Characterization and Sorption Properties of Palm Milk (Htan Nui) for the Removal of Pb^{2+} and Cr^{3+} Ions from Aqueous Solutions

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Abstract

In this research, the palm milk (Htan nui) was used for removal of lead and chromium from aqueous solutions. The raw and carbonized palm milk powder samples were used for the removal of heavy metals. The palm milk raw materials were chemically activated by phosphoric acid (H_3PO_4). The moisture content of raw and carbonized palm milk powder were found to be (5.17 ± 2.52%) and (6.8 ± 3.25%). The raw and carbonized samples were characterized by SEM technique. The external surface shows a rough area having different pore diameters distributed over the surface of carbonized palm milk powder than raw palm milk powder. So, carbonized palm milk powder was be used to continue experiment. Various parameters such as pH and adsorbent dose were studied to establish optimum adsorption condition. The lead adsorption was found to increase with an increased in pH 4 to 6 and attained a maximum value at pH 7 (91.56%). The removal percent of chromium ion increased with the weight of sample increased. In this present work, adsorption of metal ions such as Pb^{2+} and Cr^{3+} onto activated carbon of palm milk were examined by using Freundlich and Langmuir isotherms. The equilibrium parameter value of E_p is 0.2591; the type of isotherm is favorable isotherm. The sample of experimental desorption was carried out by using 8 M, 6 M and 4M HNO_3 solution and recoverable percent was calculated. The desorption process of lead and chromium loaded carbonized palm milk powder sample were increased with an increase in concentration of nitric acid solutions.

Keywords: Palm milk, aqueous solution, isotherm, desorption

INTRODUCTION

Toddy palm *(Borassus flabellifer* L.*)* or so called Htan tree is an important local plant that supports villager's life (palm sugar and building). Local people in tropical zone of middle Myanmar are mostly farmers; their local culture of self- sufficiency is still being practiced in their daily consumption.

Botanical description of toddy palm

Figure 1.1 Htan tree and palm milk (Htan nui)

Family : Arecaceae

Botanical name : *Borassus flabellifer* L.

Common name : Toddy palm

Myanmar name : Htan

Part of used : Htun nui

Production concept of farmers both in agriculture and in horticulture is still in traditional way, this means they produce staple food to cover their daily needs enough, they don't think production for infestation in the future.

Toddy palm is one of family member of Arecaceae that grows in semi -arid to humid area. This palm can grow about 15-30 m tall, with the average stem diameter of 60 cm. This plant is dioeciously (it separates between male and female plants), with fruits are arranged in a

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stem of about 20 fruits in each stem. This palm originally came from Africa and its distribution spreads from India, Malaysia, Cambodia, Indonesia and Myanmar.

Palms are vigorous, high production trees, and their importance to tropical peoples cannot be understated (Stavin, 1968). Some species, called Toddy Palms, have been tapped particularly for their sweet sap which is made into sugar and both alcoholic and non-alcoholic beverages. Their sweet fruit and young stems are also used. Palm wine is known as Htan Yay in Myanmar. Toddy is also consumed in Myanmar.

Activated carbon is used in methane and hydrogen storage, air purification, decaffeination, gold purification, metal extraction, water purification, medicine, sewage treatment, air filters in gas masks and respirators, filters in compressed air, teeth whitening and many other applications.

Adsorption is defined as the adhesion in an extremely thin layer of molecules (as of gases, solutes, or liquids) to the surfaces of solid bodies or liquids with which they are in contact. A solid substance used to collect solute molecules from a liquid or gas is known as adsorbent and a substance that has been or is to be adsorbed on a surface is known as adsorbate. Common examples of adsorbents are clay, silica gel, colloids, metals etc.

Physisorption or physical adsorption is a type of adsorption in which the adsorbate adheres to the surface only through Van der Waals (Weak intermolecular) interactions, which are also responsible for the non-ideal behavior of real gases (Mostafa, 1997).. Chemisorption in this kind of adsorption, the gas molecules or atoms is held to the solid by chemical bonds. For example, hydrogen is chemisorbed on nickel. Agricultural by products can be a source for activated carbon production with high surface areas and adsorption capacity.

Adsorption is defined as the adhesion in an extremely thin layer of molecules (as of gases, solutes, or liquids) to the surfaces of solid bodies or liquids with which they are in contact. A solid substance used to collect solute molecules from a liquid or gas is known as adsorbent and a substance that has been or is to be adsorbed on a surface is known as adsorbate. Common examples of adsorbents are clay, silica gel, colloids, metals etc (Cieslak, 1995). Freundlich isotherm is the most utilized isotherm in wastewater treatment. It has been reported that data for the adsorption involving adsorbates within a liquid phase is the best by using this isotherm. The Langmuir equation was chosen for the estimation of maximum adsorption capacity corresponding to biomass surface saturation. The main aim of this paper is to investigate the sorption properties of palm milk (Htan nui), to remove $Pb^{2+}$and Cr^{3+} ions from aqueous solutions.

MATERIALS AND METHODS

Materials and Methods of Analysis

Specific chemicals used are described in each of the experimental. All standard solution and all other diluted solutions through the experimental were prepared by using distilled water.

Generally, such the apparatuses as Mettler Balance AE-160, pH meter (Cole, Parmer) and Thermostatic shaker (Yamaha) other standard laboratory ware and glassware were used in the monitoring and routing analysis. Palm milk (Htun nui) sample was used in this experiment. The experiment was determined using Atomic Absorption Spectrophotometer.

Sample Collection and Preparation

Palm milk (Htun nui) was collected from Natmauk Township, Magway Region, in Myanmar. The palm milk was dried in sun light and then cut into 1-2 cm length pieces. The cut palm milk was made into powder by blender and meshed with (250 µm) sieve. About 50 g of palm milk powder was mixed with 100 mL of 1 M concentrated phosphoric acid. The mixture was carbonized at 300 ºC for 16 H. The sample was withdrawn from the oven and then cooled in desiccators. After cooling, sample was rinsed several times with distilled water to still pH 6-7 and filtered off. The residue was dried at 100 ºC for 24 H. The carbonized palm milk powder was used throughout the study.

Determination of Some Physicochemical Properties of Raw and Carbonized Palm Milk Samples

2 g of raw palm milk sample was placed into a beaker and 100 mL of distilled water was added to this sample. The sample solution was heated at 80º C for 2 min. Then the sample solution was gently shaken and filtered off. The filtrate was cooled at room temperature and the pH of sample was determined by using pH meter.

Clean and dry graduated cylinder (10 mL size) was weighted and the dried palm milk sample was filled into the cylinder. The total weight of cylinder including sample was again weighed. Cylinder was placed in a tapping box and cylinder was tapped until no more reduction volume. Minimum volume was recorded and bulk density of raw and carbonized palm milk samples were calculated. 2 g of raw palm milk sample was accurately weighed in the porcelain crucible. It was kept in the oven at 100 ºC for 1 H. Then it was taken out and allowed to cool down at room temperature in desiccators. After cooling the sample, it was weighted again. By these processes, the moisture content of raw palm milk sample was calculated. Similarly procedure was carried for carbonized palm milk.

Examination on the Morphology of Raw and Carbonized Palm Milk Sample by Scanning Electron Microscope (SEM)

The raw and carbonized palm milk samples were examined by SEM for a visual inspection of external porosity and morphology in Magway University.

Effect of pH on Adsorption of Lead (II) and Chromium (III) Solutions by Carbonized Palm Milk Sample

The lead (II) removal efficiency of carbonized palm milk at 300 ºC sample was determined by changing the pH of the solution. Each 20 mL of lead (II) solution (100 ppm) was added into the separated 250 mL of conical flasks and adjust to pH (4.0, 5.0,6.0, 7.0 and 8.0) using 1 M H_2SO_4 and 1 M NaOH solutions.

Then (1 g) of carbonized palm milk sample was added into each different pH of the conical flasks and these were shaken in shaker for 2 H. Then the solution was removed by filtration. The resultant filtrates for each pH were analyzed for nickel (II) determination using Atomic Absorption Spectrophotometer. According to this procedure for pH effect, Chromium (III) ion onto adsorbent was carried out.

Effect of Dosage on Adsorption of Lead (II) and Chromium (III) Solutions by Carbonized Palm Milk Samples

Lead (II) removal efficiency of carbonized palm milk at 300 ºC was determined by different weights (0.3, 0.5, 1.0, 1.5 and 2.0 g). Each 20 mL of lead (II) solution (100 ppm) was taken into separated 250 mL conical flask and adjust to pH 7.0 using 1 M H_2SO_4 and 1 M NaOH solution. Then (0.3 g) of carbonized palm milk at 300 ºC was added into a conical flask and was shaken in shaker for 2 H. Then the solutions were removed from palm milk sample by filtration. Similarly, the respective conical flasks for different dosages of (0.5, 1.0, 1.5 and 2.0 g) were carried out. The resultant filtrates were analyzed for lead (II) determination using Atomic Absorption Spectrophotometer. According to this procedure for dosage effect, Chromium (III) ion onto adsorbent was carried out.

Determination of Desorption Process for Metal Loaded Carbonized Palm Milk Powder Sample

Each (0.5)g of lead-loaded carbonized palm milk powder sample was added into separated conical flask containing 25 mL of 8 M, 6 M and 4 M nitric acid solutions and then ,this conical flasks were shaken in shaker. After 2 H, the solution was removed from metal loaded carbonized palm milk powder sample by filtration. Similarly, chromium-loaded carbonized palm milk powder samples were carried out, respectively.

The resultant filtrates were analyzed for lead (II) and chromium (III) by using Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

Figure 1.The photograph of raw palm milk powder

Figure 2. The photograph of carbonized palm milk powder

About 15 g of carbonized palm milk powder was obtained from 50 g of raw material (Figure 1). In Figure 2, carbonized palm milk powder was prepared with H_3PO_4 solution (1 M).

In Table 1, the moisture content of raw and carbonized palm milk powder were found to be (5.17 ± 2.52 and 6.8 ± 3.25). From this data the bulk density of raw and carbonized palm milk were found to be (1.419 ± 1.180 gcm^{-3} and 1.80 ± 0.02 gcm^{-3}). Therefore, the bulk density of raw and carbonized palm milk are small different.

Table 1. Some Physicochemical Properties of Raw and Carbonized Palm Milk Powder

sample	Bulk density (gcm^{-3})	Moisture content (%)	pH
Raw Palm milk	1.41 ± 0.08	5.17 ± 2.52	6.9
Carbonized palm milk	1.18 ± 0. 02	6.8 ± 3.25	6.7

The external surface shows a rough area having different pore diameters distributed over the surface of carbonized palm milk powder than raw palm milk powder (Figure 3). In the morphology of carbonized palm milk powder (Figure 4) seems that formation of cavity resulted from the removal of major components of raw materials by using phosphoric acid. Therefore the carbonized palm milk powder was used for following experiments.

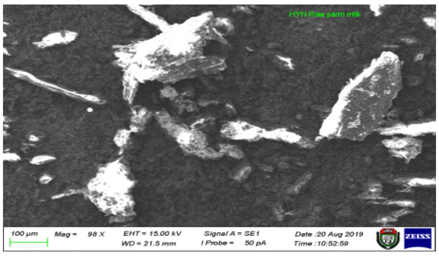

Figure 3. The SEM photograph of raw palm milk powder

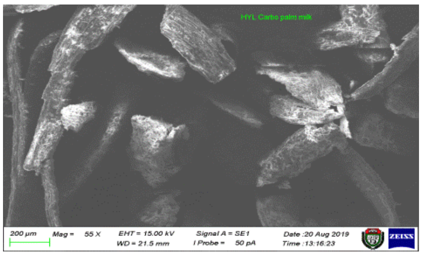

Figure 4. The SEM photograph of carbonized palm milk powder

Effect of pH on Adsorption of Lead (II) and Chromium (III) Solutions by Carbonized Palm Milk Sample

The maximum removal percent of lead (II) was found at pH 7 (86.60%) in carbonized palm milk powder sample. The removal percent of lead (II) increases with an increase pH 4 (64.66%) to pH 6 (80.52%) (Table 2). Through the pH 7, the removal percent was found to be (86.74%). Therefore, the effect of pH on sorption of lead (II) onto carbonized palm milk powder sample is not different between pH 7 and pH 8.The chromium adsorption was found to increase with an increase in pH 4 to 6 and attained a maximum value at pH 7 (91.56%). Later the pH 7 cadmium adsorption capacity was declined (Figure 6).

Effect of Dosage on Adsorption of Lead (II) and Chromium (III) Solutions by Carbonized Palm Milk Sample

In this research, the effect of dosage of carbonized palm milk powder sample on adsorption of lead (II) was studied at pH 7 for 2 H of contact time. Table 4, the result showed that the metal ions adsorbed increased with an increase in adsorbent dosage from 0.3 g to 2.0 g while keeping other parameters (pH, agitation speed 130 rpm and contact time) constant. It was found that the percent lead (II) adsorbed increasing from 53.74-77.42% with an increase in weight of sample from 0.3-1.5 g (Figure 6). From the small weight of dosage to large weight, the percent are increased more rapidly, up to 0.5 g of sample. From 0.5 g sample the percent are increased steadily with increase weight.

Adsorption of chromium (III) at pH 7 for 2 H of contact time, it was found that the percent chromium (III) adsorbed increased with an increasing in weight of adsorbent. Figure 8 shows the dosage of carbonized palm milk slowly increased from 0.3 g to 1.5 g. The optimum value of removal percent was found to be 81.07 % at 1.5 g, beyond this point the removal percent decrease with increase in weight.

Table 2. Effect of pH on Carbonized Palm Milk Powder Sample for the Uptake of Lead (II)

No.	pH	Equilibrium concentration (C_e)	Removal (%)
1.	4.0	35.34	64.66
2.	5.0	26.52	73.48
3.	6.0	19.48	80.52
4.	7.0	13.40	86.60
5.	8.0	13.26	86.74

Table 3. Effect of pH on Carbonized Palm Milk Powder Sample for the Uptake of Cadmium (III)

No.	pH	Equilibrium concentration (C_e)	Removal (%)
1.	4.0	16.13	83.87
2.	5.0	12.66	87.34
3.	6.0	10.23	89.77
4.	7.0	8.44	91.56
5.	8.0	11.03	88.97

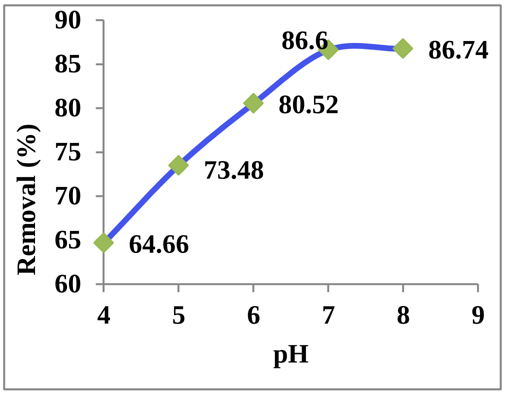

Figure 5. Effect of pH on carbonized palm milk powder sample for removal (%) of lead (II)

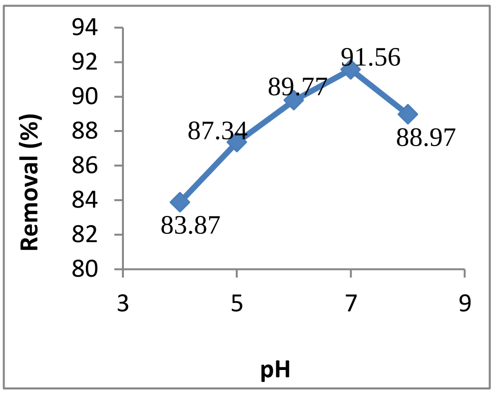

Figure 6. Effect of pH on carbonized palm milk powder sample for removal (%) of chromium (III)

Table 4. Effect of Dosage on Carbonized Palm Milk Powder Sample for the Uptake of Lead (II)

No.	Dosage (g)	Equilibrium concentration (C_e)	Removal (%)
1.	0.3	46.26	53.74
2.	0. 5	38.56	61.44
3.	1.0	30.76	69.24
4.	1.5	22.58	77.42
5.	2.0	23.76	76.24

Table 5. Effect of Dosage on Carbonized Palm Milk Powder Sample for the Uptake of Chromium (III)

No.	Dosage (g)	Equilibrium concentration (C_e)	Removal (%)
1.	0.3	48.43	51.57
2.	0. 5	40.20	59.80
3.	1.0	23.59	76.41
4.	1.5	18.93	81.07
5.	2.0	19.61	80.39

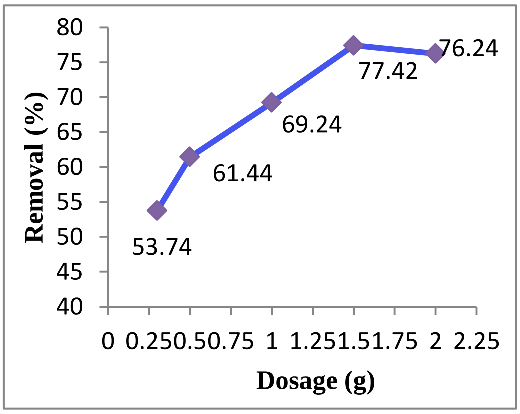

Figure 7. Effect of Dosage on carbonized palm milk powder sample for removal (%) of lead (II)

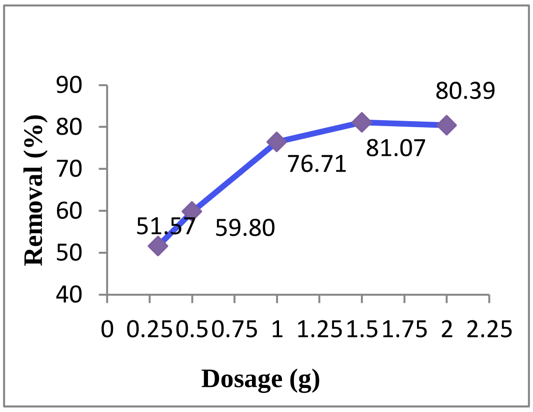

Figure 8. Effect of Dosage on carbonized palm milk powder sample for removal (%) of chromium (III)

Freundlich isotherm was found to better fit the experimental data of sorption by carbonized palm milk powder sample as shown in Table 3.9 and (R^2= 0.907) for Pb (II) and (R^2= 0.978) for Cr (III) (Figure 9 and 10). The adsorption process of two metals are obeyed the Freundlich isotherm because of the R^2 nearly one. The adsorption equilibria were also studied using the Langmuir adsorption isotherm. Figures 11 and 12 showed the comparison of the Langmuir isotherm parameters for Ni (II) and Cd (II) ions.

Table 6. Equilibrium Data for Lead (II) Adsorption on Carbonized Palm Milk Powder Sample

No	**Wt. of sample (g)**	**C_e (ppm)**	**$1/C_e$**	**$1/q_e$**	**$\log C_e$**	**$\log q_e$**
1	0.3	42.26	0.024	0.052	1.626	1.284
2	0.5	38.56	0.026	0.081	1.586	1.090
3	1.0	30.76	0.033	0.145	1.488	0.840
4	1.5	22.58	0.044	0.194	1.354	0.713

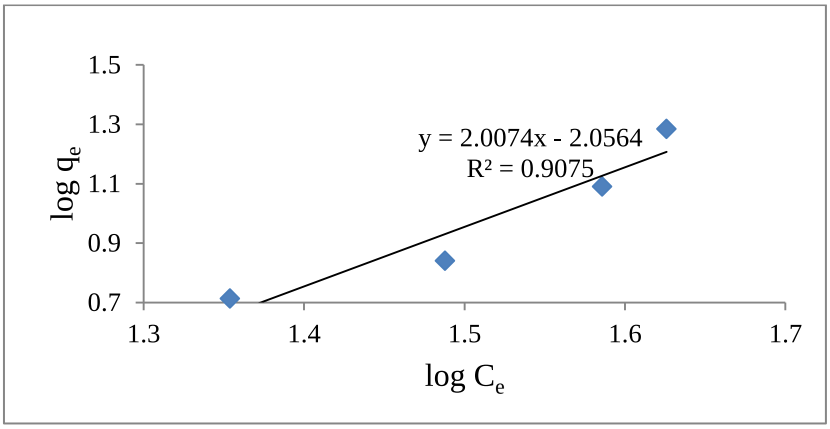

Figure 9. Freundlich plot for Lead (II) adsorption onto carbonized palm milk powder

Table 7. Equilibrium Data for Chromium (III) Adsorption on Carbonized Palm Milk Powder Sample

No	**Wt. of sample (g)**	**C_e (ppm)**	**$1/C_e$**	**$1/q_e$**	**$\log C_e$**	**$\log q_e$**
1	0.3	48.43	0.021	0.058	1.685	1.235
2	0.5	40.20	0.025	0.084	1.604	1.078
3	1.0	33.59	0.042	0.131	1.373	0.883
4	1.5	23.59	0.053	0.185	1.277	0.733
5	2.0	18.93	0.051	0.249	1.292	0.604

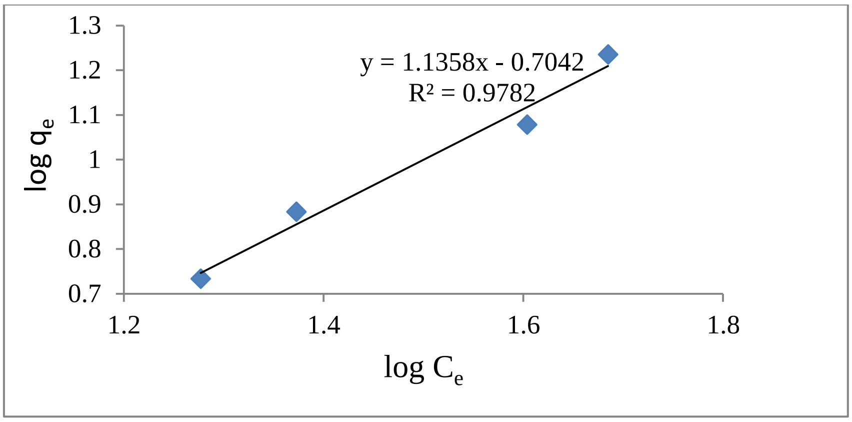

Figure 10. Freundlich plot for Chromium (III) adsorption onto carbonized palm milk powder

Table 8. Freundlich Isotherm Parameters on Carbonized Palm Milk Powder

Freundlich isotherm parameters	**Pb (II)**	**Cr (III)**
1/n	2.007	1.135
R^2	0.907	0.978
k_f (mg g^{-1})	0.009	0.198

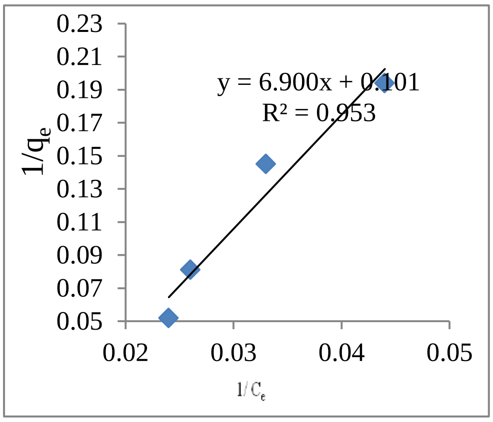

Figure 11. Langmuir plot of Lead (II) adsorption onto carbonized palm milk powder

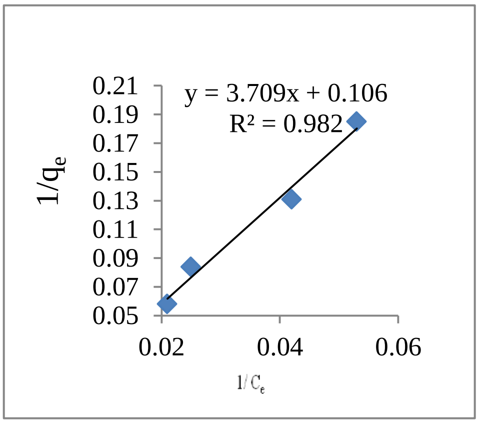

Figure 12. Langmuir plot of chromium (III) adsorption onto carbonized palm milk powder

Table 9. Langmuir Isotherm Parameters on Carbonized Palm Milk Powder

Langmuir isotherm parameters	**Pb (II)**	**Cr (III)**
Sorption coefficient, K_L (L mg^{-1})	0.0146	0.0286
Correlation coefficient, R^2	0.953	0.982
Sorption capacity, q_{max} (mg g^{-1})	9.9009	9.434

Table 10. Equilibrium Parameter for Lead (II) and Chromium (III) onto Carbonized Palm Milk Powder

No	Metal	Ep
1	Pb (II)	0.4065
2	Cr (III)	0.2591

Table 11. Relation between Concentration of Nitric Acid Solution and Lead (II) and Chromium (III) Ions Concentration in the Filtrate

No	**Nitric acid solution**	**Concentration (ppm) of metals ion in filtrate**	
		Pb (II)	**Cr (III)**
1	4M	28.91	31.28
2	6M	45.68	54.60
3	8M	60.28	83.09

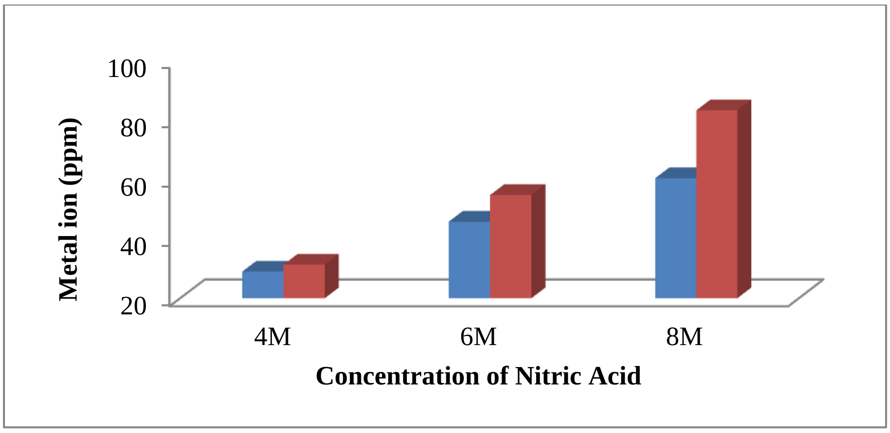

Figure 13. Comparison for the desorption of metal ions by using nitric acid onto carbonized palm milk powder

In (Table 11 and Figure 13), the desorption process of lead and chromium loaded carbonized palm milk powder sample were increased with increase in concentration of nitric acid solutions. The chromium-loaded carbonized palm milk powder sample is higher desorption (83.09 ppm) in 8 M HNO_3 than lead loaded carbonized palm milk powder (60.28 ppm) in 8 M HNO_3.

CONCLUSION

The moisture content of raw and carbonized palm milk powder were found to be (5.17 ± 2.52 and 6.8 ± 3.25). From this data the bulk density of raw and carbonized palm milk were found to be (1.419 ± 1.180 gcm^{-3} and 1.80 ± 0.02 gcm^{-3}). Therefore the bulk density of raw and carbonized palm milk is the small difference. In raw and carbonized palm milk, the external surface shows a rough area having different pore diameters distributed over the surface of carbonized palm milk powder than raw palm milk powder. At higher pH, the removal percent was also low as the binding site may not activate in basic condition. Above pH 7, the chromium started precipitating as Cr $(OH)^{3+}$, therefore the removal was not completely by adsorption.The Freundlich isotherm parameter onto carbonized palm milk the correlation coefficient of R^2 value for Pb (II) and Cr (III) nearly one, therefore the linear relationship were obtained. Freundlich isotherm was found to better fit the experimental data of sorption by carbonized palm milk powder sample (R^2=0.907) for Pb (II) and (R^2=0.978) for Cr (III). The comparison of the Langmuir isotherm parameters for Pb (II) and Cr (III) ions, the R^2 value of the Langmuir isotherm parameters for Pb (II) and Cr (III) ions on carbonized palm milk were obtained nearly one. The graph obtained linear relationship. The value of equilibrium parameter is 0.2591. The value of E_p is $E_p < 1$, the type of isotherm is favorable isotherm. The desorption process of lead and chromium loaded carbonized palm milk powder sample was increased with an increase in concentration of nitric acid solutions. Therefore, the carbonized palm milk powder can be applied to remove for various industries waste water, textile industries waste water etc.

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