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Treatment of Leachate from Municipal Solid Waste Landfills using Low Cost Adsorbent

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***Abstract**: Treatment of wastewater for their metal contents is gaining importance in these days. Amongst the various methods reported in the literature, metal adsorption potential by low cost adsorbents is found to be techno-economically feasible action. Studies carried out to evaluate adsorption potential of low cost adsorbents Rice husk (RH), Saw dust(SD) and Ground nut shell(GS) under varied experimental conditions viz. adsorbent bed depth, particle size of adsorbent are presented in this paper. The sequential order of removal potential was found to be SD>RH>GS. Inverse relationship with removal efficiency and particle size of adsorbents and linear relationship between removal efficiency and bed of the adsorbent has been recorded.*

***Keywords :** Adsorbents, Bed depth, Metals, Particle size.*

I. INTRODUCTION

The management of thousands of tonnes of Municipal Solid Waste (MSW) generated daily in metropolitans is a challenging task. The management includes collection, segregation, transportation, reuse and recovery and at the end proper disposal. Literature survey, reveal that landfill is the most commonly employed treatment for municipal solid waste disposal and around 95% of the MSW collected worldwide is disposed by landfilling. From these landfill sites leachate is generated as a consequence of precipitation, surface runoff and infiltration through a landfill. Thus leachate depending on composition of solid waste, age of landfill and other factors consists of high concentration of organic and inorganic impurities along with heavy metals. Toxic heavy metals even in small quantities, if exposed to eco system, accumulation of metal ions will occur in human bodies either through direct intake or through food chains [1]. Therefore if this leachate is not properly collected and treated, there is a major threat to quality of groundwater [2]. Various methods for treatment of physico-chemical constituents of leachate are reported by authors across the globe and widely published. Treatment of leachate for its metal constituents is gaining importance in these days.

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Amongst the various techniques available for removal of metals from wastewaters, adsorption by low cost adsorbent is reported to be techno economically feasible option. The adsorbent potential of metals by adsorbent is a function of concentration of pollutants in wastewater, contact time, adsorbent dosage and pH of wastewater. The findings of bench scale studies carried out to evaluate the feasibility of treating leachate for its metal constituents are presented in this paper.

II. MATERIALS AND METHODOLOGY

A. Adsorbents Used

Three adsorbents namely Rice husk, Sawdust and Groundnut shell were used for experimentation and Rice husk was prepared as per the procedures adopted by Oidde et al.(2009)[3], Saw dust and groundnut shell were prepared as per Shashikumar et al (2015)[4] with different sieve size . Adsorbent particle sizes of 1mm and 300 microns were used for experimentation. Also two different bed depths of adsorbents viz. 11.25 cm and 22.5 cm were adopted.

B. SEM and XRD Analysis for Adsorbents

Out of the three adsorbent, the adsorbent whose removal potential was better compared to other two was analysed for SEM and XRD. Surface morphology of adsorbent was studied using Scanning electron microscope (SEM model JSM-IT 3000). X-ray diffraction (XRD) patterns for adsorbent was recorded with PROTO A x-ray diffractometer using Cuα radiation (λ=1.5406 Å). The diffraction pattern was collected from 10 to 70^{o}, 2θ with step size 0.04^{o} and scan step time 1 second in order to acquire x-ray patterns with sufficiently high intensities.

C. Heavy Metals Used

Synthetic leachate with three metal contents, viz. Cu(II), Zn(II) and Ni(II) of concentrations 9mg/l, 20mg/l and 8mg/l respectively were used for the studies. These concentrations were selected based on the ranges of concentrations of metals in the leachate that may be present as reported by various investigators. The amount of complex salt added to get the required dosage of selected metal viz. Cu (II), Ni(II), Zn(II) details are shown in Table I.

To maintain 9, 8 and 20 mg/l of Cu(II), Ni(II) and Zn(II), 9, 8 and 20 ml of stock solution were added to 1 liter of leachate generated in laboratory by using lysimeter.

Table I. Amount of Salts Required for Preparing 1000mg/l Metal Stock Solution

Metals	Complex Salt Used Formulae	Molecular Weight of Complex Salt (g)	Stock Solution Concentration of Complex Metal (g/l)	Concentration of Metal in Stock Solution
Cu (II)	Copper sulphate penta hydrarte. $CuSO_4.5H_2O$	249.68	3.929	1 g/l
Ni (II)	Ammonium nickel sulphate) $((NH_4)_2SO_4.NiSO_4.6H_2O)$	394.69	6.725	1 g/l
Zn (II)	Zinc sulphate heptahydrate $ZnSO_4.7H_2O$	287.54	4.397	1 g/l

D. Experimental Setup

Bench scale set up used for column studies is presented in Fig. 1. A transparent pipe of 60.96cm height and inner diameter of 30.48 cm was used as column. To prevent the escape of soil, the bottom of each column was plugged with 5mm pore size steel mesh. A filter cloth was placed above the steel mesh to prevent the soil to clog the pores in the steel mesh. Further a reducer was fitted to the pipe at the bottom. However the studies were conducted for flow rate of 1.5 l/h.

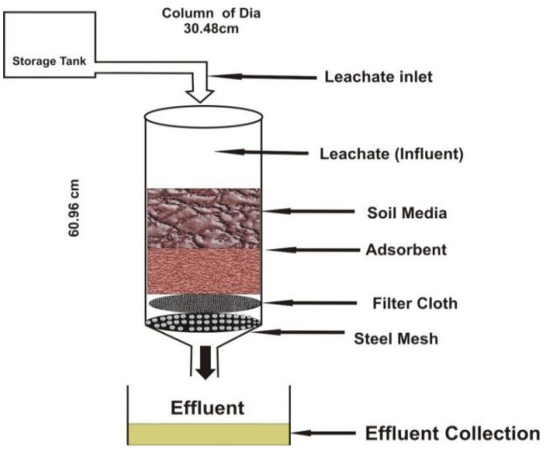


Fig.1 Line Diagram of Column Used for Studies

III. RESULTS AND DISCUSSIONS

The results of experimentation corresponding to an adsorbent bed depth of 11.25 cm, two particle sizes of adsorbent studied are shown in Table II. Also the removal efficiencies of metals considered for study by various adsorbents with different particle size of the adsorbents, depth of adsorbent bed being 22.5 cm are represented in Fig. 2.

Based on the analysis of results of these set of experimentation, the following inferences have been drawn.

Better removal efficiency was observed with an adsorption bed depth of 22.5cm compared to 11.5 cm.

Adsorbent with smaller particle size of adsorbent exhibited better degree of treatment.

Amongst the three adsorbents considered for experimentation, saw dust exhibited higher removal potential followed by Rice Husk & Groundnut shell.

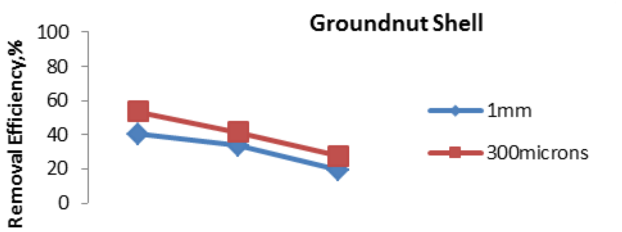
For 22.5cm of adsorbent bed depth with smaller size of particles of adsorbent Cu(II), Zn(II) & Ni(II) removal potential of sawdust were found to be 82.11%, 67.8% and 78.87%.

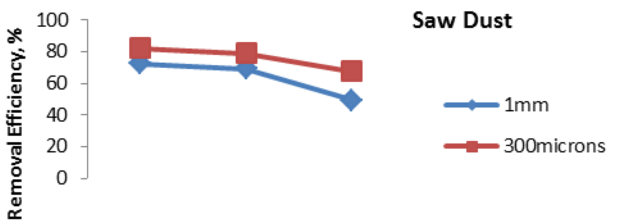
Corresponding removal efficiencies of these metals for bigger particles viz. of the adsorbent were respectively 72.44%, 49.3% and 69.37% respectively.

For optimized adsorbent bed depth and particle size metal removal efficiencies of 75.33%, 46.7% and 70.38% with rice husk were recorded for Cu(II), Zn(II) and Ni(II) respectively. The corresponding values for Groundnut Shell were found to be respectively 53.6%, 27.8% and 41.64%.

Table II. Metal Removal Potential of Adsorbents Studied (Depth of Bed=11.25cm, Diameter of Column= 0.3m, Flow rate=1.5l/h)

Metals	Removal Efficiency with reference to Adsorbent Stated					
	Rice husk		*Sawdust*		*Groundnut shell*	
	1mm	300 microns	1mm	300 microns	1mm	300 microns
Cu(II)	38.56	43.67	46.44	51.44	33.22	41.89
Zn (II)	19.2	24.3	34.3	44.8	10.35	16.25
Ni (II)	32.38	38.25	40.38	47.25	17.38	25.5





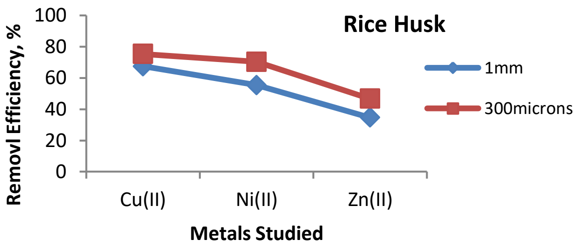


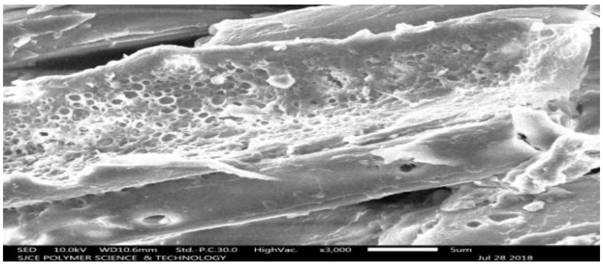
Fig. 2 Effect of particle Size in Removing Metals by adsorbents for a Bed Depth of 22.5cm.

The influence of particle size furnishes important information for achieving optimum utilization of adsorbent. The literature review revealed that percentage removal decreases with increasing geometric mean of adsorbent size. This is because adsorption being a surface phenomenon and the smaller size adsorbent particles provides greater surface area and results in higher adsorption of metals. Also smaller particle sizes reduce the external mass transfer resistance. Weber and Morris (1963)[5] stated that breaking of larger particles tends to open tiny cracks and channels on the particle surface providing added surface area. Sharma and Singh (2008)[6] reported higher percentage removal of zinc by rice husk of smaller particle size compared to adsorbent particles of larger size. Sulaiman (2015) [7] from his studies on factors affecting bio sorption of copper ion, noticed that bio sorption capacity of copper ions at equilibrium increases with decreases of particle size. Studies carried out by Deshmuk and Rathod (2008)[8] to evaluate the influence of adsorbent particle size on kinetics of adsorption of the dyes revealed that the removal efficiency decreases with increase in particle size. Studies were carried out to evaluate the effect of particle size of banana peel on adsorption of copper [9] and reported that Cu removal efficiency of powder particles is much higher than that of larger sized particles. Studies also reported that equilibrium may be achieved quickly if the smaller adsorbent particles could be used [10]. Further Daifullah et al. (2004)[11] observed higher uptake and adsorption rate from the fine particles of the activated carbon adsorbent prepared from the biomass than the larger particles of same adsorbent. Decreasing percentage removal of Cr^{+6} with increase in size of the adsorbent is reported by Madhukar et al. (2015)[12] and they inferred that when the particle size increases, the number of active sites decreases. Increase in adsorption capacity of cadmium on modified coired pith with smaller adsorbent particle size has been reported by Khongkasem et al. (2010)[13]. Also many researchers across the globe have reported better treatment potential of dyes with smaller adsorbent particle size compared to bigger size of adsorbent particles [14]-[18]. However it is cautioned that great care should be exercised with smaller size of the adsorbent particles as it may lead to problems like clogging etc.

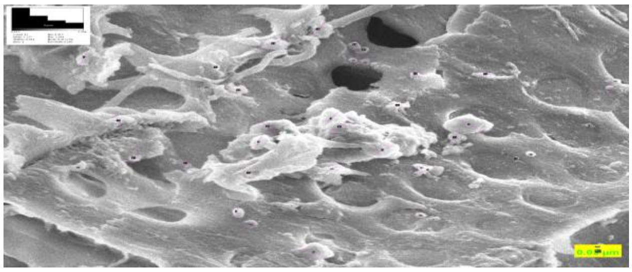
Experimentation on treatment of leachate and industrial wastewater for metal contents carried out by researchers across the globe using adsorbent has been widely reported in the literature. The result of present study was found to follow the trends reported by the researchers. Compared to zinc higher adsorption of copper from aqueous solution by sawdust has been reported [19]. Experimentation on adsorption of heavy metals from simulated landfill leachate carried out by Agubugui and Nwardozie (2015)[20] reported the higher adsorption of heavy metal by saw dust compared to rice husk. However within a statistical limitation same removal efficiencies of Cu and Ni by rice husk has been observed by Hegazi (2013)[21]. Compared to rice husk better removal of Cu and Zn by saw dust has been reported by Mahajan et al. (2014)[22]. Also Oliveria et al.(2010)[23] stated that peanut hulls have better adsorption potential for cu compared to Zn and Ni further ground shell as a adsorbent exhibited better Cu adsorption compared to sawdust.

The SEM images and XRD patterns of the optimised adsorbent (Sawdust, 300microns particle size) before and after treatment are as shown in Fig. 3 and Fig.4.

In order to study the morphology of optimized adsorbent i.e. sawdust before and after treatment SEM images at 3K magnification are taken and are presented in Fig. 3. From Fig 3(a), it is observed that prior to adsorption treatment, sawdust is having very fine pores on it and after treatment (**Fig 3(b)**), some tiny particles are found to be distributed in the non uniform manner on the surface of saw dust. The change in surface morphology is an indication of the fact that adsorption has taken place.

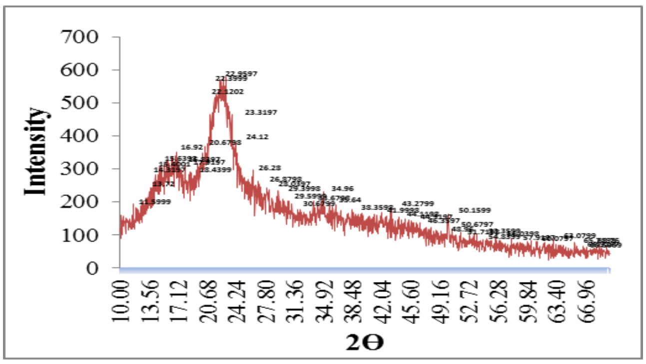


(a) Before Treatment (3K)

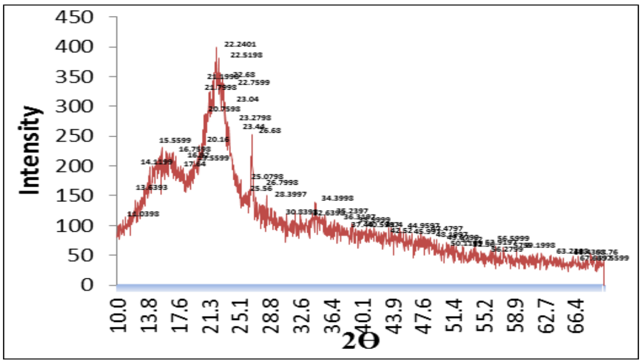


(b) After Treatment (3K)

Fig.3 SEM images for Sawdust



(a) Before Treatment



(b) After Treatment

Fig.4 XRD for Saw dust

The observed diffraction peaks (2θ) for saw dust before treatment (Fig.4(a)) are 15.49º, 18.44º, 22.90º, 41.93º, 48.97º corresponds to the presence of SiO_2 (JCPDS card 881535) and peaks 35.64º and 41.99º shows the presence of Fe_2O_3 (JCPDS card 871166,862316). The new peaks after treatment (Fig.4 (b)) corresponding to 2θ value 41.4º, 50.11º, 35.23º, 25.07º could be ascribed to $CuSO_4$ (JCPDS card 862456 and 721248) and shows that metal ions have impregnated on sawdust.

IV. CONCLUSIONS

Analysis of results of experimentation lead to a conclusion that maximum removal efficiencies of metals from the leachate can be achieved by using saw dust as adsorbent followed by rice husk and groundnut shell. Further it is concluded that the metal removal potential of adsorbent will be maximum with smaller particle size of adsorbents and at the higher adsorbent bed depth. The adsorbent capacity of saw dust for Cu(II) is maximum followed by Ni(II) and Zn(II).

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