Removal of Heavy Metals from Waste Water by using Various Adsorbents- A Review

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Abstract

Objectives: To explore maximum adsorption efficiency towards Removal of commonly occurring Heavy metals from waste water by using various Adsorbents. **Methods/Statistical Analysis:** In this review paper, we have compiled scattered available research work related to use of various adsorbents for the removal of commonly occurring heavy metals present in effluent and have calculated adsorption efficiency of all the adsorbents used by different researchers just to find out the best and most efficient adsorbent for the removal of particular metal. **Findings:** It has been found that maximum adsorption efficiency for the Zinc metal is obtained by using Cassava waste (55.9% removed), Cadmium by using Smectite Clay particle (97%), Lead by using Dried water Hyacinth stems and leaves (90%), Copper and Nickel by using Sugar Baggase (94.2% & 87%) respectively. **Application/Improvements:** This paper would be helpful for anybody to find the best and the most efficient adsorbent for the removal of a particular heavy metal present in the effluent.

Keywords: Adsorption, Agricultural Waste, Biosorption, Industrial Waste, Natural Materials

1. Introduction

Heavy metals refer to the metallic elements with high atomic weight and high density. Rapidly developed industries like fertilizer industry, metal processing, pulp-paper industry, mining activities, rubber-plastic industry, batteries etc discharge their heavy metals contaminated water into nearby water bodies. Heavy metals are highly toxic and are carcinogenic even at low concentration and are not biodegradable.[1] They cause serious threat to the human life and to aquatic, vegetation cover.[2] These heavy metals get absorbed and accumulated in human body, causing serious health diseases such as cancer, damaging of nervous system, organ damage and even death. It also retards growth and development of living organisms.

Pb, Zn, Ni, Cr, Cd, Hg and many other heavy metals are generally found in industrial waste water effluents.[3] They all are known to cause many health issues and environmental problems. Lead is a highly toxic metal causing environment degradation and many health issues. On exposure, it may cause damaging of kidney, damaging of brain in new born babies.[4] The excess intake of lead leads to loss of appetite. Other heavy metal Zinc

is popular supplement but overdosing this supplement is extremely dangerous and this should be avoided. Widely consumption of zinc may cause paralysis and neurological problems.[5] A person may also feels state of depression. Some of the other unwanted effects include dizziness, breathing problems, chest pain and many others. Nickel is other carcinogenic toxic metal known as environment pollutant. It is one of the shiny metal so is commonly used in jewellery. People who are sensitive to nickel experience skin rashes when it touches the surface. If a person inhales nickel he may at higher risk for lung cancer.[6] Additionally, it can also leads to nausea, coughing, infertility, nervous system defects and many more. Chromium is other heavy toxic metal, presences of which beyond a limit disturb many biological functions of plants. Along with this it causes several health issues in humans too such as nausea, headache, vomiting, diarrhoea.[7] Other most commonly used heavy metal is Cadmium but, if it once gets absorbed, it would accumulate inside the body throughout the life period. It is also very carcinogenic and often leads to failure of kidney.[8] One of the shiny silver liquid known as Mercury is also very toxic that causes serious health hazards. It can cause asthma and

temporary respiratory problems. Intake of mercury also contributes to rheumatoid arthritis, along with causing disorders related to kidney and circulatory processes.[5]

The harmful effects from various heavy metals have been described in the Table 1.

Table 1. The harmful health effects with the intake of heavy metals

Heavy metal	Health effect	Reference
Lead	Kidney damage, brain damaging in fetals, appetite loss	4
Zinc	State of depression, increased thrist,complete or partial paralysis,neurological problem symptoms	5
Nickel	Nausea,coughing, carcinogenic, dermatitis, chronic asthma	6
Chromium	Headache, nausea, vomiting, diarrhoea	7
Cadmium	Kidney failure, carcinogenic, renal disorders	8
Mercury	Rheumatoid arthritis, kidney problems, disorders related to circulatory and nervous system	5

Hence, there is dire need to treat heavy metal contaminated water before discharging it into environment. In this paper, removal of toxic heavy metals performance by using different adsorbents like natural materials (fruit peels, egg shells, clay, peat moss, serbian clay etc), agricultural waste materials (sugarcane baggase, onion skin, biochor, wheat bran, rice straw), industrial waste materials (lignin, saw dust, tea waste, flyash, sludge etc), biosorbents (algae, fungi, bacteria) have been discussed briefly.

2. Adsorption

Heavy metal removal can be efficiently achieved by many conventional methods like chemical precipitation, chemical oxidation, reverse osmosis, ion-exchange, electrodialysis etc.[9] All these methods are associated with discharge of toxic byproducts and are expensive. So, Adsorption emerges out to be better alternative in removal of heavy metals because of its low operating cost.[10,11] This treatment process is favourable even at low concentration of heavy metals in waste water stream.

Adsorption is phenomenon that occurs when gas/liquid solute gets accumulated on the liquid or solid surface (adsorbent) forming adsorbate film because of physical and chemical interactions.[9] Adsorption is found to be one of the effective methods for removal of toxic heavy metals from industrial waste effluents. This method appears to be more suitable because of its some of the following advantages.[12,13]

1. Process is of low operating cost.
2. It is metal selective process.
3. It is associated with high metal removal capacity.
4. There is no generation of toxic sludge in this treatment.

Numerous cost effective adsorbents obtained from natural and anthropogenic sources have been tried out for waste water treatment loaded with toxic heavy metals. The adsorbents used are mostly natural modified adsorbents, agricultural waste materials, industrial by products waste and many micro-organism species.

2.1 Adsorption on Agricultural Waste

Agricultural residues can be used as adsorbent material in removal of heavy metals as they are less costly, require little processing, easily available and possess good adsorption capacity.[14]

2.1.1 Rice Straw

Rice straw has been used to carry out adsorption process in order to remove heavy toxic metals.[14] Rice straw is one of the agricultural waste material used as low cost adsorbent material. It is basically left residue in agricultural land during harvesting time which is burnt leading to emission of black choking smoke that affects visibility and even causes breathing problems. Rice straw consists of cellulose (32-47%), hemicelloluse (19-27%), lignin (24%).[15]

Rice straw serves as potential adsorbing material possessing efficient binding sites that are capable to remove toxic metals from waste effluents.[16] It has been reported that Treated Rice straw was better adsorbing material. It was noticed that Rice Husk on treating with NaOH shows 2.954% adsorption capacity for the removal of Cd ions whereas; Rice Husk on treating with $NaHCO_3$ shows 1.618% adsorption capacity for Cd metal.[17]

2.1.2 Onion

In order to remove Pb, Cd, Cu from waste water, Onion waste skin has also been tried out as an economically

efficient method. Functional groups like –S=O, -OH, C-H str, -COOH, C=O, -NH were characterized from FT IR study, these functional groups were found responsible for binding those metal cations.[18] Lower adsorption capacity was notified with modified onion waste as compared to unmodified form (ethylene diamine modified) of onion waste because of removal of S=O, C=O functional groups that tends to decrease binding capacity during modification.

For modified onion as adsorbent, highest adsorption capacity was noticed for Cu $^{+2}$(79.36 mg/g), Pb $^{+2}$(71.85 mg/g), Cd $^{+2}$(68.03 mg/g), whereas, adsorption capacity with unmodified onion sorbent was observed 90.8 mg/g for Cu $^{+2}$, 87.49 mg/g for Pb $^{+2}$, 96.99 mg/g for Cd $^{+2}$ at initial metal ion concentration ranging from 20-200 mg/L.[19] This indicates that the material which was initially of no use with disposal problem has potential of heavy metal removal.

2.1.3 Sugarcane Baggase

Sugarcane baggase is a waste product obtained from sugar refining industry, that have been tested as adsorbent material for heavy metal removal. This consists of cellulose, lignin and pentosan. The negative charge of baggase makes it capable to absorb the positively charged heavy metal ions. It has been reported from the literature that sugarcane baggase was found to be efficient adsorbent for the removal of Cu & Ni heavy metals with greater adsorption efficiency about 87% - 95% other waste material of sugar beet industry functioning as adsorbent material but shows only 1.72% adsorption in the case of Cd removal.[20,21]

2.1.4 Biochar

Agricultural residues are converted to form biochar that has been used as a low cost heavy metal adsorbent. It is basically pyrogenic black carbon from thermal degradation of carbon rich biomass in an environment which is an oxygen limited technology. It has gained attention because of its multi-functionality including carbon- sequestration and enhancement of fertility of soil bio-energy production.[22,23] Large surface area and pore volume provides greater affinity for the metals to get sorbed on the surface of char.[24]

Due to large surface area, highly pore volume and no. of functional groups (like hydroxyl, carboxylate) made

them low cost adsorbents in heavy metal removal.[25-27] According to the literature study for waste water treatment, the biochar application was found to about 45%.

2.1.5 Wheat Bran

Wheat bran has been found good adsorbent for removal of heavy metal ions like Pb, Cu, Cd. It has been reported that wheat bran on treating with strong dehydrating agent like H_2SO_4 shows 5% adsorption efficiency for Cu ions, in 51.5 mg/g in 30 min at pH value 5, whereas, it was found 12% for Ni ions.[28,29]

2.2 Adsorption on Industrial Waste Materials

Different industrial waste materials have been tried out to carry out adsorption process for removal of heavy metals. These are quite easily available as a byproduct of many industries. Various industrial adsorbents such as flyash, blast furnance sludge, slurry waste material, lignin, coffee pulp sugarbeet pulp material, waste material of tea factories have been investigated for the removal of heavy metals.[30-32]

2.2.1 Lignin

Lignin is one of the natural occurring components that constitute wood and lignified elements of plants. It is cheaply available as a by-product from paper-pulp industry. Lignin is complex polymer with no. of functional groups like ketones, phenols that serves as adsorption sites for binding heavy metals. Hence, researchers revealed that lignin is one of most favourable adsorbent for removal of toxic heavy metal cations as well as anionic species. It has been reported from the study that about 8.902% lead removal was made with lignin. The contact time for the reaction was taken 5 min, at pH = 5.[33]

2.2.2 Flyash

Flyash is one of the residues produced in coal combustion that composed of fine particles that are driven out with flue gases. It is major air pollutant and water pollutant that disturb ecological balance and causes environmental hazards.[34] It is potentially used for the water treatment process due to its chemical composition like silica, alumina, ferric oxide, calcium oxide, magnesium oxide, carbon. Moreover, its alkalinity nature makes it good

neutralizing agent.[35] Therefore, it has been tried out by many researchers for heavy metals removal from waste water effluents. Slightly modified sludge and flyash are found to carry good adsorption property for heavy metal removal. It has been reported that Flyash one of the industrial waste serves as better adsorbent for the removal of Cu with 70% adsorption efficiency and for the removal of Ni it was 68% adsorption efficiency.[36]

2.2.3 Sludge

For removal of toxic heavy metals sewage sludge has been tried out. The different types of materials were derived from sewage sludge and were used as adsorbents. Their removal efficiency varied with pH, dosage of adsorbent, initial ion concentration and with time. The sewage derived adsorbents were found more effective for removal of Cd^{+2}.[37] In case of removal of methylene blue, sewage derived adsorbent were tried out, alternate to activated carbon because of its low cost.[38] The sludge derived adsorbent of agro-processing industry were found more suited in removal of Cr whereas, for removal of Cd^{+2}, Cu^{+2}, Pb^{+2}, Ni^{+2} adsorbents derived from municipal sewage were found more effective.[39] The municipal sewage adsorbents coated with FeO were found to be better adsorbent than uncoated sludge adsorbent. This is because FeO coated sludge possess high surface area, more pore volume and high iron content.

2.2.4 Tea Waste as a Sorbent

Tea is second most used beverage in the world after water so, tea waste has gained much attention because it is good sorbent material in heavy metal removal such as Fe, Cr, Pb and Ni. The cell wall material of tea consists of cellulose, lignin, carbohydrates that have hydroxyl, oxyl and phenolic groups and could be a good bio sorbent material for heavy metals.[40] Waste of Tea industry was found to be efficient for the removal of Ni metal ion It shows 7.1% adsorption for the removal of Cu metal. Least adsorption was notified for the removal of Cd i.e. nearly about 1.129% adsorption.

2.2.5 Saw Dust

Sawdust is by-product obtained from wood industry. It contains many organic compounds like cellulose, lignin and hemicelluloses along with polyphenolic groups that bind heavy metal.

Treated sawdust was tested as adsorbent material for the removal of Cu^{+2} and Zn^{+2} metal ions.[41]

Saw dust of Fir and Poplar woods (treated with NaOH) show maximum adsorption capacity as compared with untreated sawdust. On treating with NaOH, sawdust of Fir and Poplar woods show maximum uptake of Cu^{+2}, Zn^{+2} metalions.[42]

2.3 Adsorption on Natural Materials
2.3.1 Clay

Clay is easily available, cheap adsorbent used for removing toxic heavy metals.[43] Clay and its minerals offers a alternate to other conventional methods. The negatively charged silicate particles on clay are capable to attract and hold heavy metal cations.

Clay material has been widely used in adsorption of heavy metals like Fe^{+2}, Ni^{+2}, Zn^{+2} ions from waste effluents.[43] The Figure 1 shows the adsorption phenomena by clay particle.
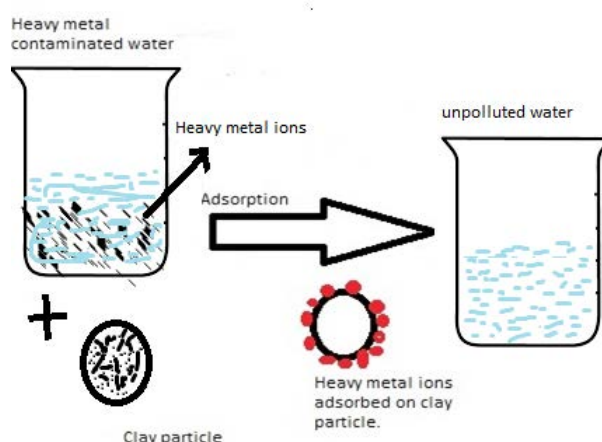

Figure 1. adsorption phenomena by Clay particle.

High removal efficiency was achieved for Fe^{+2} metal ions, then for Zn^{+2} and Ni^{+2} ions with clay as adsorbent. Removal efficiency increases with concentration of adsorbent. No doubt, high removal efficiency was also reported with Zeolites rather than clay particle but they are highly cost effective.[44-46]

2.3.2 Peat Moss

Peat Moss was found to be one of the effective natural adsorbent for heavy metals. It is complex organic substance which is obtained from residue of Sphagnum

moss, Sedges and other water logged plants when partially decomposed.

Peat Moss play vital role in removal of heavy metals from industrial waste water like lead, zinc, cadmium, chromium, copper.[47] It has been notified by researchers that maximum adsorption efficiency was observed with Biochor Peat Moss for Pb (81.3 mg/g), for Cd and Cu it was 39.8 mg/g and 1.2 mg/g.[48]

Its low cost and simplicity of system was most striking benefit of this natural adsorbent.[49]

2.3.3 Fruit Peels

Fruit peels are capable in adsorption of heavy metals as their cell walls are rich in polysacchararides that mainly composed of cellulose and pectin compounds which get ionized on alkaline treatment and generate negative charges which bind metal cations.[50]

It has been examined that cellulose based banana and orange peels (acid and alkali treated) are adsorbent material in adsorption of Cu^{+2}, Zn^{+2}, Co^{+2}, Ni^{+2}, Pb^{+2} Banana peel exhibits maximum adsorption capacity for heavy metal removal as compared with orange peels.[51]

Cationic exchange properties due to presence of carboxylic and phenolic functional groups were responsible for adsorption of heavy metal ions on carrot residues and for the removal of Cr^{+3}, Cu^{+2}, and $Zn 2$ it has been tried out.[52]

It has been investigated that cassava waste (treated with thioglycolic acid) shows adsorption for Zn^{+2} and Cd^{+2} metal ions.[53] Treated cassava waste show maximum adsorption capacity for Zn^{+2} and Cd^{+2} than untreated cassava waste. On acid treatment, it shows better adsorption capacity due to formation of microporosity that enhanced (-SH) thiol group on the surface of adsorbent. The thiol group exchange its hydrogen atom with heavy metal ion, resulting in improved adsorption rate.

3. Biosorption

Biosorption was found to be one of the promising processes in heavy metal removal. It is quite advantageous because of its high effectiveness in heavy metal removal and the use of cheap biosorbents.

Biosorbents can be derived from following sources such as –[54]

1. Non-living biomass like lignin, shrimp, krill, squid, crab shell etc.
2. Algae biomass
3. Microbial biomass like bacteria, fungi, yeasts etc.
   Some of the biosorbents has been discussed here-

3.1 Algae as a Biosorbent-

Algae is one of the autotrophic organism that has been tested and used as biosorbent material to adsorb toxic heavy metals. Its low cost, easy availability with more metal sorption capacity makes it more beneficial biosorbent. It has been reported that with the use of *Spirogyra sp.* of algae 14% removal efficiency was observed for lead.[55] For the removal of Cd, adsorption was found to be 8.4% with *Sargassum sp.*[56] For the removal of Cu metal ions 7% removal efficiency was observed with *Spirulina platensis.*[57] Removal efficiency for the heavy metal ion Cd was found to be 4.3% with the sp. named *Ulvalactuca.*[58] Nearly about 4% removal efficiency was found for Cr with the application of one of the algae *Chlorella miniata.*[59] It has been investigated that removal efficiency for zinc was found to be 3.4% by using one of the green algae *Sargassummmuticum sp.*[60] The Table 2 illustrates the various species of algae that have been investigated as biosorbents in toxic heavy metal removal.

Table 2. The various algae species that has been tried out as biosorbent

Sl No.	Metal ions	Species	Adsorption capacity%	Reference
1.	Pb	*Spirogyra sp.*	14%	55
2.	Cd	*Sargassum sp.*	8.45%	56
3.	Cu	*Spirulina platensis*	7%	57
5.	Cr	*Chlorella miniata*	4%	59
6.	Zn	*Sargassummuticum*	3.4%	60

3.2 Fungi as a Biosorbent

Fungi and yeast were other biosorbents that are used in the removal of heavy metal contaminants. They can be grown easily and produces large biomass; it shows good metal binding properties because of presence of cell wall material in large quantity. Highest removal efficiency was reported with Fungal named *Saccharomyces cerevisiae* i.e. 27%.[61] It has been studied that fungi known as *Penicillium chrysogenum* removes about 26% of Ni efficiently.[62,63] For the removal of Zn the fungal *Penicilliumsimpliccium* has

been tried out and 5.2% removal efficiency was found with it.[64,65] Nearly about 5.2% adsorption was notified for Cd with *Penicilliumsimpliccium sp.*[64,66] It has been also notified that about 4% Cr (VI) has been removed by using fungi *Pencillium purpurogenum*.[67,68] Lead adsorption was found to be 3.4% with the application of fungus named *Aspergillus niger*.[69] It has been studied that 3% removal of Cu could be achieved by using one of the sp. named as *Aspergillus niger* and nearly about 1% removal with *Penicillium chrysogenum* [70,71]. Study reported 6% removal for the Cr metal ion with *P. Chrysosporium*.[72] Moreover, it not only results in removal of heavy metal but also provides eco-friendly pathway in the environment. Table 3 summarized the removal efficiency of heavy metal ions by using different algal based biomass

Table 3. The various species of fungus that has been used as biosorbent

Sl. No	Metal ions	Fungi	% biosorption capacity	Reference
1	Pb	*Saccharomyces cerevisiae*	27%	61
2	Ni	*Penicillium chrysogenum*	26%	62,63
3	Zn	*Penicillium simpliccium*	7%	64,65
4	Cd	*Penicillium simpliccium*	5.2%	64,66
5	Cr(VI)	*Penicillium purpurogenum*	4%	64,65
6	Pb	*Aspergillusniger*	3.4%	69
7	Cu	*Aspergillusniger*	3%	70
8	Cu	*Penicillium chrysogenum*	1%	71
9	Ni	*P.chrysporium*	6%	72

3.3 Bacteria as Biosorbent

Bacteria is one of the other category that have been used as a bio sorbent material because of its size, ability to grow under controlled conditions.[73,74] Many bacterial species have been tested for heavy metal removal as they have excellent sorption capacity because of their surface to volume ratio and their active chemosorption sites.[75] It has been reported 17.7% removal of Zinc by using *Pseudomonas putida.* The removal efficiency for the Cu metal ion was found to be 32.5% with *Enterobacter sp* and 17.87% with the *Arthrobacter sp*. of bacteria.[76,77] One of the

bacterial sp. known as *Pseudomonas* was found to remove Cr efficiently with 95% removal.[78] For the removal of nickel metal ion *E.coli* has been tried out with the removal efficiency of 6.9%.[79] The removal efficiency of 46.2% was found for the removal of Cd by using bacterial sp. *Enterobacter* Table 4 summarized the variety of bacterial sp. that has been used as biosorbents.[79]

Table 4. The various bacterial species that has been tried out for the treatment of waste water

Metal	Microbial biosorbent	Sorption capacity%	Reference
Zn	Pseudomonas putida	17.7	76
	Enterobacter sp.	32.5	77
			78
Cu			
	Arthrobacter sp.	17.87	
Cr	*Pseudomonas sp.*	95	79
Ni	*E.coli*	6.9	80
Cd	*Enterobacter sp.*	46.2	80

4. Comparison of Various Adsorbents for Removal of Heavy Metals

4.1 Removal of Zinc

The Table 5 illustrates some of the selective adsorbents that have been tried out for the removal of zinc metal ions. One of the natural adsorbent Cassava waste shows maximum adsorption for the removal of while other natural adsorbents such as fruit peels of orange and banana shows least adsorption nearly about 0.5% Secondly, Clay(Kaolinite) natural adsorbent material also shows better adsorption efficiency of 25%.[80] Among agricultural adsorbents, 2% adsorption was examined with Wheat Bran for Zn removal.[81] Among industrial adsorbents, 9.5% adsorption efficiency was notified with Lignin and about 8.2% adsorption was observed with sludge of paint industry.[82,83] Saw Dust of Popular another industrial adsorbent when treated with NaOH shows 1.583% adsorption while Saw Dust of Fir shows 1.3% adsorption.

It has been shown in the Figure 2 that the high adsorption efficiency with Cassava waste when treated

Table 5. Removal of Zinc by the use of different adsorbent materials

Adsorbent	Type	Modifying agent	Adsorption capacity	Reference
Cassava waste	Natural material	Treated with Thioglycolic acid	55.97%	53
Enterobacter sp.	Bacteria	------	32.5%	77
Kaolinite	Clay	------	25%	81
Pseudomonas putida	bacteria	------	17.7%	76
Lignin	Industrial waste	------	9.5% (at 40^{0}C) 7.3% (at 30^{0}C)	83
Paint industry sludge	Industrial waste	Treated with H_2O_2	8.2%	76
Untreated cassava waste	Natural material	------	5.582%	53
Carrot peels	Natural material	Treated with HCl	2.961%	52
Wheat Bran	Agricularual waste	------	2%	82
Poplar saw dust	Industrial waste	Treated with NaOH	1.583%	42
Fir saw dust	Industrial waste	Treated with NaOH	1.341%	42
Banana peels	Natural material	Treated with HNO_3	0.58%	51
Orange peels	Natural material	Treated with HNO_3	0.525%	51

with thiogylcolic acid and least adsorption efficiency with orange peels.
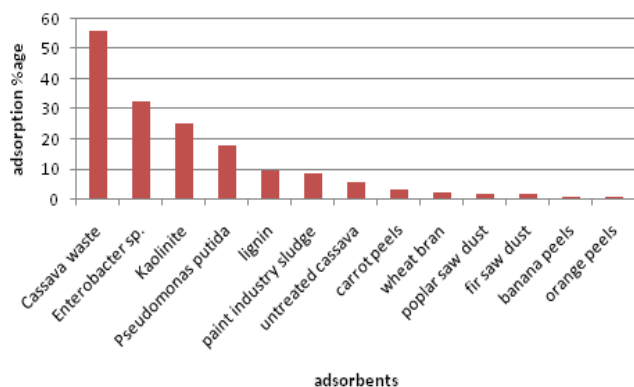

Figure 2. High adsorption efficiency.for zinc with cassava waste (treated with thioglycolic acid).

4.2 Removal of Cadmium

The Table 6 describes the various adsorbents used for the adsorption of cadmium metal ion from waste water stream. Smectic Clay was found to be efficient adsorbent material for Cd removal with 97% adsorption efficiency.[84] Secondly, Cassava waste one of the other natural adsorbent shows 65% adsorption when treated with thioglycolic acid but untreated cassava waste shows very less adsorption i.e. only 8.6%. Some other natural adsorbents show least adsorption i.e. only 10% adsorption was achieved with onion, 7% adsorption with acid treated onion, 4% adsorption with Peat. Among agricultural waste material sugarcane baggase shows 31.3% adsorption when treated with triethylene tetramine only 18.9% adsorption when treated with sodium carbonate and ethylene diamine.[85] Very less adsorption was notified with wheat bran only 5.15%, 1.7% adsorption with sugar beet pulp, 1.618% with Rice Husk. Industrial waste material was also tried out for Cd removal and found to be least effective as very less adsorption was notified with them. Only 7.4% adsorption was shown by Saw Dust (Cedrus Deodar wood).[86] Saw Dust (Pinus Cylvestris) show 1.9% adsorption sludge was found to be having 1.4% adsorption efficiency, waste of tea industry shows 1,129% adsorption efficiency.[87,88] Modified lignin was found to be less efficient for the Zn removal with very less adsorption capacity. It has been shown in the Figure 3 that high adsorption can be achieved with cassava waste on treated with thioglycolic acid and least adsorption was notified with lignin.
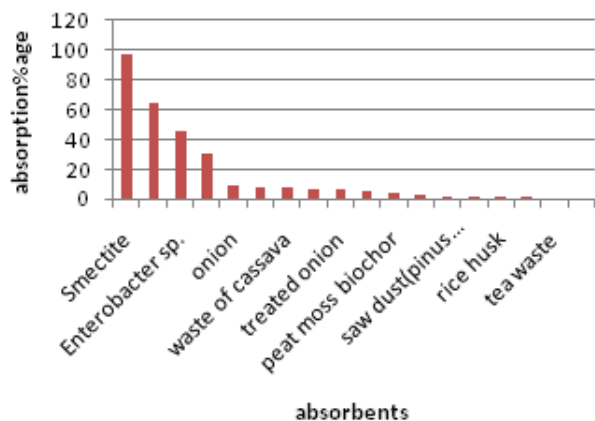
Figure 3. High adsorption efficiency for cadmium can be achieved with Smectite Clay.

4.3 Removal of Lead

Various adsorbents that have been tried out for the removal of toxic metal lead from waste water stream have been listed in the Table 7. It has been shown in the Figure 4 that highest adsorption efficiency for lead removal was noticed with one of the agricultural adsorbent like dried

water hyacinth stem and leaves i.e. 90% adsorption.[89] Among natural adsorbent material only orange peels xanthate shows 21.83% adsorption.[90] While fruit peels of banana and orange shows least adsorption i.e. 0.1%. Pb removal can also be achieved with orange barks with 11.2% adsorption efficiency.[91]
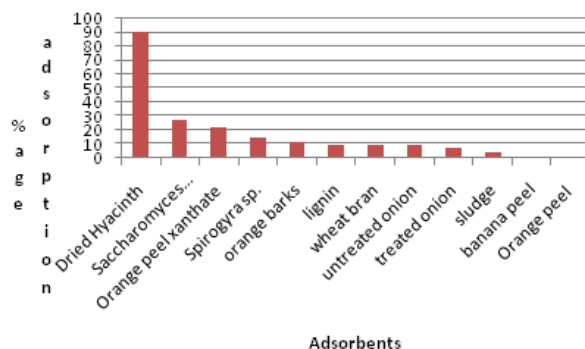

Figure 4. High percentage removal efficiency for lead was found to be with dried water hyacinth stem and leaves that is also one of the agricultural adsorbent material.

Table 6. The removal of cadmium by using different adsorbents

Adsorbent	Type	Modifying agent	Cd^{+2} removal percentage	References
Smectite	Clay	-----	97%	85
Cassava waste	Natural material	Thioglycolic acid	65%	53
Enterobacter sp.	bacteria	-----	46.2%	77
Sugarcane baggase	Agricultural waste	Triethylene tetramine	31.3%	
		Sodium bicarbonate	18.9%	86
		Ethylene diamine	18.9%	
Onion	Natural material	-------	10%	19
Sargassum sp.	algae	-------	8.45%	56
Waste of cassava	Natural material	-------	8.668%	53
Saw dust (Cedrus deodar wood)	Industrial waste	Sodium hydroxide	7.4%	88
Onion	Natural material	HCl/ H$_2$SO$_4$	7%	19
Wheat Bran	Agricultural waste	....	5.158%	82
Peat Moss Biochor	Natural material	....	4%	48
Rice husk	Agricultural waste	Sodium hydroxide	2.954%	88
Saw dust of pinus sylvestris	Industrial waste	--------	1.9%	89
Sugar beet pulp	Agricultural waste	-------	1.72%	87
Rice husk	Agricultural waste	Sodium bicarbonate	1.618%	17
Sludge	Industrial waste	------	1.47%	84
Waste of tea industry	Industrial waste	------	1.129%	90
Modified lignin	industrial waste	-------	0.75%	33

Table 7. The lead removal efficiency carried out by the various adsorbents

Adsorbent	Type	Adsorption percentage	Reference
Dried water hyacinth stems & leaves	Natural material	90%	91www
Saccharomyces cerevisiae	Fungi	27%	61
Orange peel xanthate	Natural material	21.834 %	92
Spirogyra sp.	algae	14%	55
Orange barks	Natural material	11.2%	93
Lignin	Industrial waste	8.902%	33
Wheat Bran	Agricultural waste	8.7%	94
Untreated Onion	Agricultural waste	8.74%	19
Treated Onion	Agricultural waste	7.18%	19
Sludge	Industrial waste	4.24%	84
Banana peel (acid treated)	Natural material	0.797%	51
Orange peel (acid treated)	Natural material	0.775%	51

Nearly about 7.18- 8.7% adsorption efficiency was achieved with agricultural waste material such as wheat bran onion (treated and untreated) other adsorbent material like sludge shows 4.2% adsorption for the lead removal.[84,92]

4.4 Removal of Copper

For the removal of heavy metal copper number of adsorbents has been tried out. Some of them have been listed in the Table 8. Highest adsorption capacity was examined with sugar baggase for the removal of Cu heavy metal. Saw Dust one of the industrial adsorbent shows 91% adsorption for Copper. Fly Ash second most efficient industrial adsorbent shows 70% adsorption while, some other industrial adsorbents show least adsorption like 7.1% adsorption efficiency was notified with tea waste 0.692% with saw dust of Popular and only 1.73% with sludge Agricultural waste material has also been tried out for the removal of copper and it was found to be less efficient.[93] Only 8-9.08% adsorption was examined for onion 5.15% adsorption for wheat bran. Least adsorption efficiency was notified with natural adsorbents i.e. only 0.1-0.4% adsorption was shown by fruit peels and Biochor Peet Moss. Whereas, little more adsorption was noticed with Clay Bentonite i.e. 5.4%.[94] It

Table 8. The Removal of copper carried out by different adsorbents

Adsorbent	Type	Modifying agent	Removal efficiency	Reference
Sugar baggase	Agricultural waste	------	94.2%	36
Saw dust	Industrial waste	---------	91%	36
Flyash	Industrial waste	------	70%	95
Arthrobacter sp.	bacteria	------	17.87%	78
Onion	Agricultural waste	HCl/H_2SO_4	9.08%	19
Onion	Agricultural waste	----	8%	19
Tea waste	Industrial waste	----	7.1%	36
Spirulina platensis	Algae	----	7%	57
Immobilized bentonite	Clay	----	5.4%	96
Aspergillus niger	fungi	-----	3%	69
Sludge	Industrial waste	-----	1.73%	84
Fir saw dust	Industrial waste	------	1.270 %	37
Wheat bran	Agricultural waste	H_2SO_4	5.15 %	28
Poplar saw dust	Industrial waste	-------	0.692 %	42
Banana peel	Natural material	HNO_3	0.475 %	51
Orange peel	Natural material	HCl	0.365 %	51
Biochor peat moss	Natural material	-----	0.12 %	48

was illustrated from the Figure 5 that sugar baggase one of the agricultural byproduct shows maximum adsorption in the case of copper whereas, biochor peat moss show very less adsorption.
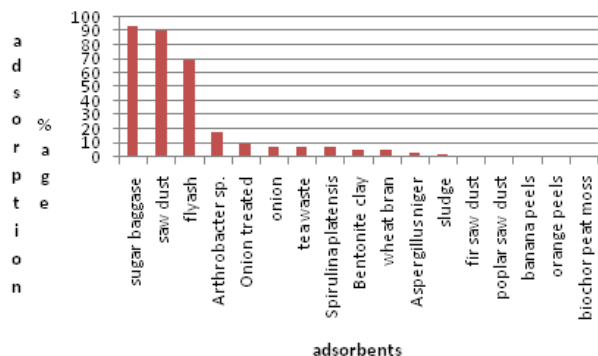

Figure 5. Removal efficiency for copper was notified with sugar baggase whereas, fruit peels show least adsorption.

4.5 Removal of Nickel

For the removal of nickel heavy metal some of the adsorbents has been listed in the Table 9.

Table 9. The removal efficiency of nickel carried out by different adsorbents

Adsorbent	Type	Removal efficiency	Reference
Sugar baggase	Agricultural waste	87%	36
Banana peels	Natural material	81%	36
Saw dust	Induatrial waste	75%	36
Tea waste	Industrial waste	72%	36
Flyash	Industrial waste	68%	36
Pencillium chrysogenum	Fungi	26%	71
Orange peels	Natural material	16%	20
Kaolinite	Clay	14%	97
Wheat Bran	Agricultural waste	12%	29
Peat Moss Biochor	Natural material	8%	48
E.coli	Bacteria	6.9%	80
P.chrysosporium	fungi	6%	72
Sludge	Industrial waste	0.78%	84

Among agricultural waste material sugar baggase shows maximum adsorption capacity 87% for the removal of nickel while, it was least notified with wheat bran nearly about 12%. Among natural adsorbents,

banana peels shows highest adsorption i.e. 81%. But, only 16% adsorption was examined with orange peels. Clay (Kaolinite) one of the other natural adsorbent only gives 14% adsorption.[95] Peat moss biochor shows only 8% adsorption efficiency for the removal of toxic heavy metal.

Among industrial waste materials saw dust, tea waste, flyash shows better adsorption efficiency nearly 75%, 72% and 68% while, very less adsorption was examined with sludge industrial material i.e. only 0.7%. It was shown in the Figure 6 that removal efficiency was high when sugar baggase was used as an adsorbent.
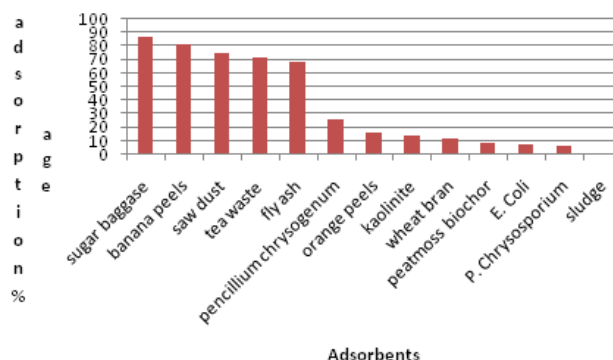

Figure 6. High adsorption efficiency for nickel can be achieved with sugar baggase.

5. Conclusion

Many investigators have tried out different adsorbents to remove heavy toxic metals from waste water efficiently. Comparitive study of removal of commonly occurring heavy metals in waste water by using different adsorbents has been done. It has been concluded that Zn removal can be removed efficiently by using Cassava waste with 55.9% adsorption. Cd show maximum adsorption on Smectite Clay particle i.e. 97%. Lead can be removed by using dried water Hyacinth stems and leaves with maximum adsorption capacity of 90%. Sugar baggase was also found to be most efficient adsorbent having 94.2% adsorption for the removal of Copper metal. Nickel shows maximum adsorption by using sugar baggase, one of the agricultural waste materials with 87% efficiency.

6. Acknowledgements

7. Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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