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Potential use of agricultural materials as bio-adsorbents to remove heavy metals from water

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***Abstract*—The study was carried out to evaluate the cadmium ion (Cd^{+2}) adsorption ability of oven dried ripen banana peels (Musa sapientum) and sun dried sponge gourds (Luffa cylindrica). Chemical modifications were not used for plant materials during the experiment. Aqueous solution with known concentration of Cadmium ion was prepared by adding cadmium ions to deionized water. Three different doses of plant materials (0.25g, 0.5g and 1g) were used to treat known cadmium ion concentrations of 5ppm. The experiments were carried out at room temperature after treating with banana peel and sponge gourd powders. Cadmium ion concentrations were measured after every 10 minutes for 02 hours by using the Atomic Absorption Spectrometer and amount of adsorption at equilibrium were calculated. During the first 10 minutes all the treated samples showed their maximum cadmium ions adsorption ability. The highest adsorption of 0.358 mg/g was given by 0.25g of banana peel powder in 25mL of cadmium solution. The lowest adsorption of 0.078 mg/g was given by 1g of sponge gourd powder. When comparing the adsorption ability of mixtures, 0.125 g of adsorbent doses at 1:1 ration showed 0.188 mg/g of cadmium ion density and 0.25g of adsorbent doses at 1:1 ration adsorbed and showed 0.10 mg/g of cadmium ion density. The results showed potential use of banana peels and sponges of sponge gourd as bio-adsorbents to reduce cadmium ions from water.**

Keywords*— Atomic absorption spectroscopy, bio-adsorbents, cadmium, Luffa cylindrica, Musa sapientum

I. INTRODUCTION

There has been increasing concern about the discharge of heavy metals into water sources and seeking on low-cost methods to remove them to clean the water. Cadmium is highly used in industries and causes harmful effects on organisms. Cadmium ions can accumulate through food chains and in the body of ultimate consumers and generates catastrophic effects on organisms. It can produce both acute and chronic intoxications with hazardous conditions [1]. Several industries act as the sources of cadmium release into the environment. Heavy metals are needed to remove from the effluents to an acceptable levels before discharge them to the environment and it is a legal condition in many countries [2]. According to the guideline by World Health Organization (WHO) 0.005 mg of Cd irons in one liter is the recommended level for drinking water [3].

Several treatment methods are used to remove heavy metals from the water such as chemical precipitation, flotation, adsorption, ion exchange, electrochemical deposition etc. Some of these methods are very expensive and also have some weaknesses. Among those, chemical precipitation is the most common and the conventional method used in several implementations [4]. Due to high capital costs these methods are not suitable for small-scale industries and adsorption has been identified as an effective method among the physicochemical processes to treat metal-bearing effluents [5]. Some of these chemical or any other modifications processes can lead to produce several side products or substances that are even more toxic than heavy metals [6]. Therefore, many industries search for cheap but successful bio-adsorbents to remove heavy metals from their effluents [7].

Banana peels are available abundantly and sponge gourds are commonly consumed vegetable in many Asian countries. The world production of banana is normally 81.3 Mt per year. The peel represents 30% – 25% of the total dry matter. Therefore, about 5 Mt of peels is produced every year and they are discarded as waste and upgraded uses of them cannot be seen [8]. Therefore, these two plant materials were selected for this study because they are highly available, low cost, safe and environment friendly.

Sponge gourd belongs to the cucumber family and grown in many tropical and subtropical countries. Mature sponge gourds are utilized as scrubbing sponges which is used at kitchens and bathrooms. Complex polysaccharides such as pectin substances are containing arabinose, rhamnos, galacturonic acid, and galactose. Carboxyl groups found in galacturonic acid make pectin substances strong metal adsorbent

in aqueous solutions [8]. Banana peel surface has a micro-rough texture and irregular shape particles which can promote the adherence of heavy metals [9]. Sponge gourds also have irregular texture and porous nature of the surface that promote the adherence of heavy metals [10]. The use of some biological material in the adsorption process is known as bio-sorption. Adsorption is known as one of the most favorable techniques applied for water treatments [8].

In this study, the ability of the banana peels and sponge gourds to remove Cd(II) ions from the water was investigated. Any chemical modification process was not implemented during the study.

II. METHADOLOGY

A. Preperation of adsorbents

Banana peels were properly washed with tap water to remove dirt and other contaminants. Washed banana peels were cut into small pieces (≤1 cm) by using a knife. Then they were washed again three times with de-ionized water. Wet banana peels were kept in the air for few minutes to drain the excess water. Next, peels were dried in an oven at 105°C for 24 hours and grounded into powder by using a grinder. Sponge gourds sponges were collected from house-level gardens and cultivations. They were allowed to over matured and dried on the vines. Then dried sponge gourds were harvested and the outer covers were removed to get the inner sponge. Then collected sponges were dried in open sunlight until crushable. Dried sponges were grounded into small particles by using a grinder. Grounded peels and sponges were sieved by using a standardized strainer to collect the particles low than 1.5mm. Prepared adsorbents were kept in air-tied bottles and stored in a refrigerator until used for experiments

B. Preperation of cadmium solution

1000ppm standardized Cd^{+2} solution was diluted with de-ionized water to prepare a Cd^{+2} solution with 5 ppm for the experiment.

C. Cd^{+2} adsorption ability of adsorbents

The experiment was conducted at room temperature (27^0C). Five clean 25 mL beakers were labeled as B1, B2, B3, B4 and B5. Then 25mL from the Cd^{+2} solution were accurately added into each beaker by using a 25mL pipette. From the banana peel powder 0.25g portions were accurately measured and added into each beaker and mixed well. After 10 minutes mixture in the B1 was filtered into a test tube through a filter paper (Whatman No.01).Then the Cd^{+2} concentration of this mixture was measured by using Atomic Absorption Spectrometer (AAS). After 20 minute mixture in the B2 was filtered into a test tube through a filter paper. Likewise, mixture in the B3, B4 and B5 were also filtered after 40, 60 and 120 minutes consecutively. All the mixtures were tested for the Cd^{+2} concentrations using AAS. The same procedure was followed by changing the weight of banana peel powder as 0.50g and 1.00g. The above experiment was repeated for sponge gourd powder by labeling the beakers as S1-S5. Again the same experiment was repeated for the powder mixtures at 1:1 ration (by adding 0.125 mg and 0.25 mg equally from both powders prepare the powder mix).

D. Calculate the adsorption density

AAS results were used to calculate the adsorption density (Qe-amount of adsorption at equilibrium) of each sample using the below equation (Adewuyi. et al, 2017).

$$Qe = \frac{(Co - Ce)V}{M}$$

Qe = amount of adsorption at equilibrium (mg/g)
Co = initial concentration of toxic metal solution (mg/L)
Ce = concentration of toxic metal solution at a given time t (mg/L)
V = volume of solution (L)
M = mass of adsorbent used (g)

III. RESULT AND DISCUSSION

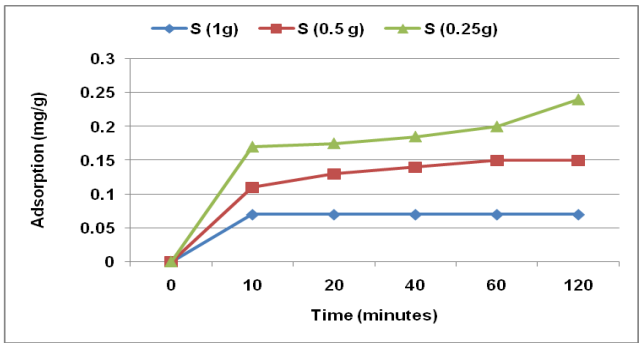

Figure 1. Cadmium ions adsorption ability of sponge gourd

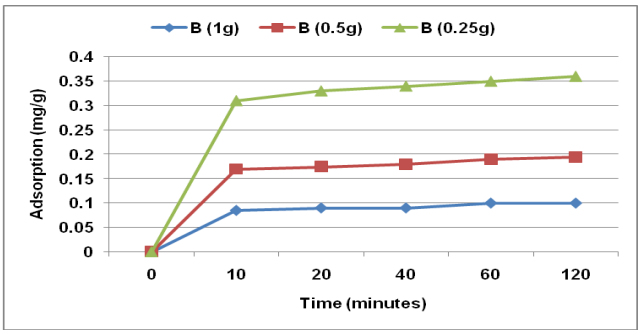

Figure 2. Cadmium ions adsorption ability of banana peels

As shown in the Fig.1 and Fig.2 both adsorbents have ability to reduce the cadmium ion concentration in the aqueous solutions. The results of all the treatments showed a same pattern of adsorption in the graphs. All the treatments adsorbed cadmium ions at increasing rate during first 10 minutes. Thereafter, few of the treatments adsorbed ions at a decreasing rate while many showed constant value of cadmium ions concentration with the time.

Further, the results showed that the adsorption ability of both sponge gourd and banana peels were reduced with increasing their dose. In the experiments, 0.25 grams of adsorbents showed higher adsorption ability than 0.5g and 1g. When increasing the dose of banana peels and sponge gourds a little colour development could be seen in the solution. This may be a reason to hinder the cadmium ion adsorption ability of solutions. Further, when adding more and more adsorbent the solution gradually converted in to a saturated solution of adsorbent. Then after a significant dose, cadmium adsorption density of adsorbents is reached to a constant value. Therefore, after the saturation process there is no considerable effect of increasing adsorbent dosage to improve adsorption process.

Further, when comparing the values shown in the Fig.1 and Fig.2 banana peels showed higher cadmium adsorption ability than sponge gourd and lower the dose showed the highest ability. Among all the experiments, 0.25g of banana peel in 25 mL of cadmium solution showed the highest adsorption value of 0.358 mg/g. The lowest adsorption of 0.078 mg/g was given by 1g of sponge gourd powder.

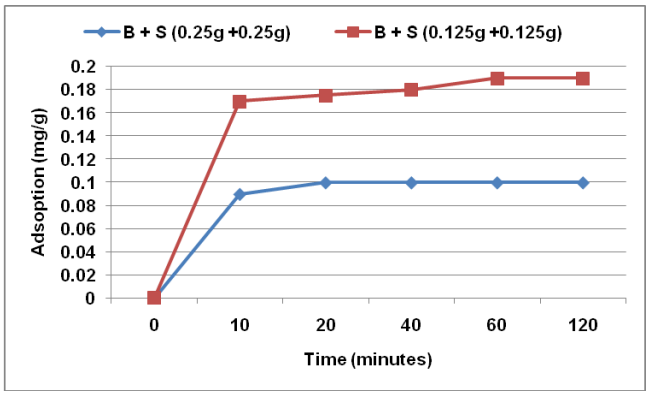

Figure 3. Cadmium ions adsorption ability of banana peels + sponge gourd mixtures

As shown in Fig.3, when compare the adsorption ability of mixtures 0.125 g of adsorbent dosage showed 0.188 mg/g of cadmium ion density and 0.25g of adsorbent dosage showed only 0.102 mg/g of cadmium ion density.

Therefore, the results showed that the mixtures of sponge gourd and banana peels did not showed higher adsorption ability than that of sponge gourd or banana peels alone even at lower doses. Further, it was found that the changes of cadmium ion density values were very similar among 1g of banana peels and 0.25g +0.25g mixture, and the same relationship was shown among 0.5g banana peel powder and 0.125g+0.125g mixture.

CONCLUSION

Dried banana peel powder showed higher Cd^{+2} adsorption ability from water than dried sponges of sponge gourd. However, when increasing the dose of the adsorbents a colour was developed in the solution and reduced the ion adsorption ability. The study demonstrated potential use of dried banana peels and dried sponges of sponge gourd as effective bio-adsorbents to adsorp Cd++ ions from water.

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