment.

Tannery industry is one of the important industries in India, which earns considerable foreign exchange through the leather export. The effluent from these industries pollutes the environment when the untreated effluents are discharged into the river streams or on land. The tannery effluent contains considerable amounts of sodium, calcium, magnesium, sulphate with excess colour affecting its aesthetical value, besides it inhibits photosynthetic activity of aquatic biota by reducing the penetration of sunlight, besides their direct toxic effects on the biota of the receiving waters (Walden and Howard, 1981). Among various industries, tannery industry ranks first in the usage of dyes for the colouration of the fibre. Today, more than 9000 types of dyes have been incorporated in the colour index.

Due to low biodegradability of dyes, the conventional biological treatment process is not very effective in treating dye industrial wastewaters. It is usually treated by physical or chemical processes which are costly and cannot effectively be used to treat the wide range of dye wastewaters. Adsorption on activated carbon (ARC) has been adopted, as tertiary treatment in various types of industries because of its excellent adsorption capability (Bailey *et al*., 1999). However, it use is limited by its high cost (El-Geundi, 1997). In this context, vermiculite mineral with its high cation exchange capacity and reactive surface area was scientifically evaluated for its potential to substitute the activated carbon could be cost effective and economically feasible treatment method. The adsorption potential of raw vermiculite grade 2 was evaluated using vermiculite clay mineral barrier system for reducing pollutant loads in specially designed treatment system for the removal of specific pollutants from chrome tannery effluent.

MATERIALS AND METHODS

The structure of the PVC (polyvinyl chloride) tub based treatment system using vermiculite as clay mineral barrier consisted of a rectangular tank of 55×40×40 cm size made of PVC (5 mm thickness). At the bottom, at the leachate collection pipe side 5 cm of pebbles (8 mm in size) were filled. Over the gravel, soil (sandy loam) was filled as

Corresponding Author: R.M. Jayabalakrishnan, Department of Environmental Science, Tamil Nadu Agricultural University, Coimbatore-641 003, India

a block up to 20 cm as vertical filling at the rear end. The next block (vertical filling) of 15 cm, vermiculite was packed, followed by 20 cm vertical filling with soil. The vermiculite clay mineral barrier system was connected to the effluent which had a hydraulic flow rate of 120 mL h^{-1}. For maintaining the flow rate, a control knob was fitted which allowed a continuous regulated flow. Flow pattern followed in the tub based vermiculite barrier treatment system was downward and lateral flow. The treated effluent was collected at the rear end from the bottom of tub and analyzed for various pollution parameters.

On the top soil *Brassica juncea* spp. (Mustard, variety: Pusa Jai Kisan) seeds were sown. In each tub 15 plants were maintained on the top soil layers and the rest were thinned out. After saturation of the bed with different industrial effluents, sowing of seeds was taken up, thereafter the effluent flow rate of 5 mL min^{-1} was maintained. The plants were harvested after 45 days. Collected plant samples, soil samples, vermiculite, raw and treated effluents from the bed treatment system were analysed.

RESULTS AND DISCUSSION

The treated chrome tan effluent registered pH of 7.01 whereas its EC was 16.3 dS m^{-1}. The BOD was lower in chrome tan recording 287 mg L^{-1}. The presence of sodium in chrome tan effluent. The sulphate content was higher in chrome tan (1579 mg L^{-1}). The presence of total chromium in treated chrome tan was 24.6 mg L^{-1}. The pH of the chrome tan, observed a marginal increase as the stages advanced. The pH was neutral in all the stages. As observed by Gupta and Tiwari (1985) the dissolution of minerals due to reaction of acidic effluent might have released several base cations and anions and increased their concentrations in the effluent resulting an increase in pH.

Prevention of lateral flow of chromium and salt by VCMB-chrome tan effluent: VCMB treated chrome tan effluent showed remarkable changes in the pollution load of the effluent. The initial pH of the chrome tan (7.01) had gradually increased to 7.79 on 45th day. There was a drastic reduction in EC, from 16.3 dS m^{-1} (initial) to 6.71 dS m^{-1} (45th day) after treatment through VCMB. The BOD of the chrome tan was significantly reduced from 287 mg L^{-1}(initial) to 98.3 mg L^{-1} (45th day) and in the same way COD load had been also reduced from 2483 to 987 mg L^{-1}.

One of the salient findings was the reduction in the Cr content of chrome tan liquor. A complete reduction in total Cr was observed in the treated chrome tan liquor when treated by VCMB system. In the raw effluent, the Cr concentration was 24.6 mg L^{-1}, whereas, in the VCMB treated effluent, the Cr concentration was below the detectable level. There were notable reductions in Na and SO_4 contents of the effluent. While Na concentration was reduced from 2316 (initial) to 626 mg L^{-1} (45th day), the SO_4 was reduced from 1579 (initial) to 279 mg L^{-1} (45th day). The chrome tan effluents contained a large amount of salts which was reflected on very high EC of 16.3 dS m^{-1}. The VCMB treatment system significantly reduced the salt content to the tune of 58.8 on 45th day in chrome tan effluents (Table 1).

Table 1: Quality/movement of pollutants of various industrial effluents under vermiculite clay mineral barrier (VCMB) treatment system

	Raw and treated effluents through VCMB			
	Tannery chrome effluent			
Parameters	Initial (raw)	15th Day	30th Day	45th Day
pH	7.01	7.32	7.49	7.79
EC (dSm^{-1})	16.3	12.8(21.5)	10.6(35.0)	6.71(58.8)
BOD (mg L^{-1})	287	206(28.2)	143(50.2)	98.3(65.7)
COD (mg L^{-1})	2483	1976(20.4)	1432(42.3)	987(60.2)
Total Cr (mg L^{-1})	24.6	BDL	BDL	BDL
Na (mg L^{-1})	2316	1127(51.3)	806(65.2)	626(72.9)
SO_4 (mg L^{-1})	1579	967(38.8)	592(62.5)	279(82.5)

Mean of three replications, BDL-Below Detectable Level

The passage of the effluents through the VCMB system reduced the BOD by 65.7% and the COD by 60.2% in chrome tan effluent. The reason for the reduction in BOD and COD might be due to adsorption, filtration and precipitation of salts in the middle vermiculite, outlet end soil layers and inlet end soil layers which resulted in significant reduction from their original value. Similar observations were made by Netter (1983) using soil filters who reported reductions of 99 and 97% of BOD and COD respectively. According to Lance *et al.* (1976), soils are very effective in removing the suspended salts by filtration and sorption. This also might have contributed for the BOD reductions.

A drastic reduction in Na and SO_4 concentrations was observed due to treatment in VCMB system. The removal of Na and SO_4 in the effluents was to a tune of 72.9 and 82.5 percentages in chrome tan. This might be due to the adsorption and retention of salts on different layers and plant uptake.

One of the salient findings of VCMB treatment system was 100% removal of Cr from tan chrome effluent. The VCMB were found very effective in achieving a complete Cr removal from the effluent. The passage of different industrial effluents through different layers could have resulted in large amount of Cr adsorption.

Table 2: Chromium and salts accumulated in different layers of vermiculite clay mineral barrier (VCMB) treatment system under downward and lateral flow of selected industrial effluents

	Quality of difference industrial effluents				
	Chrome tan effluent				
Treatment layers	pH	EC (dS m^{-1})	Total Cr (g $layer^{-1}$)	Sodium (g $layer^{-1}$)	Sulphate (g $layer^{-1}$)
Outlet end soil layer	7.33	2.95	0.02	1.66	6.30
Middle vermiculite	8.34	5.08	0.35	21.0	3.70
Inlet end soil layer	7.90	3.04	0.06	4.90	15.7

Mean of three replications

Accumulation of chromium and salts in different layers of VCMB after the treatment of chrome tan effluent: The amounts of Cr, Na and SO_4 accumulated and retained in different layers of the clay mineral barrier treatment system were assessed. The results revealed significant variations among the layers. The accumulation of chromium in different layers ranged from 0.02 (outlet end soil layer) to 0.35 g (vermiculite-middle layer). The soil at the inlet end accumulated 0.06 g of total chromium. In general, the chromium accumulated followed the order: middle vermiculite layer > inlet end soil layer > outlet end soil layer.

The same trend was followed with reference to sodium accumulation which ranged from 1.66 (outlet end soil layer) to 21.0 g (middle vermiculite) layers. The inlet end soil layer accumulated 4.90 g of Na only (Table 2).

The accumulation of sulphate in the VCMB based system was in the order of: inlet end soil layer > outlet end soil layer > middle vermiculite layer. The highest accumulation of 15.7 g was achieved in inlet end soil layer of the treatment system.

The pH of the three layers of the tub based bed system was neutral to alkaline. The EC of different layers followed the order: middle vermiculite (25.3 dS m^{-1}) > inlet end soil layer (3.04 dS m^{-1}) >outlet end soil layer (2.95 dS m^{-1}). The VCMB treatment system has reduced the Cr in the outlet end soil layer by 66.1% than the inlet end soil layer. The build up of Cr in the middle vermiculite was 6.1 times more than the inlet end soil which could be attributed to its adsorption and retention properties. With reference to Na, the vermiculite treatment layer retained 12.7 times more than the top surface soil and 4.29 times as that of the inlet end soil layer. These results confirm that for the removal of Cr, salts and Na from chrome tannery effluent, the VCMB treatment system could be viable option. But in case of sulphate, it was found that its accumulation was the highest in the inlet end soil layer and was 4.24 times lower in the middle vermiculite layer which could be due to the lower anion exchange capacity of vermiculite compared with soil layer.

Accumulation of chromium and salts in plant parts of mustard grown under VCMB treated chrome tan effluent: The mustard (Pusa Jai Kisan) has accumulated large amounts of sodium in vegetative parts (0.072 mg g^{-1}) whereas in roots it was 0.016 mg g^{-1}. The same trend was followed for total chromium and sulphate accumulation. For chromium it was 0.006 mg g^{-1} in vegetative parts, than in 0.003 mg g^{-1} roots. For sulphate, it was greatly (0.052 mg g^{-1}) accumulated in vegetative parts than in root (0.012 mg g^{-1}). In general, the accumulation and retention of salts followed a general trend for all the three parameters of Cr, Na and SO_4 was being: vegetative parts>roots. The concentration of selected industrial effluents had marked influence on Cr, Na and SO_4 content in plants. Accumulation of Cr was the highest in mustard crop grown under chrome tan. The distribution of Cr, Na and SO_4 followed: vegetative parts > roots (Table 3).

Table 3: Accumulation and retention of chromium and salts in plant parts of mustard crop (Pusa Jai Kisan)

	Chrome tan effluent		
	Total chromium	Sodium	Sulphate
Plant parts	(mg g^{-1})		
Vegetative parts	0.006	0.072	0.052
Root	0.003	0.016	0.012

Mean of three replications

CONCLUSION

A complete reduction in total Cr was observed in the treated chrome tan liquor when treated by VCMB system. The VCMB was found very effective in achieving a complete Cr removal from the effluent. The VCMB treatment system has reduced the Cr in the out let end soil layer by 66.1% than the inlet end soil layer. The build up of Cr in the middle vermiculite was 6.1 times more than the inlet end soil which could be attributed to its adsorption and retention properties. With reference to Na, the vermiculite treatment layer retained 12.7 times more than the top surface soil and 4.29 times as that of the inlet end soil layer. These results confirm that for the removal of Cr, salts and Na from chrome tannery effluent, the VCMB treatment system could be viable option. But in case of sulphate, it was found that its accumulation was the highest in the inlet end soil layer and was 4.24 times lower in the middle vermiculite layer which could be due to the lower anion exchange capacity of vermiculite compared

with soil layer. Accumulation of Cr was the highest in mustard crop grown under chrome tan. The distribution of Cr, Na and SO_4 followed: vegetative parts > roots.

ACKNOWLEDGMENT

The authors are thankful to Managing Director, Tamil Nadu Minerals Limited, Chennai for rendering financial support for this work under TNAU-TAMIN scheme project.

REFERENCES

Bailey, S.E., T.J. Olin, R.M. Bricka and D.D. Adrian, 1999. A review of potentially low-cost sorbent for heavy metals. Water Res., 33: 2469-2479.

El-Geundi, R.K., 1997. Precipitation and coagulation of organic substances in bleaching effluent in pulp mills. Water Sci. Technol., 27: 193-199.

Gupta, D.C. and V.C. Tiwari, 1985. Aluminum oxide as adsorbent for removal of hexavalent chromium from aqueous waste. Indian J. Environ. Health, 27: 205-215.

Lance, J.C., C.D. Gerba and J.L. Melnick, 1976. Virus movement in soil columns flooded with secondary sewage effluent. Applied. Environ. Microbiol., 32: 520-526.

Netter, R., 1983. Planted soil fitter-a wastewater treatment systems for rural areas. Water Sci. Tech., 28: 133-140.

Walden, C.C. and T.E. Howard, 1981. Toxicity of pulp and paper mill effluents-A review. Pulp and Paper Canada, 82: 143-146.