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Influence of adsorbent particle size on adsorption of metal Ions onto modified and unmodified biomass adsorbents

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ABSTRACT

Early studies on the adsorption and ion exchange potential of coconut coir dust (*Cocos nucifera L.*) shows that it has great proficiency for removal of trace metal ions from waste water and industrial effluents. Several factors influence the process of waste water detoxification by agricultural biomass. In this paper the effect of Particle sizes of coconut coir dust on the removal of metal ions by ion exchange has been studied by batch adsorption process for Pb(II), Zn(II), Cu(II), and Cd(II). Percentage sorption of Pb(II), Cu(II), Cd(II), Zn(II) increase with decrease in particle sizes of coir dust: 50 µm > 63 µm > 150 µm > 212 µm > 300 µm > 425 µm > 600 µm. The adsorptivities of the metal ions on the unmodified coir dust decreased in the descending order: Pb(II) > Cd(II) > Zn(II) > Cu(II).

Introduction

Over the years, enhanced industrial activities has led to the discharge of unprecedented volumes of waste waters and effluents into the environment. The various activities associated with environmental pollution are mining operations, ore-processing and smelting, urbanization, metal-plating, tanneries and agriculture-related processes [9, 10]. These metal contaminants are not biodegradable but accumulate in living organisms becoming a permanent burden on the ecosystem [2]. Their presence in the environment even at low concentration has therefore the potential of becoming a cause of toxicity to humans and other forms of life [4]. Industrial effluents and drinking water loaded with metals is thus a serious public health problem [3]. Over-abundance of the essential trace elements and particularly their substitution by non-essential ones, such as Cd, Ni, Ag can also cause toxicity symptoms.

Scientific measures taken to reduce and/or remove this toxic substances from waste water and the environment are taken including the use of agricultural waste biomass as low cost adsorbent for series of batch adsorption processes which also involves proper harnessing the particle sizes of the dried biomass to enhance efficient removal of metal ions from waste water and industrial effluents.

Materials And Method

Coir dust $(500mg)$ of different particle sizes $50-600(m$ were taken separately in conical flasks containing $50ml$ of $\frac{10mg}{l}$ of the Cu(II), Pb(II), Cd(II) and Zn(II) solution and were shaken for 3 hours on orbital shaker at agitation speed of $140rpm$ at $30°C$. At the end of this period the samples were filtered and adsorbate concentrations were determined using Atomic Absorption Spectrophotometer.

Result And Discussion

The effect of the coir dust particle sizes on the adsorption behavior of metal ions: Pb(II), Cu(II), Cd(II) and Zn(II) were evaluated and the results shown in Tables 1-4. The plots of % Adsorption of metal ions (Pb, Cu, Cd and Zn) versus particle sizes of the coir dust ranging from 50-600µm as shown in Figures 1-4. The results showed that at particle size of 50µm, the removal of Pb(II) ions from the solution was complete 100%, while for the particle sizes of 63µm – 425µm, the removal was above 90% except for particle size 600µm which recorded 89.88% (Table 1). It can be observed that the removal efficiency of the metal ion increased with decreased particle size. Similar results for the increased efficiency of the removal of Pb(II) from aqueous solution with decreasing particle size has been reported [5, 12]. The high sorption of metal ions by adsorbent with smaller particle sizes is attributable to the availability of more surface area on the adsorbent. For the adsorption of copper, the maximum adsorption of 96.0% was achieved at particle size of 50 µm while the highest particle size of 600 µm recorded the least amount adsorbed 67.23% (Table 2). Also the largest particle size of coir dust (600µm) adsorbed the least amount of metal ion for all metals- Pb(84.05%), Cd(84.05%), Cu(67.23%) and Zn(60.06%) while the lowest particle size of 50 µm, Pb(100%), Cu(96.0%), Cd(98.8%) and Zn(96.0%) respectively (Table 5).

The summary of the plots of % Adsorption of the metal ions versus particle sizes of coir dust is shown in Figure 5. The general trend for metal ions adsorbed by the coir dust followed the order of particle sizes in micron of meter (µm) of $50 > 63 > 150 > 300 > 425 > 600$ respectively. The smaller particle sizes present shorter paths for the metal ions to transverse while reverse is the case for larger particle sizes [13]. Similar results have been reported for increased adsorption with decreasing particle sizes for other adsorbents [1, 6]. The differences in the amount of metal ions adsorbed by the coir dust is determined by metal solution chemistry. Rate of adsorption is being affected by ionic radius, charge, electronegativity, electrostatic strength and the covalent index

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$(X_m{}^2 r)$, where X_m is electronegativity and r is the ionic radius. The greater the covalent index value of the metal ion, the greater is its potential to be adsorbed [8]. The electronegativities of Pb(2.33), Cd(1.69), Cu(1.80) and Zn(1.70) have been documented by [11]. Hence the adsorptivities of the metal ions by the coir dust fall in the order of Pb(II) > Cd(II) > Zn(II) > Cu(II) respectively. The higher sorbability of Zn(II) by the coir dust than Cu(II) may be due to the fact that Zn(II) is hydrolyzed in aqueous solution to a greater extent than Cu(II) rendering its more available for sorption than Cu(II) ions [7].

Conclusion

The adsorption of metal ions on coir dust increased with decrease in particle sizes. Studies carried out on the effect of particle size of coir dust (50-600µm) on the removal of metal ions showed that percentage of adsorption of metal ions (Pb, Cu, Cd, Zn) increase with decrease in particle size. The adsorptivities of the metal ions by the coir dust decreased in the following order Pb(II) > Cd(II) > Zn(II) > Cu(II).

Acknowledgement

My partner Aniekeme-Abasi Israel deserves much commendation, his unyielding seal to contribute to the scientific revolution of the twenty first century motivates me.

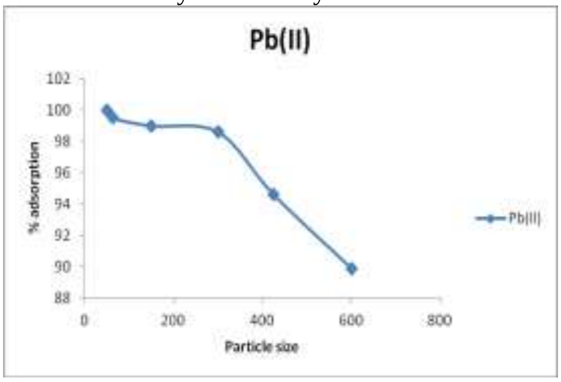

Fig. 1- **Plot of % Adsorption versus Effect of Particle Size (µm) of Coir dust with Zn(II), Pb(II), Cu(II), Cd(II).**

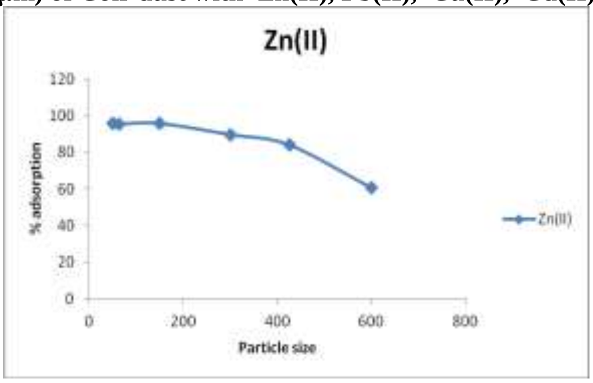

Fig. 2 **- Plot of % Adsorption versus Effect of Particle Size (µm) of Coir dust with Zn(II), Pb(II), Cu(II), Cd(II).**

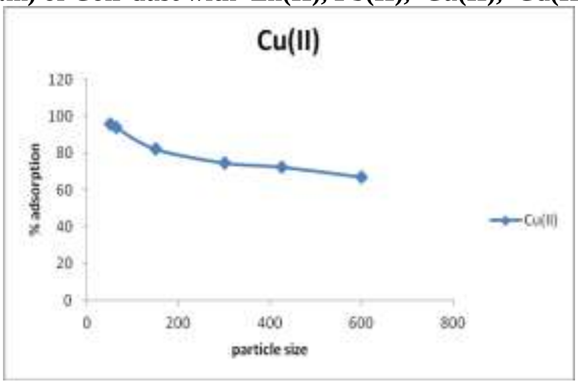

Fig. 3 **- Plot of % Adsorption versus Effect of Particle Size (µm) of Coir dust with Zn(II), Pb(II), Cu(II), Cd(II).**

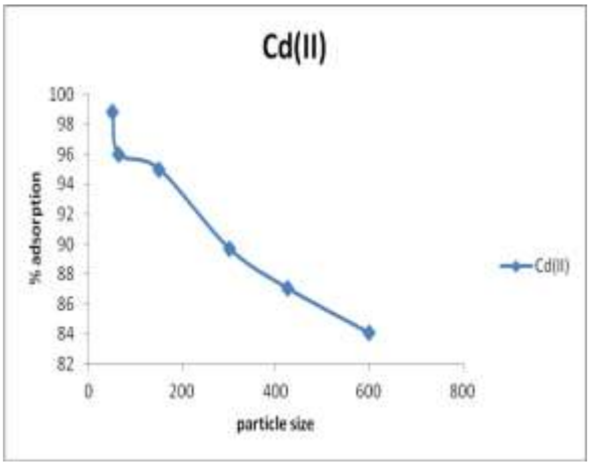

Fig. 4 **- Plot of % Adsorption versus Effect of Particle Size (µm) of Coir dust with Cd(II).**

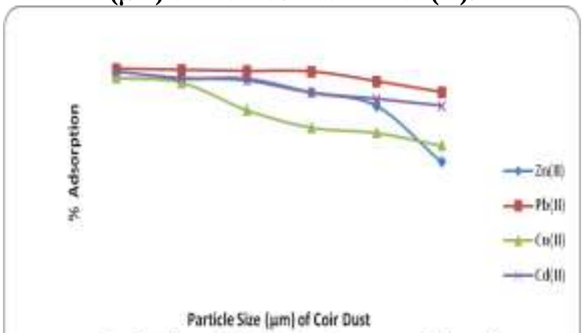

Fig. 5 **- Plot of % Adsorption versus Effect of Particle Size (µm) of Coir dust with Zn(II), Pb(II), Cu(II), Cd(II).**

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Table 1: Effect of Particle Size on Adsorption of Pb(II) on Coir Dust

Particle size (μm)	Amount unadsorbed C_e(mg/l)	Amount of Pb(II) adsorbed	Selectivity K_D	Quantity of adsorbed ion exchange qmg/g	% Adsorption
50	0.814	19.186	23.57	0.96	100.00
63	0.105	19.890	189.43	0.99	99.50
150	0.199	19.801	99.50	0.99	99.0
300	0.236	19.764	83.75	0.98	98.60
425	1.084	18.916	17.45	0.94	94.60
600	2.025	17.975	8.88	0.89	89.88

Initial concentration = 20mg/l, dose = 1g, temp = 30°C, pH = 7, volume of solution = 50mL, time 90 mins

Table 2: Effect of Particle Size on Adsorption of Cu(II) on Coir Dust

Particle size (μm)	Cu(II) C_e(mg/l)	Xmg/l	Selectivity K_D	Quantity adsorbed mg/g	% Adsorption
50	0.814	19.186	23.57	0.96	96.00
63	1.201	18.799	15.63	0.94	93.99
150	3.554	16.466	4.63	0.82	82.73
300	5.031	14.969	2.98	0.75	74.85
425	5.483	14.517	2.65	0.73	72.59
600	6.554	13.446	2.05	0.67	67.23

Initial concentration = 20mg/l, dose = 1g, temp = 30°C, pH = 7, volume of solution = 50mL, time 90 mins

Table 3: Effect of Particle Size on Adsorption of Cd(II) on Coir Dust

Particle size (μm)	Amount of Cd(II) Unadsorbed (mg/l)	Amount of Cd(II) adsorbed (mg/l)	Distribution coefficient K_D	Quantity adsorbed (mg/g)	% Adsorption
50	0.236	19.764	83.75	0.99	98.8
63	0.822	19.178	23.33	0.96	96.0
150	0.851	19.149	22.50	0.95	95.0
300	2.056	17.944	8.73	0.89	89.70
425	2.595	17.405	6.71	0.87	87.05
600	3.186	16.814	5.28	0.84	84.05

Initial concentration = 20mg/l, dose = 1g, temp = 30°C, pH = 7, volume of solution = 50mL, time 90 mins

Table 4: Effect of Particle Size on Adsorption of Zn(II) on Coir Dust

Particle size (μm)	Amount of Zn(II) Unadsorbed C_e(mg/l)	Amount of Zn (II) adsorbed Xmg/l	Distribution coefficient K_D	Quantity adsorbed (mg/g)	% Adsorption
50	0.770	19.230	24.97	0.960	96.0
63	0.766	19.234	25.11	0.962	95.50
150	0.696	19.304	27.74	0.967	95.73
300	0.556	19.444	34.97	0.972	89.72
425	0.586	19.414	33.13	0.971	84.07
600	0.961	19.039	19.81	0.950	60.06

Initial concentration = 20mg/l, dose = 1g, temp = 30°C, pH = 7, volume of solution = 50mL, time 90 mins

Table 5: Summary of Variation of % Adsorption of Metal Ions with Particle Size.

	Pb(II)	Zn(II)	Cu(II)	Cd(II)
Particle size (μm)	% Adsorbed	% Adsorbed	% Adsorbed	% Adsorbed
50	100.00	96.00	96.00	98.8
63	99.50	95.50	93.99	96.0
150	99.0	95.73	82.33	95.00
300	98.60	89.72	74.85	89.70
425	94.60	84.07	72.59	87.05
600	89.88	60.86	67.23	84.05

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