Review on toxic metal ions removal by using activated carbon prepared from natural biomaterials

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Abstract. Heavy metals has wide range of applications including industrial, domestic, medical, agricultural and technological field. Due to industrialization and urbanization variety of heavy metal ions are released in the environment. Toxicity of heavy metal ions depends on the route of exposure, media of exposure and its dose. Some of the metals, due to its high degree of toxicity are incorporated in CERCLA (Comprehensive Environmental Response, Compensation and Liability Act) priority list of hazardous substances. According to CERCLA, arsenic is the top most toxic metal followed by lead and mercury. These metals are proven to be carcinogens for human beings even at lower concentration. Contamination of water resources by toxic metal ions is a common problem since past years. There exists different methods for removal of toxic metal ions from waste water but adsorption is the most widely used and effective method. There are several adsorbents used for adsorption of toxic metal ions but, adsorbents prepared from low-cost and ecofriendly raw materials like coconut shells, rice husk, sugarcane bagasse, banana peels, potato peels, corncob, wheat straw, neem barks, almond shells and others are capturing researcher’s attention due to its easy availability and effective removal efficiency. This review highlights low cost adsorbents used for elimination of heavy metal ions from waste water and its other usage possibilities based on the literature study. This paper also highlights emerging potential bio-adsorbents which can provide maximum removal efficiency.

Keywords. adsorbent, adsorption, biomaterials, heavy metal ions

1. Introduction
Technological advancement give rise to many environmental challenges. Industrial, domestic, agricultural and mining activities are causing contamination of environmental resources like water [1]. World is currently struggling with a problem of water pollution. Water pollution is caused by natural activities such as volcanic eruptions and weathering of rocks which is responsible for heavy metal release. Heavy metals are naturally occurring, high atomic weight elements with density five times more than that of water. Some of the heavy metals like, zinc, copper, cobalt, chromium, manganese and iron are essential nutrients. These are required for biochemical, physiological
functions and deficiency of these nutrients can invite chronic diseases [2]. But, excess of Heavy metal contamination and human exposure is a result of natural and man-made (anthropogenic) activities. Air, water, soil, food, biota and sediments are the major media of exposure of toxic metals. There are various routes of exposure like inhalation, ingestion and skin or dermal absorption [3]. Excessive exposure of toxic metals affects normal function of the body causing toxic metal poisoning [4]. Toxicity can result due to acute exposure and chronic exposure. Symptoms can vary depending on the nature of exposed metal, the amount of metal absorbed, and the age of the person. Acute exposure can cause vomiting, diarrhea, and abdominal pain whereas chronic exposure leads to body organs damage, and risk of cancer [5]. Although toxic metal poisoning could be clinically identified and cured, the best way is to prevent toxic metal pollution and the subsequent human poisoning [6]. There are various methods exists for elimination of toxic metal ions from water and waste water. Methods applied for the elimination of heavy metals includes chemical precipitation, ion exchange, chemical oxidation, reduction, reverse osmosis, ultrafiltration, electrodialysis and adsorption. Amongst these methods, adsorption is the most efficient technique because of its flexibility in design and possibility of regeneration of adsorbent. Other methods have certain restrictions like large amount of sludge generation or precipitate, less efficient, critical operating conditions and costly sludge disposal [7]. Hence, adsorption method is preferred for removal of heavy metal ions from water or waste water. Many researchers have studied various commercial adsorbents and adsorbents prepared from natural raw materials. The commercial adsorbents available are graphene, activated carbons, alumina and silica gel, but, due to its high cost they are not preferable. Therefore, low-cost bio-adsorbents are preferred over costly commercial adsorbents [8].

2. Various heavy metal ions and its toxic effects
Some of the heavy metals like As, Pb, Hg, Cd and Cr are posing severe health effects. Arsenic toxicity can be of acute or chronic type. Acute arsenic toxicity may results in damage of vessels of blood, tissues of gastro intestine and can affect the heart and brain. Chronic arsenic toxicity called as “arsenicosis” usually focus on skin problems like pigmentation and keratosis [9]. Lead poisoning is mostly associated with gastrointestinal tract and central nervous system problems in youngsters and adults [10]. Acute exposure of lead can cause headache, loss of appetite, abdominal pain, fatigue, sleeplessness, vertigo, hypertension and arthritis while chronic exposure may cause birth defects, mental retardation, allergies, paralysis, dyslexia, hyperactivity, kidney damage, brain damage and may even cause death. Exposure to mercury can damage the kidney, brain and developing fetus [11]. Short-term exposure to metallic mercury vapors at higher levels can lead to vomiting, nausea, skin rashes, diarrhea, lung damage, high blood pressure. Chronic levels of mercury exposure can cause a disease condition characterized by excitability, tremor of the hands, memory loss, timidity, and insomnia [12]. Long-term exposure to cadmium leads to its saturation in bones and lungs. Inhalation of cadmium can results in severe damages to the lungs and respiratory irritation while its ingestion in higher dose can cause stomach irritation resulting to vomiting and diarrhea [13]. Cadmium exposure leads to “Itai-itai” disease, an epidemic of bone fractures in Japan [14]. Chromium (VI) has the tendency to cause allergic reactions to the body. Inhaling high levels of chromium (VI) can cause irritation to the lining of the nose and nose ulcers. Exposure of extremely high doses of chromium (VI) compounds can result in severe cardiovascular, respiratory, hematological, gastrointestinal, renal, hepatic, and neurological effects and possibly death [15].

3. Methods for heavy metal ions removal
Methods available for heavy metal removal includes ion exchange [16, 17], chemical precipitation [18, 19], coagulation [20], membrane separation [21], electro-coagulation [22], reverse osmosis [23, 24], adsorption [25] and disinfection [26]. Due to high cost and low feasibility of these methods, adsorption [25] is one of the preferred method for heavy metals removal with high efficiency and low cost. The various methods adopted for reducing water pollution are listed below:
3.1. Precipitation and coagulation
Precipitation process converts water soluble salts into insoluble precipitates by adding chemical reagents. This technique is used for softening of water, removal of heavy metal ions, phosphorous removal, fluoride removal and removal of dyes. Limitation: Sludge formation and disposal

3.2. Distillation
In this method, impurities are separated by applying heat based on the boiling points. Different components present in water have different boiling point were separated by vapour pressure characteristics. Limitation: Consume large amount of heat (Expensive method)

3.3. Ion-exchange
Ion exchange resins are long chain polymers containing loosely bonded ions capable of exchanging cation or anion present in water. Limitation: Acidic or alkaline water may limit the ion-exchange capability. Oil or grease can clog the pores of resin and are expensive than adsorbents.

3.4. Reverse osmosis
In this process, flow of ions takes place from solution to solvent side through semipermeable membrane. Limitation: Membrane may clog after prolonged use.

3.5. Adsorption
It is surface phenomenon in which dissolved components gets adhere to the porous surface of adsorbent. Due to vanderwalls forces (Physisorption) and covalent forces (Chemisorption), adsorption phenomenon takes place. This is very cost-effective and popular method. For adsorption process, activated carbons, activated alumina, zeolite, silica gels type of conventional adsorbents as well as natural adsorbents can be used. “Adsorption” is the high capacity method in which regeneration of spent adsorbent was also possible.

4. Adsorption
Adsorption phenomenon takes place on the surface of ‘adsorbent’. The substance which is to be removed is called as ‘adsorbate’. The substance which is used for adsorption is called as ‘adsorbent’. The process of accumulation of adsorbate on the surface of adsorbent is called as “Adsorption”. The adsorption process is used to remove inorganic and organic pollutants from water. Various conventional adsorbents were used for adsorption like commercial activated carbons prepared from wood, peat, coconut shells and coals. Adsorbents from inorganic materials like activated alumina, silica gel, zeolites and ion-exchange resins were also used. Non-conventional adsorbents includes, adsorbents from natural materials, agricultural waste, industrial byproducts and biomass [27-29]. Commercial activated carbon is pretty costly depending upon its quality. On the basis of conditions of carbonization, activation and function of the raw material used different qualities of carbon can be prepared. The high absorbing capacity of activated carbons is its bigger advantage and no longer needs to be proved, sometimes the regeneration of spent carbon is very expensive which may results in loss of the adsorbent. Because of this reason use of commercial activated carbon is restricted in particular small and medium scale industries [30]. Hence, adsorbents from natural raw materials such as agricultural waste products are seeking attention of researchers due to its low cost and easy availability.

5. Natural raw materials as a low cost adsorbents
Activated carbon is the form of carbon with porous structure and which is used as an adsorbent. Activated carbon has high adsorption property. It binds molecules, atoms or ions. It is obtained from environmental friendly waste materials which has high carbon content. Preparation of activated carbon
means heating carbonaceous materials to very high temperature. The activation of charcoal makes the bonding sites free. Activation process will reduce pore size in charcoal and makes more holes in the molecules thereby increasing its overall surface area which increases adsorption property. The parent material selection for activated carbon production should satisfy these points (i) Inorganic matter should be low (ii) Easy availability and low cost (iii) Less degradation during storage (iv) Easy to activate and hence, demand of naturally available materials is increasing day by day [31].

Activated carbon obtained from natural biomaterials exhibit various properties like catalytic activity, adsorption efficiency, high porosity and high surface area [32]. Environmentally friendly, economically feasible and easily designable adsorbents for removal of toxic metal ions from water have gained popularity in recent years. In this regard, use of adsorbents from agricultural biomass has become important. These adsorbents have proven to be an ideal material for removal of heavy metals from water. The potential of adsorbent is influenced by different factors such as source of biomass, method of preparation, reaction conditions and reaction mechanism [33, 34].

5.1 Toxic metal ions removal by activated carbon prepared from Rice husk
Nhapi I. et al. (2011) reported the preparation of activated carbon from activated and carbonized rice husks for the removal of Cu (II), Cd (II), Pb (II) and Zn (II). In his experiment, rice husk was first washed with distilled water and dried at 100°C. Then, the dried husk allowed to heat at 500°C in oven for 3 hours so as to obtain carbonized rice husk. Based on the adsorption studies, it was found that activated rice husk has high potential to remove heavy metals than carbonized rice husk [35]. Ying Zhang et al. (2014) was studied removal of Cu (II) by using phosphoric acid activated rice husk. The rice husk was washed and dried at 60°C. The rice husk was mixed with 1M H₃PO₄ for 24 hours. The modified husk was washed till pH reaches to 7 and then dried for 4 hours at 110°C. Based on the adsorption studies it was found that maximum adsorption amount was 17.0358 mg/g with adsorbent dose of 2 g/l at pH 4. The % removal of Cu (II) found to be 88.9% [36]. Hanum F et al. (2017) utilized HCl activated rice husk for Pb removal from car battery waste water. The activation temperature was 400-600°C for 90-150 min. The results showed that adsorption capacity was 0.56731mg/g and % removal was 54.85 [37]. Liu Zhiyuan (2020) removed Hg (II) from aqueous solution by using rice husk derived activated carbon. The chemical activation was carried out by using KOH at 850°C for 1 hour. The results revealed that maximum removal capacity was 55.87 mg/g [38]. El-Shafey (2010) studied removal of Zn(II) and Hg(II) by using rice husk as a precursor and sulphuric acid as an activator. The study was based on adsorption by Zn(II) & Hg(II) dry sorbents and wet sorbents. The sorption capacity of sulfuric acid treated rice husk (dry sorbent) and (wet sorbent) for removal of Zn was found to be 18.94 mg/g and 19.38 mg/g respectively. The sorption capacity of sulfuric acid treated rice husk (dry sorbent) and (wet sorbent) for removal of Hg was found to be 303.03 and 384.62 mg/g respectively [39].

5.2 Toxic metal ions removal by activated carbon prepared from Sugarcane Bagasse
Thuan Van Tran et al. (2016) done the comparative study of removal of Cu⁺, Ni⁺ and Pb⁺ by Zinc Chloride activated sugarcane bagasse. In his study, bagasse was washed and dried. The dried bagasse was soaked in ZnCl₂ for 24 hours. The mixture was then heated at 500°C for 1 hour under nitrogen condition. The final material was washed till pH=7 was obtained and then dried at 105°C for 24 hours. The results showed that, the highest removal % was 98 for Pb, 90 for Cu and 65 for Ni with adsorption capacity of 19.3 mg/g, 13.24 mg/g and 2.99 mg/g [40]. Javidi Alsadi et al. (2019) studied usage of Sugarcane Bagasse for preparation of Activated Carbon and used this for Adsorption of Mercury. In this, how contact time of adsorbent (10, 20, 30, 45, 60, 90, 120, 180 min), pH (2, 3, 4, 5, 6, 7, and 8), agitation speed (220, 320, 420 rpm), activated carbon mass (0.2, 0.3, 0.5, 0.7 g) and the initial concentration of mercury (0.52, 5, 10, 15, 20 ppm) affects the mercury adsorption were studied. The results of the experiments indicated that pH 8 is the best pH for removing the highest amount of mercury with % removal efficiency of 82.88, 100 and 79.5 for Hg, Pb and Cd respectively [41]. Mohd Adib Mohammad Razi et al. (2018) studied Heavy Metals ions removal from Wastewater of Textile industries. Researcher used Sugarcane Bagasse for making of activated carbon. Chemical activation was done by
using phosphoric acid as an activator at 500 °C for 2 hours. The final product obtained was allowed to washed and dried. The optimum pH and dose of adsorbent was 6 and 4 g/l for Fe and 5 and 4 g/l for Zn respectively. The removal efficiency was 91% and 89% for Fe and Zn respectively [42]. I U Salihi et al. (2017) studied adsorption of Pb ions on activated carbon made from sugarcane bagasse. From the study, it was found that extent of adsorption dependent on adsorbent dose and pH. The optimum pH for adsorption was 5 with dose of adsorbent as 10 g/l. The maximum removal efficiency found to be 87.3% with adsorption capacity of 23.4 mg/g [43]. Ghulam Shah et al. (2018) used natural, pyrolyzed and acid assisted pyrolyzed sugarcane bagasse for removal of lead from polluted water. Author showed the comparative study of natural bagasse, pyrolyzed bagasse and acid assisted pyrolyzed bagasse. Results revealed that, acid assisted pyrolyzed bagasse gives best removal efficiency of 98 % followed by pyrolyzed and natural bagasse [44].

5.3. Toxic metal ions removal by activated carbon prepared from Banana Peels
Yingchun Li et al. (2016) utilized banana peel derived activated carbon for removal of Cu, Pb, Cd and Cr ions from water. The adsorption capacities of Cu\(^{2+}\), Pb\(^{2+}\) Cd\(^{2+}\) and Cr\(^{3+}\) was estimated to be 49.5, 45.6, 30.7 and 25.2 mg/g respectively with % removal efficiency of 99.84, 97.53, 94.69 and 88.02 for Cu, Pb, Cd and Cr respectively [45]. Tran Van Thuan et al. (2016) used banana peels for removal of Cu\(^{2+}\), Ni \(^{2+}\) and Pb \(^{2+}\). For activation, researcher used KOH as an activating agent. Under N\(_{2}\) atmosphere, precursor was first carbonized at 500 °C for 1 h with rise in temperature of 10 °C/min. KOH was used to soak the char for 24 h. The impregnation ratio of prepared char and KOH was 1:1 (weight %). Under N\(_{2}\) atmosphere KOH impregnated char was further heated at 500 °C for 0.5 h. Finally, obtained activated carbon was washed with distilled water followed by drying at 105 °C for 24 h. The maximum adsorption capacity found was Cu\(^{2+}\) (14.3 mg/g), Ni\(^{2+}\) (27.4 mg/g) and Pb\(^{2+}\) (34.5 mg/g) [46]. Olaoye R A (2018) studied HCl activated banana peels for removal of cyanide, lead, chromium and cadmium. It was observed from studies that, with increase in dose of adsorbent and reaction time, cyanide removal also increases. The maximum removal % at pH 7.2 for CN\(^{-}\), Pb, Cr and Cd was found to be 96.45, 98, 88.9 and 98.4 respectively with adsorption capacities of 0.93, 0.98, 0.84 and 0.93 respectively [47]. Bibaj E et al. (2018) utilized phosphoric acid activated banana peels for removal of nickel ions. Activation done at 400, 500 and 600°C by two methods hydrothermal and pyrolysis treatment for 2 hours. It was concluded from the results that adsorption capacity of pyrolyzed carbon was higher than obtained by hydrothermal process. The adsorption capacities was 282.98 and 265 mg/g for pyrolyzed and hydrothermal formed carbons respectively [48].

5.4. Toxic metal ions removal by activated carbon prepared from Coconut Shells
Gueu S. et al. (2006) prepared activated carbon from coconut shell or seed shells of palm tree for removal of Pb, Cu and Zn. Researcher mixed coconut shells with conc. orthophosphoric acid and carbonized at 300°C for 16 hours. After rinsing of mixture with distilled water, it was dried at 105°C in oven for 24 hours. The optimum pH found was 4 and optimum activation temperature was 400°C. The % removal capacity was 19, 34 and 39 for Pb, Cu and Zn respectively [49]. Singh & Waziri et al. (2019) studied adsorption of heavy metal ions like Cd, Cr, Cu, Pb, Ni and Zn by using corncob and coconut shell based activated carbon. The raw materials were dried, grinded and crushed. Precursor was pyrolyzed at 300-400°C in muffle furnace for 1 hour. Pyrolyzed material was soaked with KOH at ratios 1.0, 1.5 and 2.0. Then, mixture was heated at 500°C, 550°C and 600°C for 1 hour to improve surface area. The characterization of activated carbon were done. Based on the adsorption studies, it was found that the order of performance is Ni>Cr>Pb>Zn>Cu>Cd in case of corncob activated carbon whereas, it is Cu>Pb>Cr>Zn>Ni>Cd in case of coconut shell [50]. Mokhlesur M. Rahman et al. (2014) studied oil palm and coconut shell based activated carbon for removal of heavy metal ions such as Ni(II), Pb(II), and Cr(VI). Researcher used phosphoric acid for activation. Cr(VI) removal was studied by acid activated and commercial activated carbons at different pH. The adsorption capacity found was 74.6, 19.6 and 46.3 mg/g for Pb, Ni and Cr respectively. The % removal of Pb, Ni and Cr was found to be 97, 95 and 64 respectively. It has been observed from the isotherm studies that prepared activated carbon
works better at lower concentration while, commercial carbon works better at higher concentration [51]. Chemgwen Song et al. (2013) utilized coconut shell based activated carbon for removal of lead ions from aqueous solution by using KOH as an activator. Two different impregnated carbon with ratio 1:2 and 2:1 activated at 800°C for 1 hour. The adsorption capacity achieved was 112.36 and 151.52 mg/g for the ratio 1:2 and 2:1 respectively [52]. Bernard et al. (2013) utilized coconut shell based activated carbon for removal of Cu²⁺, Fe²⁺, Zn²⁺ and Pb²⁺. The activation carried out at 500°C for 2-3 hours by using zinc chloride as an activator. The % removal efficiency found to be 88.07, 84.29, 45.40 and 100 for Cu²⁺, Fe²⁺, Zn²⁺ and Pb²⁺ respectively [53]. L Onyeji (2011) removed Hg(II), Pb(II) and Cu(II) present in dye effluent by coconut shell activated carbon. The activator used was zinc chloride and activation temperature was 450°C for 1 hour. It was observed from the studies that, for adsorption of Pb(II) ion, Hg(II) ion and Cu(II) ion , the optimum pH was 12 with % removal of 88, 90 and 32 respectively. The adsorption capacities of Pb(II), Hg(II) & Cu(II) in mg/g were 24.4, 17.24 & 10 respectively [54].

5.5. Toxic metal ions removal by activated carbon prepared from Potato peels
J.C. Moreno-Piraján removed Cu (II) ions by using activated carbon obtained from potato peels. Chemical activation was done by using zinc chloride at 823K for 4hours. A well-developed pore structure, high adsorption capacities and surface area of 1078 m²/g was obtained on pyrolysis of potato peels impregnated with zinc chloride. The pore volume was 0.97cm³/g. The sorption capacity achieved was 62 mg/g. From the results, it was found that low impregnation ratios leads to microporous ACs with low areas and high impregnation of ZnCl₂ achieves high areas [55]. Z George (2014) used pyrolyzed potato peels for removal of Cobalt ions. Chemical activation was done by using phosphoric acid at 400°C, 600°C and 800°C for 2 hours. It was observed from the study that if pH increases from 2-5, % removal also increases for all temperatures. At pH 6, highest cobalt adsorption of 85.7 % at 400°C and 92 % at 600°C was found. The adsorption capacity obtained was 373 mg/g at 400°C and 405 mg/g at 600°C [56].

5.6. Toxic metal ions removal by activated carbon prepared from Tamarind seeds
Sumrit Mopoung et al. (2015) used KOH activated tamarind seeds carbon for removal of Fe (III) adsorption. In his study, activation temperature was 500°C, 600°C and 700°C for 1hours. The adsorptions capacity at 500°C using KOH to tamarind seed charcoal ratio of 1:1 is found to be 0.0069 -0.019 mg/g. From the study, it has been observed that, as temperature increases from 500-700°C, % yield of tamarind seeds based activated carbon decreases [57].

5.7. Toxic metal ions removal by activated carbon prepared from Wheat Straw and Corn Straw
Suhong C et al. (2010) used wheat straw carbon for removal of Cr(VI). In his study, the maximum adsorption capacity of modified wheat straw for the removal of Cr(VI) was found to be 322.58 mg/g at 328K [58]. Youning Chen (2020) prepared activated carbon from wheat straw and corn straw for removal of Cr(VI) and Cr(III). The adsorption capacity of wheat straw was 125.6 mg/g and 68.9 mg/g for Cr(VI) and Cr(III) respectively whereas for corn straw it was 87.4 mg/g & 62.3 mg/g respectively [59].

5.8. Toxic metal ions removal by activated carbon prepared from Waste Coirpith
K. Kadirvelu et al. (2010) removed Pb(II) from aqueous solution by using waste coirpith (material that binds coconut fiber in the husk). As pH increases from 2 to 5, % removal of Pb ions also increases. The adsorption capacity determined was 263 mg/g at pH 5. Desorption was also carried out by using dil. Hydrochloric acid [60].

Mathew Blessy et al. (2016) presented review on reduction of toxic metals by using bioadsorbents. In this review types of adsorption, factors affecting adsorption, existing technologies and green technologies were discussed. The conclusion drawn for this review was, as temperature increases, adsorption capacity
decreases. As pressure increases, adsorption also increases up to saturation point but after that, no adsorption takes place. As surface area increases, adsorption efficiency also increases. Existing technologies discussed were physical method, chemical method and biological methods [61]. Vinod Kumar Gupta et al. (2015), presented review on bioadsorbents for remediation of heavy metals. This paper includes review of different biomass used for removal of different toxic metal ions like Cd(II), Cr(VI), Cu(II), Pb(II), Hg(II), Ni(II), Zn(II) and Se(IV). The biomass used were rice husk, wheat waste, coconut waste, fruit peels, date seeds, coffee waste, tea waste, barks etc. Cd(II) removal by using phosphate treated rice husk gives highest adsorption capacity as 2000 mg/g [62].

The study of various researchers using activated carbons prepared from natural biomaterials is tabulated in table 1.

| Natural biomaterials used | Heavy metal ions removed | Adsorption capacity (mg/g) | % Removal | Ref no. |
|--------------------------|---------------------------|-----------------------------|-----------|--------|
| Rice Husk                | Cu(II)                    | 54.3                        | 74.4      | 32     |
| Rice Husk                | Cd(II)                    | 8.24                        | 43.4      | 32     |
| Rice Husk                | Pb(II)                    | 51.4                        | 70.08     | 32     |
| Rice Husk                | Zn(II)                    | 56.7                        | 77.2      | 32     |
| Rice Husk                | Cu(II)                    | 17.0358                     | 88.9      | 33     |
| Rice Husk                | Pb                         | 0.56731                     | 54.85     | 34     |
| Sugarcane Bagasse        | Cu                         | 19.3                        | 98        | 37     |
| Sugarcane Bagasse        | Ni                         | 13.24                       | 90        | 37     |
| Sugarcane Bagasse        | Pb                         | 2.99                        | 65        | 37     |
| Sugarcane Bagasse        | Hg                         | 107.75                      | 82.88     | 38     |
| Sugarcane Bagasse        | Pb                         | 0.625                       | 100       | 38     |
| Sugarcane Bagasse        | Cd                         | 2.425                       | 79.5      | 38     |
| Sugarcane Bagasse        | Pb                         | 23.4                        | 87.3      | 40     |
| Acid assisted Sugarcane Bagasse | Pb | 66.225 | 98 | 41 |
| Pyrolyzed Sugarcane Bagasse | Pb | 57.803 | 95 | 41 |
| Natural Sugarcane Bagasse | Pb | 53.475 | 90 | 41 |
| Banana Peels             | Cu                         | 49.5                        | 99.84     | 42     |
| Banana Peels             | Pb                         | 45.6                        | 97.53     | 42     |
| Banana Peels             | Cd                         | 30.7                        | 94.69     | 42     |
| Banana Peels             | Cr                         | 25.2                        | 88.02     | 42     |
| Banana Peels             | Cu²                         | 14.3                        | 46.3      | 43     |
| Banana Peels             | Ni²                         | 27.4                        | 52.2      | 43     |
| Banana Peels             | Pb²                         | 34.5                        | 43.8      | 43     |
| Banana Peels             | CN                         | 0.93                        | 96.45     | 44     |
| Banana Peels             | Pb                         | 0.98                        | 98        | 44     |
| Banana Peels             | Cr                         | 0.84                        | 88.9      | 44     |
| Banana Peels             | Cd                         | 0.93                        | 98.4      | 44     |
| Banana Peels: Pyrolyzed method | Ni | 288 | 98.8 | 45 |
| Banana Peels: Hydrothermal method | Ni | 222 | 99.2 | 45 |
| Coconut shell & Oil Palm | Pb                         | 74.6                        | 100       | 48     |
| Coconut shell & Oil Palm | Cr                         | 46.3                        | 78        | 48     |
| Coconut shell & Oil Palm | Ni                         | 19.6                        | 95        | 48     |
| Coconut shell             | Pb                         | 112.36                      | 35        | 49     |
| (Impregnation Ratio 1:2) |                            |                             |           |        |
| Coconut shell             | Pb                         | 151.52                      | 45        | 49     |
| (Impregnation Ratio 2:1) |                            |                             |           |        |
6. Conclusions

This review displays the use of different bio-adsorbents for removal of toxic metal ions like Pb, Cu, Zn, Cr, Cd, Ni, Hg, Co etc. Bio-adsorbents can be advantageous replacements for commercially available carbons. In some research, optimum conditions for maximum removal efficiency were studied, whereas in some papers, comparison of commercial activated carbon over bioadsorbents was studied. Pore size of adsorbent, pH, initial concentration, activation temperature, particle size of adsorbent, time of contact are the factors which affects adsorption capacities and removal efficiencies. Bioadsorbents are not only cheap, easily available, regenerated easily but also have great affinity towards removal of heavy metal ions. Hence, in line with this one can go for further research and can search optimum conditions for maximum removal by changing the temperature, dose of adsorbent and other parameters.

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