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Adsorption Of Heavy Metals From Aqueous Solutions Using Fibres Of *Ceiba Pentandra* (L.)

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ABSTRACT:

Ceiba pentandra (L.) Gaertn (Kapok) fiber belongs to a group of natural fibres that are mainly composed of cellulose, lignin and pectin. These fibres are light weight with hollow tubular structure and is resistant to water. Kapok fiber is comparatively weak and is also flammable. Such characteristics of Kapok fiber have limited its industrial applications, simply being used for filler material. Bio-adsorption of heavy metals by Kapok fibers has been valued as potential alternative to the existing physiochemical technologies for detoxification of heavy metals. Heavy metal pollution has become one of the most serious environmental problems. In this context the property of Kapok fiber as bio adsorbent for removal of copper and lead metal ions is investigated. Adsorption of the heavy metal is studied using colorimetric method. Also, pre-treatment method for changing the nature of fiber from hydrophobic to hydrophilic is used. Maximum adsorption of ions was observed with increase in soaking time. These results indicated that *Ceiba pentandra* fibers could be used as low-cost adsorbent for the removal of copper and lead metal ions from aqueous solutions.

Key words: adsorption, heavy metals

INTRODUCTION:

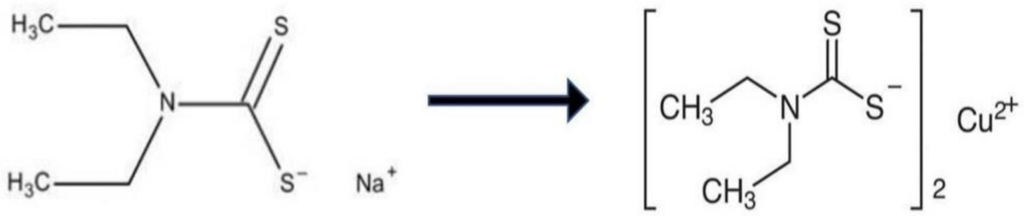
The massive expansion in the usage of heavy metals in industrialization over the past few decades has unavoidably led to a significant problem on a worldwide scale. A significant problem with water pollution is heavy metal contamination. As a result of result of industrial activities and technological development, increasing release of heavy metal to the environment has been continuously posing a significant threat to the environment, public and soil health (Cerbasi and Yetis; 2001). In contrast to organic contaminants, the majority of which are susceptible to biological degradation, heavy metal ions do not break down into safe by products and they remain in the environment for very long period. Aqueous waste from a variety of businesses, including those that manufacture alloys, mine, produce paper and pulp, use chloro-alkali, manufacture radiators, make storage batteries, plate metal, tan leather, and smelt metal, invariably has heavy metal contamination. (Hegazi, 2013; Rao, Rao, Seshaiah, Choudary and Wang, 2008; Kadirvelu, Thamaraiselvi and Namasivayam, 2001). The pulp and paper industry and the metal plating industry both produce copper (Cu), which is regarded as an inorganic pollution. (Valesky and Holan 1995). Additionally, it can be found in fertilisers, pesticides and fungicides. For many enzymatic processes Copper is an essential trace element (Xie *et al*. 2017). Limit of copper Cu (II) heavy metal ions in drinking water according to World Health Organization (WHO) is 2 mg/L (ppm) and for lead Pb is 0.01 mg/L (WHO, Guidelines for Drinking-Water Quality.). High levels of Cu and Pb can, however, be hazardous and result in a number of diseases, including hypertension, gastrointestinal irritation, tardive dyskinesia, autism, hepatic and renal failure, allergies, anaemia, increase risk of miscarriage (Jarup, L. 2003) (Pleiffer and Mailloux, 1987). As lead is a potential neurotoxic agent, exposer to lead can harm the brain and, it can also harm various soft tissues and organs. Exposure to Lead can be fatal as production of blood may be obstructed. (United States Environmental Protection Agency). Water quality is not the only thing affected by heavy metal poisoning; crops, such as wheat, and aquatic products like fish are also affected. There are many various strategies for removing heavy metals, and phytoremediation is one of them. It is a method of bioremediation that deals with pollutants by using a variety of plant species. A variety of materials have been used by researchers modified activated carbons made from biomaterials like oil palm shells, sugarcane bagasse, and cellulose (Gurgel, Jnior, Gil, and Gil, 2008), rice husk (Aliyah, 2012), coir pith carbon (Kadirvelu and Namasivayam, 2000), peanut shells (Liu, Sun, and Li, 2010), olive pulp, and banana peel to extract lead (Pb) and copper. In present study, we used *Ceiba pentandra* fibres to adsorb copper and lead heavy metal ions. *Ceiba pentandra* i.e. Kapok is a natural fibre who possesses porosity volume of 90% or more along with massive hollow structure (Hori, Flavier, Kuga, Lam, Iiyama, 2000). It is a natural and fibre that contains mainly cellulose, hemicellulose, lignin, along with pectin and wax. Additionally, it had excellent oil adsorption capacity, good water repellence, it has an excellent hydrophobic-oleophilic characteristics and really helpful quality for oil absorption mechanism that is well reusable (Mohd Ali, 2014). Therefore, much research on the problem of oil spills, the use of kapok as an adsorbent has been focused.

In the present study, for adsorption of copper and lead heavy metal ions Kapok fibers have been used. The Project purpose was to investigate the possibility of using *Ceiba pentandra* fibres for phytoremediation by adsorbing the heavy metal ions present in aqueous solutions.

METHOD:

Estimation of copper by carbamate reagent method

For the determination of copper, colorimetric method with carbamate was adopted. In an alkaline medium copper displaces sodium in the sodium diethyl dithio carbamate to produce a colloidal yellow brown copper diethyl dithio carbamate. Addition of citrate removes the interference of other metal ions. (Noll, C. A., & Betz, L. D.1952)



Sodium diethyldithiocarbamate   Copper diethyldithiocarbamate

Estimation of lead by Sodium sulphide method

In an alkaline medium lead react with sulphide to form a brown precipitate of lead sulphide. This remains as a fine suspension. The intensity of this colour measured on a colorimeter at 440 nm is proportionate to the amount of lead present in the sample.

$$Pb\,(CH_3COO)_2 + 2\,NaOH \longrightarrow Pb\,(ONa)_2 + 2\,CH_3COOH$$

Lead acetate

$$Na_2S + H_2O + Pb\,(ONa)_2 \longrightarrow PbS + 4\,NaOH$$

Sodium sulphide   Lead sulphide

Collection of *Ceiba pentandra* pods for fibres

For the present investigation plants of *Ceiba pentandra* (L.) Gaertn. (Kapok) belonging to family Malvaceae were selected. Pods of same were collected for its fibres from TPS Lane 3, CGS Colony, Pant Nagar, Ghatkopar East, Mumbai, Maharashtra 400086. The collected plant material was authenticated by Blatter Herbarium on 23rd June 2022. Pods were broken and seeds were hand picked manually and the fibers were separated.

Figure 1: Image showing distribution of *Ceiba pentandra* trees from aerial view

Figure 2: Collected pods of *Ceiba pentandra*

Figure 3: A break open pod.

Figure 4: Seeds and fibres separate.

Treatment of fibers to transform hydrophobic fibres into hydrophilic fibres

Ceiba pentandra fibres consist of cellulose, lignin and xylan (Fengel and Przyklenk, 1986; Gao et al., 2012) and its surface is smooth with a thick layer of wax (Mwaikambo and Bisanda, 1999; Chung et al., 2008).

Fibers are added in a beaker along with water. The fibres float on water as they are hydrophobic. Add some weight from above to submerge the fibres fully in water. It is kept in microwave and water is boiled for 2 minutes. Due to this, the hydrophobic property of fibre is converted to Hydrophilic.

For adsorption experiments the initially air-dried kapok fibres were later oven-dried at 100℃ for 2 days to remove the moisture content and stored in plastic containers.

REAGENTS:

I) For Copper

Copper sulphate ($CuSO_4$) was used as a source of copper. The amount of copper was detected by carbamate reagent using colorimeter.

Standard stock copper solution (0.1 mg/ml) was prepared by dissolving 251 mg of $CuSO_4$ in some water and raise the volume to 1 lit with distilled water.

Standard working copper solution (5 µg/ml) was prepared by diluting 5 ml of the stock solution to 100 ml using distilled water.

15% sodium citrate solution was prepared by dissolving 15 gm in 100 ml of distilled water. Liquor ammonia was also used.

In 100 ml of distilled water, 100 mg of carbamate was dissolved to make Carbamate reagent (0.1% - aqueous)

For Lead

Lead acetate was used as a source of lead. The amount of lead was detected by colorimeter using sodium sulphide.

Standard stock lead solution (10 mg/ml): Dissolve 13.5 g of lead acetate in some water (add acetic acid drop wise to dissolve) and raise the volume to 1 lit with distilled water.

Standard working lead solution (0.1 mg/ml): In 1ml of stock solution to 99 ml of distilled water was added.

1% NaOH solution: 1g of NaOH dissolved in 100ml distilled water.

10% sodium sulphide solution: 10 g of Na_2S dissolved in 100ml distilled water.

INSTRUMENTATION:

Solutions were constantly agitated using an Orbital shaker –NEOLAB CAT NO. 05-261 ARTM (Rotatory shaker). The absorbance was recorded with EQUIPTRONICS – Digital colorimeter EQ 650A. Oven was used to dry the fibres and electronic weighing machine – EUREKA E-Series MODEL EWT 223 was used to weigh fibres.

Other requirements include test tube, test tube stand, pipettes, micropipette, beakers, conical flask, etc.

PROCEDURE:

I) For Copper

The reaction was processed at the room temperature (37^0 C). Series of dilution of standard working copper solution were prepared like 0 ml std. working copper solution and 5 ml distilled water, 0.5 ml working solution and 4.5 ml distilled water, 1 ml working solution and 4 ml distilled water, ……., 5 ml std. working copper solution and 0 ml distilled water.

To each tube 1 ml of sodium citrate, 0.2 ml of liquor ammonia and 0.5 ml carbamate reagent were added. The tubes were shaken by hand for 60 seconds after addition of these reagents and later the tubes were kept standing for 10-15 min.

The optical density was read on a colorimeter at 440 nm. This gives us the standard graph of ΔO.D against concentration of copper and the standard value was obtained to be 1ΔO.D = 76.38 µg of Cu/ml. Considering these values the experiment was set up to see the effective use of Kapok fibres for removal of copper.

0.5 g of Kapok fiber were soaked in 100 ml of standard working copper solution. Optical density of the solution was measured at different time intervals by taking 5 ml of working copper solution and adding 1 ml of sodium citrate, 0.2 ml of liquor ammonia and 0.5 ml carbamate reagent. The content were shaken by hand and kept the tubes standing for 10-15 min. The optical density was read at 440 nm. The variation of time and optical density was considered in the experiment.

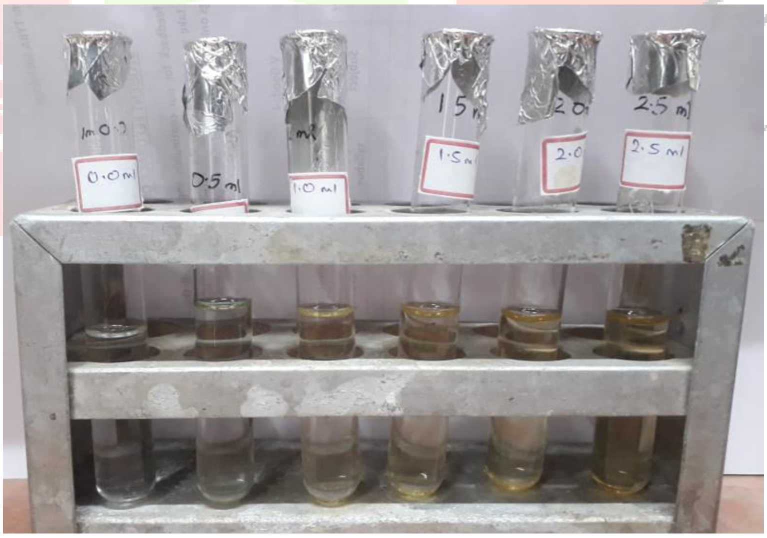


Figure 5: Standardisation for copper detection

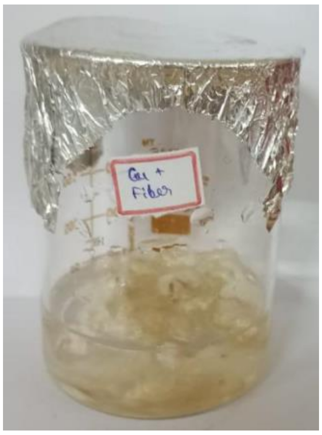


Figure 6: Fibres of *Ceiba pentandra* soaked in working copper solution

II) For Lead

The reaction was processed at the room temperature (37^0 C). Series of dilution of standard working lead solution were prepared like 0 ml std. working lead solution and 5 ml distilled water, 0.5 ml working solution and 4.5 ml distilled water, 1 ml working solution and 4 ml distilled water, …….., 5 ml std. working lead solution and 0 ml distilled water.

To each tube 2 ml of NaOH solution, 0.5 ml of Na_2S solution. The contents of tubes were mixed and kept standing for 10 min.

The optical density was read on a colorimeter at 440 nm. This gives us the standard graph of ΔO.D against concentration of lead and the standard value was obtained to be 1ΔO.D = 1.8 mg of Pb/ ml

Considering these values the experiment was set up to see the effective use of Kapok fibres for removal of lead.

0.5 g of Kapok fiber were soaked in 100 ml of standard working lead solution. Optical density of the solution was measured at different time intervals by taking 5 ml of working lead solution and adding 2 ml of NaOH solution and 0.5 ml of Na_2S solution. The content was mixed and kept standing for 10 min. The optical density was read at 440 nm. The variation of time and optical density was considered in the experiment.

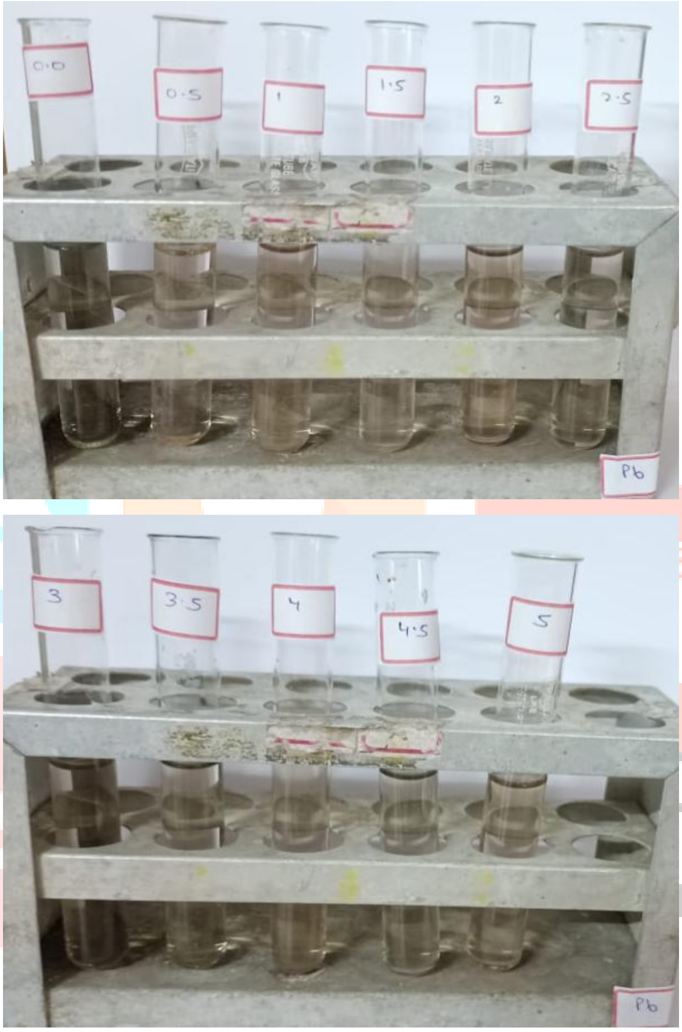
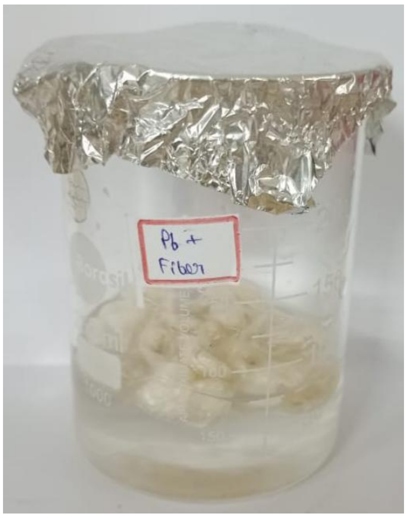


Figure 7: Standardisation for lead detection



RESULT :

The adsorption of copper and lead ions was observed to be increase with time as there was reduction in the readings of optical density.

The adsorption of Cu per hour is 1.14 µg of Cu/ml and the adsorption of Pb per hour is 0.078 mg of Pb/ml

This shows that with increase in soaking time there is maximum adsorption of ions, indicating that the Kapok fibres have efficiency to adsorb heavy metal ions.

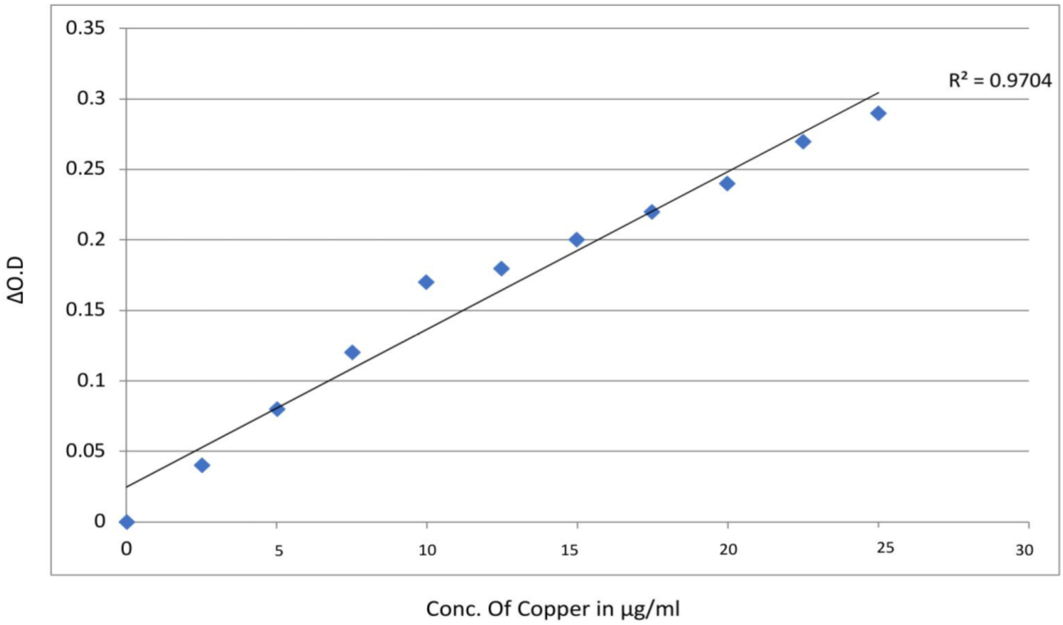


Figure 9: Standard value of copper

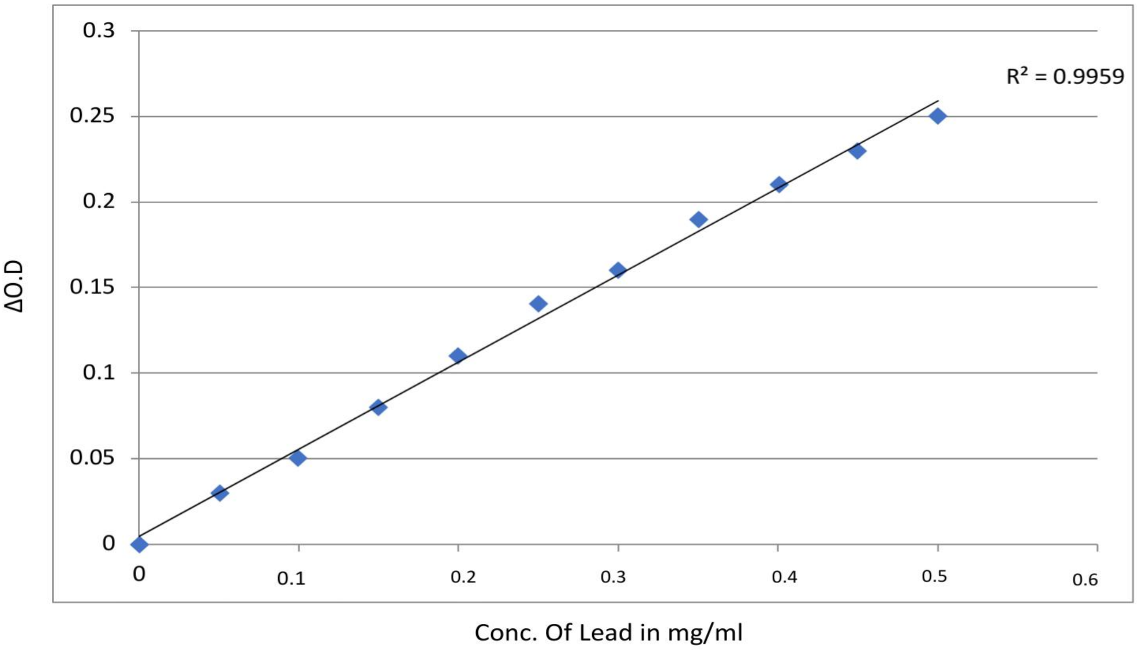


Figure 11: Standard value of lead

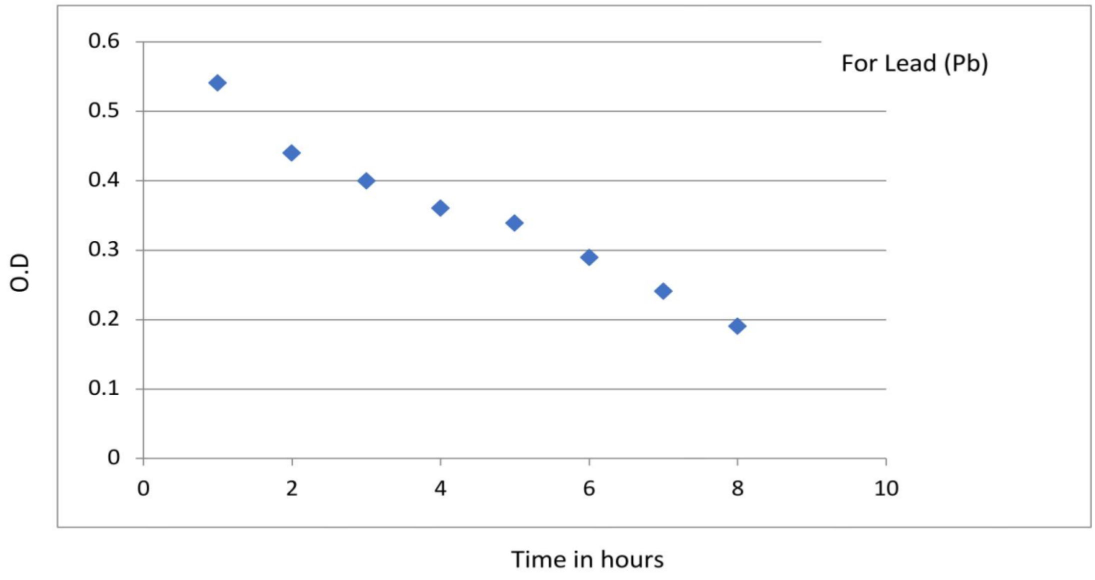


Figure 12: Graph Showing adsorption of lead at varying time

DISCUSSION:

This study is significant as it addresses the serious problem of heavy metal contaminant. It can be inferred from the progressive adsorption of copper and lead (heavy metal) by fibres of *Ceiba pentandra* that it is extremely capable of adsorbing heavy metal if exposed for the optimum period of time and with enough number of fibres. It could be concluded, on the basis of the findings of the study, that kapok is a potent adsorbent for the treatment of wastewater in removal of heavy metals. In future various techniques could be investigated to change hydrophobic fibres into hydrophilic fibres. Similarly, to ascertain the efficacy of Kapok fibres in adsorbing various kinds of heavy metals could be investigated. Different ways could be found to recover adsorbed heavy metal, reuse the metal, and utilise the fibres again.

This study significantly shows that Kapok fibres could be used as a crucial plant material for remediation of copper and lead heavy metal ions. The wastewater containing copper and lead that can be hazardous to the microbiota in the water drainage system can be cleaned up using this environmentally friendly approach. Significant contribution to serious environmental and human health due to changes in heavy metal concentration above acceptable levels, whether due to natural or anthropogenic factors are possible. Soil and water samples evaluation is crucial because it has the potential to endanger the environment and human health. Fibers can be used to extract heavy metal from the effluents of industrial waste. They are eco-friendly, biocompatible, biodegradable and can be used as cost-effective sorbent for heavy metal ion removal. If the best technique could be developed and applied in industry, to meet the demands large-scale agriculture would be in demand that would increase employment for people.

Kapok fibres are environmentally beneficial adsorbent for heavy metals and this work examined the efficiency of fibers in removal of copper and lead ions from the aqueous environmental. This work can be seen as a preliminary investigation, for the purpose of determining if *Ceiba pentandra* fibres are an effective and acceptable material for the adsorption of heavy metal ions like copper and lead from aqueous solution.

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