
Removal of Lead from Industrial Water Using Natural Adsorbents

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Abstract

Due to their acute toxicity and accumulation in food chains, water contamination by heavy metals such as lead, arsenic, mercury, aluminum, zinc, chromium, and iron is a significant environmental problem. Lead is one of these highly toxic heavy metals that can occur naturally or be manufactured in industries such as storage batteries, radiators, and joint solder. As a result, this research examined the feasibility of using low-cost adsorbents to remove lead from contaminated water. Thus, our study aims to investigate the ability of natural bio sorbents for removing very toxic Pb^{2+} ions from an aqueous solution. Contact time, concentration, adsorbent-based dosage, and pH are evaluated as important factors in the adsorption mechanism. The adsorption efficiency discovered was pH reliant, rising as the pH of the solution to some ranges of 2.5 - 6.5. After 120 minutes, stability is attained, and the optimum removal rate was obtained with a 1.5-gram adsorbent loaded weight.

Keywords: Adsorbents, Biosorbents, Lead, Removal, Water.

Introduction

Lead is an element, that belongs to group IV in the periodic table. Mostly it is corrosion resistant to most acids and occurs as an insoluble and biologically innocuous element submerged in the earth's crust. Lead is also found naturally in soils and the atmosphere. In inhabited areas, the primary source of soil in lead is due to the contamination through weathering, chipping, scraping, sanding, and sandblasting of structures painted with lead-based paint. The primary lead sources present in atmospheric air are ores, metals treating methods, and aviation fuels [1,2]. Other sources include waste incinerators and manufacturers of lead-acid batteries. Lead concentrations in the air are typically highest near lead smelters.

Lead hazards can be found in homes, such as painted toys, lead pipes, or pipes connected with lead solder, which can contaminate the water supply. The maximum permissible limit lead in our freshwater is about 0.01 mg/l. When the percentage of lead in domestic water increases, the World Health Organization (WHO) recognized this as a significant risk factor that may cause different dangerous diseases such as anemia, kidney malfunction, and brain tissue damage [3]. Lead and other toxic metals like zinc, cadmium, chromium, silver, copper, nickel, and arsenic could be filtered off from wastewater with the help of conventional methods like chemical precipitation, membrane filtration, reverse osmosis, electrocoagulation, chelation, and ion exchange [4]. However, the above-mentioned techniques are frequently inefficient as well as prohibitively costly for lower metal contents. As a result, solutions for metal removal from aqueous technology have been sought recently. Adsorption is one of these technologies. Adsorption is preferred due to its efficacy in removing impurities from dilute solutions. Zeolites, activated carbon, silica gel, and chitosan are the most frequently used adsorbents for heavy metal removal from aqueous solutions. While commercially available adsorbents are still widely used, these materials are quite expensive. Recently, biosorption of impurities using natural sorbents has increased significant reliability because of their high capacity and cheap price [5]. Since the uptake capacity is high and the cost-effectiveness of raw constituents, biosorption is an advanced technique. The potential advantages of the use of low-cost adsorbents are:

1. Easily available
2. Cheap cost
3. Better adsorption ability
4. Simple chemical adaptation
5. Simple renewal
6. Easy disposal

Sources and Environmental Levels

Lead is considered as one of the utmost easily available dense metals, with higher toxicity contributing to atmospheric pollution due to their persistence in affected areas and the complication of the biological toxicity effects. The following article discusses the consequence of lead on different environmental components such as the atmosphere, topsoil, and water. The environmental cycling of lead species is shown in Figure 1.

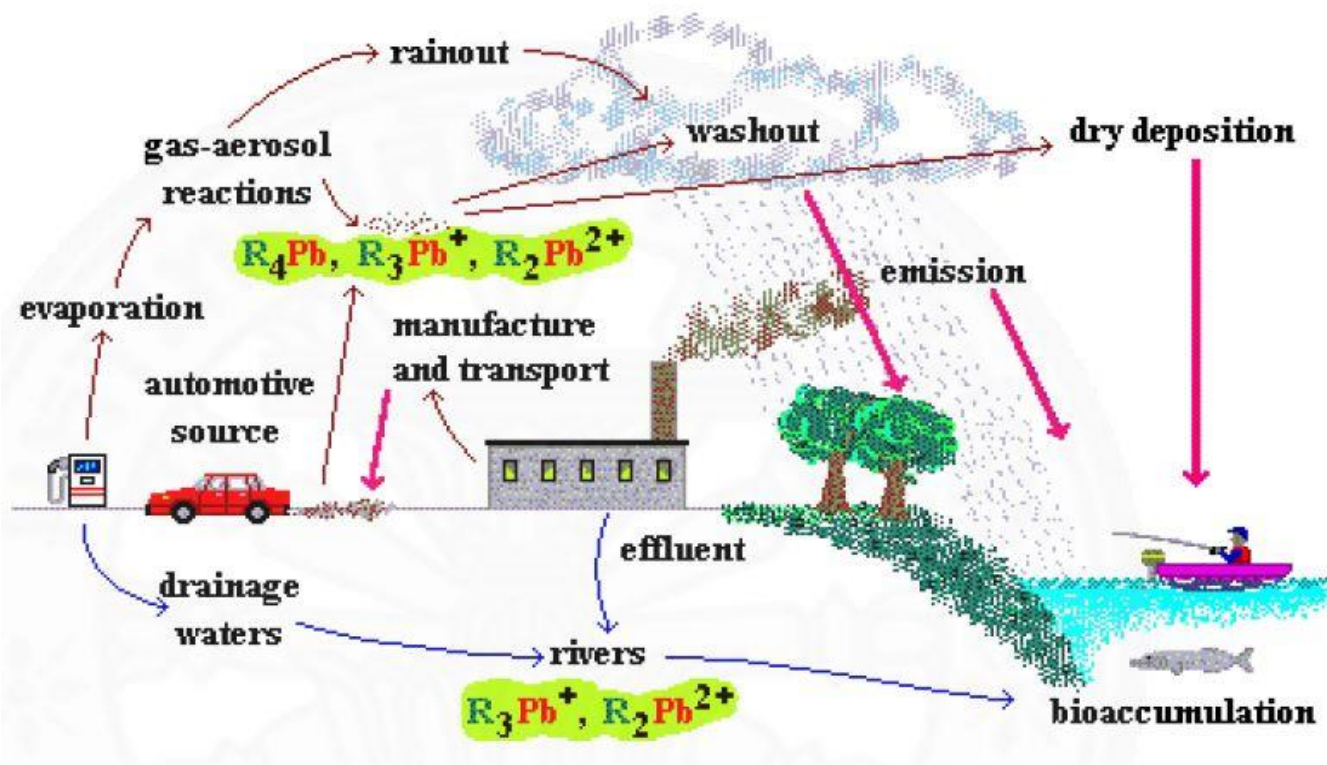


Figure 1. Environmental cycling of lead species

a) Lead in atmosphere

Lead is one of the most dangerous heavy metals found in the environment. It is retained in the atmosphere as particulate matter and is transported to a large extent via airflow [3]. Lead is one of the most dangerous metals. Approximately 98 percent of lead in the atmosphere is a result of human activity. Lead is found in both outside and inside air. The majority of the lead content outside is from industrial bases (such as manufacturers of lead-acid batteries, waste incinerators, smelters, and utilities). Naturally, occurring lead can be found in wind-blown soil and road dust, as of industrial wastes/sources such as depreciated paint, burning of gasoline with lead, and flight fuels. Lead can be found both inside and outside breathing air, for example, when stained glass objects are made with the help of lead solder or when gunfire using lead bullets in shooting choices. Lead in dust and soil can persist for several years due to its inability to degrade or decompose [4].

b) Presence of Lead in earth's soil layer

Lead is frequently found on the top layers of clay and biological elements in the soil. As a result, when the lead is combined with soil at the surface, which accumulated on the top layers of soil at 1 - 2 inches. Lead is supremely present in extremely small soil units, which are capable of adhering to human skin layers and wear, forming dust of soil particles. Lead availability in layers of soil is determined by the solidity with which is carried out by soil dust and its soluble nature. It is a lesser amount of tightening and highly soluble when the pH is low (acidic nature). It is further strong carried by soils with a high pH (neutral to basic conditions), and soluble nature is extremely lower. Lead particles are strongly bound to the organic matter present in the soil. As a result, when the quantity of organic matter raises, lead obtainability declines. Lead particles in the soil will react along with other metals in the soil to form minerals like lead phosphate ($Pb_5(PO_4)_3Cl$) or pyromorphite. These minerals form a high pH soil, which contains a higher concentration of lead and phosphate. These situations occur with the excessive application of limestone and phosphate fertilizers in soil [5].

c) Presence of Lead in earth's water sources.

Lead is extensively used in solder and plumbing constituents that come in interaction with drinking water on their way from their source to homes [6]. The presence of Lead elements in drinking water is due to its dissolution from primary causes. Leaching of polyvinyl chloride (PVC) pipes resulted in elevated lead levels in domestic water. The lead content in water is calculated from indicators like dissolved oxygen (DO) and chloride, the temperature, pH, water suppleness, and the water's standing time. While leaching of lead pipes forms lead particles, this study demonstrates that leaching on soldered linkages and brass taps declines over time. Lead levels in domestic water can be decreased through anti-corrosion techniques like lime adsorption and pH regulation to less than 7 – 8 or 9. Since water is not belonging to plumbosolvent, lead carbonate flaking on the lead pipes and iron deposits from galvanized pipes can release and accumulate lead from lead sources such as plumbing and service connections [7]. Contamination of ground and surface waters can occur naturally when stormwater (which is normally slightly acidic) comes into contact with lead-contaminated soil. When the water becomes dissolved in the lead, it can be conveyed to adjacent ground/surface water. If enough lead is mobilized, it may affect environmental receptors besides causing harm to the health of mankind.

Additionally, contamination of groundwater with lead may occur as a result of lead dissolving from the earth's crust, where it is typically found in the form of a carbonate and hydroxide complex with varying degrees of solubility. Contamination of ground and surface waters can occur naturally while rainstorm water (which is generally a little acidic) approaches into connection with lead polluted soil. When the water becomes melted in the lead, it can be conveyed to neighboring ground/surface water. If enough lead gets mobilized, it may affect environmental receptors besides cause harm to humans. Additionally, contamination of groundwater with lead may occur as a result of lead dissolving from the earth's crust, where it is typically found in the form of carbonate and hydroxide complexes with varying degrees of solubility [8].

d) Presence of Lead in food

Lead can contaminate food in a variety of ways. The most common method in the development and growth of plants with an abnormally higher percentage of lead content. The plant may become polluted because of soil, dust, or mature plants may absorb lead from the soil. Lead-containing containers can also leach lead into foods – for example, any paint decorations or improperly burned ceramic coat. Lead may also be present in meat when cattle graze on green grasses and small plants due to sump oil, paint chips, discarded paint cans, lead-acid batteries, scrap lead, etc. used in farms and are not properly removed [9,10].

Health Impacts of Lead

Lead can enter the human body in two ways: through inhalation or consumption. For instance, lead may reach the human body via food or inhalation of paint in the form of dust. The soil surrounding the house may contain lead from exterior painting. Additionally, lead can enter drinking water via plumbing. Adults and children are both sensitive to lead's effects [11,13]. Children under the age of five years are particularly vulnerable, as their bodies, brains, and metabolisms are still developing. Two-year-olds are more likely to have the highest blood lead concentrations, as they can put a variety of objects in their mouths, including toys and other products containing lead.

a. Lead exposures and problems in children

Lead contact causes some negative health issues on children's growth and development. When lead concentrations in blood are less than 10 g/dL causes some behavioral problems, hindered puberty, hearing problems, reasoning function, and perinatal progress or elevation. Some adverse

health issues are observed even at blood-lead concentrations lower than 5 g/dL, comprising decreased IQ grooves, reduced academic accomplishment, and growths in behavioral difficulties and care-allied behaviors. There are a large number of behavioral effects allied with lead and the most dangerous issue is deficit hyperactivity disorder (ADHD). Lead has a more dangerous effect on children from low-income families [12].

a. Lead exposures and problems in adults

Adult contact to lead causes a variety of health problems. As the lead content increases, the greater the risk of developing health problems. Over 15 g/dL blood lead levels are associated with impaired kidney function, cardiovascular problems, neurological issues, infertility, late conception, and contrary problems in sperm as well as semen, like decreased sperm amounts and mobility [14]. Lead content in the bloodless than 10 g/dL is related to impaired kidney working, increased bp, hypertension, and tremor. Additionally, results showed that when adults are exposed to lead at a range below 5 g/dL may affect impaired kidney working. Pregnant women, in particular, should exercise caution around the lead. Lead levels in pregnant women less than 5 g/dL are related to decreased fetal development. The study discovered that chronic lead contact will affect developments in cataracts, a blurring of the lens in the eyes that results in restricted vision failure in older adults [15]. Ironworkers, welders, miners, construction workers, firing range operators, smelters, those involved in the production and dumping of car lead-acid batteries, metal shop work, vehicle radiator restoration, and those involved in the production of earthenware or stained glass are mainly at danger due to lead exposure [16].

Agricultural wastes based lead adsorbents

Biosorption is a naturally occurring physiochemical process in some biomass that enables it to passively concentrate and bind contaminants to its cellular structure. Biosorption occurs as a result of a variety of metabolism-independent processes that vary according to the type of biomass. Biosorbents are composed of chemically active groups [17,19]. Biosorbents and adsorbents derived from agricultural wastes have gained attention in recent years as an alternative to conventional methods for removing heavy metals from water and wastewater. Adsorption capacities of different plants and agricultural residue wastes as adsorbents for lead are shown in Table 1.

Name of adsorbents	pH	Dosages	Contact time	Pb ²⁺ Removal %	Ref
Rice husk and Maize cobs	2.5-6.5	1.5g	120min	98.5	1
Sour sop seeds	5	1.0g	10 min	40.6	2
Spent tea leaf	Neutral	2.0g	8 hrs	55.2	4
Papaya seeds	5	10-1000 mg/l	90 min	90	5
Palm Kernal Shell Charcoal (PKSC)	-	80.0 g/l	50 min	89	7
Coconut leaf powder	7	2.0 g	30-180 min	90	12
Tea waste	5-6	1.25-7.5g/l	15-20 min	96	13
Raw banana stalk	4-8	0.1-1.0mg/l	180 min	63.97	15
Coffee grounds	Neutral	0.5 mg/l	1 hr	87.2	20
Banana stalk	8	0.90 g	152 min	96.41	2
Agro waste	6	15.0g/l	60 min	89.960	23

Table1. Adsorption capacities of different plants and agricultural residue wastes as adsorbents for lead.

In the present study, *Moringa oleifera* (MO) leaves and coconut fibers were used to study the biological way of absorption of lead(II) from the solution. A consequence of various constraints like measure, pH quantity, exposure time, excitement speed, and initialed-removal concentration are planned. The MO plant has received much attention within the scientific community due to its impressive medicinal properties and environmental applications. Coconut coir is an ideal carbon precursor, a lower-cost abundantly available farming waste in Kanya Kumari, India. Coconut coir is considered as one of the important biomass scum that was parted from coconut and it was rich in hemicellulose, lignin, and pectin. The activating methods utilized determine the physical and chemical features of activated carbon. The production of activated carbon is usually done in one of two ways. Physical and chemical stimulation boost adsorption capacity

through mixing mineral and metal adsorbents with certain polymers, acid alteration as well as grafting using different functional groups [18].

Activated carbon is preferred over physical activation because it allows for the development of a more porous structure [20]. Moreover, the activation compounds could be easily recycled and reused. Carbon activation with phosphoric acid was commonly employed on large scales [21,22] and Phosphoric acid boosts yield by altering the pyrolysis process disintegration of lignocellulosic materials along with depolymerization, dryness, and distribution of components. Because of advancements in the acid recovery period, phosphoric acid has grown increasingly popular in recent years [23,24]. As previously said, finding lower-cost material to make activated carbon is naturally a major undertaking.



Figure 2. Raw moringa leaves and coconut fiber

The aim of the current research was designed to eliminate Pb^{2+} ions from an aqueous solution through the biosorption process by employing biological materials like moringa leaves and coconut fibers, as shown in figure 2. Moringa leaves are a natural material with a high adsorption capacity for eliminating heavy metals from wastewaters. The use of moringa leaves and coconut fibers as adsorbents for removing heavy metals is discussed in this article. These are low-cost amino acid-containing materials. The amino acid is a key component of functional groups that assist in heavy metal elimination via metal ion exchanges or complexation that was influenced primarily via pH, bio sorbent dosage, and contact duration.

2. Materials and Methods

Preparation of Precursors

The groundwater samples containing Pb were collected from the river Cauvery, Karur District, Tamilnadu. The heavy metals of Cu, Cd, Fe, and Pb were higher in the river water samples. The pH of the solution is found to be 5.4. The concentration of metals in river samples is shown in Table 2. The chemicals employed in the study contain, HCl, H₃PO₄, KOH, and NaOH were of analytical grade and attained from Sigma-Aldrich (Australia) and utilized without further refinement. The pH of the water specimens was adjusted by employing either 0.1 M HCl or 0.1 M of NaOH. The MO leaves, and coconut fibers were collected from Kanyakumari District, Tamil Nadu, India, as it is readily available in villages.

Table 2. The concentration of heavy metals in the water sample

Metal	Initial m/L
Pb	1.718
Cu	1.64
Cd	1.306
Fe	1.054

Processing of Activated Carbon (ACC)

The leaves of MO were washed with deionized water for 5 min to remove any suspended materials on their surface and desiccated in an oven at 70°C for 72 h. The dried samples were ground using a domestic blender and separated over a 200 µm stainless steel sieve. The bio sorbent samples were stored in glass bottles for further studies.

Coconut coir was chopped into small pieces and cleaned in hot distilled water before being oven-roasted for 12 hours at 110 degrees Celsius. The coconut coir was then filtrated with a 1 mm screen after it had been washed. Some sieved coir of 25.0 g of was cooked for a few hours after being handled with 500 ml of 50 percent phosphoric acid. The phosphoric active ACC was then oven-baked till reaches 100°C and maintained for 48 hours before being pyrolyzed at 450°C till remains 1 hour. Allowing the specimen to approach room temperature, it must have been thoroughly cleaned with distilled water before being treated with lower concentration KOH to eliminate any residual phosphoric acid, when the water's PH reached 6.0 to 7.0 levels. The ACC

baked at 90°C for 4 hours. The bio sorbent samples were stored in glass bottles for further studies.

Press cake preparation

The activated moringa leaves and coconut coir were pressed mechanically and examined in water therapy. The residual chemicals were extracted from the press cake by soaking it in water overnight, as well as the clean pressing cake was employed in this research. To achieve the proper mass for the bio sorbent applied to water, the water content was determined.

Batch Adsorption Study

For 4 minutes, the stirring rate was set to 200 rpm, then 40 rpm for 30 minutes. All therapies were carried out in triplicate, and after each optimization, the solutions were left to settle for 60 minutes before being filtered with filter papers. Lastly, the residual heavy metals concentration was examined by employing Thermo Fisher Scientific iCE 3500 AAS Atomic Absorption Spectrometer and shown in table 3.

Table 3. The concentration of heavy metals in the sample after inserting press cake

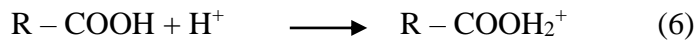
Metal	Initial m/L	Final m/L	Removal %
Pb	1.718	0	100%
Cu	1.64	0.29	82.31%
Cd	1.306	0.035	98%
Fe	1.054	0.019	98%

Results and Discussions

Influence of pH on the elimination of Pb²⁺

Figure 2 exemplifies the variation in the elimination efficacy of Pb²⁺ versus the final pH of solutions comprising moringa leaves and coconut coir. An amount of metal removal by moringa leaves and coconut coir was significantly exaggerated by changing the pH of a solution. At a lower pH ranging from 2–3.5, adsorption of Pb²⁺ utilizing moringa leaves and coconut coir was relatively lesser ranging from 12–45 percent. At greater pH (3.5 to 6), the % of Pb²⁺ elimination enlarged remarkably nearby 100%. This relation among the pH and the quantity of Pb²⁺ uptake through moringa leaves and coconut coir can be accredited to the circumstance that at lower pH values, the surface functional assemblies, essentially carboxylic acid functional assemblies of the bio sorbent, get protonated through H⁺ ions, results in a net +ve charge on the exterior of the bio

sorbent, as explicated by Equation (6); thus this makes a repulsive force among Pb^{2+} cations and the positively charged exterior of the biosorbent, impeding the biosorption method. Moreover, the rise in the H^+ ions generates competition among them and the metal ions over the energetic sorption spots on the exterior of the biosorbents.



The surface functional subunits, on the other side, are stimulated as the pH rises. The carboxylic acid group deprotonates and disintegrates into carboxylate anions ($\text{R}-\text{COO}^-$) at greater pH values than happens in the pH levels of 3.5–5.5, which corresponds to the acid dissociation constant (pKa) of carboxylic acids. The negative charges interface of a rice straw inevitably causes an electrostatic attraction seen between positive ions of Pb^{2+} and the negative charges interface of the bio sorbents, facilitating the biosorption. Furthermore, as the pH of the solution rises, the concentration of H^+ ions drops, reducing competition among H^+ ions and Pb^{2+} for binding sites. Furthermore, the pH of a solution disturbs the solubility of metal ions; hence, when the pH rises, the solubility of metal ions falls, making the sorption process easier. The rise in percent elimination at $\text{pH} > 6$ is mostly owing to precipitation, as seen in Figure 3 since insoluble metal species of Pb^{2+} develop at $\text{pH} > 6$. 100% Pb^{2+} removal is obtained by activated moringa leaves adsorbent. Activated coconut fiber shows Pb^{2+} removal above 98%.

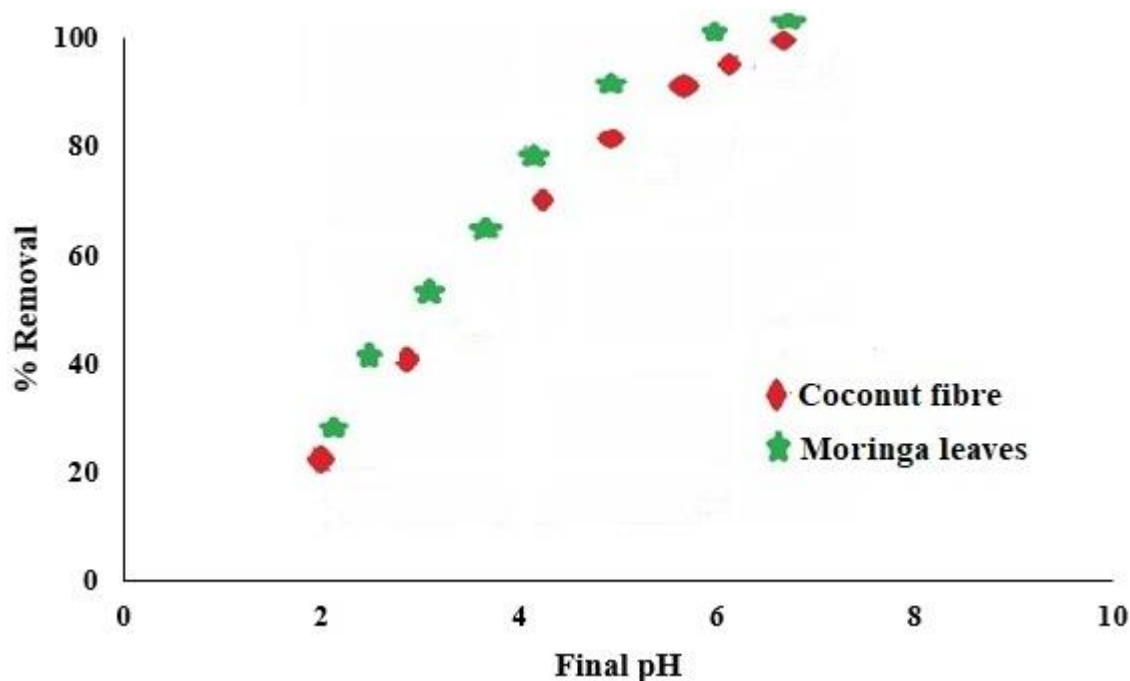


Figure 3. End pH of the solution versus the % elimination of Pb^{2+} by moringa and coconut fiber

Effect of concentration on the elimination of Pb^{2+}

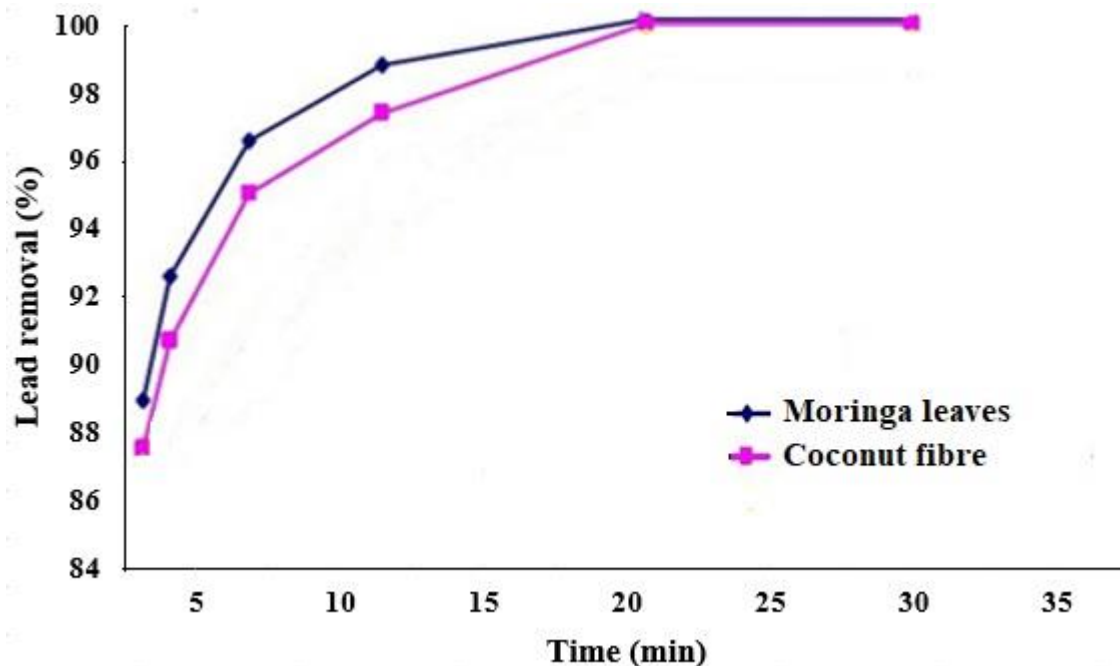


Figure 4. The percentage removal of Pb^{2+} by moringa and coconut fiber

The proportion of lead removed is greatly influenced by the original levels of lead. The instantaneous relationship among the lead concentration as well as the accessible binding affinity on an adsorbent surface determines the influence of the first Pb^{2+} concentration factor. The % of lead removed generally reduces as the initial lead concentration rises, which might be owing to the saturated adsorption sites on the adsorbent, or because the adsorption rate improved as the original lead level. There are unfilled active spots on the surface of the adsorbent at lower concentrations, and then when the initial dye concentration rises, the adsorption sites needed for Pb^{2+} adsorption would be unavailable. The rate of removal of Pb^{2+} by moringa leaves and coconut fiber is shown in figure 4.

Impact of contact period on the elimination of Pb^{2+}

As shown in Figure 5, the contract period was changed from 15 to 120 minutes to see how it affected lead elimination. Initially, when contact duration improved, lead extraction efficiency improved as well. This could be because the metal-binding period on the active surface of an adsorbent rises. The extreme lead elimination efficacy was identified as 100.0% at 90 min for moringa leaves and 98.2% at 90 min for coconut fiber respectively.

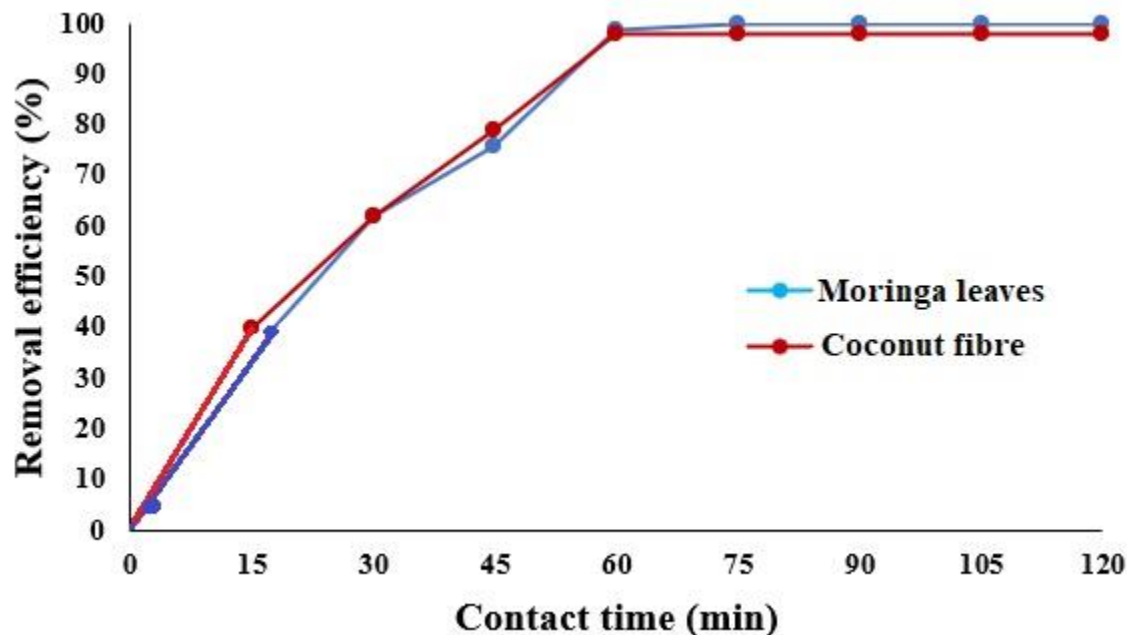


Figure. 5 Impact of contact period on the lead elimination

Impact of adsorbent dosage on the elimination of Pb^{2+}

The adsorbent dosage was changed from 5 to 40 g/L to see how effective it was at removing lead. Figure 6 shows that at 25 g/L, percentage removal varied from 37.0–100.0 percent for moringa leaves and 41.0–98.0 percent for coconut fiber. Owing to the accessibility of more binding sites over onto the surface area of the adsorbent materials, the rate of lead extraction improved when the adsorbent dosage adjusted from 5 to 15 g/L, making metal (lead) penetrating simpler to the adsorbent surface. The removal efficiency was reduced as the adsorbent dosage was enhanced to 25 g/L, as well as the rate of elimination remained nearly constant up to 40 g/L. Leading to a shortage of surface area and overlapping active surface area, the rates of lead elimination slow at increasing adsorbent doses. The optimal dosage was 25 g/L having lead removal efficacy 100% and 98.2% for moringa leaves and coconut respectively; indicating moringa leaves are improved adsorbent amongst the two verified adsorbents.

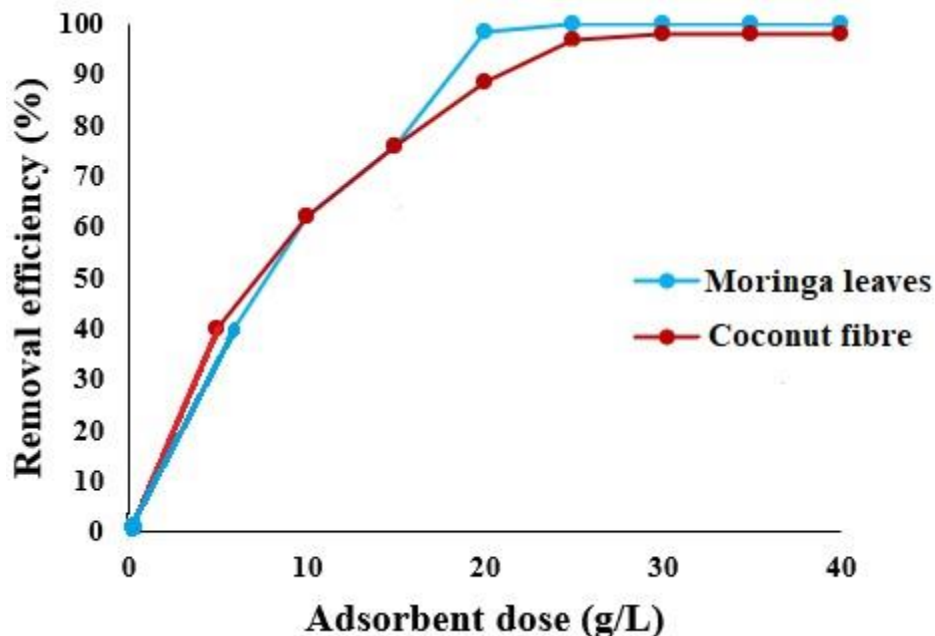


Figure 6. Impact of adsorbent dose on the lead elimination

Conclusion

The purpose of this paper is to describe how we eliminated lead ions with the help of activated moringa leaves and coconut fiber from an aqueous solution. His work mainly focuses to improve and utilize microporous triggered adsorbent materials capable of effectively removing lead ions from the aqueous stage. The results indicate that these adsorbents are an attractive low-cost alternative for removing lead ions. This novel green material derived from these plants has been considered as an active, cost-effective, and environmentally friendly adsorbent that helps in the elimination of lead ions from aqueous solution and also can be further applied for the elimination of further heavy metal ions. This research gives an ideal stage to change moringa leaves and coconut fiber which is highly abundant in Kanya Kumari, Tamil Nadu, into activated carbon that can be commercialized for the elimination of Pb^{2+} impurities from the aqueous stage. As per the research, it was determined that the manufactured activated carbons are possible candidate use for eliminating Pb^{2+} in sewage water to avert ecological impurity and related health hazards.

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