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Research paper

Removal of Lead from Aqueous Solution Using Bagasse and Bagasse Fly Ash as Adsorbents

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Abstract: The main approach of this research is to use the concept of adsorption technology having low cost & high efficiency as adsorbent material. Using such cost-effective sorbent materials may reduce the overall environmental compliances. This research focuses on the efficiency and comparative study of utilization of bagasse and bagasse fly ash as adsorbent for removal of lead. Batch-scale adsorption experiments were performed as a function of adsorbent dose, contact time, initial concentration and pH to establish optimum conditions for remediation of lead. Adsorption isotherm tests revealed that the Freundlich equation fitted the isotherm data better than the Langmuir. Bagasse fly ash was more favorable than bagasse in removing lead and thus was a better adsorbent.

Keywords: Bagasse, Bagasse fly ash, Lead, Adsorption, Isotherms

INTRODUCTION

Lead is a naturally occurring element. It is a common industrial metal that has caused widespread contamination of air, water, soil, and food. Many industries, such as painting, petrochemical, coating, newspaper, electroplating, smelting, battery, and plumbing discharge lead into the environment (Manahan, 1990). Lead causes severe health effects even at relatively low levels in the body. It often causes irreversible brain damage and injury to the blood forming systems. Lead can cross the placenta and damage developing fetal nervous systems at the typical levels that individuals are exposed. It can be accumulated in food chains and persistence in nature for long time. Unlike organic compounds, lead is non-biodegradable; therefore, it must be removed from wastewater. Current methods for wastewater treatment of lead include precipitation, coagulation/flocculation, sedimentation, flotation, filtration, membrane process, electrochemical process, ion exchange, biological process, and chemical reaction. It is known that adsorption is one of the most efficient methods for removal of heavy metals from waste streams. Activated carbon is the most widely used adsorbent due to its excellent adsorption capability for heavy metals (Juang, 2002). However, its use is often limited due to high cost, making these methods unfavorable for the needs of developing countries. When removing lead from wastewater, particular attention is given to effective and simple processes. Lead removal by low-cost adsorbent materials may be advantageous, compared with abovementioned traditional processes. These low-cost adsorbent materials recently studied include activated carbon and modified activated carbon, biosorbents, mineral adsorbent, biopolymer adsorbents and widespread and cheap natural materials or reused wastes such as clay, slag, peat and fly ash (Naseem and Tahir, 2001; Wu and Wang, 2003; Yu B. *et. al*., 2001; Zhan and Zhao, 2003). Activated carbon adsorption is a well-known method for the removal of heavy metals but the high cost of activated carbon restricts its large-scale use for the abatement of heavy metal pollution in developing countries Cheremisinoff and Ellerbush 1979; Lalvani *et. al*., 1998). A number of workers have used different adsorbent systems, developed from various industrial waste materials, for the removal of heavy metals Aly and Daifullah 1998; Ferraiolo et. al., 1990; Periasamy and Namasivayam 1994; Galiatsatou *et. al*., 2002 Gupta and Ali 2000). There still exists a need to develop a low cost, and efficient adsorbent for the removal of lead from drinking water. The preparation of low cost adsorbent for water purification and wastewater treatment has recently been reviewed by Pollard *et. al*., 1992. Only a limited number of studies, however, have so far been focused on the use of bagasse and its fly ash for the removal of heavy metal ions from wastewater (Peternele *et. al*., 1999; Rao *et. al*., 2002; Gupta and Ali, 2001; Gupta *et al*., 2002; Janusa *et. al*., 2001; Ayub *et. al*., 2001; Gupta *et. al*., 2003). In the present work, an attempt has been made to develop an inexpensive and ecofriendly adsorbent system for the removal of lead from drinking water using bagasse and bagasse fly ash as an alternative to existing costly adsorbents.

Experimental Details

Adsorbent Material

Bagasse is a spent fiber produced from the sugarcane milling after crushing and extraction of juice. It is a typical example of an agricultural waste product that is available in large quantities and has a high potential as an energy source and feedstock for variety of value-added products. It is not a homogenous material but can be considered as peripheral fibers enclosing soft central pith. It is characterized as a low density with wide particle size distribution. The surface area was analyzed by BET method using low temperature N_2 gas adsorption technique. The porosity and density of the adsorbent were determined using mercury porosimetery and specific gravity bottles.

Bagasse preparation

Bagasse was collected from a local sugar factory. It was subjected to treatment under acidic condition to eliminate cellulose fibers as much as possible and to liberate the lignin and all soluble sugars within bagasse. The bagasse was boiled with 0.1 M HCl for approximately 45 minutes, with the residue washed free of sugars and hydrolysis products. This procedure was repeated 3-4 times until the filtrate was virtually colorless. The residual product was oven dried at 110°C overnight and ground to 200 µm fineness. Sorbent materials were stored separately in a vacuum desiccator until use.

Bagasse fly ash preparation

Bagasse fly ash was collected at same place as bagasse. It was oven dried at 110°C overnight and sieved to the desired particle size of 160 µm before use. The bagasse fly ash was stored in a vacuum desiccator for further use. The constituents of prepared carbon were analyzed following the standard methods of chemical analysis.

Synthetic wastewater preparation

Synthetic wastewater samples containing Pb(II) were prepared from lead nitrate ($Pb(NO_3)_2$). The synthetic lead samples were prepared by dissolving known quantity of analytical-grade lead nitrate in double distilled water and used as a stock solution.

Equipment

A Perkin-Elmer model 800 Atomic Absorption Spectrometer (AAS) was used for lead analysis. All of the measurements were made under optimization of wavelength, bandwidth, air/C_2H_2 flame, detection limit 0.05 ppm. pH meter measurements were obtained using a digital pH meter Consort model C 830. The adsorption of lead on the surface of adsorbent was studied by Scanning Electron Microscopy Energy Dispersive X-ray analysis (SEM Model JEOL - 5600). The surface area was measured by Quantasorb surface area analyzer (Model QS-7).

Adsorption experiments

Adsorption studies were conducted by the batch technique to obtain the data. A series of 50-mL plastic conical tubes were used. The tubes were shaken at room temperature (27±2°C) and the shaking speed was 125 rpm. The pH values of solutions were adjusted by addition of HNO_3 and NaOH. The following adsorption experiments were carried out:

Experiment 1*. *Effect of contact time or shaking time: contact time ranging from 3-360 minutes, initial Pb concentration was 10 ppm, initial pH solution was 4 and adsorbent dose was 10 g/L.

Experiment 2. Effect of initial pH and initial lead ions concentrations: pH ranging from 2 to 6. Buffers of different chemical composition were used for this purpose. The initial Pb concentration ranging from 5 to 80 ppm, and adsorbent dose is 10 g/L. This experiment operates at best contact time which result from experiment 1.

Experiment 3*. *Suitable condition to remove lead: Find out equilibration time at the best initial pH and initial lead ions concentrations which result from experiment 2.

Experiment 4. Effect of adsorbent dose: adsorbent dose ranging from 5 to 40 g/L at best contact time from experiment 3 and best initial pH and initial lead ions concentrations from experiment 3.

Experiment 5. Adsorption isotherms for Pb onto each adsorbent: Based on above results set experimental conditions for lead adsorption.

RESULTS AND DISCUSSION

Characterization of adsorbent

Chemical analyses of bagasse and bagasse fly ash are shown in Table 1 and 2.

Table 1. Physical and Chemical analysis of Bagasse

Physical Properties	
Surface area (m^2g^{-1})	22.45
Bulk density($g\ cm^{-3}$)	0.1241
Particle size (µm)	200
Chemical Analysis	**%**
Cellulose	43.58
Pentosan	25.8
Lignin	23.12
Ash	4.8
Silica	2.7

Table 2. Physical and Chemical characteristics of bagasse fly ash

Physical Properties	
Surface area (m^2g^{-1})	956
Bulk density ($g\ cm^{-3}$)	0.375
Particle size (µm)	160
Chemical Analysis	**%**
Ash	49
Moisture	7.6
Percent Volatile Matter	20
Porosity (%)	65.07

Thermogravimetric analysis of Adsorbent

The thermogravimetric analysis of bagasse was carried out using a TA Series Thermogravimetric Analyser. A sample of approximately 15mg was heated to around 800^{0}C at heating rates of 10 and 20^{0}C/min using nitrogen as purge gas. **Figure 1** shows the weight loss and rate of weight loss with respect to temperature the heating rate of 10 and 20^{0}C/min.

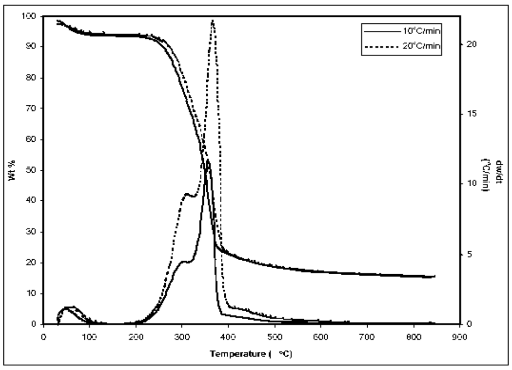

Figure 1. Thermogravimetric Analysis of Bagasse

The effect of contact time or shaking time on lead adsorption

The time-dependent behavior of lead adsorption between adsorbate and adsorbent was measured using conditions that were previously described in Experiment 1. The results were plotted in Figure 2. From the figure, it is clear that the equilibriums for both bagasse and bagasse fly ash were achieved at 15 min of shaking time. The adsorption of lead increased with increasing contact time, but it became almost constant after 15 minutes.

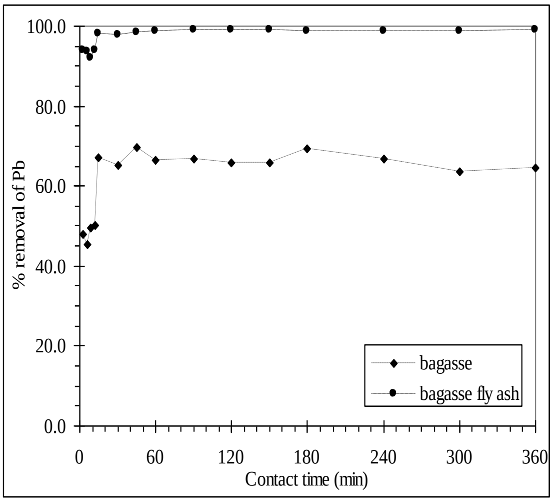

Figure 2. The effect of contact time for adsorption of lead onto bagasse and bagasse fly ash.

The effect of initial pH on lead adsorption

The adsorption of lead on bagasse and bagasse fly ash was studied at conditions described in Experiment 2. It was apparent that removal efficiency increased from 2.7% to 95.6% for bagasse and from 88.1% to 99.1% for bagasse fly ash at pH 2 to pH 6.0 (the initial concentration was 5 ppm). It can be observed that the removal of lead on bagasse and bagasse fly ash exhibited similar trend; that is, it increased with increasing pH, from its minimum at lower pH to its maximum at a certain pH range. It was occurred at all initial concentrations. Figure 3 showed lead removal efficiency at different initial lead ion concentrations. The greatest increases in the sorption rate of lead on bagasse fly ash were observed in a range of pH from 2 to 3. The results are presented in Figure 4; it shows at different initial lead ion concentrations. Further experiments at a solution pH above 6 were not conducted due to the precipitation of lead occurring in the solution. When initial solution pH was 2, 3, 4, and 5 at initial concentration of lead ion is 5 ppm, lead removal efficiencies were 2.7 %, 31.8 %, 64.8 %, and 79.3 %, respectively for bagasse; and 88.1 %, 99.1 %, 99.1 % and 99.1 %, respectively for bagasse fly ash.

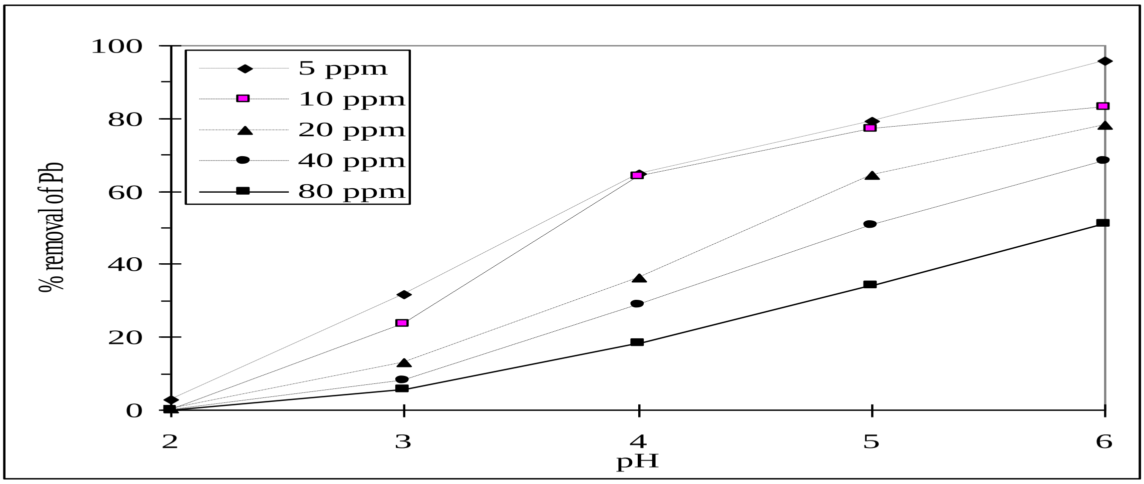

Figure 3. The effect of initial pH on the adsorption of lead onto bagasse.

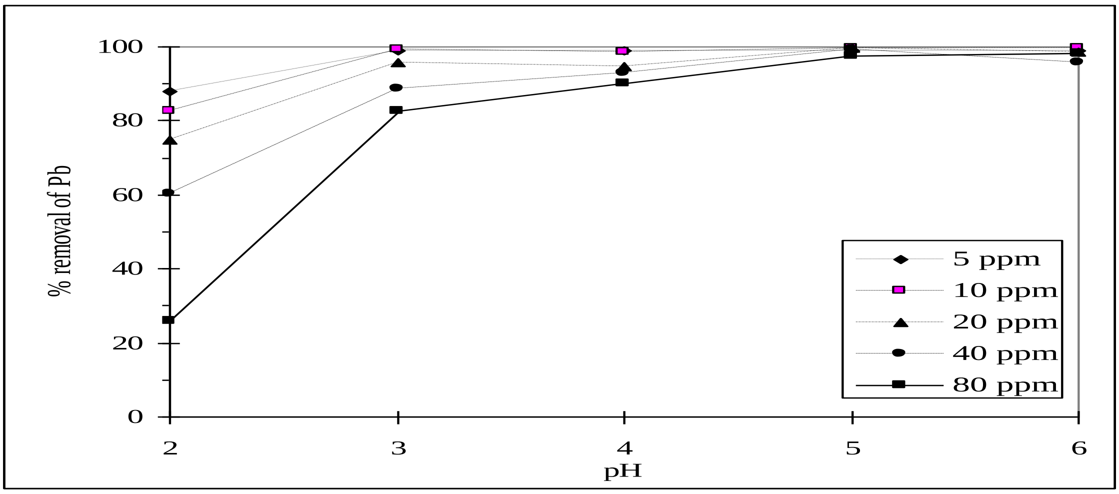

Figure 4. The effect of initial pH on the adsorption of lead onto bagasse fly ash.

The effect of initial lead ions concentrations on lead adsorption

The adsorption experiments were carried out in the conditions explained in Experiment 2. The results are given in Figures 5 and 6 for adsorption on bagasse and bagasse fly ash, respectively. The figures showed the percent removal of lead as a function of initial concentration at different initial pH values. It was observed that, bagasse reduced lead from 64.8 % to 18.4 % when the initial lead ion concentration varied from 5 to 80 ppm with a constant adsorbent dose at pH of 4. In the case for bagasse fly ash, the removal efficiencies were 99.1 % and 90.1 % at an initial concentration of lead ion 5 and 80 ppm at pH at 4, respectively. More than 50 % removal was observed with bagasse; when the initial lead ion concentration was less than 20 ppm at pH lower than 4. In case of bagasse fly ash; more than 50 % removal was observed with almost condition, expect at pH of 2 and initial lead ion concentration is 80 ppm.

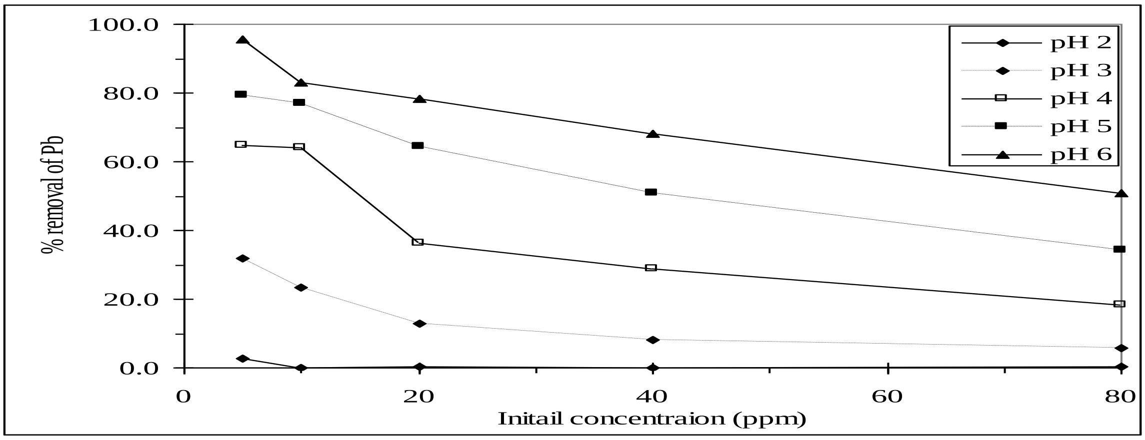

Figure 5. **The effect of initial concentration on the adsorption of lead onto bagasse.**

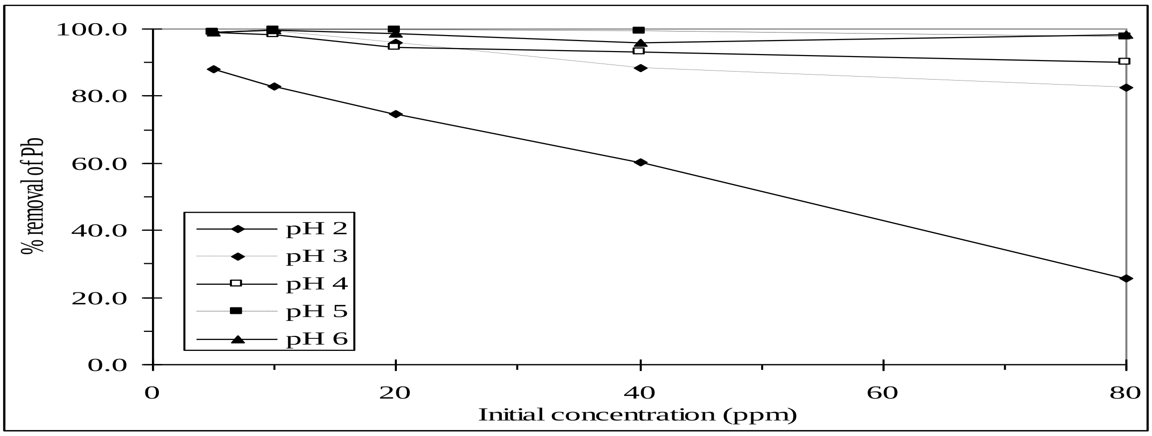

Figure 6. **The effect of initial concentration on the adsorption of lead onto bagasse fly ash.**

The equilibration time on lead adsorption

The adsorption data for the uptake of lead onto bagasse and bagasse fly ash versus contact time are shown in Figure 7. From the figure, the equilibrium time to remove lead should be at least 3 minutes for both adsorbents. The best condition to remove lead ion, for bagasse was at initial pH of 6 and initial concentration of 5 ppm. For bagasse fly ash, the optimal condition occurred at the initial pH of 6 and initial concentration of 20 ppm. Therefore, a 3-min shaking time was found to be appropriate for maximum adsorption and was used in all subsequent measurements.

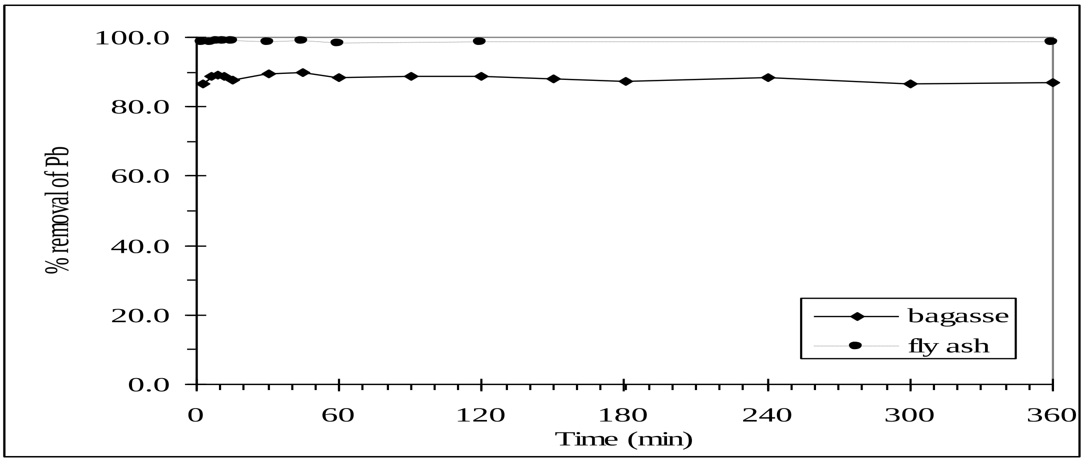

Figure 7. **The equilibration time on lead adsorption onto bagasse and bagasse fly ash.**

The effect of adsorbent dose on lead adsorption

To achieve the maximum adsorption capacity of adsorbent for lead, the experiments were conducted under conditions at fixed contact time of 3 minutes, pH of 6 and initial concentration of 5 and 20 ppm for bagasse and bagasse fly ash, respectively. These findings were plotted in Figure 8. It was found that the dose of 5 g/L was sufficient for the optimum removal of lead onto both adsorbents. In both cases, the percent removal of lead ion increased with increasing adsorbent concentration. The adsorption increased from 24.2 % at 0.5 g/L dose to 90.1 % at 20 g/L dose for bagasse and from 67.4 % at 0.5 g/L dose to 99.0 % at 20 g/L dose for bagasse fly ash, and became almost constant in both cases at 5 g/L dose. It was apparent that the percent removal of lead increased rapidly with increase in the concentration of the adsorbent due to the greater availability of the exchangeable sites or surface areas at higher concentrations of the adsorbent.

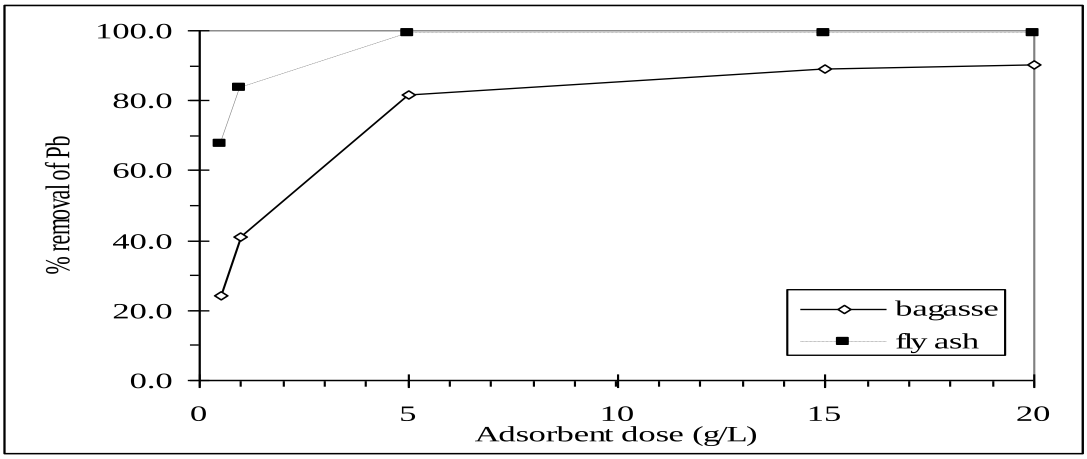

Figure 8. **The effect of bagasse and bagasse fly ash dose on lead adsorption.**

SEM and EDAX Studies

The adsorbent material surface was characterized before and after treatment. The representative SEM micrograph of the fibre surface is shown in the [Fig.9] at 400 resolution. The fibres of the material have large pores as clearly visible and indicated by smaller circle. As is evident from the treated micrograph [Fig.10] at 400 resolution the pores are almost completely occupied by lead ions resulting from the diffusion through the pores of the fibre. The corresponding EDAX is shown in [Fig.11].

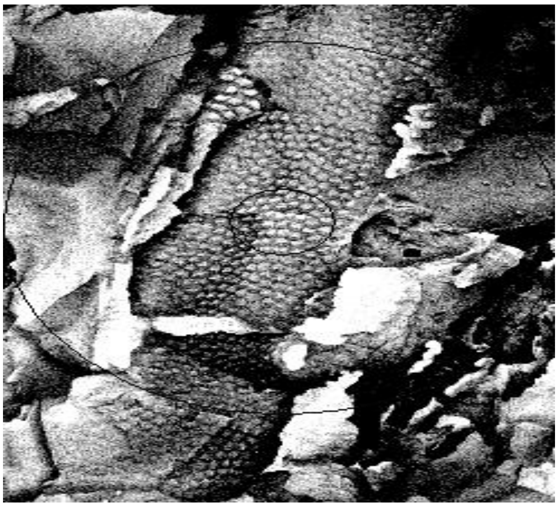

Fig. 9– SEM showing adsorbent material material Surface at 400 resolution before treatment

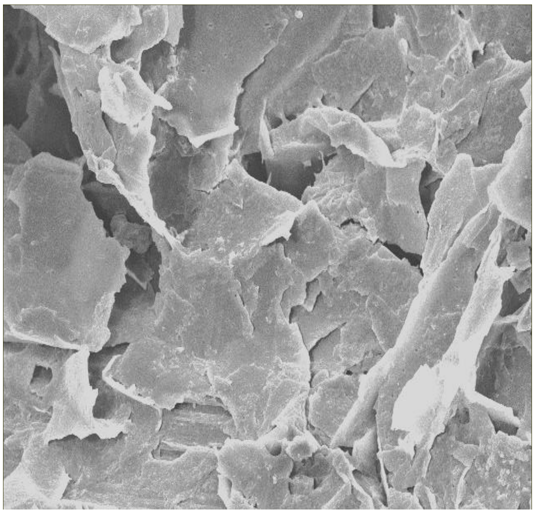

Fig. 10– SEM showing adsorbent material Surface at 400 resolution after treatment

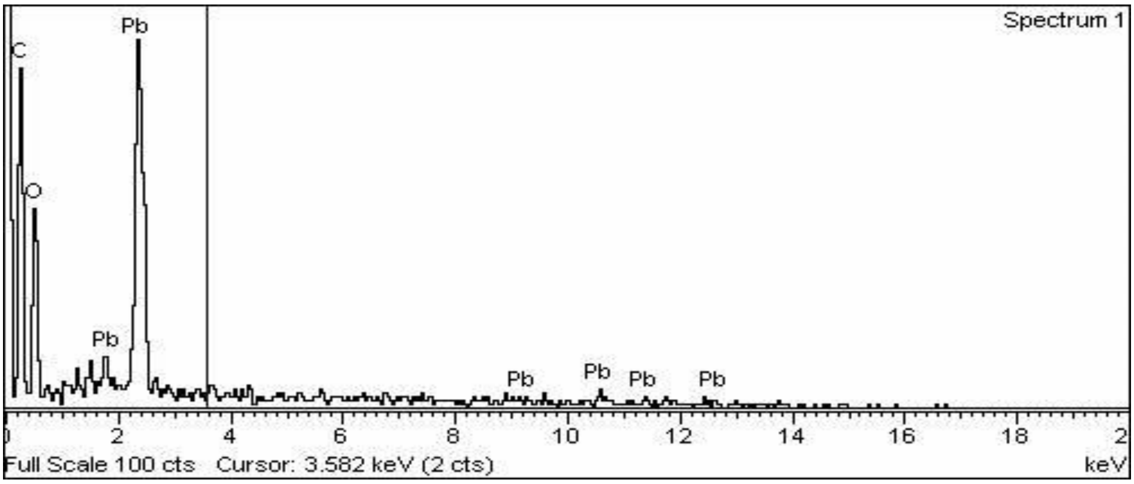

Figure 11. EDAX of sample treated with Lead

Adsorption isotherms for lead adsorption

The Langmuir and Freundlich isotherms described well the observed sorption phenomena for lead. Therefore, this study used them to describe the lead adsorption on bagasse and bagasse fly ash. Langmuir isotherms for the removal of lead ion onto bagasse and bagasse fly ash are shown in Figures 12 and 13, respectively.

Langmuir isotherm has been used by many workers to study the sorption of a variety of compounds. The model assumes uniform energies of adsorption onto the surface and no transmigration of adsorbate in the plane of the surface. The linear form of the Langmuir isotherm is given by equation (1):

$$m/x = 1/q_e = 1/Qo + 1/bQoCe \quad (1)$$

Where: q_e is the amount of lead ions adsorbed per unit weight of adsorbents, Ce is the equilibrium concentration of the adsorbate (mg/L) and Qo and b are the Langmuir constants related to maximum adsorption capacity and energy of adsorption, respectively. When m/x or $1/q_e$ is plotted against 1/Ce, a straight line with slope 1/bQo is obtained and intercept is correspond to 1/Qo.

The essential characteristics of a Langmuir isotherm can be expressed in terms of a dimensionless separation factor, r, which describes the type of isotherm and is defined by equation (2)

$$r = 1/(1+bCo) \quad (2)$$

Where: b is a Langmuir constant and Co is the initial concentration of lead ion. The cases where r > 1 means unfavorable; r = 1, linear; 0 <r < 1, favorable; and r = 0, irreversible. The calculated r values were shown in Table 3.

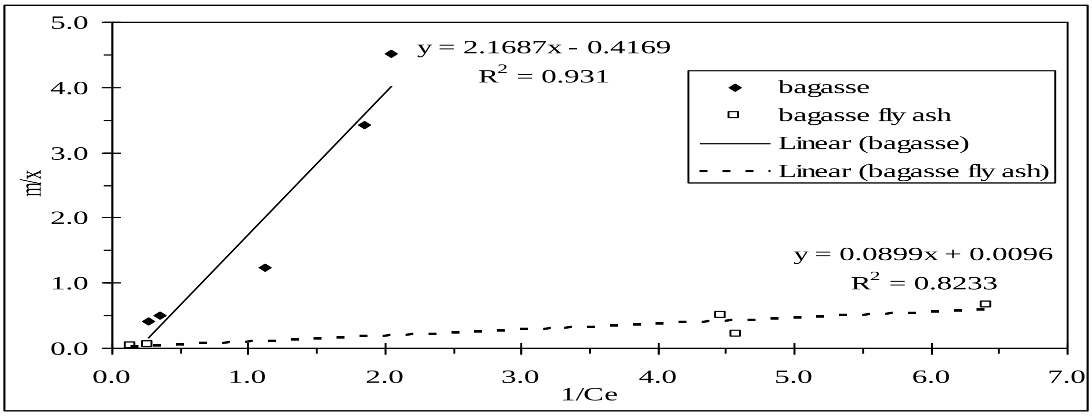

Figure 12. The Langmuir isotherm for lead adsorption onto bagasse and bagasse fly ash.

Freundlich isotherm: the logarithmic form of the Freundlich model is given by the equation (3)

$$\log (x/m) = \log q_e = \log K_f + 1/n \log Ce \quad (3)$$

Where; K_f and n are the Freundlich constants that are associated with adsorption capacity and adsorption intensity, respectively. The value of n between 2 and 10 shows good adsorption. The other parameters have been defined as in equation (1). A plot of log(x/m) against log Ce gives a straight line, the slope and intercept of which correspond to 1/n and log K_f, respectively.

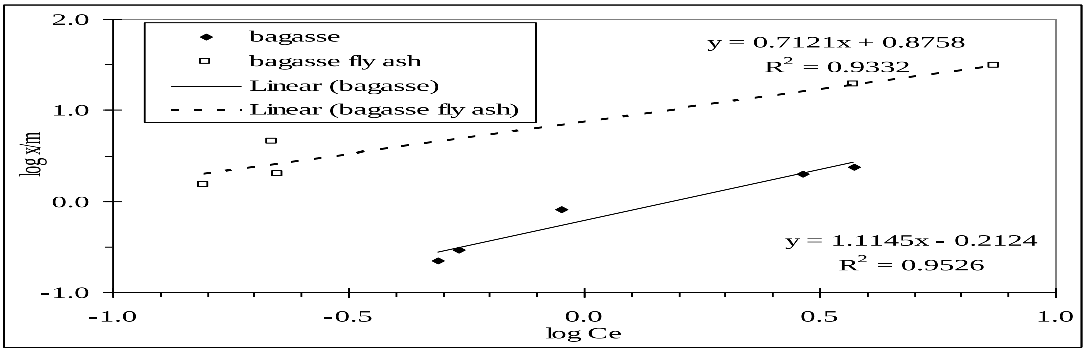

Figure 13. The Freundlich isotherm for lead adsorption onto bagasse and bagasse fly ash.

Table 3. **Values of Langmuir and Freundlich isotherm constants for sorption of lead**

Adsorbent	Langmuir constants			Freundlich constants			Separation factor, r
	Qo	b	R^2	K_f	n	R^2	
Bagasse	-2.399	-0.192	0.931	0.613	0.897	0.9526	18.191
Bagasse fly ash	104.167	0.107	0.823	7.513	1.404	0.9332	0.291

The coefficients of determination (R^2) in **Table 3** indicated that Freundlich isotherm fitted the adsorption data for lead better than Langmuir isotherm for both adsorbents. The separation factors indicated unfavorable sorption for bagasse and favorable sorption for bagasse fly ash. The K_f values which are related to adsorption capacity indicated that bagasse fly ash had more adsorption capacity than bagasse for lead removal. Like K_f, bagasse fly ash had adsorption intensity, n, more than that of bagasse.

CONCLUSION

The comparative efficiency of bagasse and bagasse fly ash as adsorbent materials for lead removal helped to conclude –

1. lead adsorption onto bagasse and bagasse fly ash were found to be between 0.05 to 95.6 % and 25.7 to 99.5 %, respectively,
2. pH of aqueous solutions affected lead removal, i.e. removal efficiency increased with increasing solution pH,
3. the best adsorptions were obtained under condition of pH 6 and contact time 3 minutes, for both adsorbents and the initial concentration was 5 and 20 ppm for bagasse and bagasse fly ash, respectively. The maximum adsorption was about 95.6 % and 99.0 % for bagasse and bagasse fly ash, respectively at this optimal condition,
4. the amount of both adsorbent to remove lead ion from solution is about 5 g/L,
5. adsorption isotherm can be described by Freundlich equation. The equation, $\log x/m = 1.1145 \log Ce - 0.2124$ and $\log x/m = 0.7121 \log Ce + 0.8758$ for bagasse and bagasse fly ash, respectively,
6. bagasse fly ash was a better adsorbent for lead than bagasse as bagasse fly ash has more adsorption capacity than bagasse for lead removal.

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REFERENCES

Manahan S.E. (1990) Hazardous waste chemistry, toxicology and treatment. Michigan: Lewis publishers. 378.

Juang R.S., Wu F.C. and Tseng R.L. (2002) Characterization and use of activated carbons prepared from bagasse for liquid-phase adsorption. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 201, 191-199.

Naseem R. and Tahir S.S. (2001) Removal of Pb(II) from aqueous/acidic solutions by using bentonite as an adsorbent. Water Res. 35, 3982-3986.

Wu Z., Gu Z and Wang X. (2003) Effects of organic acids on adsorption of lead onto montmorillonite, goethite and humic acid. Env. Poll. 121, 469-475.

Yu B. Zhang Y, Shukla A, Shukla SS, Dorris KL (2001) The removal of heavy metals from aqueous solutions by sawdust adsorption-removal of lead and comparison of its adsorption with copper. J. of Haz. Mat. B84, 83-94.

Zhan X.M. and Zhao X. (2003) Mechanism of lead adsorption from aqueous solutions using an adsorbent synthesized from natural condensed tannin. Water Res. 37, 3905-3912.

Cheremisinoff P., Ellerbush F. (1979) Carbon adsorption handbook. Michigan: Ann Arbor Science Publishers.1979.

Lalvani S.B., Wiltowski T., Hubner A., Weston A., Mandich N. (1998) Removal of hexavalent chromium amd metal cations by a selective and novel carbon adsorbent. Carbon. 36, 1219-26.

Aly H.M., Daifullah A.A.M. (1998) Potential use of bagasse pith for the treatment of wastewater containing metals. Adsorp. Sci. Technol. 16, 33-38.

Ferraiolo G., Zilli M., Converti A. (1990) Fly ash disposal and utilization. J. Chem. Technol. Biotechnol. 47, 281-306.

Periasamy K., Namasivayam C. (1994) Process development for removal & recovery of cadmium from wastewater by a low cost adsorbent : adsorption rate and equilibrium studies. Ind. Eng. Chem. Res. 33, 317-20.

Galiatsatou P., Metaxas M., Kasselouri-Rigopoulou V. (2002) Adsorption of zinc by activated carbon prepared from solvent extracted olive pulp. J. Hazard Mater. B91, 187-203.

Gupta V.K. and Ali I. (2000) Utilization of bagasse fly ash (a sugar industry waste) from the removal of copper and zinc from wastewater. Separation and Purification Technology 18, 131-140.

Pollard S.J.T., Fowler G.F., Sollars C.J. and Perry R. (1992) Low cost adsorbents for waste and wastewater treatment: A Review. Sci. Total Environ. 116, 31-52.

Peternele W.S.,Winkler-Hechenleitner, A.A. Pineda, E.A.G. (1999) Adsorption of Cd(II) and Pb(II) onto functionalized formic lignin from sugar cane bagasse. Biores. Technol. 68, 95-100.

Rao M., Parwate A.V. and Ghole A.G. (2002) Removal of Cr^{6+} and Ni^{2+} from aqueous solution using bagasse and fly ash. Waste management 22, 821-830.

Gupta V.K. and Ali I. (2001) Removal of DDD and DDE from wastewater using bagasse fly ash - a sugar industry waste. Water Res. 35, 33-40.

Gupta V.K. Jain CK, Ali I, Chandra S, Agarwal S. (2002) Removal of lindane and malathion from wastewater using bagasse fly ash - a sugar industry waste. Water Res. 36:2483-2490.

Janusa M.A., Laine, P.L., Fanguy, J.C., Champagne C.A. (2001) An alternative use for bagasse: stabilizing agent for lead waste. Sugar Journal 19-23.

Ayub S., Ali S.I., and Khan N.A. (2001) A study on the removal of Cr(VI) by sugarcane bagasse from wastewater. Poll. Res. 20(2), 233-237.

Gupta V.K., Jain C.K. Ali I., Sharma M. and Saini V.K. (2003) Removal of Cd & Ni from wastewater using bagasse fly ash – a sugar industry waste. Water Res. 37, 4038-404.