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A Review on Factors Affecting the Adsorption of Heavy Metal Using Different Biosorbents

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ABSTRACT

Agricultural, industrial, and household debris can be employed as biosorbents to extract heavy metals from water that has been contaminated. Kitchen waste includes, among other things, peels from promotional gates, lemons, avocados, apples, kiwis, watermelons, and onions. Moreover, coffee and tea grounds are considered to be household refuse. This review illustrates the scholarly investigations that explored the potential of various waste materials as adsorbents for wastewater treatment. An extensive array of experiments was conducted to determine the variables that influence the capacity of these materials to adsorb heavy metals. To undertake the experiments above, different concentrations of biosorbent were introduced into the effluent at various contact times and pH levels. The researchers investigated the effects of varying these parameters and found that the biosorbent's ability to adsorb heavy metals is directly proportional to these factors. The results and conclusion indicated that the impact of biosorbent concentration and contact duration on the pH of contaminated water was assessed. To encourage the incorporation of industrial, agricultural, and household refuse into water treatment processes rather than permitting it to accumulate as an environmental hazard.

1. Introduction

Heavy metal water contamination is hazardous because heavy metals build up in the human body and damage several organs, including the kidney, central nervous system, liver, bones, lungs, brain, and placenta [1]. Furthermore, a host of health issues, including hepatic, immunological, reproductive, and developmental damage, are brought on by heavy metal exposure in humans. [2] Both carcinogenic and noncarcinogenic effects [3] Water polluted by heavy metals and its contaminants: Worldwide heavy metal (HM) pollution of waterways is caused by the mining, lead acid batteries, industrial coolant, smelting, electroplating, ceramics, fluorescent lamps, bangle industry, fuel combustion, paint sludge, incineration, salts manufacturing, spent catalyst, leather tanning, and hospital waste sectors. [4].

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The mining, pharmaceutical, medical, and heavy metal processing sectors are rivers' primary sources of heavy metal pollution.Heavy metals have accumulated in aquatic habitats due to the growth of industrial development, and living things have been able to detect them there. Since then, these metals have made their way up the food chain, severely impairing the central nervous and reproductive systems. Furthermore, human health is at risk due to excessive levels of heavy metals in the body [5, 6]. HMs are a serious problem since they are not biodegradable and may accumulate in organisms, leading to illnesses and other negative consequences. [7] Heterogeneous photocatalysts and bioremediation are used to remove heavy metals from wastewater. Among the procedures that have been used are adsorption on activated carbons and ion-exchange resins, precipitation, electrodialysis, solvent extraction, phytoextraction, ultrafiltration, and coagulation/flocculation [8,9,10,11,12]. Heavy metals may be eliminated using chemical and physical methods [13, 14]. Physical separation procedures include hydrodynamic classification, mechanical screening, flotation, gravity concentration, electrostatic separation, attrition scouring, and magnetic separation.[15]Convective chemical techniques such as electrochemical treatments, membrane filtration, ion exchange, chemical precipitation, coagulation and flocculation, and electrodialysis may remove heavy metals from wastewater.[16]Alternatives that are less expensive and better for the environment must be used since these techniques are costly and harmful.Biosorption is an additional method.Ions are moved from the solution phase to the solid phase via sorption. Biosorption is made up of adsorption and precipitation processes. Adsorbents from natural sources, modified biopolymers, industrial waste, and agricultural residue are all used for heavy metal adsorption [17, 18]. Adsorption has been the subject of several investigations using adsorbents sourced from various materials, such as red soil and coal [19]. [20] The following are examples of industrial by-products: hydrous titanium oxide [28,29], waste iron and iron slags [30], fly ash [31], biomass [24], photocatalytic beads [23], nanoparticles [22], biomass [21], and industrial waste from fertilizer [25]. Moreover, organic materials like rice straw, coconut shells, rice husks, hazelnut shells, jackfruit, pecan shells, maize kernels, or husks may be used to create adsorbents. These adsorbents may be made into activated carbon by heating them, improving heavy metal adsorption [32, 33].

Conventional heavy metal removal is costly and produces hazardous chemical sludge [34, 35]. As such, it is essential to use low-cost and widely accessible methods. This is where biosorption enters the picture. It uses living or non-living microbes that can adsorb heavy metals from aqueous solutions [36], including plant and animal remnants [37, 38] and agricultural waste. For instance, adsorbents made of cellulose lignin material show excellent removal efficiency for various heavy metals [39].

The purpose of this study is to compile the findings from earlier research that used various low-cost materials as heavy metal absorbents from wastewater and to conclude these findings regarding the different factors influencing the adsorption process' ability to develop the absorption process.

2. Supplies and methods

2.1 Materials or Biosorbents.

Many writers have used various biosorbent materials from industrial, agricultural, animal, plant, and food waste to remove heavy metals from polluted water. Tables 1 and 2 provide the materials stated before.

Table 1. Agricultural, industrial, animal, and plant wastes are used as biosorbents.

Adsorbent	Heavy Metal Removed	Conclusions	Reference
snail shell powder	Cadmium (II) and Iron (II)	The optimum physical condition was investigated, such as contact time, agitation speed, shell powder dosage, and pH. The maximum adsorption for Cadmium (II) and Iron (II) was 588 %,5599.9%, respectively, Langmuir and Freundlich isotherm models used to fit adsorption isotherm.	, *Open*
winemaking waste (cluster stalks)	Pb^{+2}	demonstrated the capability of producing active carbon from cluster stalks, a byproduct of viticulture. Following a pseudo-second-order kinetic model. At equilibrium, the Langmuir isotherm model was fitted.	, [28]
bark, chitosan,xanthate,zeolite,clay,peat moss ,seaweed and dead biomass	cadmium, chromium, lead, and mercury	natural material had a high ability to remove heavy metals	, [40]

tree bark		As a low-cost biosorbent, removal with unmodified tree bark was comparatively effective and thus acceptable.	, , [41]
leaf .stem and root Phytomass of Quercus ilex(holly oak)	chromium ,nickel,copper,cadmium and lead	the root is most effective in the metal adsorption	[42]
Aspergillus Niger, Penicillium chrysogenum ,Rhizopus Nigerians,Ascophyllum nodosum ,Sargassum natans , Chlorella fusca,Oscillatoria anguistissima,Bacillus Firmus and Streptomyces sp	Pb,Zn,Cd ,Cr,Cu and Ni	it is economical method with no chemical sludge	[43]
dead and live anaerobic biomass	Pb(II)Cr(III)Cd(II)	dead anaerobic biomass more effective in removing Pb(II)Cr(III)Cd(II) ions from wastewater than live anaerobic biomass	[44]
Al-Khriet, which is a substance found in the legs of typha Domingensis	lead and cadmium	the highest adsorption capacity for cadmium was 90% and for lead 96%, 6333 ppm of ions concentration and 1g dosage of adsorbent and 5.5pH but these capacities were reduced at the binary mixture at about 12% for cadmium and 8% for lead	[45]
smectite clay particles,cassava waste, sugar bagasse ,dried water hyacinth stems	Cadmium,zink,copper and nickel	smectite clay particle capable of removing cadmium at an adsorption efficiency of 97%. Cassava waste capable of removing zinc 55.9%.sugar baggage to remove copper and nickel 78.2%&87% respectively, and dried water hyacinth stems and leaves 90%	[46]
brake of pine untreated and treated with algae sawdust of pine and absol(sand, lime, cement, and water)	Zn, Cu , Pb ,Ni and Cd	the best adsorbent was absol	[47]
expanded perlite	Cu(II)	The capacity of expanded perlite to absorb Cu(II) from industrial effluent was exceptional.	[48]
denim fiber scraps	(Pb^{2+}, Cd^{2+}, Zn^{2+} and As)	The HM ions the adsorbent capacity of denim fiber fragments surpassed that of synthetic and natural sorbents that are more frequently employed, including activated carbons and zeolites. It was also discovered that denim fiber fragments had sorption capacities more significant than 1.5 mg/g for aqueous solution As (V).	, [49]
Bombax Costatum Calyx	$Fe^{+3}, Pb^{+2}, Zn^{+2}, Cr^{+3}$ and Cd^{+2}	metal ion sorption capacity increased with pH increasing and decreased with ionic strength	[50]
banana trunk	Cu, As, Pb and Zn	investigate the effect of various parameters such as contact time,pH and dosage	[51]
rice husk	heavy metals	They found these low-cost biomass environmental and economical methods to clean the water and recycle the waste .	[52]
oil-free Moringa oleifera cake and sweet potato peel	Cr (VI) ions	The improved surface metal-binding ability of the biosorbent may be ascribed to the alteration of the bio sorbent by	[53]

		separate treatments of its powder with 6N HCl (acid treatment) and 1N NaOH (alkaline treatment).	
dried and ground root hyacinth(Eichhornia Crassipes)	lead ,cadmium ,chromium and copper	this study investigated the effects of the initial concentration of heavy metals and pH of the aqueous solution. The results showed that the removal capacity increased with the increasing of initial concentration. The best removal was achieved with pb and the lowest removal was achieved with cr	[54]
caster seed husk	Cr(II),Cu(II)and Zn(II)	The parameters influenced were studied such as initial metal concentration ,percentage recovery metal ion, concentration of adsorbent ,pH & contact time Langmuir and freundlich adsorption isothermal model was used to analyze experimental results. Pseudo first-order system was used to determine kinetic data as well as thermodynamic parameters, such as ΔH, ΔG and ΔS	[55]
yeast Saccharomyces Cerevisiae	mercury and nickel	the results showed the effects of pH,initial concentration ,contact time and bio-sorbent dosage on the bio-sorption process	, [56]
Maize stalks	Zn(II),Cd(II) and Mn(II)	used to remove from aqueous solution by El-Sayed et al. also the effect of different factors was studied such as pH ,contact time ,ionic strength ,temperature and initial metal concentration .isotherms were analyzed by Langmuir ,freundlich and temkin	[57]
waste tire rubber ash	copper ions	The influence of pH,adsorbent dose , and initial Cu (II)concentration was studied, and found that the adsorption equilibrium was achieved after 2hr at pH 4-6. The optimum removal of copper ions was achieved at 1.5 g/L dose of adsorbent	[58]

Table 2. Kitchen waste used as bio-sorbent

Adsorbent	Heavy Metal Removed	Conclusions	Reference
walnut shell and lemon peel	Pb(II)	The ability of acid and/or base-activated walnut shell and lemon peel to remove Pb(II) from the water also studied the ability of activation to improve the adsorption capacity pseudo-second order kinetic model was used to determine the adsorption rate also found Freundlich, model. Was the best one to find the equilibrium data	[26]
eggshell membrane	Au, Pt, and Pd	The efficacy of eggshell membrane in the removal of heavy metals The concentrations of gold (Au), platinum (Pt), and palladium (Pd) in an aqueous solution are 55, 25, and 22, respectively.	[59]
almond skin, walnut shell, sawdust, rice bran, and eggshell	Cd (II), Cr (II), Ni (II), and Pb (II)	The removal effectiveness of these adsorbents was compared with two conventional materials, activated carbon and an ion exchange resin. The researchers discovered that the most effective removal method was accomplished using discarded eggshells, which exhibited a performance comparable to that of activated carbon.	[60]
banana ,kiwi and tangerine peels	$Cd^{+2}, Zn^{+2} and\ Cr^{+3}$	The experimental findings demonstrated that the peels of kiwi and tangerine exhibited superior efficacy compared to banana peels in the process of heavy metal removal.	[61]

Pomegranate	lead	Pomegranate Used with carbonization and modification with iron ions to remove lead from aqueous solution and found that the optimum conditions contact time of chemical adsorption is 90 min, pH was selected within 6.0-6.5,initial Concentration 6333 ppm and the adsorbent dose 1.0g/100 ml .	[62]
egg shell	Pb and Cu	It was discovered that apart from its use as a biosorbent for heavy metal adsorption, eggshell had the potential to serve as a substitute for conventional sand filter medium. Rather than sand . The use of a mixture comprising of egg shell powder and Chitosan is a viable alternative to using a sand filter, exhibiting notable efficacy in removing Pb (97.8%) and Cu (78.11%).	[63]
Banana (*Musa sapientum*) and potato (*Solanum tuberosum*) peel	Cu	The researcher discovered that potato peel had a higher capacity for copper adsorption compared to banana peel.	[64]
orange and lemon peels	Copper and Lead	They found that these materials are available and less expensive bio sorbent . .the factors that affected the bio sorption also studied .these factors are temperature and pH so they must be optimized .	[65]
pomegranate peel	iron(II)ions	They studied the parameter that effected the adsorption capacity such as contact time ,pH, metal concentration, sorbent weight and temperature.	[66]
orange peels	cobalt (III)	She investigated the effect initial concentration ,pH ,temperature and contact time on the removal of Co (III) and she found that the optimum results ,initial Co (III) (5mg/L) contact time 90min ,pH 2,temperature 30C also she found that the best agent in the process is 0.1 M ammonia chloride.	[67]
pineapple peels, potato peels, tomato peels ,citrus fruits peels, orange peels ,pomegranate peels and banana peels		They found the factors affecting the removal of heavy metal are initial concentration ,sorbent dose ,pH, and temperature .	[68]
banana peels	copper	sorbent dosage and contact time effect on ability of adsorption and the results found was the optimum pH was 6 and the sorbent dose was 622.6762 mg/g.	[69]
pomegranate peels	lead	the effect of experimental parameter studied such as pH, weight of sorbent, contact time, temperature and concentration of metal	[70]
eggshell	Cu(II) and Cd(II)	Temperature, agitation speed, beginning metal concentration, adsorbent dosage, initial solution pH, and contact duration all affect the capacity to adsorb.	[71]
lemon,watermelon,banana ,orange peels		The study examined the factors that affected the adsorption capability, including temperature, contact duration, pH, adsorbent dosage, and beginning metal concentration.	[72]
Tea waste	Cd	The investigation found that starting Cd content, pH, adsorbent dosage, and contact duration all had an impact on removal efficiency. At a pH of 5, 90 minutes of contact time, and 10 g/L of adsorbent, the maximum efficiency of Cd adsorption was 99.6333%. The isotherm data for the Langmuir and Freundlich isotherm models fit the data	[73]

		acceptably, and kinetic analysis revealed that the adsorption kinetics followed a second-degree kinetic adsorption model.	
potato peel	Cu^{2+}, Pb^{2+} $and\ Ni^{2+}$	temperature, contact duration, and pH all affect removal .efficiency	[74]
mango leave	Cu(II) ion	the impact of agitation rate, pH, particle size, contact duration, and chelating agent presence were investigated.	[75]
chicken eggshells, banana peels, and pumpkin	Cu and Pb	This research looked at the impacts of many variables, including pH, agitation speed, and contact duration. It discovered that at pH 7 and 100 rpm, the best removal was accomplished in 90 minutes.	[76]
tea waste	Ni (II) and Cu (II)	They discovered that removal efficiencies were more impacted by pH than by temperature. At 6333 ^oC, the greatest removal efficiencies of Cu(II) (59%) and Ni(II) (43%), were noted.	[77]
pomegranate peels	Zinc ,chromium and nickel	Three parameters were examined that affected the adsorption capacity: pH, contact duration, and temperature.	[78]
Zalacca edulis peel	Cu^{+2}	The rate of adsorption was confirmed by a pseudosecond order system after the initial concentration and pH values were examined.	[79]
banana peel (Musa sapientum)	lead,copper,zinc and nickel metal ions	They discovered that when metal concentration increased, so did metal sorption.	[80]
minced banana peel	copper and lead	They discovered that the adsorption capacity increased beyond pH = 3 and that the kinetic adsorption achieved .equilibrium at 10 minutes	[81]
Eggshells	many different HMs	from aqueous solution, where pH, egg concentrations, and contact duration all impacted removal efficiency. The high concentrations of calcium and carbon and the high porosity and availability of functional groups on the eggshell surface were responsible for the removal's success.	[82]
eggshells	lead	the contact time, initial pH, and eggshell dose affected removal efficiency .	[83]
potato peel	Cu	They discovered that the adsorbent dosage, starting Cu concentration, pH, and contact duration all affected the removal effectiveness. With an adsorbent dosage of 5 g and an initial Cu centration of 10 ppm, an optimal Cu removal efficiency of 75.5% was attained at ambient temperature and .pH 6	[84]
banana peels	zinc, chromium and nickel ions	Three types of bananas were used: powder, dried little chunks, and fresh.The findings showed that although fresh bananas provided the greatest outcomes in terms of eliminating chromium and nickel, powdered bananas eliminated all zinc.Dried peels had the lowest bioremoving capacity. In addition, the environmental effects of pH, temperature, and contact duration were investigated.	[85]
potato peel	As(III), Pb^{2+} and Hg^{2+}	They found that pH was the most important parameter affecting biosorption \ .	[86]
watermelon shell	Cu(II)	the effects of temperature, agitation speed ,dose, , time, concentration, , pHand particle size Was studied . The monolayer adsorption Capacity was 111.1 mg/g. found from the Langmuir adsorption equation. pseudo-second-order kinetics was suggest to find kinetic measurement	[87]
water melon rind	zinc		[88]

		the optimum condition (zinc concenfration, contact time, biosorbent amount, and pH)was determined	
Cucumis sativus peel	pb(II)	varying condition like adsorbent dosage and contact time were studied. maximum metal adsorption was found at 5 pH at initial pb concentration 25 mg/l at 25 C	[89]
waste tea leaves	Pb	the initial metal concentration, amount of adsorbent, temperature, contact time, and pH all affected Pb (II) adsorption, a maximum removal efficiency of 97.9%, .	[90]
pomegranate peel	Cr (VI)ions	the temperature variation was studied and found that the process is endothermic	[91]

2.2 **Experimental Procedure.**

1. To create a powder, the byproducts of the different materials listed in Tables 1 and 2 above were desiccated and ground into a fine powder. This process created the adsorbent.
2. Use polluted water to test an adsorbent's ability to absorb heavy metals.
3. Use the pH of the polluted water to estimate the amount of heavy metals present.
4. Transfer the polluted water into a known volume of the step 1 adsorbent and let it come into contact for a predetermined amount of time.
5. After the adsorbent has had its contact period, ascertain the amount of heavy metal that is still in the polluted water.
6. The percentage of HM elimination was then calculated using the following equation: Percentage of removal = C Was the concentration of HM at first (in mg/L) before adsorption? Ce: After adsorption, the equilibrium concentration of HM in solution (mg/L).

7-To ascertain how adsorbent dosage affects adsorption, repeat steps four through six with different adsorbent concentrations.
To find out how contact time affects adsorption, carry out the previously indicated steps (4) through (6) while adjusting the contact time.
9. Repeat steps 4 through 6 from the previous approach while changing the water's pH to see the impact of the change.

2.3. Further applications of biosorbent

For HM adsorption, a vast array of common waste biosorbents have been utilised. The efficacy of inexpensive adsorbents extends beyond the removal of HMs; they can also be utilised to remove other prevalent pollutants from wastewater, as illustrated in Table 3 below. A biosorbent is employed to absorb pollutants, including heavy metals, from refuse water.

Table 3 Adsorbent used to remove another pollutant from waste water.

Adsorbent	Pollutant removed	Reference
barley husks and eggshells	Levofloxacin is an antibacterial agent that becomes a high environmental risk when contaminating aquatic environments…	[92]
water melon rind	reduce the microbial properties by killing pathogens organism	[93]
eggplant peel	oil	[94]

Additionally, HMs from soil may be absorbed using cheap organic wastes. For example, potato peels and tea trash are successful sorbents for reducing the amount of mercury (Hg) in soil. More specifically, both waste sorbents decreased the Phaseolus vulgaris plant's absorption of heavy metals when it was planted in greenhouse conditions on polluted soil [95]. Previous studies have shown that heavy metals (HMs) are eliminated in two stages. HMs first attach themselves to the biosorbent's active surface sites. Then, by intraparticle diffusion, metal ions progressively permeate the adsorbent's pores [96]. This process is probably heavily influenced by the physiochemical characteristics of the heavy metal to be adsorbed and the biosorbent. Additionally, HMs from soil may be absorbed using cheap organic wastes. For example, applying potato peels and tea residue to a soil sample to reduce mercury (Hg) toxicity worked well.

Table 4. Removal of heavy Metal Vs contact time

	Ref [98]	Ref[99]	Ref [100]
Contact Time(min)	Removal of Lead % adsorbent biochar from corn cobs waste	Removal of Lead % By using commercial activated carbon	Removal of Lead % By using green synthesized silica
0	0		
10	23.4		29.72
20	41.6		42.7
30	60.2	27.6	56.06
40			68.17
45	64.8		
50			65.06
60	66.6	33.2	
75	67.8		
90	68.4	47.5	
120	68.8	51.4	
150		55.8	
180		56.2	

The impact of parameters on the biosorbent's ability to bind heavy metals. A few of the several variables that influence the adsorption of heavy metals via biosorption include the pH of the water, the amount of time the biosorbent is in contact with the heavy metals, and the dosage of the biosorbent. According to earlier research, contact time has the following effects on HM adsorption: Prior studies [7], [48], [74], [76], [82], [83], and [97] showed that heavy metal adsorption increased with contact time until equilibrium was reached. This allows the metal ions sufficient time to interact with all of the adsorption sites on the biosorbent, as seen in Fig. 1 and Table 4 [96]. As a result, all accessible sites were occupied, preventing further adsorption.

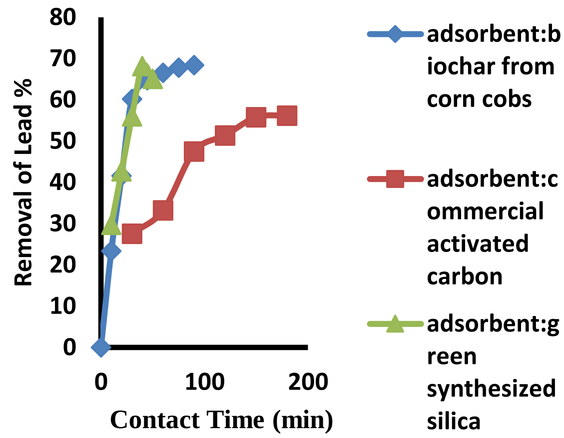

Fig 1 . Contact time vs. heavy metal removal using different adsorbents. Ref [98], [99], [100].

- Effect of solution pH on HM adsorption.

Metal speciation, which affects the interaction between the metal ion and the active functional sites on the adsorbent, is another way to control an adsorbent's effectiveness [101]. Phosphorus may affect adsorption in the same manner as [H+] rises at lower pH and can, therefore, compete with HM cations for the active sites of the biosorbent, leading to reduced removal of HMs (i.e., higher HM release) under too acidic circumstances [102]. Similar increases in HM adsorption with pH changes have been reported in other studies [7], [55]; [74], [76], [82], [83], [77], [73], [103]..This conclusion is shown in Table 5 and Fig 2

Table 5. Removal of heavy metal vs. pH of wasted water

pH	**Ref [98]**	**Ref[99]**	**Ref [100]**
	Removal of Lead % adsorbent biochar from corn cobs waste	Removal of Lead % By using commercial activated carbon	Removal of Lead % By using green synthesized silica
1			40
2		20.8	46
2.5	17		
3			51
3.5	22		
4		25.6	57
4.5	44		
5		32.8	63
5.5	64		
6		30.2	68
6.5	72		

7	24.8	62
8	21.9	57

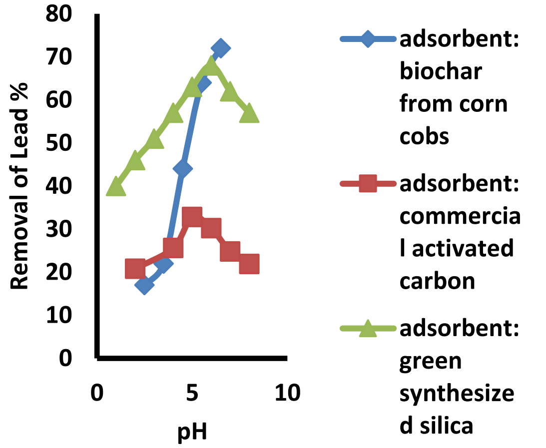

Fig 2. pH of the water vs. heavy metal removal using different adsorbents. Ref [98], [99], [100].

- **The effect of biosorbent dose on HM adsorption.**

The observed enhancement in HM removal as the dose of the biosorbent increased, shown in Table 6 and Fig 3, can be ascribed to the augmented surface area of the adsorbent and the increased accessibility of more active binding sites. This result was consistent with numerous prior investigations [48], [53], [55], [82], [83], [84] [104] and was not unexpected.

Table .6 Removal of heavy metal vs dosage of biosorbent.

Dosage g/l	**Ref[99] commercial activated carbon**	**Ref [105] Almond Shells**	**Ref[98] adsorbent biochar from corn cobs**
0.25			15
0.5			26
1	15.3	555	676.8
1.5			5599
2		80.4	72
3		85	555
4		89.3	
5	18.6	91.5	
10	28.5		
15	40.2		

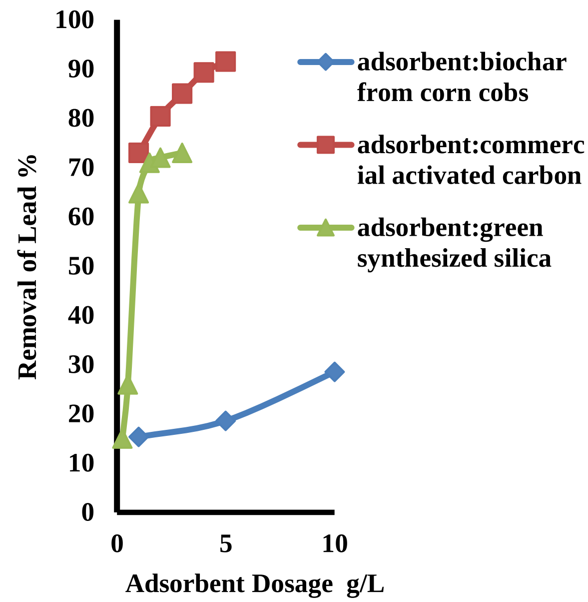

Fig3. Adsorbent dosage vs. removal of heavy metal by using different adsorbents. Ref [98], [99], [105].

3-Langmuir and Freundlich models

The amount of metal adsorbed onto the biosorbent (q_e) was then calculated using equation 2 [106]

$$q_e = \frac{c_i - c_e}{W} V \quad ....(2)$$

Where C_i: was the initial concentration of HM before adsorption (mg/L),
C_e: is the equilibruim concentration of HM in solution after adsorption (mg/L), V was the volume of the solution (L) and W was the weight of biosorbent added (g).The adsorption data where then fitted to the Langmuir or Freundlich isotherm model s

Adsorption Isotherm

A-Langmuir isotherm

According to the Langmuir equation, there is homogenous adsorption, meaning that each molecule on the surface has an identical sorption activation energy. Equation 3 [107], [108] represents the Langmuir isotherm in its linear version.

$$\frac{1}{q_e} = \frac{1}{q_m k_l C_e} + \frac{1}{q_m} .... (3)$$

Where Ce (mg/L) is the concentration of heavy metals in solution at equilibrium, KL (L/g) is the Langmuir equilibrium constant, qe (mg/g) is the quantity of adsorbate per unit weight of adsorbent, and qm (mg/g) is the maximum capacity of adsorbed onto the adsorbent as a monolayer.

B-Freundlich isotherm

The Freundlich adsorption isotherm assumes adsorption to a heterogeneous surface where the linear form of this isotherm is expressed as Freundlich [109]:

$$\log q_e = log k_f + \frac{1}{n}\log C_e$$

Where K_F (L/g) is the Freundlich constant, n (g/L) is the Freundlich exponent. In the studies [26], [28], [55], [64], [73][77], . Adsorption rate expressed mathematically by Langmuir and Freundlich models.

Conclusion

The two primary benefits of using household, agricultural, and industrial waste to purify polluted water are waste reduction and the ability to purify heavy metal-laden water that is not economically viable for human consumption. The buildup of waste causes human organ damage and deadly illnesses. It was discovered that the water's pH, the amount of biosorbent used, and the length of contact all impacted the adsorption process. An assessment of the researchers' findings concerning these variables has been carried out. It was shown that the ability of residues to adsorb increases with these factors. Kitchen trash is used to examine these variables to remove heavy metals from wastewater. In addition to household garbage, heavy metals have also been absorbed from industrial and agricultural waste. This overview illustrates most research papers using organic waste for heavy metal adsorption from effluent.

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