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Removal of heavy metals from textile industries with natural adsorbents

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Abstract

Persistent execution of heavy metals contaminating wastewater from textile industries remains a major threat to environmental life. The general studies stated that textile industries polluted about 20-30% freshwater. Such heavy metals are highly reactive even at very low concentrations by accumulating in the food chain. This review highlights the employment of natural adsorbents in removing heavy metals in terms of economic benefits, availability, simple pre-treatment, and pollution-free aspects. This review discusses toxic heavy metals and their potential effects. It highlights the possible natural absorbents like rice husk, banana peel, sugarcane bagasse, absorbents, *and Prosopis juliflora* bark presented within the state of art methods. The review also enumerated the adsorption capacity of the absorbents like Rice husk forCadmium as 108mg/sugarcane bagasse for a nickel at 123.46 mg/g, and Banana peel on the lead as 54.76 mg/g, which are considered beneficial and effective. The economic utilization of natural adsorption also reveals the importance of the potential application of natural absorbents.

Keywords*: bio-adsorbents; effluent contamination; heavy metals; industrial pollution; textile dyes.*

1. Introduction

Textile industries utilize a huge amount of heavy metals in various systematic processes and significant losses and are consequently discharged in the effluent. With the emergence of advancing technologies, hazardous heavy metals constantly deteriorate the purity of groundwater. It was estimated that only 8% of the industrial effluent had been treated before discharging. Natural absorbents play a vital role in removing heavy metals from textile industrial effluents with easy availability and cost-effectiveness. Heavy metals like chromium, lead, cadmium, copper, arsenic, zinc, iron, magnesium, sulphur and mercury are extensively used to produce colouring pigments for textile dyes.

Nevertheless, the textile industries are major contributors to polluting our environment (Quansah et al., 2020). The usage of water in textile industries day today is over a million gallons. This water contains several chemical compounds, which are discharged from industries without any treatments. This adversely impacts the environment and also causes several health hazards for humans, including dermatitis, skin irritation, nausea, ulcers, and haemorrhage(Gharaghani, & Malakootian, 2017). Further, synthetic fibres, protein fibres as well as cellulose fibres are utilized for manufacturing various textile products. In which every fibre is dyed with various chemical dyes. Indigo dyes, naphtha dyes, direct dyes, and reactive dyes are utilized for dying the cellulose fibres. In contrast, acid dyes dye protein fibres, and direct, basic, and dispersed dyes are utilized for dying synthetic fibres (Malakootian, Radhakrishna, Mazandarany, & Hossaini, 2013).

Additionally, the usage of a large amount of water as well as different chemicals is considered the major limitation of textile industries (Nasiri, Malakootian, & Javid, 2022). Such that this water is used for chemical applications and product rinsing. During this process, a huge amount of wastewater comprising chemicals and dyes like Zn (Zinc), Cu (Copper), As (Arsenic), Cr (Chromium), (Cd) Cadmium, and Pb (lead), which are significantly capable of influencing human health and environments like soil, water, and air, even at a lower concentration (Honarmandrad, Javid, & Malakootian, 2021). These are known as heavy metals, naturally occurring in the Earth's crust. As our Earth's crust comprises these heavy metals, a small amount of these heavy metals drains into groundwater (Pasgar, Nasiri, & Javid, 2022). Several processes such as electro dialysis, microbial reduction, thermal treatment, solvent extraction as well as ion exchange were implemented with a different successful degrees in extracting heavy metals and dyes from textile industries.

Among the extracting methods, the adsorption technique gained more impressions because of its efficacy, handling, availability as well as cost-efficiency. The bio adsorbents were considered feasible alternatives for extracting heavy metals. Various natural adsorbents were introduced to eliminate heavy metals, as well as the cost-effective adsorbents, which have been derived from different agri-wastages such as peanut shells, neem bark powder, tea waste, and coir pith, and rice husk. Fungi, plants, and algae are bio-absorbents capable of extracting heavy metals and metalloids from industrial wastewater. Moreover, bio adsorption offers various benefits over the traditional techniques, such as no additive nutrient requirement, metal recoveries, bio-adsorbent regeneration, minimization of chemical and biological sludge, low cost as well as higher efficiency. Similarly, the Nano-adsorbents were used for capturing the various molecular sizes, speciation attitudes and hydrophobicity (Alalwan, Alminshid, Mohammed, & Mohammed, 2022).

Figure 1 compares dye effluent discharge percentages from textile, dyeing, paper and pulp, tannery and paints and dye manufacturing industries. This depicts that textile industrial effluent discharge occupies a major position which has to address quickly by cost-effective methods. Hence the present review focuses on providing comprehensive information about the removal of heavy metals from the textile industries with the use of more universal natural absorbents associated with the prevailing challenges.

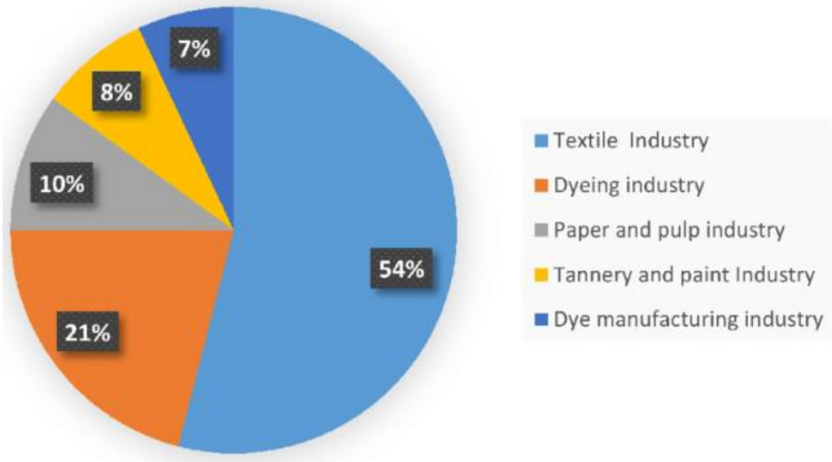

Figure 1 Comparison of dye effluent discharge from various industries (Velusamy, Roy, Sundaram, & Kumar Mallick, 2021)

1.1 Economic utility

An extensive range of low-cost natural absorbents was used as valued products for removing heavy metals. Instead of mere disposing of the products such as rice husk and Banana peel, their ability to remove heavy metals can be effectively upgraded and used to uplift the adsorption capacity economically. In this article, Lim and Aris (2014) enumerate the greater cost-effective potential in water treatment applications (Lim & Aris, 2014). Furthermore, this article provided a SWOT (Strength Opportunity Weakness Threat) analysis to predict the availability and utilization of such low-cost absorbents in sustained wastewater management. The utilization of the investigated bio absorbents prevents the complex industrial steps since the requirement of chemical synthesis and its corresponding purification step is eliminated. It reduces the drastic emission and generation of undesirable products while synthesizing polymer-based absorbents. Further bioremediation is also easier, and hence natural absorbents can act as highly economic target systems.

The massive increase in the employment of these heavy metals over the past decades results in the increased flux in the aquatic environment. To investigate this, the paper aims

- To create awareness and significance of natural Absorbent based heavy metal removal for the maintenance of a balanced ecosystem
- To provide a comprehensive review of the removal of heavy metals from the textile industries using various natural absorbents like rice husk, banana peel, sugarcane bagasse, absorbents, *and Prosopis juliflora* bark.
- To compile scattered information on the different adsorbents that are used for heavy metal removal and to provide information on the commercially available and natural adsorbents used for the removal of chromium, cadmium, and lead.
- To show that these low-cost and eco-friendly adsorbents can effectively be used to remove heavy metals.

2. Adverse impacts of heavy metals

Polluted surroundings with heavy metals are hazardous to plants, animals, and humans. When the heavy metals in wastewater are ingested into the human body via numerous pathways, it affects the brain, lungs, liver, kidneys, and bones. Further, when these metals are exposed to the ecosystem, heavy metal ions like Cd, Cr, Pb, and mercury (Hg) are accumulated in our bodies via direct intakes or through the food chain [3]. These toxic heavy metals can bio-accumulate and retain their position as destructing elements. Heavy metals such as Pb, Zn, Cd and metalloids like Ar in drinking water causes adverse impacts on human health like pulmonary disease, hypertension, cardiovascular diseases, hyperpigmentation, neurological effect, allergies, cancer, and skin lesions. Cd (Cadmium) is a toxic heavy metal, and it has zero beneficial roles to human beings.

Cadmium exposure causes various health issues, which also include hostile reproductive health. Such that, (Kumar & Sharma, 2019) comprehensively discussed adverse impacts of cadmium, which causes reproductive issues like pregnancy. The study collected data by utilizing different websites as well as reports, consulting books, etc. From these data, the study stated that cadmium could adversely impact female and male reproduction. Additionally, the study recommended that efforts be taken to prevent exposure to cadmium. Generally, the primary source of human exposure to heavy metals is contaminated drinking water.

Further, the impacts of drinking water, which is contaminated with heavy metals like cadmium, nickel, chromium, lead, mercury as well as arsenic, have caught the attention of pertinent departments. Figure 2 describes the toxic effects of dyes on the environment and living beings. Moreover, the heavy metal toxicity is via the appearance of oxidative damage and the production of ROS (Reactive oxygen species). Thus, contaminated water with toxic heavy metals globally causes mortality and morbidity. To address these impacts, (Fu, & Xi, 2020) reviewed sources, distribution as well as the impacts of heavy metals on human beings. Table 1 provides information on the toxic potential of heavy metals.

Table 1 Toxic potential of heavy metals (Ayangbenro & Babalola, 2017)

Heavy metal	Potential toxicity to human
Cadmium	Vomiting, bone diseases, prostate and lung cancer, itai-itai, and other potential effects.
Arsenic	Cardiovascular disorder, dermatitis, brain damage, skin cancer.
Nickel	Nausea, kidney diseases, chest pain, shortness of breath, and lung cancer.
Copper	Liver damage, abdominal pain, metabolic disorders, diarrhoea, vomiting, and nausea.
Lead	Chronic nephropathy, Anorexia, neuron damage, insomnia, hyperactivity, decreased fertility, damage to the renal system, and short attention span.
Mercury	Attention deficit, deafness, blindness, gastrointestinal irritation, pulmonary edema, and reduced rate of infertility.

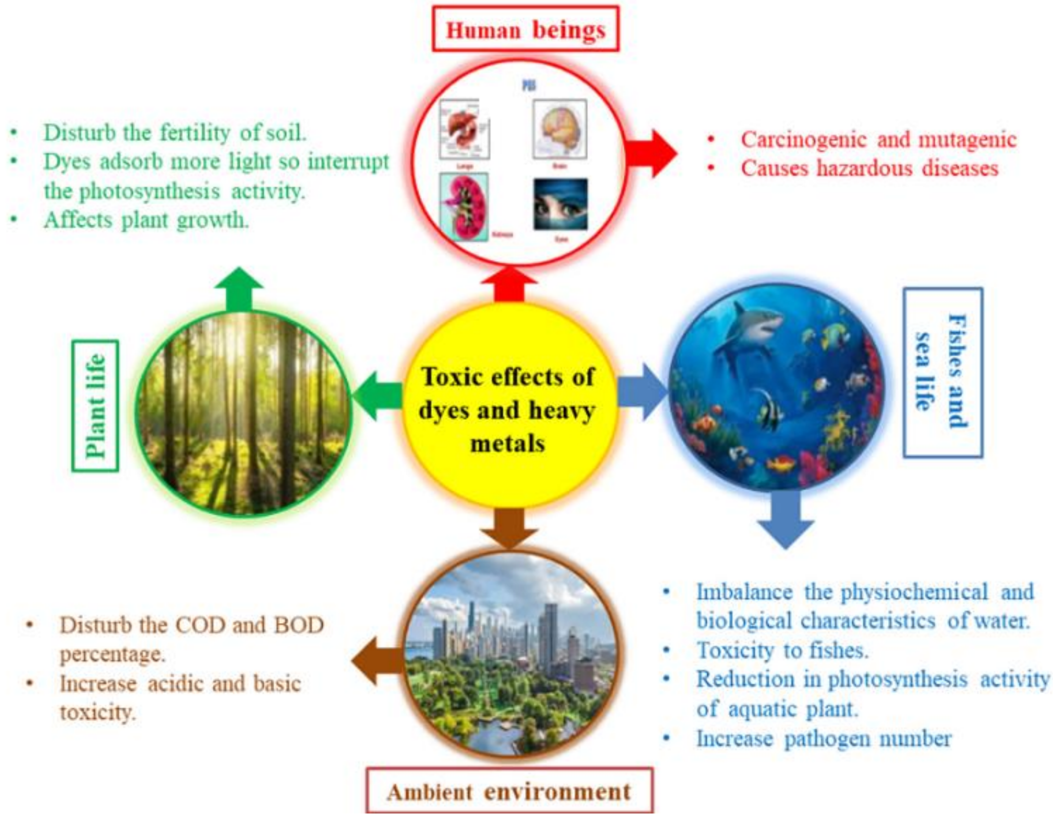

Figure 2 Toxic effects of dyes on the environment and living beings (Yadav, Yadav, Bagotia, Sharma, & Kumar, 2021)

3. Review on various natural absorbents in the removal of heavy metals from textile industries

Many methods are being implemented to remove heavy metals; using activated carbon has become a competitive process. But the high cost of activated carbon has made heavy metal removal a great concern. Many researchers have been conducted to remove heavy metals using different materials. Various adsorbents have been used to remove different types of heavy metal ions from textile wastewater, especially those harmful to humankind and are discussed in this section.

3.1 Rice husk

Rice husk, a comparatively cheap and thick substance, could be investigated as a potential absorbent for removing heavy metals from the textile excretes. The following survey on the effective removal of heavy metals and pesticides with rice husk enables the recent researchers to provoke the utilization of rice husk affordably.

A previous study reported a rice husk-based composite membrane to remove hexavalent chromium using electrospinning and chemical polymerization methods [3].

The study characterized the membrane configuration by scanning electron microscope (SEM), fibre diameter measurements, water contact angle, FTIR, UV Vis spectroscopy, and tensile strengths. They suggested that the investigated membrane functions as a good active substance for absorbing various textile contaminants. Their results indicate that 10% rice husk as filler conferred high mechanical resistance to composite membranes. This could reach large adsorption capacities in a comparatively short time. Further, the adsorbed species could be desorbed easily from membranes that allow the recycling of the material.

Sharma and Singh (Sharma, & Singh, 2020) described the removal of toxic substances from textile wastewater from rice husks by the sorption method. For this purpose, the study conducted batch experiments and provided significant results. Further, the biological oxygen demand (BOD) and chemical oxygen demand (COD) values suggested a better percentage of efficiency with rice husk. Rice husk-based carbonaceous adsorbent using sulphur impregnation for removing heavy metals was investigated by (Wajima, 2018). The study immersed rice husk in 0.05 – 3 M potassium sulphate solution followed by heating in nitrogen gas at 100 to 700˚C for the pyrolysis process. Then they examined the ability of carbon and sulphur contents in the adsorbent removal of heavy metals. The study stated that the adsorbent effectively removed heavy metals such as nickel (Ni), Zn, Cd, Pb, Cu, and iron (Fe). The study also stated that with the rise in the pH value, the increasing order of heavy metal removal was found to be Ferric > Lead > copper > zinc >cadmium > nickel. Similarly, the removal of metals like Ni, Cr, and Pb from wastewater is achieved using rice husk and hen eggshells (Tariq et al., 2018). Rice husk pre-treatment was applied with formaldehyde treatment for the optimum removal of chromium. Their study utilized the selected bio sorbents in different doses and temperatures. The maximum effectiveness of rice husk for removal of chromium was observed to be 95%, and for Ni, it was observed to be 100% with one gram dosage to water. The removal effectiveness of rice husk reduces with the increasing dosage. Likewise, recently. (Quansah et al., 2020) found that treatment of rice husk at 75 °C was superior to other temperature ranges for the removal of methylene blue (MB) and crystal violet (CV). However, the rice husk pyrolysis above 300°C has been observed to be not effective in promoting the adsorption capacity for MB and CV. The following Table 2 represents the composition of rice husk (da Rocha et al., 2020). As another application of rice husk, the RHA- rich husk ash was considered a promising pozzolanic alternative component for the partial replacement of ordinary Portland cement in the range of increasing the strength and durability of concrete and the corrosion effect caused by harsh environmental conditions was also reduced (Al-Alwan et al., 2022).

Table 2 Composition of rice husk

Composition	Percentage
Cellulose material	32.3
Lignin	21.5
Hemicellulose	21.3
Mineral ash	15.1
Water	8.1
Other extractives	1.9

3.2 *Prosopis juliflora* bark

Prosopis julifora tree is known for the extraordinary character of water adsorption. (Panigrahi & Santhoskumar, 2020) examined the efficacy of heavy metal extraction by utilizing activated carbon from *P. julifora* bark. This study prepared the activated carbon through a chemical and thermal process. This study conducted batch experiments to analyze heavy metals in textile industrial effluents collected from Erode, Tamilnadu, India. It has been observed that these eco-friendly and cost-effective adsorbents could efficiently be exploited to eliminate heavy metals. Likewise, (Gautam, Singh, Shukla, & Mohan, 2020) utilized the seeds of *P. Juliflora* for extracting lead. Additionally, the bark of *P. Juliflora* has been used as a new natural adsorbent for the extraction of chromium. This was assessed by changing the parameters such as pH, temperature, metal concentration, contact time as well as adsorbent dosage (Kumar & Tamilarasan, 2017). The assessments using Langmuir isotherms and Freundlich, and the characterization utilizing FTIR (Fourier transform infrared spectroscopy), SEM methods, and XRD (X-ray diffraction) exhibited the properties of the tree. Similarly. (Andal, Charulatha, & Gayathri, 2016) Emphasized the usage of *P. Juliflora* bark for the elimination of copper. Moreover, the raw PJB (*P. Juliflora* Bark) was treated with 0.1N HCL acid to enhance adsorption efficiency. The study noticed a good relation between inputs and output adsorbent variables by implementing SPSS software. Activated carbon from *P. juliflora* seeds possesses good adsorption capability for Zn, and also it can be employed for the elimination of zinc from industrial wastewater (IWW). This study (Zulfareen, Venugopal, & Sajitha, 2018) stated that reactors could be introduced for investigating the extraction of Zn from IWW as there was a very minimum extraction time. Moreover, it has been identified that marginally alkaline pH was considered the optimal condition to remove Zn from IWW. This study identified that the matrix effect was minimum in Zn extraction from *P. Juliflora* seeds.

3.3 Bio-adsorbent

The readily available lignocellulosic materials, which were recovered from the sugarcane industries, revealed a potent adsorbent to extract textile dyes. Recently, Tony (Tony, 2021) used wet bagasse with alkali and treated them with sulphuric acid (H_2SO_4) to produce cellulose fibres. The SEM and XRD were utilized to characterize the Absorbent. The images of SEM briefly explained that the chemically-treated bagasse possesses a micro-fibre structure, which increases the capability of the adsorbent. From the experimental analysis, it was observed that the adsorbents from chemical treatment and sugarcane bagasse were effective in the removal of Procion Blue dye from IWW. Introduced a novel eco-friendly, nano-structure, micro-structure good recycling and bio-adsorbent were fabricated through green cross-linked technology for the removal of Cu (II) (Zhao, Ye, & Cui, 2022) and then stable surface such as HCA structure was confirmed through XRD,SEM,XPS and FTIR .

Moreover, the study implemented BGT and observed the highest dye removal. This investigation also suggested that bagasse residue can be used as a more effective and cost-efficient adsorbent for eliminating textile dye effluents. Cellulose is an eco-friendly, renewable, abundant polymer obtained from trees and plants. A previous study prepared an adsorbent by grafting NH_2-HBP (amino terminated hyperbranched polymer) as well as β-CD (Beta cyclodextrin) onto the cotton fibres (Yue, Huang, Jiang, Lin, & Chen, 2019). Further, the adsorbents have been characterized by utilizing FTIR, SEM, and XRD analysis. The study also evaluated adsorption parameter influences in batch mode by incorporating initial dye concentration, contact time, and pH. (Qamar, Ashiq, Jahangeer, Riasat, & Bilal, 2020) emphasized the properties of chitosan via surfactant impregnation, graft copolymerization, and crosslinking to develop chitosan-based hybridized materials with the improved properties of dye adsorption.

Additionally, the nanostructures of chitosan were investigated for the degradation of textile industrial effluents and dyes. Also, this study offered insights into the chitosan-based adsorbents and encouraged the researchers to utilize chitosan for extracting different types of dyes (Qamar et al., 2020). The following Figure 3 lists the synthesizing route of bio-adsorbent through physical treatment methods.

3.4 Banana peel

The BPAC (Banana Peel Activated Carbon) could be employed as a natural adsorbent for eliminating chromium and copper ions and dyes in textile industrial effluents (Prastuti, Septiani, Kurniati, & Setyawan, 2019). Even though this adsorbent possesses comparatively less carbon content, this can diminish about 55 to 51% of heavy metal ions (Prastuti et al., 2019). Similarly, a previous study (Ali, & Saeed, 2015) utilized UTBPs (untreated banana peels), BBPs (bleached banana peels), AcBPs (Acid hydrolyzed banana peels) as well as AIBPs (Alkali hydrolyzed banana peels) were utilized as natural adsorbents for extracting Manganese and chromium from textile industrial effluents. From the batch experiments, the study depicted that the chemically-treated BPs could be suitably used as cost-efficient adsorbents. Also, their results demonstrated that the AIBPs possess high efficiency in eliminating heavy metal ions. Similarly, (Maruf, 2019) investigated the efficiency of powdered BPs in extracting Cu from textile industrial effluents. This study gathered BPs from domestic waste and grounded them in dried powder. Further, the study's outcomes depicted that powdered BPs could be exploited as a natural adsorbent in Cu extraction from textile industrial effluents. Likewise, (Badessa, Wakuma, & Yimer, 2020) utilized BPs for chromium extraction. (Tharani, Harish, Mageshkumar, & Ramesh, 2017) used different adsorbent complexes like activated carbon from coconut shells and banana peel. The banana peel was used in the removal of dyes in the textile effluent (Akter, Rahman, Abedin, & Kabir., 2021) and it was also used in the removal of Pb2+ in the aqueous solutions (Nurain, Sarker, Rahaman, Rahman, & Uddin, 2021).

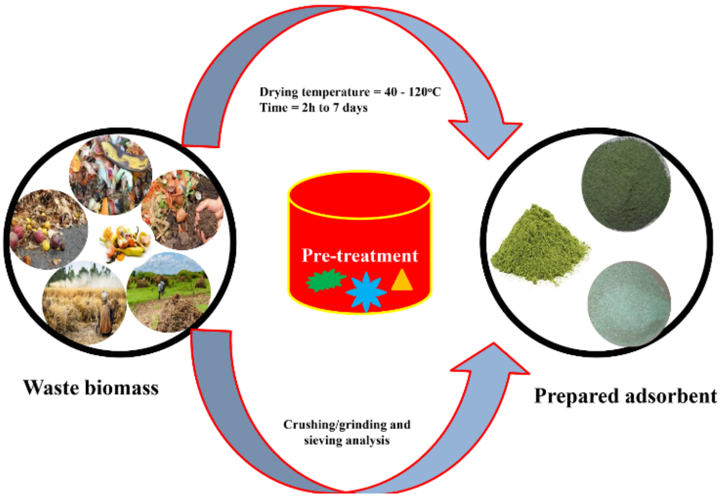

Figure 3 Schematic route of bio-adsorbent preparation by physical treatment (Dey, Haripavan, Basha, & Babu, 2021)

3.5 Sugarcane bagasse

The efficacy of SBAC (sugarcane bagasse activated carbon), modified by phosphoric acid, was utilized as an adsorbent in a recent study (Razi, Al-Gheethi, & Za, 2018). This study tried to extract Fe and Zn from textile industrial effluents. Further, the predominant factors identified to regulate the adsorption efficacy of SBAC comprised pH, contact time as well as adsorbent dose. It has been proven that this adsorbent has extracted about 89% of Zn and 91% of Fe, respectively. Finally, the study stated that sugarcane bagasse could be taken into account for treating textile wastewater in terms of cost as well as availability.

Similarly, Isa et al. (Isa, Harripersadth, Musonge, Sayago, & Morales, 2020) established the efficiency of utilizing two agricultural wastes such as eggshells and sugarcane bagasse, in extracting Cd and Pb from wastewater. Moreover, a pseudo-second-order model has been utilized to describe the adsorption process in Cd and Pb ions. From these findings, the study stated depicted the efficacy of these adsorbents. The steps involved in removing heavy metals have been enumerated in Figure 4. Using sugarcane bagasse, the waste water treatment was performed in textile industry (Reza, Sheikh, Abedin, & Kim, 2015).

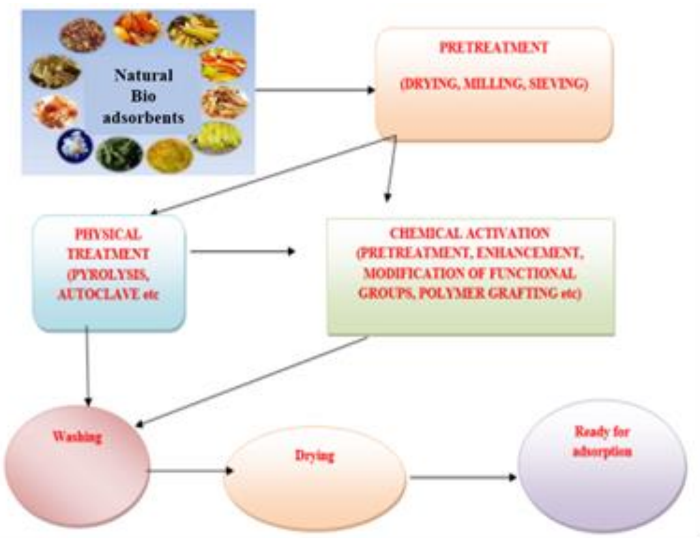

Figure 4 Process of various absorbents in heavy metal removal

4. Review on the removal of various heavy metals from textile industries

Chromium (Cr)

Generally, chromium is a toxic heavy metal which causes crucial environmental as well as health issues. Several studies addressed the extraction of Cr from textile industrial effluents. Such that, (Badessa et al., 2020) extracted Cr ions from IWW by utilizing low-cost and eco-friendly adsorbents such as BPP (banana peel powder) and MSSP (*Moringa stenopetala* seed powder) and estimated the adsorption capabilities. Further, the characterization of adsorbents depicted a variation in functional groups in both adsorbents. In addition, the adsorption kinetics for Cr has been represented by a pseudo-second-order model. From the experimental analysis, the outcomes of the study depicted good performance in terms of heavy metal extraction. Likewise, another study investigated a cost-efficient and readily available clay mineral as an eco-friendly and non-toxic adsorbent. Further, this adsorbent was prepared from NC (natural clay) and treated with diluted HCL (Ashour, & Tony, 2020). From this analysis, the study's outcomes demonstrated the efficiency of Cr extraction. Similarly, (Gebretsadik, Gebrekidan, & Demlie, 2020) produced an environment-friendly and cost-effective bio adsorbent from *Eucalyptus camaldulensi*, a readily available material for extracting heavy metals from IWW. Moreover, this adsorbent has been investigated for its capability of extracting total Cr, Cd, and Pb from industrial and synthetic wastewater of the leather and textile industries. This extraction of heavy metal ions was hugely reliant on the physiochemical nature and the adsorbent's concentration. The maximum extraction for Cr and Pb in terms of pH was 10, whereas pH was 12 for cadmium. From the outcomes of the study, it was suggested that this naturally occurring Eucalyptus camaldulensis adsorbent could be implemented as a cost-effective method for the elimination of Cr, Cd, and Pb from IWW. Moreover, (Shiferaw, Yassin, & Tedla, 2019) reported the employment of modified NC minerals in the extraction of methyl red dye and Cr ions from the aqueous solution. This study gathered three types of minerals like MehalMeda, Seladengay as well as Zemero clays from various parts of Ethiopia, the Amhara region, North Shoa zone, modified with various concentrations of sulphuric acid, nitric acid, and hydrochloric acid. Further, the study established the concentration of Cr by utilizing atomic adsorption spectroscopy. Finally, the study concluded that about 96.99% of Cr ion has been extracted by these adsorbents. (Nwosu-Obieogu & Okolo, 2020) implemented Luffa Cylindrica as a cost-efficient adsorbent to remove Cr ions from textile industrial effluents.

4.1 Lead (Pb)

Lead (Pb) influences the enzyme activities, which results in deactivating anti-oxidants as well as inhibiting the adsorption of trace minerals. This study by (Gautam et al., 2020) deals with natural adsorbents like a peanut shell, *P. julifora*, and *Moringa oleifera* seeds for heavy metal extraction from textile industrial effluents. Further, these adsorbents have been characterized by FT (Fourier transform) and SEM for predicting surface morphology and functional groups. The impact of pH, metal concentration, contact time, and adsorbent dose on heavy metal extraction has been investigated. The maximum lead extraction from peanut shells was 72%, *P. julifora* was about 78% as well as *M. oleifera* was 86%. Several experiments utilized eggshells as a natural adsorbent for extracting heavy metals. But using a continuous stirred tank reactor gained the very least impressions among researchers. Thus, Pandey et al. (Pandey, Singh, Shukla, & Tiwari, 2017) investigated the extraction of Cu and Pb from textile industries utilizing eggshells by a continuous stirred tank reactor. From the experimental analysis, the study's outcomes demonstrated that pseudo-second-order adsorption had a higher correlation coefficient. The study conducted by (Sruthi & Shabari, 2018) used *Aloe vera* (*Aloe barbadensis*) gel as well as orange peels (*Citrus aurantium*), which are readily available and naturally occurring biomass that provides eco-friendly solutions for metal extraction.

Moreover, this study utilized these as natural adsorbents to remove lead. From the analysis, it has been observed that 76% of efficiency was obtained by using orange peel. Whereas 78% of efficiency was obtained using *Aloe vera*. Finally, the study stated that *Aloe vera* is more effective than orange. And this treatment offers a good solution when considering the environment and health.

4.2 Cadmium

Among heavy metals, cadmium is considered as most carcinogenic and hazardous heavy metal in contamination of water in industrial sectors. Recently (Isa et al., 2020) estimated the efficiency of utilizing two agricultural wastages such as eggshells and sugarcane bagasse in extracting Cadmium from the aqueous solutions. Further, the functional groups in eggshells were carbonyl and carboxylic, whereas carbonyl and hydroxyl are the functional groups in sugarcane bagasse. The crystallographic information showed only the crystalline phase for eggshells, whereas it showed a crystalline and amorphous phase for sugarcane bagasse. (Islamuddin, Gautam, & More, 2017) examined a modified form of SB (sugarcane bagasse) activated powder, which was utilized as a cost-effective natural adsorbent for extracting Cd (Cadmium) from an aqueous solution. Further, their study employed adsorption studies to determine the impact of pH, stirring rate effect, adsorbent dosage as well as contact time. Based on the outcomes, this study concluded that the suggested sugarcane bagasse has achieved better performance in the adsorption of cadmium from an aqueous solution. Particularly, the higher concentration of cadmium has obtained excellent results. Ramie fibre is one of the oldest and strongest natural fibres, significantly impacting heavy metal adsorption. Nevertheless, it was limited because of lower adsorption capacity and response rates. (Peng et al., 2018) introduced a new type of CPRM (carboxymethyl functionalized porous ramie microspheres) with an integrated emulsification evaporation technique and carboxymethylation reaction to remove cadmium from wastewater efficiently. Further, they noticed that this method demonstrated its potentiality in wastewater purification.

4.3 Other metals

Luffa Cylindrica is a non-edible plant, which is excessively found across Asia, and it is lignocellulose in nature. Further, it is composed of recyclable, bio-degradable fibrovascular stem; thereby, it is promoted as a well-suitable adsorbent choice (Nwosu-Obieogu, Dzarma, Okolo, Akatobi, & Aguele, 2021) examined the usage of Luffa cylindrical activated carbon as a cost-effective adsorbent to extract Vanadium (V) from the textile industrial effluents. The study evaluated the adsorption rate for adsorbent dosage, pH as well as contact time. From these evaluations, the study depicted a maximum extraction efficiency was about 99.90%. Finally, the expected outcomes from SEM and FTIR indicated the Absorbent's potential capacity. (Simonič & Fras Zemljič, 2020) have obtained a more effective wool-based adsorbent to remove Zn from Industrial wastewater. This study functionalized wool with chitosan for increasing functional groups for metal binding. Moreover, the study performed a chemical and physical modification of the chitosan to analyze the impacts of coating bonds. Similarly, (Imen, Hassani, & Borghaee, 2019) assessed the adsorption of Cd, Pb, Ni, Zn, and Fe on thermally modified dolomite and natural dolomite. Further, the study evaluated the potential of thermally modified dolomite and natural dolomite in heavy metal adsorption from the aqueous solutions. From the experimental analysis, the comparison outcomes depicted that Cd and Pb possess short contact time, whereas, Ni and Fe possess long contact time. From these results, the study stated that modified dolomite poses a huge potential for extracting heavy metals and metals. (Tariq et al., 2018) investigated Pb, Ni, and Cr adsorption on eggshell bio sorbents and rice husks.

5. Adsorption capacity

Table 3 represents the adsorption capacity of the natural absorbents discussed in the study, such as rice husk, sugarcane, and banana peel. Meanwhile, comparisons with other synthetic absorbents like activated carbon and zeolite were also discussed.

Table 3 Absorbent capacity in mg/g of natural and synthetic absorbents.

S.No	Author	Adsorption Capacity of natural absorbents	Adsorption Capacity of synthetic absorbents
1	(Lata & Samadder, 2014).	Rice husk for cadmium 108mg/g	Fe_3O_4-SiO_2 nanoparticles for methylene blue removal - 40 mg/g
2	(Ezeonuegbu et al., 2021).	Sugarcane Bagasse for nickel is 123.46 mg/g	Activated carbon for lead removal - 58.82 mg/g
3	(Afolabi, Musonge, & Bakare, 2021).	Banana peel on lead is 54.76 mg/g	Zeolite for removing Cd^{2+} - 60.24 mg/g

Table 4 Kinetic and thermodynamic analysis

S.No	Author	Investigated absorbent material	Investigated Heavy metal	Kinetic and thermodynamic analysis
1	(Kalash, Alalwan, Al-Furaiji, Alminshid, & Waisi, 2020)	algae Chara species	Pb(II) Cu(II) and Ni(II)	The Q max, which is the maximum metal absorbed / unit algal weight, is described below ***Ni(II)*** **-** 3.725 mg/g ***Cu(II)*** **-** 4.935 mg/g ***Pb(II)*** **-** 8.340 mg/g
2	(Kalash et al., 2020)	Activated carbon	Copper	***Cu (II)*** - 2.23 mg/g
3	(Alalwan, Abbas, & Alminshid, 2020)	Lemon peel	Cyanide	The thermodynamic studies revealed that the adsorption of cyanide by lemon peel was spontaneous and endothermic.
4	(Zafar et al., 2019)	rice husk	Cerium ions	Favourability, feasibility, and endothermic results were encouraged for the removal of cerium ions by rice husk.
5	(Mahindrakar & Rathod, 2018)	Banana peel	Strontium (II)	The maximum biosorption ability of banana peels was determined to be 41.50 mg/g at 120 rpm at pH 7 and 323 K at a contact time of 10 minutes.

6. Kinetic and thermodynamic analysis

Table 4 provides the kinetic and thermodynamic observation of the adsorption of heavy metals by various compounds

7. Challenges faced in the removal of heavy metals

It is obvious that the capacity of sorption completely relies on several factors like experimental conditions, sorbent properties as well as sorbent surface nature. Since the particle size is relatively small, a huge amount of heavy metalloids and metals and a larger surface area are adsorbed. Further, it is difficult for the prevailing literature to compare these outcomes as they vary in methodology and adsorption conditions. Almost in every experiment, the adsorption capacity was increased with the rapid increase in pollutant concentration, and the adsorption efficiency was increased with an increase in the adsorbent dosage. This increases adsorption sites and surface area. Therefore, research is needed on the desorption process, adsorption mechanism, and long-term stability. However, few studies concentrated on recovering desorbed and adsorbed metals from regenerating agents and saturated adsorbents. Even though research in this field is essential, there are very limited researches that have taken into account the spent adsorbent's fate before disposal. In the following, consolidated information on heavy metal removal through several types of adsorbents is represented in Table 5. Correspondingly, the heavy metal contents in textile dyes are presented in Table 6.

Table 5 Comprehensive survey on the heavy metal removal by various adsorbents

S.no	Name of Absorbent	Heavy metal extracted	Advantages	References
1	This study used activated carbon as an absorbent.	The heavy metals extracted in this study are Cu (Copper), Pb (Lead), Cr (Chromium), Hg (Mercury), S (Sulphur), As (Arsenic), Zinc	The major advantage of this study is that the Absorbent is readily available, and utilizing them for extracting heavy metals can significantly reduce expenses.	(Panigrahi & Santhoskumar, 2020)

S.no	Name of Absorbent	Heavy metal extracted	Advantages	References
		Fe (Iron), Mg (Magnesium) and Cd (Cadmium).		
2	The absorbents used in this study were of natural origins, such as chitin, peat moss, clay, and zeolites.	The heavy metals extracted in this study were Chromium, Magnesium, Copper, Zinc, Cadmium, and lead.	Since the absorbents were of natural origin, using them was more cost-efficient.	(Tripathi & Ranjan, 2015)
3	MSP (moringa seed powder), as well as WSP (waste shell powder), was utilized as the absorbents in this study.	Resistant bacteria, dyes, and Heavy metals were extracted from IWW (Industrial wastewater).	Since this is a combination of two absorbents, this method could efficiently treat the industrial wastewater before it reaches the environment.	(Ahmed, Aktar, Zaman, Jahan, & Bari, 2020)
4	The study used 2D three montmorillonite-based ion-imprinted polymers as absorbents.	In this study, heavy metal ions such as lead ions from the SWW (Smelting wastewater) have been removed.	Since this method was highly effective, it seemed to be very promising.	(Zhu et al., 2018)
5	Nano-polymer biomass was utilized as an absorbent in this study.	Heavy metal ions like lead and copper have been extracted from contaminated water in this study.	Even with less biosorbent, this method seemed to be highly efficient.	(Naeimi, Amini, & Okati, 2021)
6	In this study, *Marcia marmotata* calm shell biomass was used as an absorbent.	The heavy metal ions removed from wastewater in this study are copper, zinc, cadmium, iron, and lead.	Since only natural absorbents were used instead of any chemical mixtures, this research was not harmful to the environment.	(Wong, Zulkifli, Nordin, & Teow, 2021)
7	Sugarcane Pressmud was utilized as a natural absorbent in this study.	Iron, lead, cadmium, chromium, zinc, and magnesium extracted heavy metals from wastewater in this study.	This study was not harmful to the environment, Since only natural absorbents were used instead of chemically mixed ones.	(Azme, Murshed, Ishak, & Adnan, 2019)
8	This study utilized calcium alginate with polyvinyl alcohol as an absorbent.	Heavy metal named MN (VII) Manganese was removed from the IWW.	Using this method was eco-friendly, simple as well as safe for treating IWW.	(Rahman & Wilfred, 2018)
9	This study utilized the aqueous solution from an efficient absorbent and Tannin immobilized cellulose microspheres.	This study eliminated heavy metal ions such as Pb (II) lead.	This Absorbent was considered effective and cost-efficient, for the Objectives were unclear. Since proposed methods and analysis are not mentioned. The introduction is not clear.	(Pei, Xu, Wu, Tang, & Wang, 2019)

S.no	Name of Absorbent	Heavy metal extracted	Advantages	References
			Sentence formation is not clear. Add recent refs (2017 to 2021) The hypothesis is not properly framed. (only negative hypotheses are there, the positive hypothesis should also be included) e removal of heavy metal ions.	
10	In this study, an *Aloe berbadednsis*gel, as well as *Citrus aurantium* peel, were used as the absorbents for the extraction of heavy metals from textile industrial effluents.	Pb (Lead) has been eliminated from the textile industrial effluents.	Since only natural absorbents were used instead of any chemical mixtures, this method was not harmful to the environment.	(Sruthi & Shabari, 2018)
11	This study used *Prosopis julifora* seeds, peanut shells as well as MO (*Moringa oleifera*) seeds as absorbents for the extraction of heavy metals.	The heavy metal named Pb (Lead) was extracted in this study.	This approach is harmless to the environment Since only natural absorbents were used instead of chemically mixed ones.	(Gautam et al., 2020))
12	Banana peel-activated carbon has been used as a natural absorbent to eliminate heavy metals.	Heavy metal ions like chromium and copper have been extracted, followed by dyes.	It is a readily available natural absorbent, and also, they were eco-friendly; this method was harmless to the environment.	(Prastuti et al., 2019)
13	This study utilized NC (natural clay) from tangier Tetouan as an absorbent to eliminate heavy metals.	This study eliminated cadmium ions from synthetic wastewater.	Since it is a natural product, it is eco-friendly and readily available.	(Es-sahbany et al., 2021)
14	In this study, the activated carbon from *Gmelinaar borea, and Cordia millennia* were used as absorbents for extracting heavy metals.	The heavy metals extracted from textile industrial effluents in this study were Manganese, zinc, and cadmium.	This method is harmless to the environment Since only natural absorbents were used instead of chemically mixed ones.	(Fatokun, Owofadeju, Ewemoje, & Ewemoje, 2021)
15	In this study, CS/Clinic (silk/clinoptilolite) has been synthesized and utilized as an absorbent.	RG (red-green), KE-4BD as well as CR dyes (congo red) were eliminated from textile industrial effluent in this study. Reactive green KE-4BD (RG) and Congo red (CR) dyes in textile industrial effluent.	It is a natural product, and it is eco-friendly and readily available.	(Moradi, Hosseini Sabzevari, Marahel, & Shameli, 2021)

S.no	Name of Absorbent	Heavy metal extracted	Advantages	References
16	This study used the stem (petiole part) of the water lily in diverse experimental conditions.	Toxic dyes such as CR, the based textile dye, have been extracted in this study.	Since it is a readily available, environmentally friendly and low-cost solution, it is used more efficiently.	(Rahman, Sarker, Ahmed, Mustofa, & Awal, 2021)
17	In this study, treated clay mineral has been utilized as an adsorbent for extracting heavy metals.	Heavy metals such as iron and chromium were eliminated in this study.	It is an effective and suitable method for extracting iron and chromium from the WW (wastewater) medium.	(Dim & Termtanun, 2021)

Table 6 Heavy metal content in textile dyes (Oksal et al., 2022)

Heavy metal	In Effluent	Leaching from Dyed Textile	In Dyestuff
Antimony (Sb)	-	5.0 10.0 ppm	50 ppm
Lead (Pb)	-	0.2 1.0 ppm	100 ppm
Cadmium (Cd)	-	< 0.1 ppm	20 ppm
Nickel (Ni)	0.1 2.0 ppm	1.0 4.0 ppm	200 ppm
Zinc (Zn)	-	-	1500 ppm
Cobalt (Co)	0.1 2.0 ppm	1.0 4.0 ppm	-
Total Chromium (Cr)	0.1 2.0 ppm	0.2 1.0 ppm	100 ppm
Copper (Cu)	0.1 2.0 ppm	25.0 50.0 ppm	250 ppm
Arsenic (As)	-	0.2 1.0 ppm	50 ppm
Mercury (Hg)	-	< 0.02 ppm	4 ppm
Chromium 6	0.02 0.70 ppm		-
Tin (Sn)	-	-	250 ppm

8. Significance and applications

In recent years, great efforts have been devoted to the search for new cost-effective adsorbents derived from biomass (Tamjidi, Esmaeili, & Moghadas, 2019). The main significance of the study is to collect information about the removal of toxic heavy metal ions from textiles wastewater which has received much attention in recent years. Precipitation, ion exchange, and electrochemical methods are often used techniques that are adequate to remove heavy metals from wastewater, but ion exchange resins are quite expensive (Noor, Othman, Mubarak, & Abdullah, 2017). Some natural waste products act as natural ion-exchange or chelating agents and are usually available at no cost. Natural ion-exchange agents are reported to be very effective in removing heavy metals from dying wastewater (Habineza et al., 2017). This article reviewed the various metal-containing dye types and their heavy metal ions pollution from the entryway to the wastewater. It then briefly explored the effects on human health and the environment (Kadhom, Albayati, Alalwan, & Al-Furaiji, 2020). These exceptional adsorption properties of natural Absorbent support a position of ubiquity in our everyday lives. The collective representation of the textile wastewater's effective remediation methods is discussed and focused on the natural adsorption methods(Gu, Kang, Wang, Lichtfouse, & Wang, 2019). Hence there exists an urgent requirement that all kinds of possible natural and inexpensive adsorbents have to be explored to determine their feasibility in heavy metal removal (Abalaka et al., 2021). Understanding the critical impact of the natural materials' adsorption portfolio for heavy metal ions removal is also discussed. Various heavy-metal ions and their pollutant effect, ways to remove such heavy metal ions, and the role of natural absorbents, including their demand, perspective, limitation, and relative scopes, are discussed elaborately in the review.

Therefore, there is an urgent need that all possible sources of agro-based inexpensive adsorbents should be explored, and their feasibility for the removal of heavy metals should be studied in detail

9. Conclusions

The analysis of previous studies and existing literature suggested that adsorption is an effective technique in extraction percentage and economic possibility. If the adsorption was performed with natural adsorbents such as agricultural wastages, it further enhances the stability of the environment. Natural absorbents benefit from an ordered structure, high specific surface area, and flexible surface functionalization options, which are indispensable to realizing a high performance of heavy metal ion removal. This study provides a comprehensive review of the extraction of heavy metals with different natural adsorbents such as *P. juliflora* bark, bio-adsorbents, sugarcane bagasse, banana peels, and rice husk. Additionally, special focus is given to the extraction of cadmium, lead, and chromium. The study contributed explored less expensive adsorbents and their utilization possibilities for various natural bio absorbents for the elimination of heavy metals from wastewater. In recent years, the urgent need for safe and economical methods for the elimination of heavy metals from contaminated waters has necessitated research interest in the production of low-cost alternatives to commercially available activated carbon. Therefore in the future, all possible sources of agro-based inexpensive adsorbents will be explored, and their feasibility for the removal of heavy metals will be studied in detail.

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