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Peel Wastes of *Ananas comosus* (L.) Merr., *Sandoricum koetjape* Merr., *Citrus nobilis* Lour. as Lead and Cadmium Biosorbent in Manila Tap Water

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ABSTRACT

Contaminated water from Manila, Philippines must be remediated. The use of peel wastes from Ananas comosus(L.) Merr. (Pineapple), Sandoricum koetjape Merr.(Santol) and Citrus nobilis Lour. (Dalanghita) , as agents in removing heavy metals from water could be cost effective. This study aimed to evaluate the capacity of peels to remove lead and cadmium in contaminated water. Furthermore, it aimed to determine the optimum pH, effect of contact time and the initial concentrations of heavy metals on the bio-sorption in the identified peels. The study was carried out by batch process. Biomass was added to known amounts of metals in solution with adjusted pH. After vacuum filtration, the filtrates were analyzed for residual heavy metal concentration using atomic absorption spectroscopy. Peel bio-sorption was optimum at pH 5. The amount of heavy metals adsorbed increased with time until 120 mins. The percent bio-sorption efficiency decreased with an increase in initial heavy metal concentration. The peels followed the pseudo second order kinetics, and the langmuir isotherm model with the bio-sorption of lead. For cadmium removal, pineapple and santol followed Langmuir isotherm model. For the actual contaminated tap water from Manila, santol showed the highest percent biosorption efficiency for lead and cadmium.

Key words: *Biosorption, isotherm models, kinetics, Manila, Philippines, peels, Ananas comosus(L.) Merr, Sandoricum koetjape Merr., Citrus nobilis Lour*

INTRODUCTION

Metro Manila is polluted with heavy metals like lead and cadmium. Lead was found in street foods (*Solidum 2010*), water (*Solidum, Dahilig, Omran 2010*), air, soil and plants (*Solidum 2008*). Cadmium was also seen in raw vegetables (*Solidum 2011*), fruits (*Solidum 2012*) and rice (*Solidum et al. 2012*). Lead may cause adverse health effects to children and adults. Literature have provided evidences that lead may be implicated in the occurrence of several diseases, primary of which may be related to neurological dysfunctions after chronic exposure (*Cecil et al. 2008; Bull et al. 1975*). Chronic signs and symptoms may result to subtle neuropsychiatric, reproductive and renal effects, IQ deficits, behavior disorders, slowed growth and impaired hearing. Children are more susceptible to adverse effects of lead but adults may manifest its adverse effects as well (*Schonwald 2001*). Lead also attacks the bone marrows, the peripheral and central nervous system on chronic exposure (*Dart 2004*).

Cadmium was once an environmental toxicant in Japan that led to itai-itai (ouch-ouch) disease characterized by arthralgia and osteomalacia in middle aged, post menopausal women with low calcium and vitamin D intake. Cadmium attacks the kidneys on chronic poisoning, lungs on acute inhalation and gastrointestinal tract on acute ingestion (*Dart 2004; Elinder 1985*).

The earth is a closed system where only energy can be exchanged with the external environment but not matter (*Knebel and Wright 2000*). Heavy metals that have been introduced and are still being introduced will stay in the environment for a long time. Continuous exposure to heavy metals like lead and cadmium may result to adverse health effects to the public.

Biosorption is a process wherein certain types of biomass are able to sequester toxic heavy metals from even very dilute solutions (*Saikaew et al. 2009*). It has been studied because of the advantages it offers over the conventional wastewater treatment methods. Some of these advantages are the low operating cost, minimization of the volume of chemical or biological waste to be disposed of, and high efficiency in detoxifying very dilute solution (*Ajay Kumar et al. 2009*).

Different mechanisms of heavy metal uptake have been postulated in biosorption, namely: chemisorption by ion exchange, complexation, coordination, chelation; physical adsorption and microprecipitation by polymers (*Volesky 2001*). Biosorbents from the agriculture industry were studied for water treatment. Some of these are orange wastes other than its peels, olive stones, papaya wood, grape stalk waste, peas, lemon peels, grapefruit peels, apple kernel, apple core, grape skin, coconut shell powder, and coconut copra meal (*Saikaew et al. 2009*). These agricultural by products and wastes contain lignin, tannin, pectin, and cellulose as major constituents

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and may also include polar functional groups as alcohols, aldehydes, ketones, carboxylic acids, phenolic and ether groups (*Saikaew et al. 2009*).

The capacity of biomass to concentrate heavy metals has been shown to be dependent on several factors namely: the type of biomass, the mixture in solution, the physicochemical process undergone, environment and the type of biomass preparation (*Volesky 2001*). The pH of the aqueous solution significantly affects the uptake of heavy metals via absorption. Most research conducted has shown a direct relationship between pH of the solution and heavy metal affinity. Studies on the biosorption of cadmium ions by coconut copra meal (*Ho and Ofomaya 2006*) and pomelo peel (*Saikaew et al.2009*) have shown that in very acid pH the biosorptive capacity of biomass was negligible. Meanwhile, as the pH increased towards 7, the binding affinity of cadmium ions reached its maximum. But since cadmium is precipitated in alkaline pH, further increase in pH is hard to research on.

Isotherm models are used to investigate the effect of the initial concentration ions to the biosorption capacity of the biosorbent. Many theoretical models may be used in the study, but Langmuir and Freundlich models are the most commonly used. The experimental data of monolayer biosorption of solute uptake is equated in the said models. Also, analysis of the effect of contact time is done through kinetic models. Two of the most frequently used models for the biosorption of solutes from a liquid solution are pseudo first order rate equation of Lagergen and pseudo second order (*Saikaew, Kaewsarn, Saikaew 2009*).

Manila is burdened with biodegradable wastes. By studying the ability of fruit peel wastes in biosorbing lead and cadmium in simulated and actual contaminated water, recycling will be enhanced. The activity will not only help lessen solid waste problems but will also help improve the health of the public by lessening vectors of diseases. Further, as biodegradable wastes are reduced, methane production will also decline and the progress of global warming will somehow be slowed.

In general, this study aimed to evaluate the capacity of peel wastes of *Ananas comosus* (L.) Merr., *Sandoricum koetjape* Merr. and *Citrus nobilis* Lour. as biosorbent of lead and cadmium in contaminated water. Specifically, it aimed to determine if the chosen peel wastes can reduce the levels of lead and cadmium from simulated and actual Manila tap contaminated water. Further, it is aimed to determine the optimum pH , effect of contact time and initial concentrations of heavy metals on the biosorption in the identified peels.

This study focused mainly on the investigation of the ability of peels of *A. comosus*, *S. koetjape* and *C. nobilis* to reduce the levels of lead and cadmium ions in simulated and Manila contaminated tap water through biosorption. Different factors which might affect the biosorption capacity of peels were explored, namely: pH of the solution, initial concentration of heavy metals, and contact time between peels and sample water. The effect of presence of co-ion was not studied. Pre-treatment of the peels was limited to comminution and drying. The mechanisms of sorption and the re-use of the samples were not explored. Isotherm and kinetic models were applied to the results to evaluate the biosorption capacity of the peels.

METHODOLOGY

Research Design

The solution was analyzed for lead and cadmium content before and after the introduction of the pre-treated peels to determine the extent of adsorption of the heavy metals. The optimum pH, temperature, contact time and initial concentration for the biosorption of lead were determined (*Saikaew et al. 2009*).

Sample preparation

Peel wastes of *A. comosus*, *S. koetjape* and *C. nobilis* were collected from street vendors in Manila, Philippines. The collected materials were washed several times with distilled water to remove extraneous materials. The washed materials were cut into small pieces (10-20 mm) then dried in a hot air oven at 60˚C until constant weight was achieved. Finally, the materials were ground using a mortar and pestle and screened using a sieve of mesh size 80 to an approximate size of 1.5-2 mm.

Reagent preparation

Stock solutions of lead and cadmium (1,000 mg L^{-1}) were prepared by dissolving the desired quantity of lead and cadmium salts in distilled water. Other concentrations were obtained by proper dilution of stock solution. The chemicals used were of analytical reagent grade.

Determination of biosorption capacity

Simulated contaminated water. Biosorption studies were carried out by batch process. Biomass was added to conical flasks containing a known amount of metal solution of desired concentration. The mixture was agitated using Burell Wrist Action Shaker model 75 for two hours, time more than sufficient to reach equilibrium. The pH of the solutions were adjusted by adding 0.1 N NaOH or 0.1N HNO_3. The biomass was then removed by filtration using a vacuum filter (pore size of 0.45 μm) and the filtrates were analyzed for residual lead concentration by atomic absorption spectroscopy with an air-acetylene flame. Blank samples were run under similar experimental conditions but in the absence of the biosorbent.

Determination of the optimum pH of the solution. Batch experiments were carried out by contacting 0.5 g peel wastes and 50 ml of lead and cadmium salt solutions with a concentration of 50 mg L^{-1} placed in conical flasks and subjected to agitation using a shaker for 2 hr at room temperature (28˚C). The solution pH values ranged from pH 3-6 (*Saikaew et al. 2009*).

Kinetic of adsorption. Kinetic studies were carried out in a conical flask with constant agitation of 0.5 g peels in 50 ml of lead and cadmium salt solution with a concentration of 50 mg L^{-1} at room temperature (28˚C). Samples were taken at predetermined time intervals (0, 900, 1800, 3600, 7200 sec) using 25 mL transfer pipets and filtered immediately through vacuum filtration. A pH value of 3, 4 and 5 were maintained throughout the experiment by adding 0.1N NaOH or 0.1N HNO_3 (*Saikaew et al. 2009*).

Adsorption isotherm. A constant mass of 0.5 g of peel materials were added to conical flasks containing 100 mL of metal solution. The lead and cadmium salt concentrations were varied in the range of 12500, 37500 and 50000 mg m^{-3}. Contact time of 60 min was allotted with constant agitation, at room temperature (28˚C). A pH value of pH 3, 4, or 5 were maintained throughout the experiment by adding 0.1N NaOH or 0.1N HNO_3 for biosorption efficiency in relation to initial heavy metal concentration. Contact time of 900, 1800, 3600, 7200 seconds were allotted with constant agitation, at room temperature (28˚C). The optimum pH was maintained throughout the experiment by adding 0.1N NaOH or 0.1N HNO_3 in relation to isotherm models (*Saikaew et al. 2009*).

Manila tap water

Manila tap water was collected from five sites in Manila along the stretch of Manila City Hall to Vito Cruz. The samples were placed in five 1.5-L bottles were the prepared peels were placed at 0.1 %, 1 % and 10 % concentrations. Optimum conditions obtained in the first segment of the study were applied. The concentrations of the heavy metals were analyzed using AAS before these were transferred to the container after a day, two, three, four and five days after continuous contact with the peel wastes.

Digestion of samples

Fifty ml of the filtrate was collected in a beaker. Fuming nitric acid at 2.5 mL was added to the filtrate and the resulting solution was immediately covered with watch glass. Samples were heated in a hotplate and evaporated to 25 mL without boiling. When the volume was reduced to half, the sides of the beaker and the watch glass were washed with freshly distilled water and then 3 mL of fuming nitric acid were added to the solution. The samples were heated again and evaporated to around 20 mL. When the samples have cooled down, they were filtered again using #2 Whatman filter paper. The filter paper was washed around the funnel three times and the washings were also collected in 25 mL volumetric flask. Samples were diluted to volume using distilled water and transferred to a high density polyethylene container and was analyzed using AAS (*Prester 1998*).

Data Analysis

The amount of metal ion that was taken up by the pomelo peel per gram of biomass was calculated using the expression adapted from *Saikaew et al. (2009)*

$$qe=(V(C_i – C_e))/m \qquad (1)$$

While, the efficiency of pomelo peel biosorption was determined using the equation from *Babarinde, Babalola, and Adebisi* (*nd*).

$$\%E=((C_i – C_e)/C_i) \times 100 \qquad (2)$$

Where:
qe = equilibrium ion capacity (mg kg^{-1})
E = biosorption efficiency
V = suspension volume (L)
m = mass of pomelo material (kg)
Ce = ion concentration at equilibrium (mg L^{-1})
Ci = initial ion concentration (mg L^{-1})

Modeling error analysis

The root mean squared error (RMSE) was calculated to determine the model fit. The squared difference between the experimental metal uptake (q) and the corresponding model predictions for the uptake (qm) were summed up. The sum was divided by the number of data points (p) for each data set to calculate the mean square error. The RMSE was obtained by taking the square root of that term. The RMSE may be considered as the average deviation between the predicted and actual uptake of the metal ion. The equation for RMSE, adapted from *Schiewer and Patil* (*2008*), is:

$$RMSE = \sqrt{\frac{\sum_1^p (q - q_m)^2}{p}} \qquad (3)$$

RESULTS AND DISCUSION

Following to the ion exchange theory of absorption, lead and cadmium ions could be taken up by negatively-charged sites in the peel wastes. The pH of the solution then is an important factor for optimum biosorption of biomass. At pH 3, the concentration of H^+ ions competing with lead and cadmium for anionic sites is greatest. At qe of 377.2 and 195.3; 485.94 and 315.3; 478.1 and 298.1 mg kg^{-1} for *A. comosus*, *C. nobilis* and *S. koetjape*, respectively, the biosorption of cadmium and lead then at pH 3 is at its lowest. The percent efficiency of biosorption of cadmium and lead is at 42.2 % and 21.02 %; 53.94% and 34.07 %; 54.13 % and 32.27 % for *A. comosus, C. nobilis* and *S. koetjape* peels respectively. With further increase in pH, the biosorption sites in the peel wastes became relatively deprotonated hence becoming more available for lead and cadmium interaction. Optimum biosorption was at initial pH 5, where the biosorption efficiency for cadmium and lead is 71.73 % and 68.06 %; 77.06 % and 67.2%; 73.13% and 74.55 % for *A. comosus* (Pineapple), *C. nobilis* (Dalanghita) and *S. koetjape* (Santol) peels, respectively, (**Figures 1** and **2**). Biosorption is greatest at a pH just slightly more acidic than the pH at which there is bulk precipitation of the metal hydroxide (*Schneider et al. 2006*). At initial pH 6, the solutions became slightly cloudy suggesting that the bulk solubility limit was approached and so the biosorption was reduced because of the unavailability of lead and cadmium ions to bind with the active sites.

Percent biosorption efficiency of the peel wastes for cadmium is slightly higher at 60 min. The biosorption efficiency of the peel wastes from *A. comosus* and *C. nobilis* Lour. for lead followed the pattern observed from cadmium while for *S. koetjape* Merr peels, it is at 7200 seconds or 120 min were the highest amounts of the heavy metal underwent biosorption (**Figures 3** and **4**).

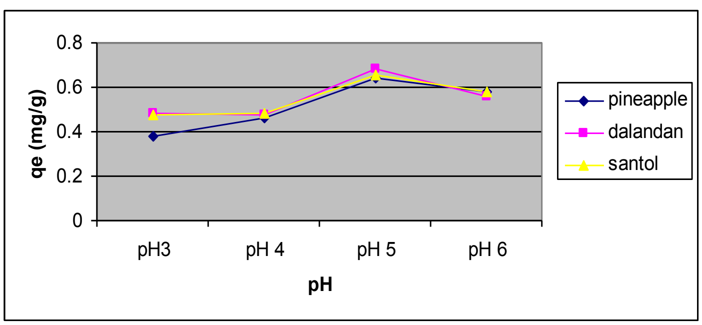

Figure 1. Equilibrum of cadmium ion capacity qe(mg/0.001kg) at pH 3-6 at 28°C.

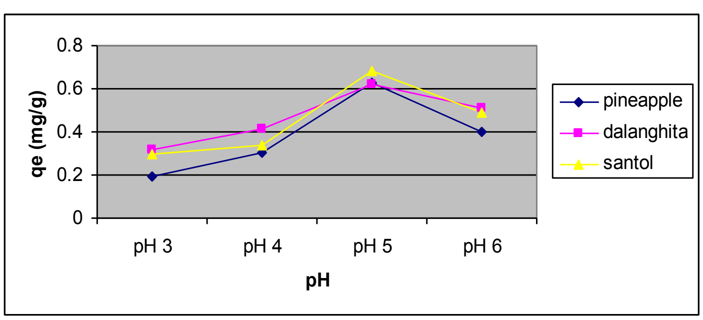

Figure 2. Equilibrum of lead ion capacity qe(mg/0.001kg) at pH 3-6 at 28°C.

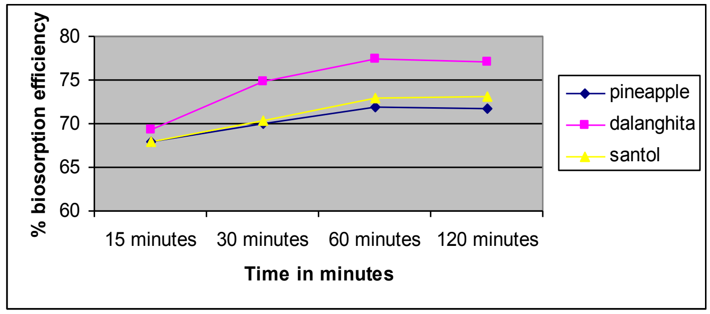

Figure 3. Time course of Cadmium biosorption by peel wastes at 50,000 mg m^{-3} at 28˚C and pH 5.

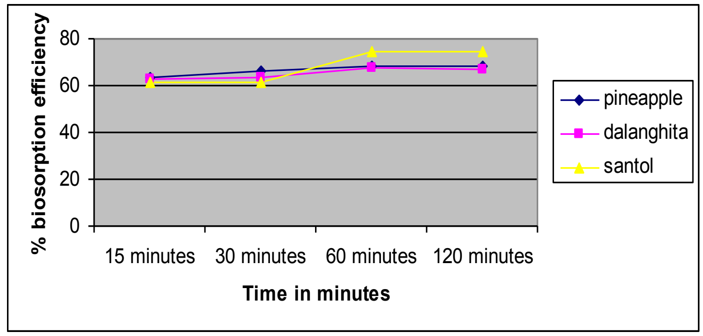

Figure 4. Time course of lead biosorption by peel wastes at 50,000 mg m^{-3} at 28˚C and pH 5.

The Lagergren first order and pseudo second order kinetics models were applied to determine the biosorption kinetics. The pseudo second order model represented the data with correlation coefficient greater than 0.99. The pseudo first order was not employed since the optimum contact time (qe) at equilibrium was not reached. For purposes of discussion, the expression for the Lagergren first order model is:

$$\frac{dq_t}{dt} = k_1(q_e - q_t) \quad (4)$$

$$\log(q_e - q_t) = \log q_e - \frac{k_1}{2.303}t \quad (5)$$

This equation (4) can be integrated to yield a linearized form as:

$$\frac{dq_t}{dt} = k_2(q_e - q_t)^2 \quad (6)$$

Integration and rearrangement of equation (6) yielded the following equation:

$$\frac{t}{q_t} = \frac{1}{k_2 q_e{}^2} + \frac{1}{q_e}t \quad (7)$$

Where, k_2 is equilibrium rate constant of second order kinetics model (kg mg^{-1} sec^{-1}), qe is the equilibrium capacity and q_t is the biosorption capacity at any time t. The time, t was plotted against t/qt (**Figures 5** and **6**). The correlation coefficients of 0.99 indicated the applicability of pseudo second order model to the present system. This model suggested that biosorption of lead and cadmium on *A. comosus*, *C. nobilis* and *S. koetjape* peels was based on chemical reaction, between the metals and the active sites of the biosorbents. The equilibrium rate constant, k2 and equilibrium capacity, qe were determined from the slope and intercept of the lines in **Figure 5**. The pseudo second order model parameters are listed in **Table 1**. It is suggested that, the pseudo-second order model, where the rate is proportional to the square of the number of free site, describe the kinetics of lead and cadmium biosorption using *A. comosus*, *C. nobilis* and *S. koetjape* peels. Divalent ions when it binds to two monovalent negatively charged sites, the rate is proportional to the square of the remaining sites, as assumed by the pseudo-second order model (*Schneider, I.A.H., Rubio, J. and Smith, R.W. 2006*). Equation (2) was used to determine the effect of initial concentration of lead and cadmium ions on biosorption efficiency of *A. comosus*, *C. nobilis* and *S. koetjape* peels at pH 3 to 5. **Figures 7 to 12** shows the efficiency plot of the peel biosorption.

There is a decrease in percent efficiency of absorption with increase in the initial concentration of both lead and cadmium. The proposed mechanism in biosorption processes include ion exchange between H+ and metal ions at the surface of the biomass hence saturation of the available binding sites on the biosorbent is most likely to happen. When the number of metal ions competing for the binding sites is increased, there will be a reduction in ion exchange with the biomass (*Babarinde et al. nd*).

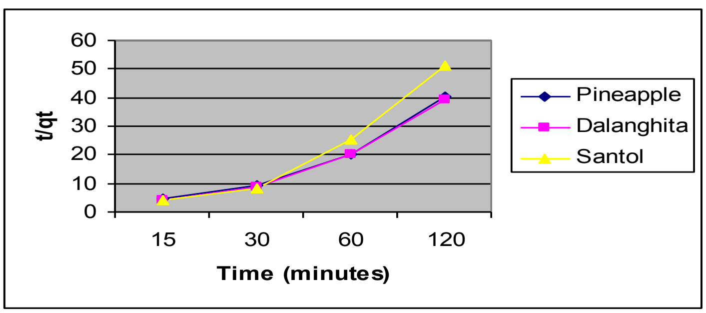

Figure 5. Pseudo-second order plot for the biosorption of lead by pineapple, dalanghita and santol peels at 28˚C and pH 5.

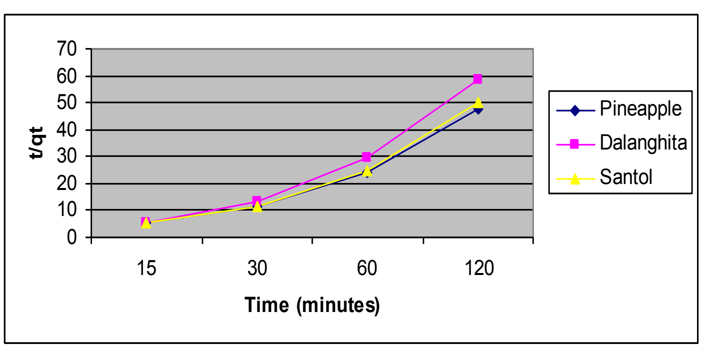

Figure 6. Pseudo-second order plot for the biosorption of cadmium by pineapple, dalanghita and santol peels at 28˚C and pH 5.

Table 1. Pseudo second order parameters.

	K_2 (kg mg^{-1} sec^{-1})	qe (mg kg^{-1})	R^2
Pb -Pineapple	0.00005103	623.477	0.999796
-Dalanghita	0.00001429	634.616	0.999925
-Santol	0.00000463	708.761	0.998684
Cd -Pineapple	0.00001894	650.674	0.999973
-Dalanghita	0.00002757	685.774	0.999674
-Santol	0.00001816	657.049	0.999976

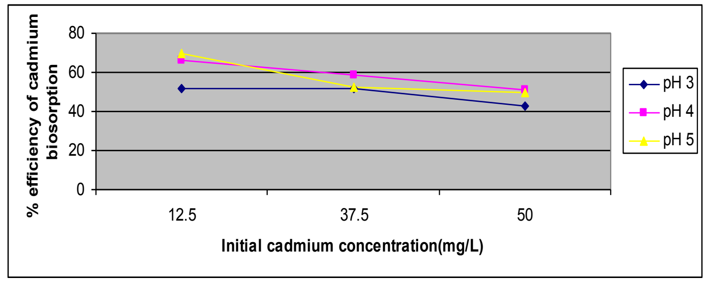

Figure 7. Efficiency plot for cadmium biosorption using pineapple peels at 28˚C.

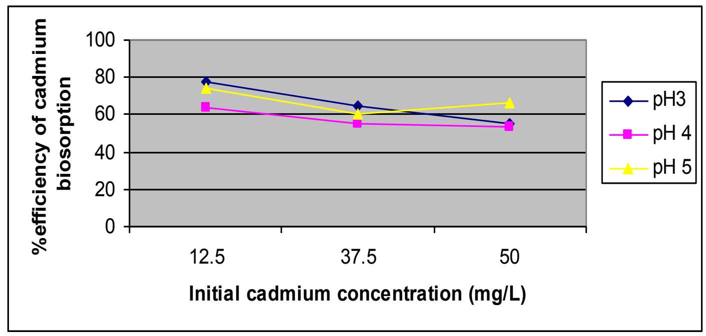

Figure 8. Efficiency plot for cadmium biosorption using dalanghita peels at 28˚C.

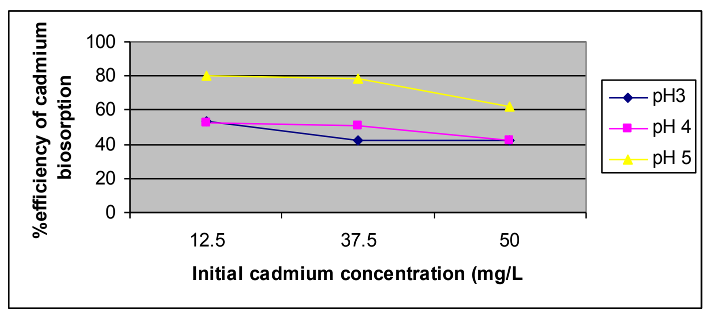

Figure 9. Efficiency plot for cadmium biosorption using santol peels at 28˚C.

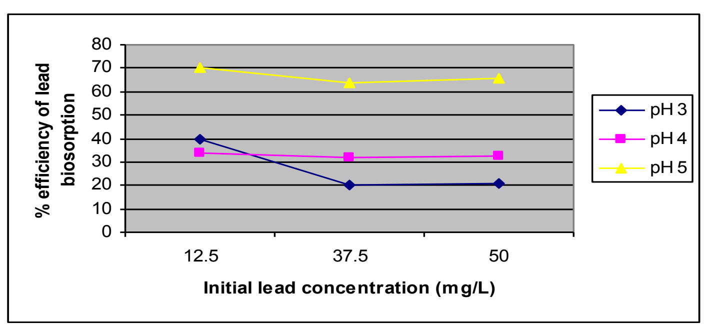

Figure 10. Efficiency plot for lead biosorption using pineapple peels at 28˚C.

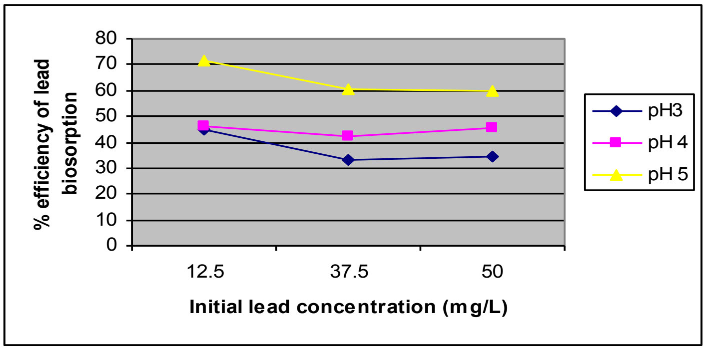

Figure 11. Efficiency plot for lead biosorption using dalanghita peels at 28˚C.

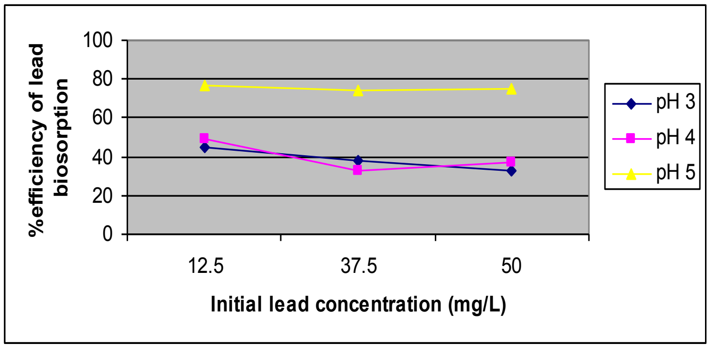

Figure 12. Efficiency plot for lead biosorption using santol peels at 28˚C.

To evaluate the biosorption isotherms, Freundlich and Langmuir models were used. These reflect the performance of the sorption system. Freundlich isotherm is expressed as:

$$qe = k_F Ce^{1/n} \tag{8}$$

and its linearized form is:

$$logqe = logk + \frac{1}{n} logCe \tag{9}$$

While the Langmuir isotherm is described as:

$$qe = \frac{qmax\ bCe}{1+bCe} \tag{10}$$

and after integration, this equation (16) yields its linearized form as:

$$\frac{1}{qe} = \frac{1}{qmax} + \frac{1}{bqmax\ Ce} \tag{11}$$

Where qe and qmax are equilibrium and maximum uptake capacities (mg kg^{-1} peel), respectively; Ce is the equilibrium concentration (mg L^{-1}); kF, n and b are constant characteristics of the system (*Perez-Marin et al. 2007*).

In general, the biosorption of lead at its observed optimum pH of 5, using *A. comosus*, *C. nobilis* and *S. koetjape* can be described by both the Freundlich and Langmuir isotherm models. The biosorption process however best fits the latter model, for lead, with R^2 ranging from 0.92433 to 0.99982. Cadmium biosorption by *A. comosus* and *S. koetjape* is best described by the Langmuir isotherm model with R^2 ranging from 0.8978 to 0.9999. *C. nobilis* showed very low R^2 (**Tables 2** and **3**).

Using *A. comosus*, *C. nobilis* and *S. koetjape* Merr. peels as biosorbent for lead and cadmium in Manila tap water, 10 % peels adsorbed the heavy metals with highest efficiency. There is a decline in efficiency with a decline in peel concentration. More sites in the peels are available for biosorption of the contaminants with higher concentration of the former. The removal efficiency values are close to each other from days 1-4 of biosorbent application. The use of the biosorbents to actual contaminated water followed the results from the controlled portion of the study showing that cadmium removal has a slightly higher efficiency than lead. In general, lead and cadmium removal is most efficient using *S. koetjape* peels followed by *C. nobilis* and lastly by *A. comosus* (**Figures 13** to **15**).

Potential heavy metal biosorbents like *Acomosus*, *C. nobilis* and *S. koetjape* should be further analyzed for its reusability. This will help conserve resources.

Table 2. Langmuir isotherm adsorption of cadmium (a) and lead (b) by pineapple, dalanghita and santol peels at 28˚C.

Peels	Time (sec)	B (m^3 kg^{-1})	qmax (mg kg^{-1})	R^2
Pineapple	7200a	1.3925	718.136	0.897826
	b	0.501796	1992.843	0.982861
	3600a	1.162326	860.344	0.910754
	b	0.569056	1757.296	0.966876
	1800a	1.307544	764.793	0.912014
	b	0.717905	1392.942	0.931159
	900 a	1.255366	796.58	0.910809
	b	0.153273	6524.324	0.970662
Dalanghita	7200a	2.670554	374.454	0.281051
	b	0.812088	1231.394	0.936783
	3600a	2.647612	377.699	0.285967
	b	0.89939	1111.865	0.924327
	1800a	3.31701	301.476	0.235481
	b	-1.61738	-618.29	0.998244
	900 a	3.665991	272.778	0.248551
	b	-3.54994	-281.7	0.996841
Santol	7200a	0.111359	8979.968	0.994776
	b	-0.06208	16107.8	0.997225
	3600a	0.484459	2064.157	0.99904
	b	0.315469	3169.884	0.997998
	1800a	-1.38374	-722.68	0.999987
	b	1.047969	954.227	0.99982
	900 a	-2.45127	-407.95	0.999518
	b	1.121821	891.408	0.972166

Table 3. Freundlich isotherm adsorption of cadmium (a) and lead (b) by pineapple, dalanghita and santol peels at 28˚C.

Peels	Time (sec)	Kf (mg m^{-3})	n	R^2
Pineapple	7200a	209.98	1.34427	0.734561
	b	236.71	1.22467	0.964204
	3600a	198.53	1.238681	0.752984
	b	237.78	1.247798	0.940782
	1800a	191.78	1.328008	0.745873
	b	220.71	1.32228	0.876144
	900 a	169.06	1.285494	0.729496
	b	159.94	1.025799	0.941566
Dalanghita	7200a	520.78	-3.27966	0.294272
	b	247.1	1.416939	0.885976
	3600a	566.87	-3.2656	0.303312
	b	255.01	1.495497	0.864415
	1800a	539.96	-2.7511	0.239405
	b	83.01	0.639759	0.9884
	900 a	523.73	-2.72445	0.252225
	b	43.67	0.480902	0.999872
Santol	7200a	319.59	1.117962	0.980595
	b	292.32	0.990082	0.994902
	3600a	333.52	1.234414	0.989796
	b	317.43	1.149328	0.997299
	1800a	160.32	0.742408	0.995092
	b	317.43	1.747319	0.994437
	900 a	111.44	0.640022	0.996857
	b	244.48	1.678529	0.964393

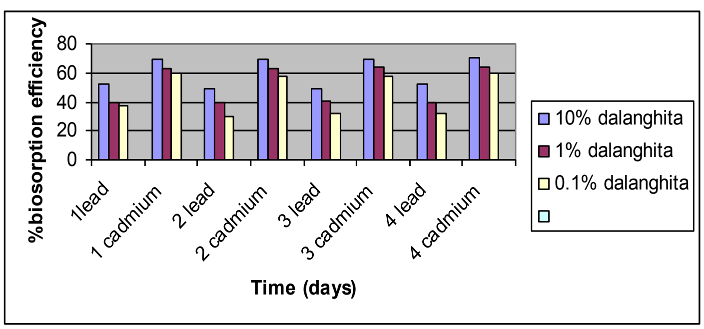

Figure 13. Biosorption efficiency of dalanghita with lead and cadmium.

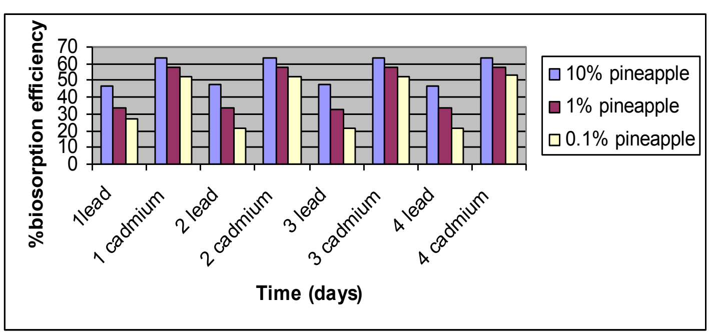

Figure 14. Biosorption efficiency of pineapple with lead and cadmium.

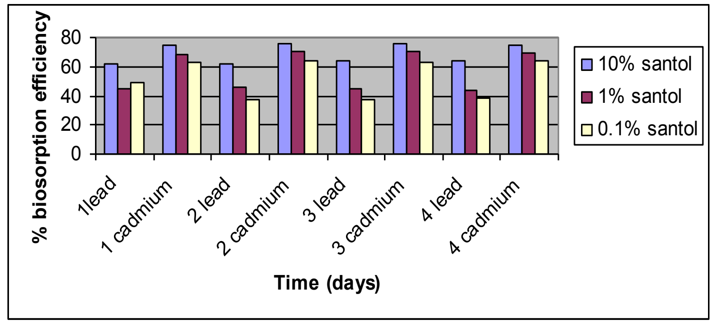

Figure 15. Biosorption efficiency of santol with lead and cadmium.

The adsorbed heavy metals are best recovered prior to discarding of the biosorbents to prevent re-entry of the contaminants in the environment. The recovered heavy metals may be re-used in academic chemical laboratories for qualitative experiments and related works.

CONCLUSIONS

The peel wastes of *S. koetjape*, *A. comosus* and *C. nobilis* has biosorbent capacity for the removal of lead and cadmium in contaminated water. Using simulated contaminated water, the optimum biosorption was observed at initial pH 5, where the biosorption efficiency for cadmium and lead is 71.73 % and 68.06 %; 77.06 % and 67.2 %; 73.13 % and 74.55 % for *A. comosus*, *C. nobilis* and *S. koetjape* peels, respectively. Percent biosorption efficiency of the peel wastes for cadmium is slightly higher at 3600 sec or 60 min relative to 7200 sec or 120 min. The biosorption efficiency of the peel wastes from *A. comosus*, and *C. nobilis* for lead followed the pattern observed from cadmium while for santol peels, it is at 120 minutes were the highest amounts of the heavy metal underwent biosorption. The peels followed Langmuir isotherm model with the biosorption of lead. For cadmium removal, *A. comosus* and *S. koetjape*, followed the Langmuir isotherm model. Pseudo second order kinetics best fit the biosorption activity of the studied peels for the removal of lead and cadmium. For the actual contaminated tap water from Manila, S. *koetjape* showed the highest percent biosorption efficiency for lead and cadmium at 64.02 % and 76.04 % respectively. The removal efficiency values are close to each other from days 1-4 of biosorbent application. In general, as the initial concentration of lead and cadmium increased, the percent biosorption efficiency decreased.

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