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EFFICIENCY OF SOME LOW-COST NATURAL PRODUCTS FOR REMOVING COPPER AND LEAD FROM SYNTHETIC POLLUTED WATER

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Abstract

Most available technologies applied in the removal of metal contaminants in aqueous systems use the well established processes of adsorption. Adsorbents currently in use are either too expensive or not readily available for wastewater treatment. There is a need to develop new adsorbents which are readily available at low cost to remove metal contaminants in aqueous system. Thus, the present study aims to investigate the efficiency of maize leaves, banana peels and hens egg shells as inexpensive, widely abundant natural adsorbents to remove heavy metals from synthetic polluted water. Three different concentrations:1, 2 and 3 g/l of each of the investigated materials were tested for their removal efficiency for 5 mg/l Cu and Pb. 2 g/l gave the highest removal efficiency for both Maize leaves and egg shells, while 1 g/l was the best concentration when banana peels were used either for copper or lead. The effect of some experimental parameters such as, solution pH (5, 7 and 9) as well as Contact period (20, 40, 60, 80 and 100 minutes) also has been investigated for their effect on the removal efficiency. Results indicated that the highest removal efficiency percentages were obtained at pH 5 for maize leaves and egg shells and pH 9 for banana peels. Concerning contact period, removal efficiency increase with the increasing in contacting period except for maize leaves where, there were no significant differences between 80 and 100 minutes in case of copper removal, and among different contacting periods in case of lead removal. Application of Langmuir, Freundlich and Temkin isotherm models indicated that using maize leaves for removing lead (R^2 = 0.999) and egg shells for removing copper (R^2 = 0.93) were highly fitted to Langmuir model. It's observed that using banana peels for removing lead (R^2 = 0.96), maize leaves for removing lead (R^2 = 0.886) and egg shells for removing copper (R^2 = 0.81), were the most fitted to Freundlich model, while using banana peels for removing lead (R^2 = 0.996) and egg shells for removing copper (R^2 = 0.696) were the most fitted to Temkin model. Isothermal studies proved that the investigated materials highly potential for removing both copper and lead from polluted water.

Key words: Maize leaves, Banana peels, Hen egg shells, low-cost natural substances.

INTRODUCTION

Water pollution due to heavy metals is an issue of great environmental concern (Vasuderan *et al*.,2003). Heavy metals have a harmful effect on human physiology and other biological systems when they exceed the tolerance levels (Kobya *et al*., 2005). Besides, chronic exposure to these contaminants present even at low concentrations in the environment can prove to be harmful to the human health. For these reasons, heavy metals must be removed as much as possible from industrial effluents (Babarinde, *et al*., 2006). The conventional methods used to remove heavy metals include chemical precipitation, ion exchange, electrodialysis, membrane separations, reverse osmosis, and solvent extraction (Matlock et. al., 2002; Mohammadi *et al*., 2005). The search for new, effective and economical technologies involving the removal of toxic metals from wastewaters has directed attention to biosorption based on metal binding capacities of various biological materials at little or no cost (Babarinde and Oyedipe, 2001; Aksu, 2002; Abia, *et al*., 2003; Ajmal *et al*., 2003 and Feng and Aldrich, 2004).

Natural materials or waste products from industrial or agricultural processes with large adsorptive capacities can be ideal sorbents, since they are abundant in nature, require little processing, and can be disposed off in a sustainable manner if necessary (Bailey *et al.*, 1999). These sorbents are referred to as ‘low cost’ sorbents.

Babarinde *et al*. (2006) reported that maize leaf as an agricultural waste could be used as potential adsorbent for the removal of lead from aqueous solutions.

Memon *et al*. (2008) described banana peel as a new cheaper, economical and selective adsorbent as an alternative to costly adsorbents for the removal of some heavy metals, such as Cr (III) ions.

Arunlertaree *et al.* (2007) mentioned that the egg shell could remove lead due to its physical and chemical properties such as $CaCO_3$ contents (95-96 %), pore structure and functional group i.e., carboxyl, amine and sulfate group. Moreover, egg shell was a neutralizing agent, any aqueous solution equilibrated with egg shell became more basic so heavy metals could precipitate and deposit on egg shell particles.

Some previous investigations on the removal of heavy metal ions with many agricultural byproducts have been reported (Ansari *et al.*, 1999, Mohan and Singh, 2002, Yoshihiro *et al.*, 2005 and Al Nagaawy and Shalaby, 2009).

The present study was conducted to investigate the efficiency of maize leaves, banana peels and egg shells as low cost, widely abundant, natural materials, for removing both Copper and lead from synthetic polluted water. This study aims also to determine the optimum condition for adsorption process (pH, adsorbents concentrations and contacting period).

MATERIALS AND METHODS

Polluted solutions preparation:

Synthetic polluted water prepared using 1000 mg Pb/l and 1000 mg Cu/l standard solutions. (Perkin Elmer Co.). The pH of the solution was adjusted to various pH values (5, 7 and 9) using 0.1 N solutions of H Cl and NaOH.

Sorbents preparation:

Maize leaves and banana leaves: 10 g of each dried material were added to 2 L of distilled water in a beaker agitated vigorously by a magnetic stirrer at ambient temperature of 25 ± □1°C for 4 hours, then filtered, continuously washed with distilled water until constant pH to remove the surface adhered particles and water soluble materials, and oven-dried overnight at 80 °C for 24 hours after filtration. Each sorbent material was crushed and sieved to obtain between 60-100 mesh (0.25-0.104 mm) size particles for further batch sorption experiments (**Benaïssa**, 2008).

Natural hen egg shells: were washed with tap water several times then

air-dried and incubated in hot air oven at 40 ^{o}C for 30 minutes (because protein component in egg shell can denature at high temperature; > 40 ^{o}C). Consequently, egg shells were ground to a powder in a grinder, and sieved to obtain between 60-100 mesh (0.25-0.104 mm) size particles **(Arunlertaree, *et al*. 2007)**.

Experiment:

Optimum pH determination (step A).

3 grams of each of the investigated materials were added separately to 5, 7 or 9 pH prepared waste water to determine the optimum pH value for each material which achieved maximum adsorption of both copper and lead.

Optimum sorbents concentration (step B).

1, 2 or 3 g of each of the investigated sorbents (maize leaves, banana leaves and fresh hen egg shells) was added separately to the prepared polluted solution with pH value for each substance that was determined from the last step (A), to determine the optimum concentration for each investigated material.

Optimum contact period (step C).

Optimum concentration of each substance which achieved from step B was added to polluted solution with the optimum pH value which achieved from step A and then the effect of contact time was investigated where samples were taken after 20, 40, 60, 80 and 100 minutes of steering, for determining Pb and Cu residues after applying each materials at the mentioned periods of contact.

Heavy metals determination in polluted solutions:

Solutions were prepared according to (Parker, 1972), for Pb and Cu measurement, and then both metals were measured by using Atomic Absorption Spectrophotometer (Model Thermo Electron Corporation, S. Series AA spectrometer, UK).

Isothermal studies:

The experimental data for the removal of copper and lead metal ions by maize leaves, banana peels and natural hen egg shells over the studied concentration range were processed in accordance with the three of the most widely used adsorption isotherms: Langmuir, Freundlich and Temkin isotherms in order to calculate adsorption maximum and binding energies for using these adsorbents for the removal of both copper and lead ions from contaminated water.

The Langmuir isotherm equation (Rao, *et al*., 2009) can be written in linear form as:

$$C_e / q_e = C_e / Q_m + 1 / Q_m b$$

Where: q_e and C_e are the metal equilibrium concentration in adsorbed and liquid phase in mmol/g and mmol/l, respectively. These constant were calculated from the intercept and slope of the linear plot of C_e/q_e vs C_e.

The Fruendlich isotherm equation (Rao, *et al*., 2009) can be written in the linear form as:

$$\log q = \log k + 1/n \log C$$

Where, k and n are indicators of sorption capacity (in mg/g) and intensity respectively. These Fruendlich constants were calculated from the slope and intercept of the linear plot, with log q vs log C.

The Temkin isotherm equation can be written in the linear form as:

$$X = a + b \log . C$$

Where C is the concentration of adsorbate in solution at equilibrium (mg/l), **X** is the amount of metal adsorbed per unit weight of adsorbent (mg/gm), a and b are constants related to adsorption capacity and intensity of adsorption (Abdel-Ghani, *et al*. 2007).

Statistical analysis:

Comparison of treatment means using one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) was performed to compare the different treatment means at 5% level of significance. The software SPSS, version 10 (SPSS, Richmond, USA) was used as described by Dytham (1999).

RESULTS AND DISCUSSION

Effect of pH values.

As shown in Table 1 and illustrated in Figures 1-4, pH values have a significant effect on the efficiency of the different tested materials towards both copper and lead removal. Concerning maize leaves removal efficiency, there were no significant differences among the different pH values toward copper, while the highest value was in the pH 5 solution (94.362 % ± 0.318). The highest removal efficiency for banana peels, was recorded in pH 9 solution either for copper or lead. Its efficiency percentages were 92.7626 ± 0.875 and 94.7069 ± 0.584 for copper and lead respectively. The highest ($p < 0.05$) egg shells removal efficiency (93.2178 % ± 0.299 and 92.3044 % ± 0.237) were in pH 5 solution for both copper and lead respectively.

Table 1. Removal efficiency of the tested materials at different values of pH.

Tested materials	pH values	Cu	Pb
Maize leaves	5	91.0975 ± 0.00837[a]	94.3615 ± 0.3184 [a]
	7	89.4340 ± 0.1387 [a]	90.5813 ± 0.6131 [b]
	9	89.8093 ± 0.9381 [a]	92.0785 ± 0.3094 [b]
Banana peels	5	88.9015 ± 1.2873 [b]	78.4610 ± 0.3481 [c]
	7	87.8340 ± 0.6137 [b]	85.8680 ± 1.0438 [b]
	9	92.7626 ± 0.8745 [a]	94.7069 ± 0.5840 [a]
Egg shells	5	93.2178 ± 0.2995 [a]	92.3044 ± 0.2369 [a]
	7	89.6390 ± 0.2174 [b]	90.7405 ± 0.1019 [b]
	9	89.4214 ± 0.01063 [b]	89.5464 ± 0.04918 [c]

Means followed by different letters in each column for each tested material are significantly different (Duncan's Multiple Range Test $P<0.05$).

Abdel-Ghani *et al.* (2007) indicated that lead removal recorded its minimum values at pH 2.5.This can be justified on the bases that at lower pH values, the H^+ ions compete with the metal cation for the adsorption sites in the system, which in turn leads to partial releasing the later. The heavy metal cations are completely released under extreme acidic conditions (Forstner and Wittman, 1981).The adsorption percent increases in the pH range of 4.5-6.5, showing the maximum adsorption at pH 6.5. The greatest increase in the rate of adsorption of lead (II) ions on rice husk, maize cobs and sawdust was observed in the pH range from 2.5 to

4.5. In contrast to our results Babarinde *et al*. (2006) indicated that maximum adsorption of lead by maize leaves, occurred at pH 3. Memon *et al*. (2008) found that the maximum uptake of Cr (III) onto banana peel was achieved at pH 4. They explained this behavior by the fact that At pH > 4, the carboxylic groups is deprotonated and became negatively charged hence increasing the availability of binding sites for positively charged metal ions. Arunlertaree, *et al*. (2007) reported that Optimum removal efficiency of all types of egg shells was at pH 6.

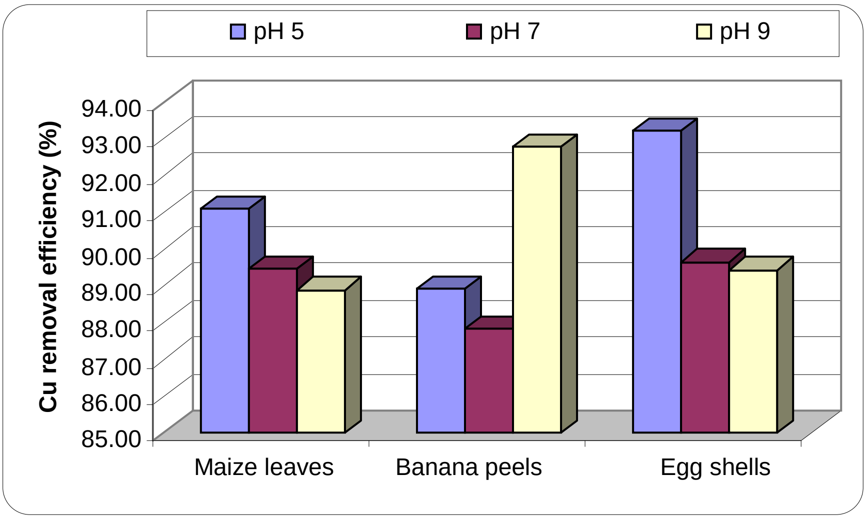

Fig. 1: Cu removal efficiency for each investigated material at different pH values.

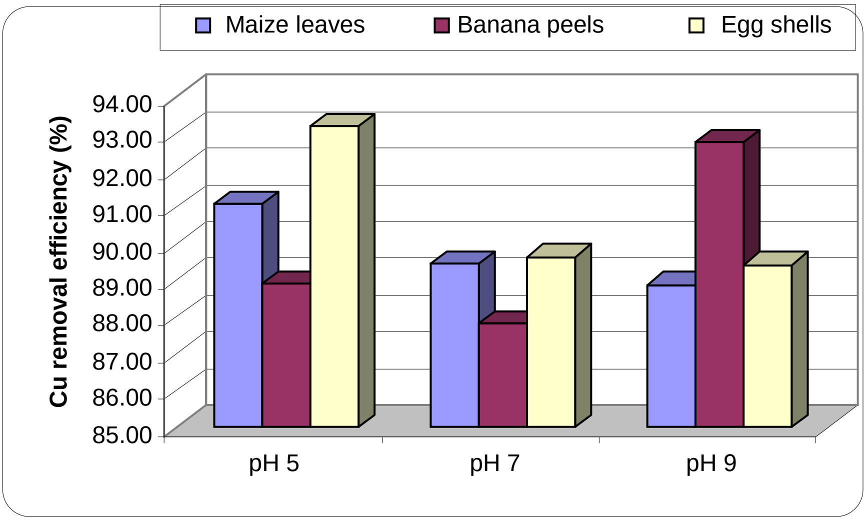

Fig. 2: Comparing Cu removal efficiency of the tested materials at each investigated pH value.

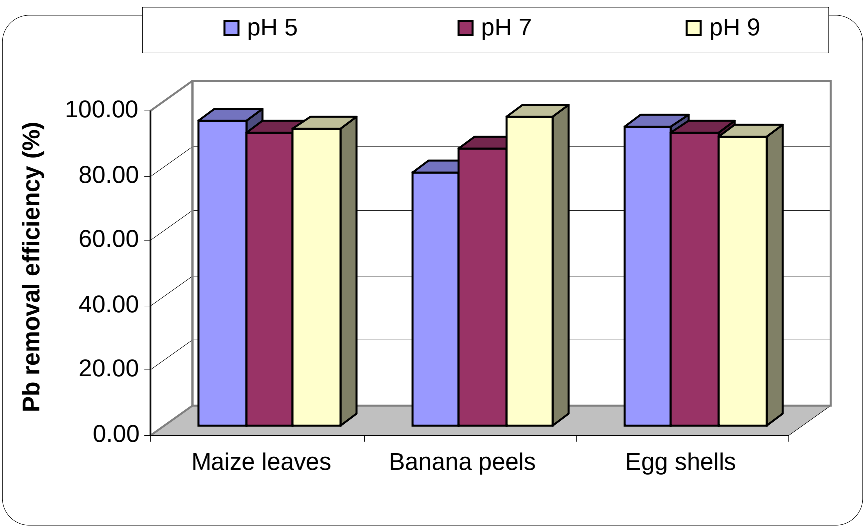

Fig. 3: Pb removal efficiency of each investigated material at different pH values.

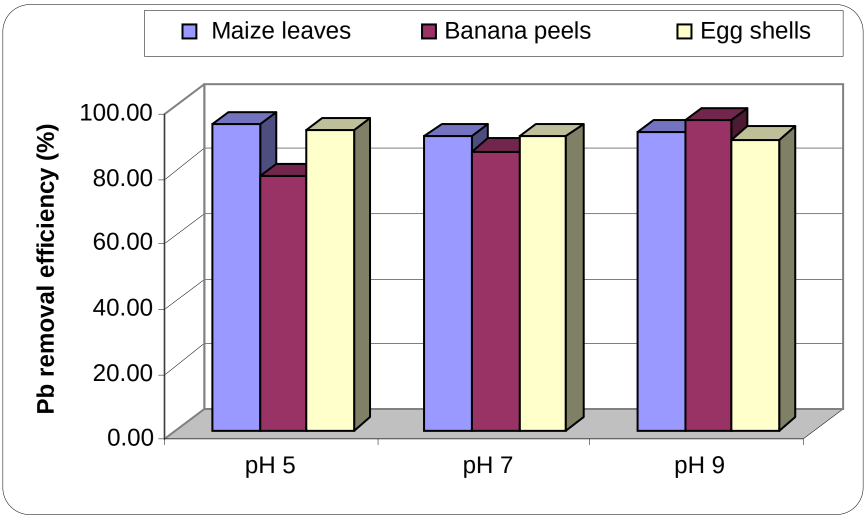

Fig. 4: Comparing Pb removal efficiency of the tested materials at each investigated pH value.

Effect of adsorbent concentration.

Table 2 and Figures 5-8 indicating that 2 grams/l of maize leaves had the highest ($p < 0.05$) removal efficiency (90.246 ± 0.732 %) toward copper, while there were no significant differences for their removal efficiency percentages toward lead between 1 and 2 g/l which were 96.99 ± 0.009 and 95.703 ± 0.293, respectively. With respect to banana peels removal efficiency percentage, there were no significant differences for their values among different concentrations toward copper. These percentages were 86.052 ± 0.743, 83.354 ± 3.211 and 84.667 ± 0.672 for 1, 2 and 3 g/l respectively. Concerning banana peels removal efficiency toward lead, results showed that the highest value (84.039 ± 0.34) was obtained after applying 1g/l. Obtained results showed that there were no significant differences for egg shells removal efficiencies among different concentrations toward copper. These values were 96.871 ± 0.558, 96.647 ± 0.402 and 95.76 ± 0.311 % for 1, 2 and 3 g/l respectively. The highest removal efficiency for egg shells toward lead was 98.574 ± 0.107 and was obtained as a result of applying 2 g/l.

Table 2. Removal efficiency of different concentrations of the tested materials.

Tested materials	Tested materials concentrations (g/l)	Cu	Pb
Maize leaves	1	85.4657 ± 0.5710 [c]	96.9912 ± 0.00878 [a]
	2	90.2460 ± 0.7321 [a]	95.7032 ± 0.2928 [a]
	3	87.6923 ± 0.5810 [b]	90.1745 ± 0.6099 [b]
Banana peels	1	86.0519 ± 0.7426 [a]	84.0395 ± 0.3399 [a]
	2	83.3538 ± 3.2106 [a]	80.3003 ± 1.2124 [b]
	3	84.6674 ± 0.6724 [a]	79.3908 ± 0.8965 [b]
Egg shells	1	96.8709 ± 0.5575 [a]	94.1943 ± 0.3415 [c]
	2	96.6474 ± 0.4018 [a]	98.5735 ± 0.1071 [a]
	3	95.7600 ± 0.3113 [a]	96.2663 ± 0.1981 [b]

Means followed by different letters in each column for each tested material are significantly different (Duncan's Multiple Range Test $P<0.05$).

Arivoli *et al*. (2009) mentioned that the percentage of copper adsorbed by activated carbon, increased with the increase in the carbon concentration. This was attributed to increased carbon surface area and the availability of more adsorption sites (Namasivayam *et al*., 1996 and Namasivayam and Yamuna, 1995).

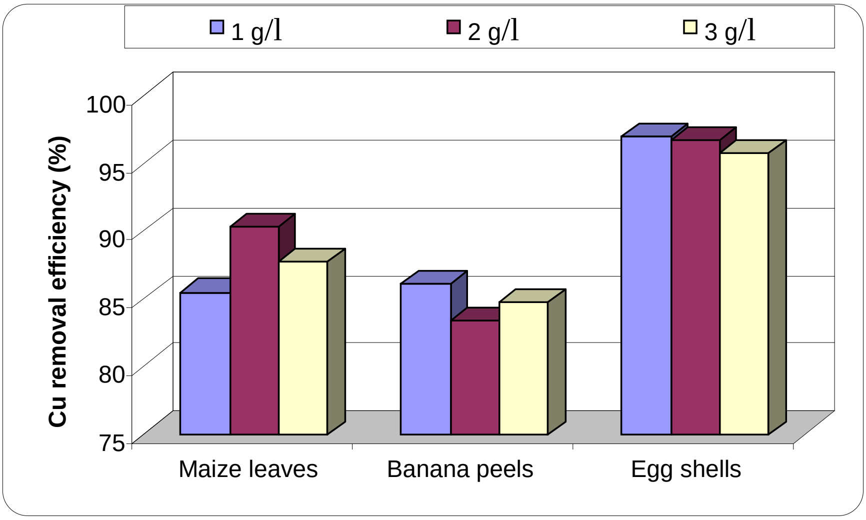

Fig. 5: Cu removal efficiency of different concentrations of each investigated material.

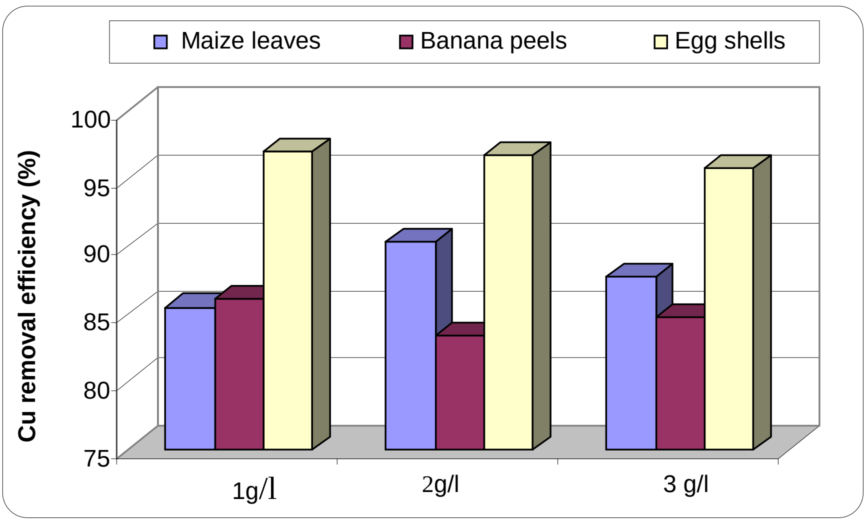

Fig. 6: Comparing Cu removal efficiency percentages of the tested materials of each investigated concentration.

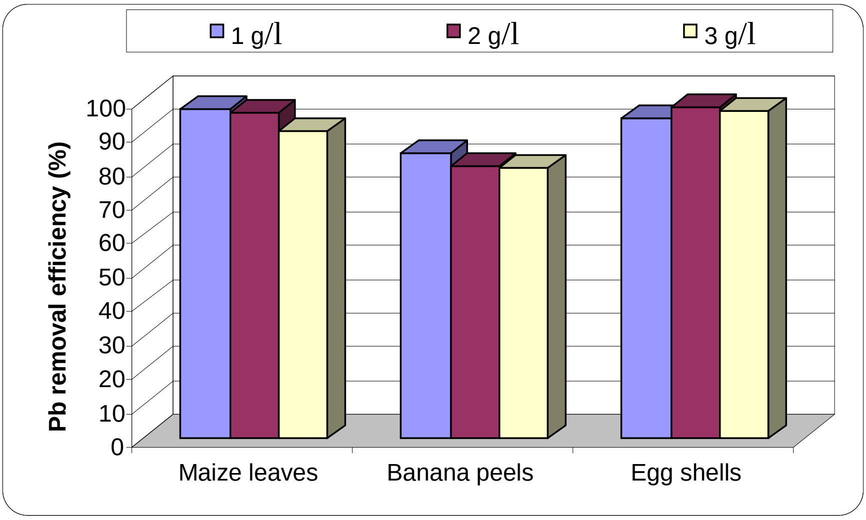

Fig. 7: Pb removal efficiency of different concentrations of each investigated material.

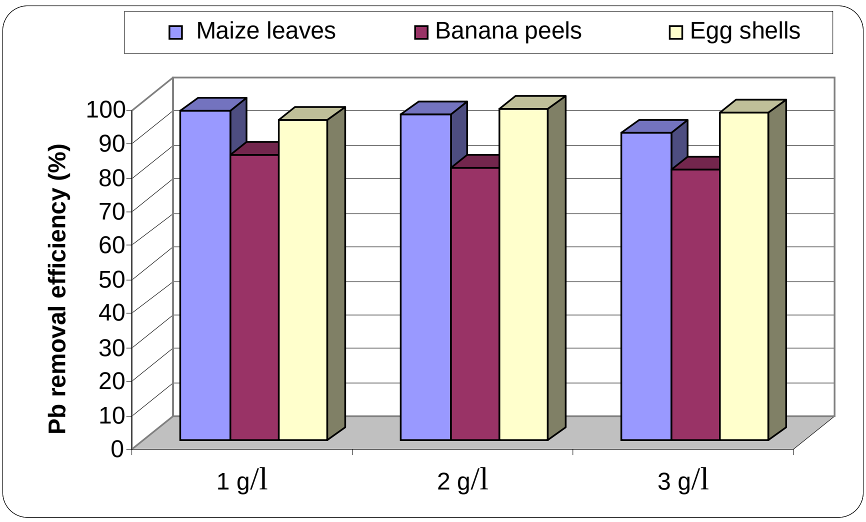

Fig. 8: Comparing Pb removal efficiency of the tested materials of each investigated concentration.

Effect of contacting period.

Obtained results showed in Table 3, and illustrated in Figures 9-12 indicated that, as a general trend, removal efficiency increases with increasing contacting period for each of the investigated materials toward both copper and lead. Obtained results indicated that there were no significant differences in removal efficiency of maize leaves toward copper after both 80 and 100 minutes of contacting periods (88.82 ± 1.019 and 89.601 ± 0.625 % removal efficiency, respectively). Its obtained also that there were no significant differences in removal efficiency of maize leaves toward lead after 20, 40, 60, 80 and 100 minutes of contacting periods (95.035 ± 0.261, 96.34 ± 0.21, 96.317 ± 0.183, 95.8 ± 0.68 and 95.675 ± 0.589 % removal efficiency, respectively). Concerning removal efficiency of banana peels, results indicated that the efficiency increased with increasing contact period. The highest efficiencies toward both copper and lead were obtained after 100 minutes with the values 73.94 % ± 0.157 and 63.42 % ± 0.415 respectively.

Table 3. Removal efficiency of different tested materials at different contacting periods.

Tested materials	Contact period (minutes)	Cu	Pb
Maize leaves	20	84.3420 ± 0.2023 [c]	95.0347 ± 0.2613 [a]
	40	86.4700 ± 0.3460 [b]	96.3400 ± 0.2100 [a]
	60	88.2000 ± 0.2646 [ab]	96.3167 ± 0.1833 [a]
	80	88.8233 ± 1.0193 [a]	95.8000 ± 0.6762 [a]
	100	89.6007 ± 0.6247 [a]	95.6753 ± 0.5881 [a]
Banana peels	20	57.4313 ± 0.6242 [e]	42.1773 ± 0.8522 [e]
	40	63.4693 ± 0.1257 [d]	45.0473 ± 0.3039 [d]
	60	68.4600 ± 0.4743 [c]	51.5800 ± 0.9989 [c]
	80	71.0000 ± 0.2082 [b]	56.2667 ± 0.1202 [b]
	100	73.9360 ± 0.1569 [a]	63.4240 ± 0.4152 [a]
Egg shells	20	55.0333 ± 0.5239 [e]	44.8000 ± 1.4844 [e]
	40	62.8433 ± 0.1885 [d]	52.8200 ± 0.3292 [d]
	60	68.8800 ± 0.2444 [c]	67.1400 ± 0.2914 [c]
	80	73.0867 ± 1.1887 [b]	73.7833 ± 1.1525 [b]
	100	83.3900 ± 1.3754 [a]	88.8167 ± 0.7361 [a]

Means followed by different letters in each column for each tested material are significantly different (Duncan's Multiple Range Test $P<0.05$).

Similar results were achieved for egg shells where the removal efficiency increased with increasing contact period. The highest values

(83.39 % ± 1.38 and 88.817 % ± 0.736) were obtained after 100 minutes of contacting period for both copper and lead respectively.

Similar results were previously obtained by Abdel-Ghani *et al.* (2007), who reported that the removal of Pb from the synthetically prepared wastewater increases with increasing contact time and attains equilibrium at about 90-120 min by using rice husk, maize cobs and sawdust as biosorbents. Arunlertaree *et al*. (2007) mentioned also that the optimum contact time for all types of egg shell should be at 90 minutes. This result was consistent with Pawebang and Sukcharoen (1999), who reported that the equilibrium time to remove lead in synthetic wastewater by egg shell could be reached at about 80 minutes. Similarly the study of Lee *et al*. (1998) on the removal of lead by crab shell particle showed that the necessary contact time to reach equilibrium was about 90-120 minutes. Babarinde *et al***.** (2006) find that the kinetic studies show that uptake of lead ions increases with time and that maximum adsorption was obtained within the first 30 min of the process.

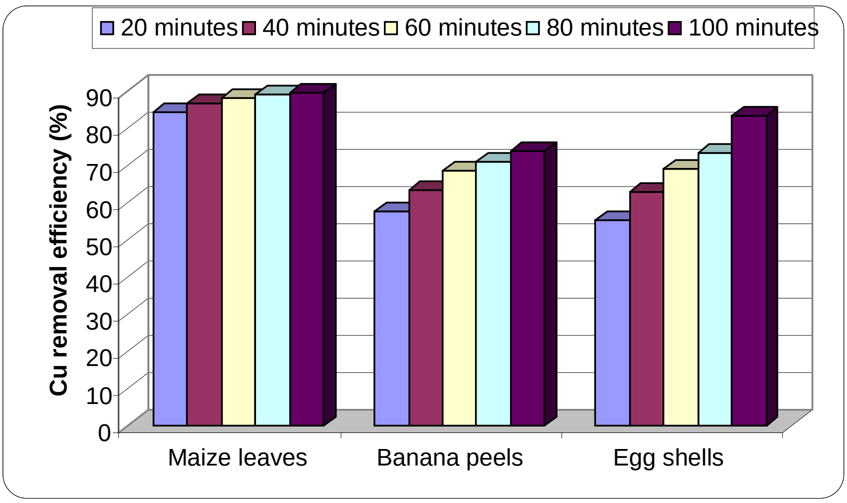

Fig. 9: Cu removal efficiency of each investigated material atdifferent contacting periods.

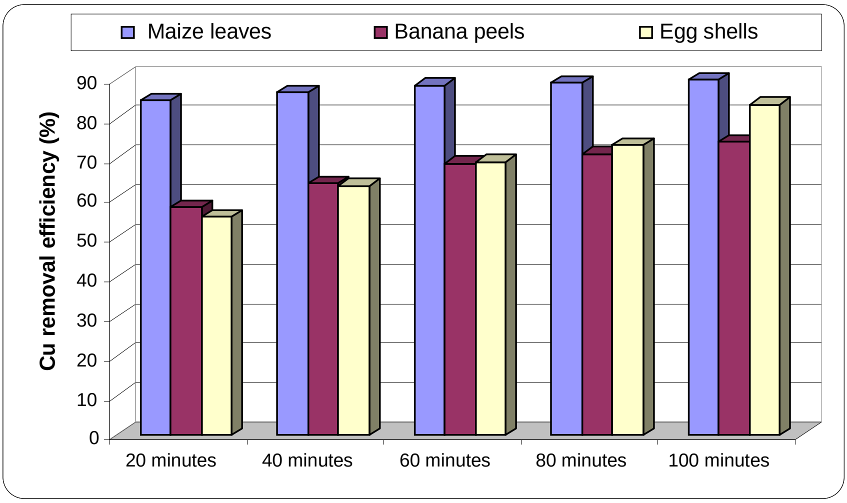

Fig. 10: Comparing Cu removal efficiency of each of the tested materials at different contacting periods.

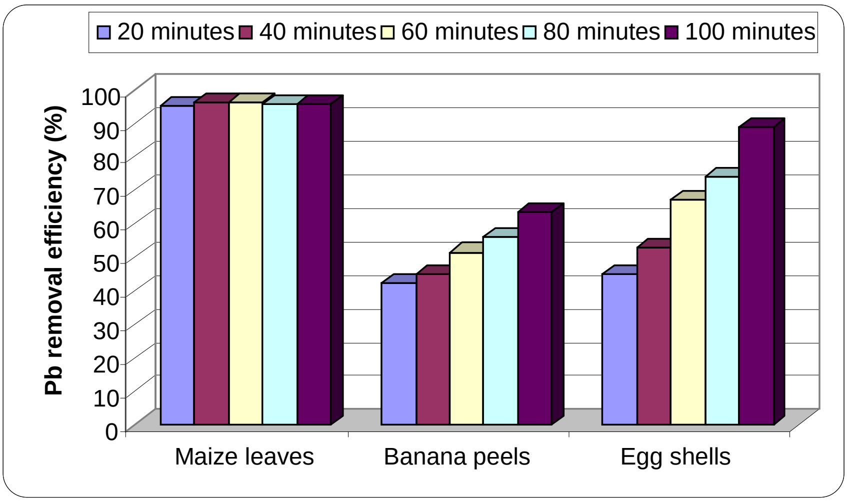

Fig. 11: Pb removal efficiency of each of the investigated materials at different contacting periods.

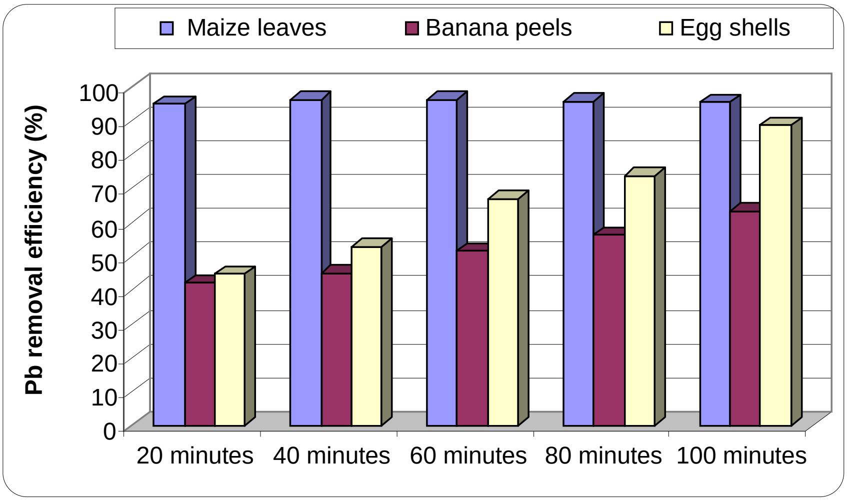

Fig. 12: Comparing Pb removal efficiency of the tested materials at different contacting periods.

Isothermal studies.

The Langmuir isotherm equation.

As indicated in Table 1 and Figures 13 – 18, the most fitted Langmuir equation were maize leaves for lead, egg shells for copper and banana peels for lead, where there R^2 values were 0.999, 0.93 and 0.87 respectively.

Table 4: Langmuir parameters for the adsorption of both copper and lead on the different investigated materials.

Adsorbent	Adsorption maximum a (mg/kg)		Binding energy B (mg/kg)		R2 for Langmuir equation	
	Cu	**Pb**	**Cu**	**Pb**	**Cu**	**Pb**
Maize leaves	0.210	0.100	0.090	0.870	0.110	0.999
Banana Peels	1.180	1.060	2.020	2.210	0.330	0.870
Egg shells	0.200	0.010	1.740	0.380	0.930	0.020

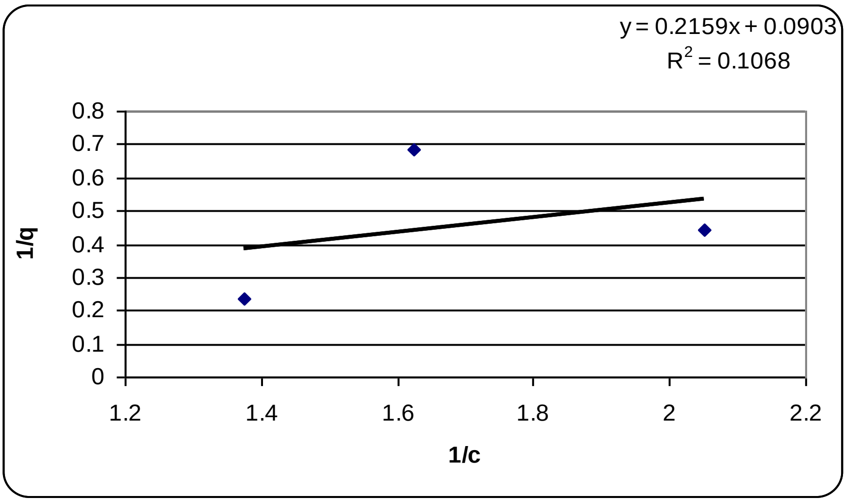

Fig. 13: Langmuir adsorption isotherm of Cu by maize leaves.

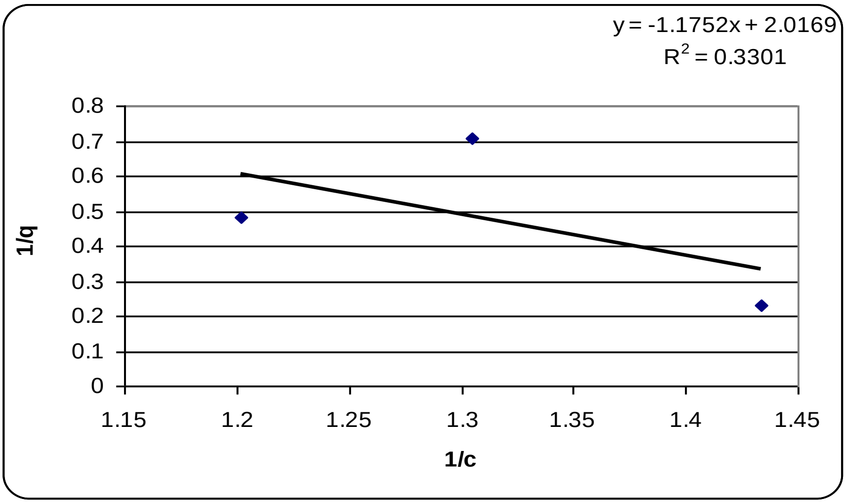

Fig. 14: Langmuir adsorption isotherm of Cu by banana peels.

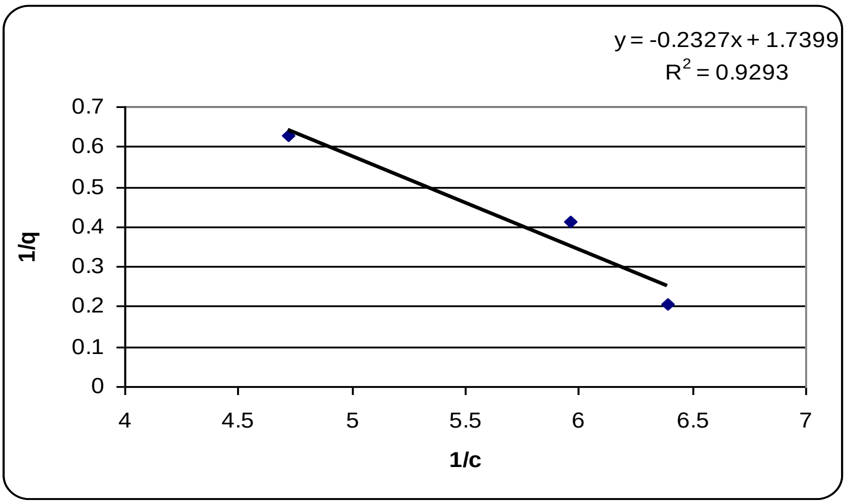

Fig. 15: Langmuir adsorption isotherm of Cu by egg shells.

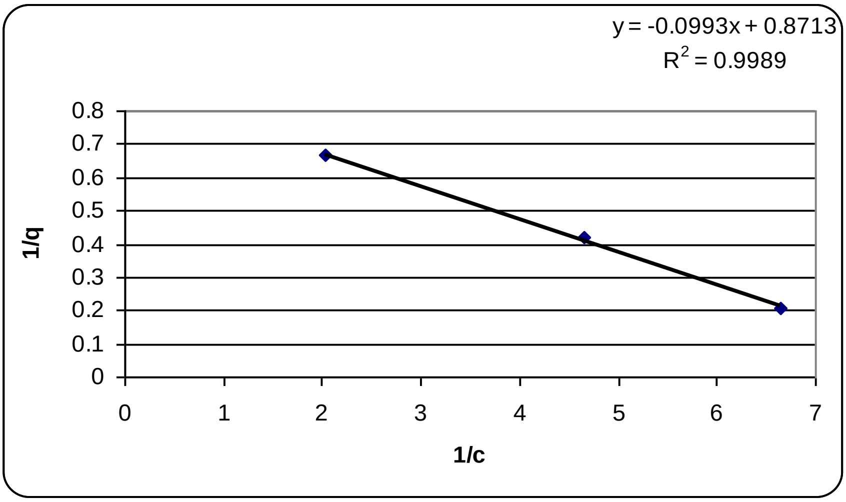

Fig. 16: Langmuir adsorption isotherm of Pb by maize leaves.

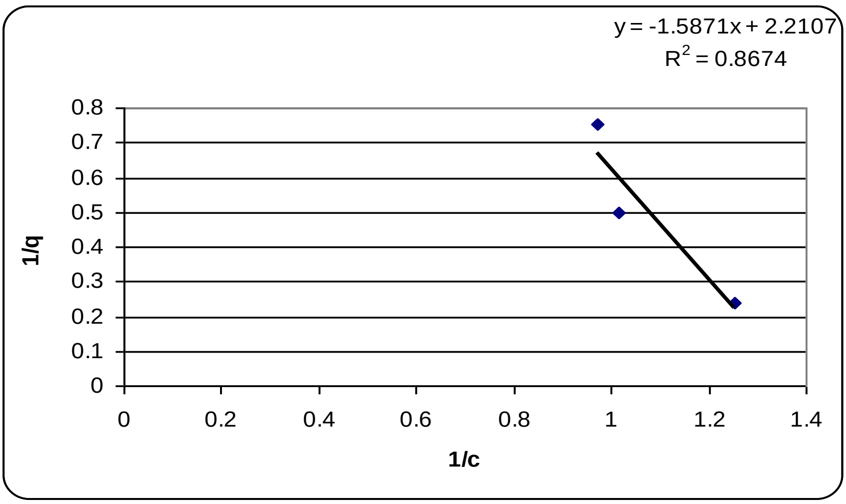

Fig. 17: Langmuir adsorption isotherm of Pb by banana shells.

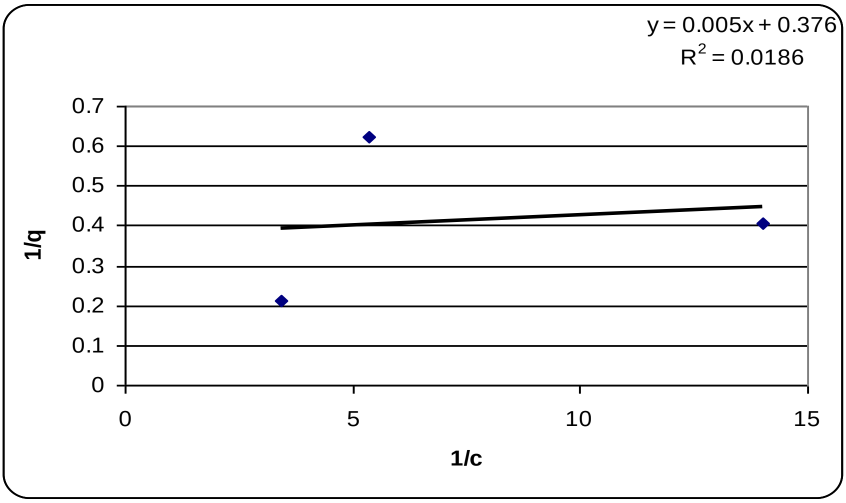

Fig. 18: Langmuir adsorption isotherm of Pb by egg shells.

The Fruendlich isotherm equation.

Banana peels, maize leaves for adsorbing lead, and egg shells for copper adsorption were most fit to Fruendlich model where there R^2 values were 0.96, 0.886 and 0.68 respectively.

Table 5: Fruendlich parameters for the adsorption of both copper and lead on the different investigated materials.

Adsorbent	**Adsorption capacity, K**		**Adsorption intensity, n**		**R^2 for Langmuir equation**	
	Cu	**Pb**	**Cu**	**Pb**	**Cu**	**Pb**
Maize leaves	1.38	0.92	0.69	0.135	0.26	0.886
Banana peels	4.29	4.21	0.14	0.22	0.45	0.96
Egg shells	3.17	0.31	1.96	0.68	0.81	0.17

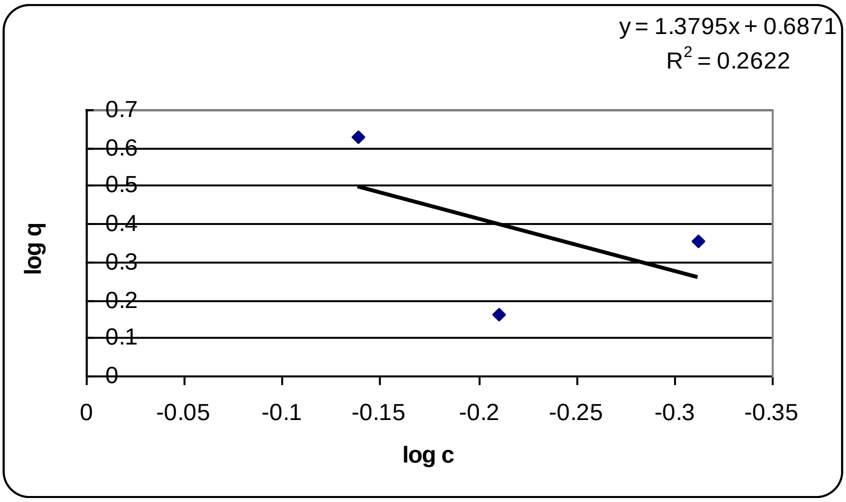

Fig. 19: Fruendlich adsorption isotherm of Cu by maize leaves.

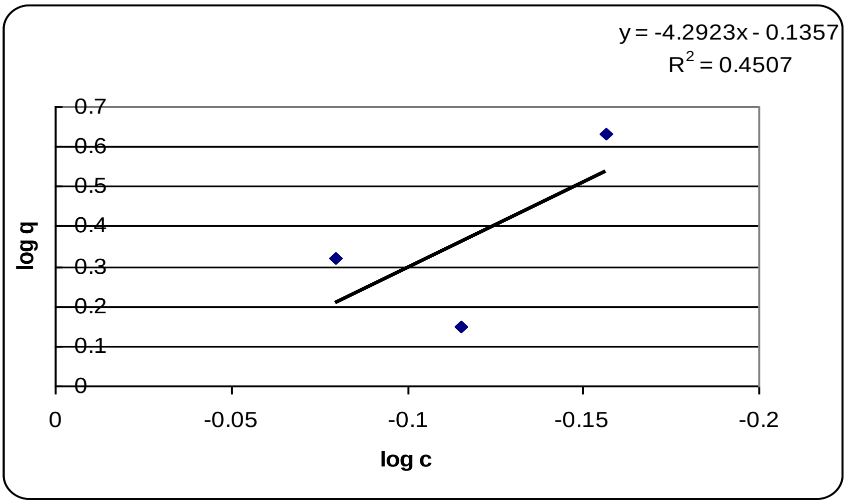

Fig. 20: Fruendlich adsorption isotherm of Cu by banana peels.

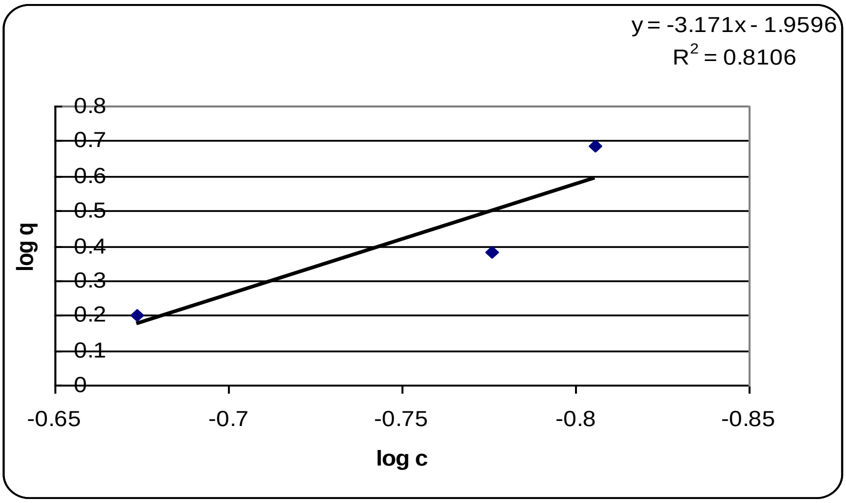

Fig. 21: Fruendlich adsorption isotherm of Cu by egg shells.

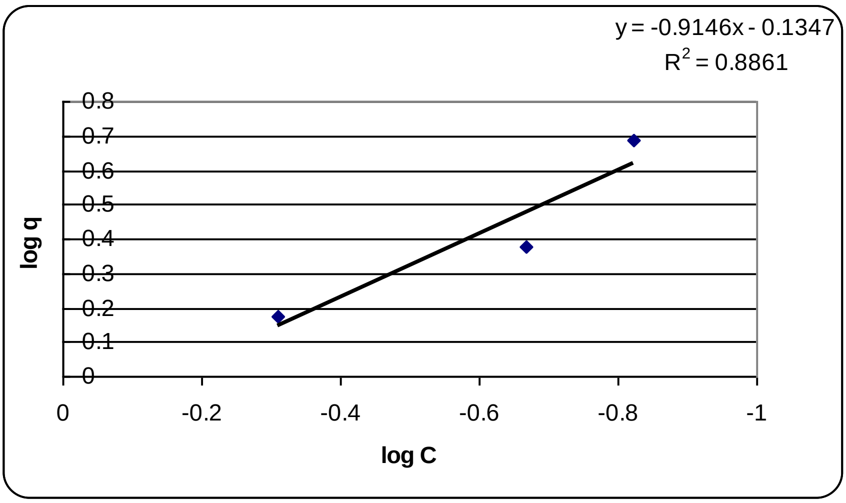

Fig. 22: Fruendlich adsorption isotherm of Pb by maize leaves.

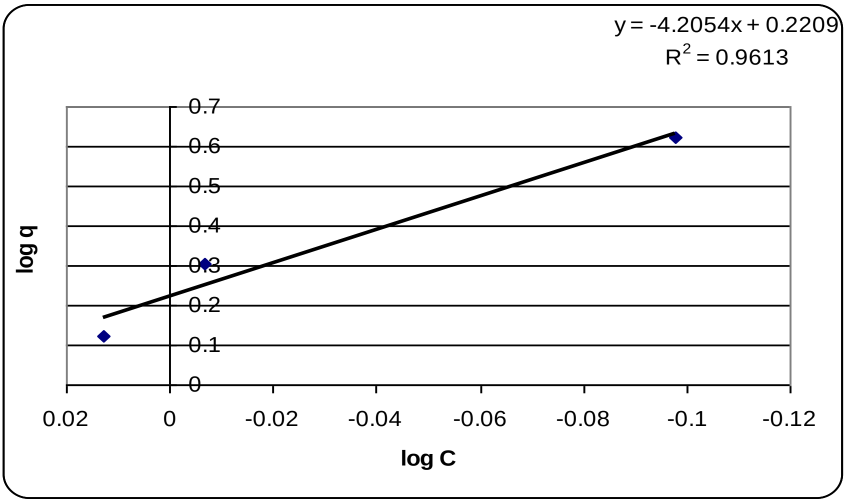

Fig. 23: Fruendlich adsorption isotherm of Pb by banana peels.

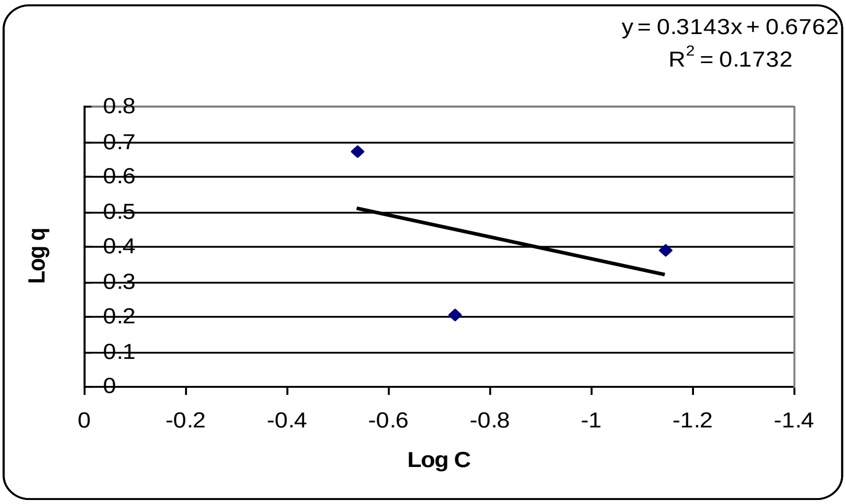

Fig. 24: Fruendlich adsorption isotherm of Pb by egg shells.

The Temkin isotherm equation.

By processing the obtained data for the uptake of either copper or lead metal ions by the three investigated materials over the studied concentration range in accordance with Temkin model of adsorption isotherms. The most material found to fit the Temkin isotherm model, were banana peels toward lead, maize leaves toward lead, egg shells and banana peels toward copper, where R^2 values were: 0.996, 0.779, 0.696 and 0.578 respectively. These results achieving Temkin,s theory of the presence a chemical adsorption between both copper and lead ions and the used adsorbents.

Table 6: Temkin parameters for the adsorption of both copper and lead on the different investigated materials.

Adsorbent	Adsorption capacity, K		Adsorption intensity, n		R^2 for Langmuir equation	
	Cu	**Pb**	**Cu**	**Pb**	**Cu**	**Pb**
Maize leaves	10.397	5.801	4.956	0.564	0.389	0.779
Banana peels	29.929	25.332	0.909	1.738	0.578	0.996
Egg shells	20.373	2.753	12.361	5.14	0.696	0.286

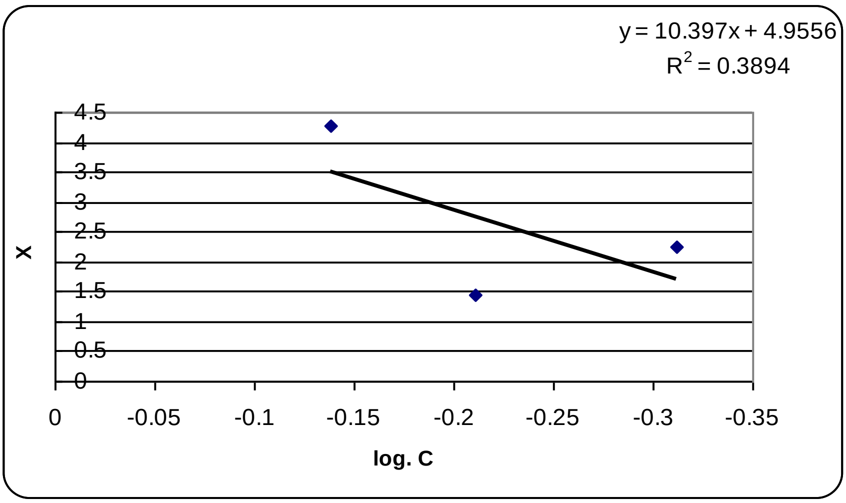

Fig. 25: Temkin adsorption isotherm of Cu by maize leaves.

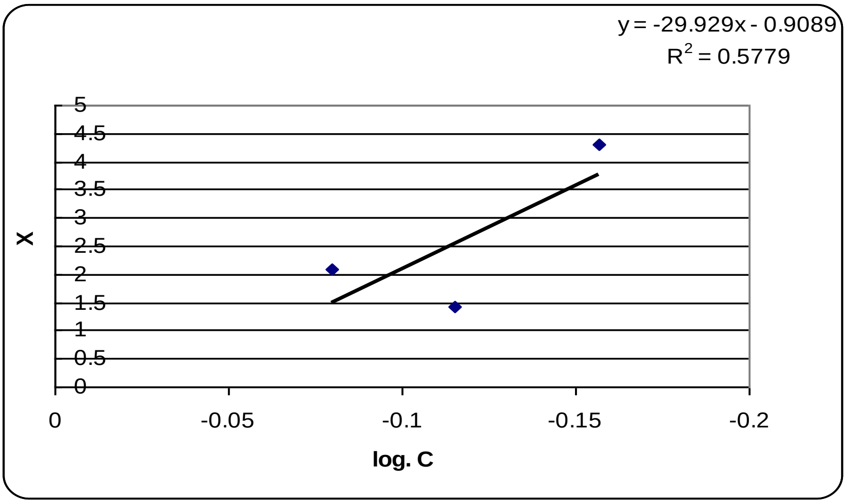

Fig. 26: Temkin adsorption isotherm of Cu by banana peels.

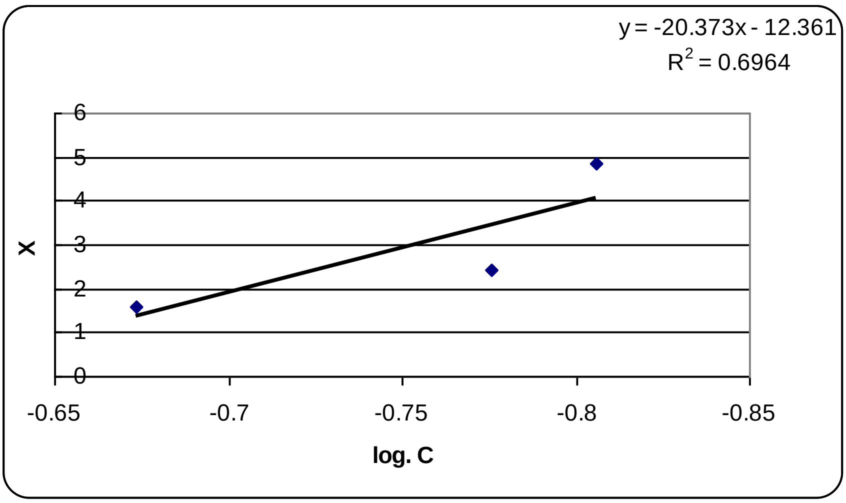

Fig. 27: Temkin adsorption isotherm of Cu by egg shells.

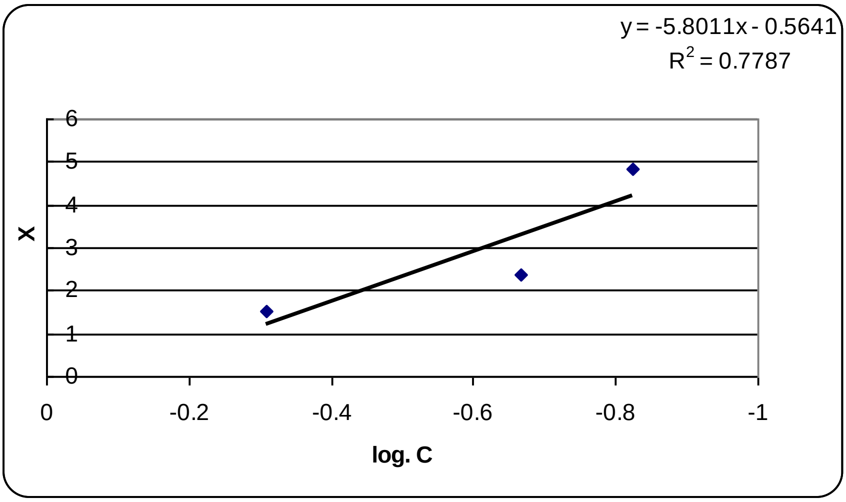

Fig. 28: Temkin adsorption isotherm of Pb by maize leaves.

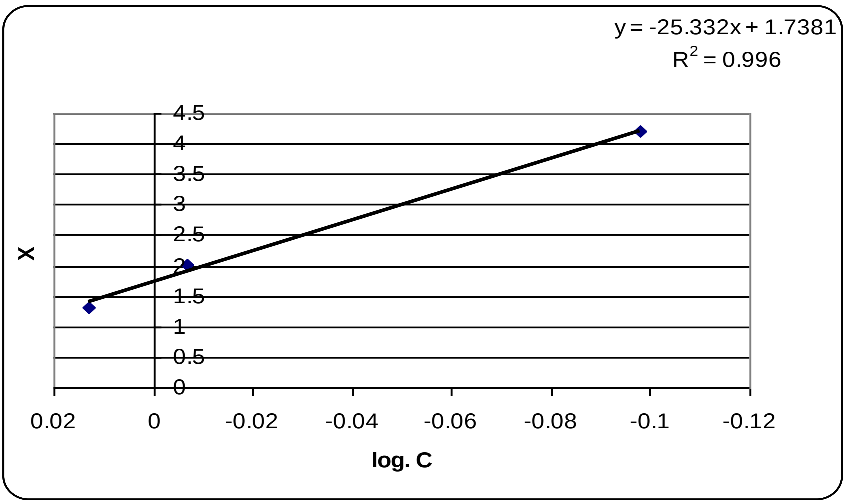

Fig. 29: Temkin adsorption isotherm of Pb by banana peels.

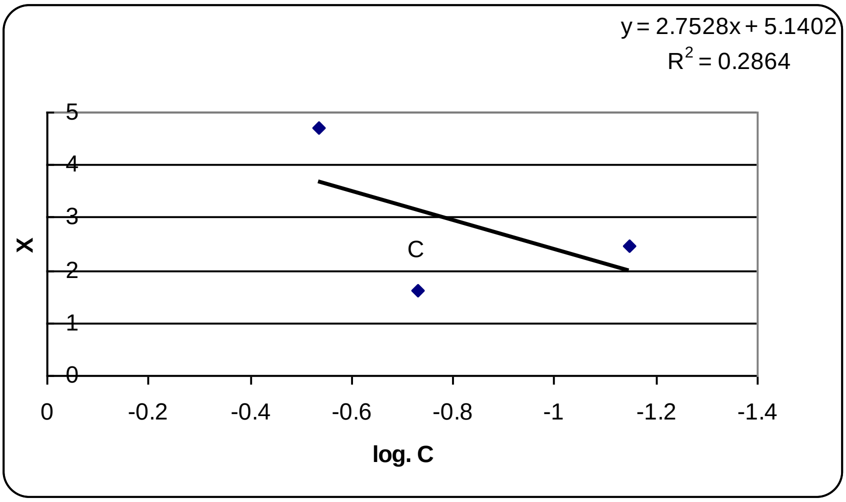

Fig. 30: Temkin adsorption isotherm of Pb by egg shells.

Conclusion.

This work showed that locally available, low-cost materials such as maize leaves, banana peels and egg shells can be used as efficient sorbents for copper and lead ions removal, representing an effective and environmentally clean utilization of waste matter.

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كفاءة بعض المواد الطبيعية رخيصة الثمن لإزالة كل من النحاس والرصاص من المياه الملوثة

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تم إستخدام كل من أوراق الذرة وقشور ثمار الموز وقشور بيض الدجاج في هذه الدراسة كمواد طبيعية واسعة الإنتشار رخيصة الثمن في إزالة كل من النحاس والرصاص من مياه ملوثة بهما معدة صناعيا بالمعمل. وقد تم إختبار تركيزات مختلفة من المواد المختبرة (١، ٢ ، ٣ جم/ لتر) وقد تم إختبار تأثير إختلاف تركيز أيون الهيدروجين.وكذلك تم إختبار تأثير مدة الإختلاط بين المواد المختبرة والمحلول حيث تم قياس متبقيات العنصران بعد ٢٠ ، ٤٠ ، ٦٠ ، ٨٠ ، ١٠٠ دقيقة. وقد كانت أهم النتائج المتحصل عليها كالتالي:

بالنسبة لتأثير تركيز أيون الهيدروجين فقد تبين أن أفضل قيمة له كانت ٥ بالنسبة لكل من أوراق الذرة وقشور البيض حيث كانت نسب الإزالـه لهما ٩١.٠٩٧٥ % ± ٠.٠١ و ٩٤.٣٦٢ % ± ٠.٣١٨ و ٩٣.٢١٧ % ± ٠.٢٩ و ٩٢.٣٠٤ %± ٠.٢٣٧ من كل من النحاس والرصاص علي التوالي. بينما كانت أفضل نسبة إزالة لأوراق الموز (٩٢.٧٦٣ % ± ٠.٨٧٥ و ٩٤.٧٠٧ % ± ٠.٥٨٤ من كل من النحاس والرصاص علي التوالي) عند القيمة ٩ لتركيز أيون الهيدروجين.

بالنسبة لتأثير تركيز المواد المستخدمة، كان أفضل تركيز لأوراق الذرة ٢ جم/لتر حيث أزال ٩٠.٢٤٦ % ± ٠.٧٣٢ و ٩٥.٧٠٣ %± ٠.٢٩٣ من كل من النحاس والرصاص علي التوالي. بينما كان أفضل تركيز لأوراق الموز ١ جم/لتر حيث أزال ٨٦.٠٥٢ % ± ٠.٧٤٣ و ٨٤.٠٤ % ± ٠.٣٤ من كل من النحاس والرصاص علي التوالي. بينما كان أفضل تركيز لقشور البيض هو ٢ جم/لتر حيث أزال ٩٦.٦٤٧ % ± ٠.٤٠٢ و ٩٨.٥٧٤ % ± ٠.١٠٧ من كل من النحاس والرصاص علي التوالي.

بينت النتائج أن كفاءة الإمتصاص لكل المواد المختبرة تزداد بصفة عامة مع زيادة وقت الإختلاط بين تلك المواد والمياه الملوثة، فيما عدا حالة واحدة وهي حالة أوراق الذرة مع الرصاص حيث لم يكن هناك أية فروق ملموسة بين نتائج الإمتصاص عند أي من الأوقات المختبرة (بعد ٢٠ و ٤٠ و ٦٠ و ٨٠ و ١٠٠ دقيقة). بينما مع النحاس لم يكن هناك فروقا في نسب الإمتصاص بعد كل من ٨٠ و ١٠٠ دقيقة. بالنسبة لقشور كل من الموز والبيض كانت أفضل نسب الإدمصاص ، كما سبق الإشارة، هي المتحصل عليها بعد ١٠٠ دقيقة من الإمتزاج

مـع الميــاه الملوثــة. وكانــت النسـب المئويــة ٧٣.٩٣٦ % ± ٠.١٥٧ و ٦٣.٤٢ % ± ٠.٤١٥ و ٨٣.٣٩ % ± ١.٣٧٥ و ٨٨.٨١٧ % ± ٠.٧٣٦ لكل من النحاس والرصاص علي التوالي.

- تم تطبيق معادلات لانجمير وفريندلش وتمكن لقياس كل من معدلات الإدمصاص وقوة الإرتباط للمواد الثلاثه المختبرة. وقد كانت نتائج تطبيق تلك المعادلات كالتالي:

- إستخدام كل من أوراق الذره لإزالة الرصاص وقشور البيض لإزالة النحاس أعطي أفضل تطابق مع معادلة لانجمير حيث كانت قيم معامل الإنحدار (R^2) ٠.٩٩٩ و ٠.٩٣ علي التوالي.

- إستخدام كل من قشور الموز لإزالة الرصاص و أوراق الذره لإزالة الرصاص وقشور البيض لإزالة النحاس أعطي أفضل تطابق مع معادلة فريندلش حيث كانت قيم معامل الإنحدار (R^2) ٠.٩٦ و ٠.٨٨٦ و ٠.٨١ علي التوالي.

- إستخدام كل من قشور الموز لإزالة الرصاص وقشور البيض لإزالة النحاس أعطي أفضل تطابق مع معادلة تمكن حيث كانت قيم معامل الإنحدار (R^2) ٠.٩٩٦ و ٠.٦٩٦ علي التوالي.

نتائج تطبيق تلك المعادلات يشير لإمكانية الإستفاده من تلك المواد (أوراق الذرة وقشور ثمار الموز وقشور بيض الدجاج) لكفائتها في إزالة كل من النحاس والرصاص من المياه الملوثه.

نخلص من هذه الدراسة لإمكانية إستخدام كل من أوراق الذرة وقشور ثمار الموز وقشور بيض الدجاج للتخلص من كل من النحاس والرصاص بكفاءة ، خاصة وأنهم من المواد الطبيعية آمنة الإستخدام واسعة الإنتشار رخيصة الثمن مما يزيد من قابليتهم للتطبيق العملي، ومن جهة أخري يتيح الإستفادة الفاعلة من تلك المواد بصورة آمنة مفيدة بدلا من أن تصبح مخلفات مضرة للبيئة.