REVIEW ARTICLE

European Journal of Energy Research
www.ej-energy.org

Roles of Biomass in the Absorption of Heavy Metals

I. A. Adegoke, A. R. Ige, O. R. Adejoba, D. A. Aruwajoye, J. James

ABSTRACT

Mining, plating, dyeing, automobile manufacturing, and metal processing all emit toxic heavy metals into the environment. The environmental challenges, socioeconomic and environmental effects of toxic heavy metals released into the environment cause environmental problems that have exposed our ecosystem to a greater threat, as well as contamination of aquatic water bodies through water runoff, with a subsequent effect on people's health. As a result, research into the roles of biomass as a mitigation process in heavy metal absorption is required. As a result, the purpose of this paper is to investigate the roles of biomass as a medium for heavy metal absorption in contaminated soil. The use of bio-char and other carbonaceous materials such as activated carbon, sawdust, and agricultural residues has shown great potential for the removal of various inorganic and organic pollutants and radionuclides due to properties such as large surface area, micro porous structure, and high adsorption capacity. Pulverized activated charcoal, a promising material based among nano-structured carbon materials, continues to attract a lot of attention due to its unique physical and chemical properties. Lower greenhouse gas emissions and a cleaner environment are two additional environmental benefits of biomass as a renewable energy source. The importance of biomass as a potential natural remediation material cannot be overstated based on the use of biomass waste to treat or resolve anthropogenic environmental problems.

Keywords: Biomass, bio-char, pollution, remediation, toxic heavy metals.

Published Online: April 15, 2022

ISSN: 2736-5506

DOI :10.24018/ejenergy.2022.2.2.47

I. A. Adegoke*
Department of Forestry, College of Agriculture, Fisheries and Forestry, Fiji National University, Fiji Island.
(e-mail: idowu.adegoke@fnu.ac.fj)
A. R. Ige
Department of Applied Chemistry, Kebbi State University of Science and Technology, Kebbi State, Nigeria.
(e-mail: igeayodeji2@gmail.com)
O. R. Adejoba
Department of Forest Product Development & Utilization, Forestry Research Institute of Nigeria, Jericho Hill, Ibadan, Oyo State, Nigeria.
(e-mail: dejob_j@yahoo.com)
D. A. Aruwajoye
Department of Forestry Technology, Federal College of Agriculture Akure, Nigeria.
(e-mail: aruwajojeadewale@gmail.com)
J. James
Department of Forestry and Wildlife Management, Federal University, Gashua, Yobe State, Nigeria.
(e-mail: james4realx@gmail.com)

****Corresponding Author***

I. INTRODUCTION

Mining, plating, dyeing, vehicle manufacture and metal processing are just a few of the industries that leak toxic heavy metals into the atmosphere. Heavy metals' presence in the environment has resulted in a slew of environmental problems. To achieve most countries' eco-friendly quality principles, heavy metal concentrations in the environment need be controlled [1]-[4]. The dumping of heavy metals into aquatic systems has been a cause of widespread concern in recent decades. These contaminants are heavily injected into aquatic systems as a result of numerous industrial processes. For decades, the community has been committing concerted efforts to the treatment and removal of heavy metals in order to tackle this problem. Metal ions are commonly removed from dilute aqueous streams by chemical precipitation, reverse osmosis, and solvent extraction [5]. These approaches, on the other hand, have limitations such as insufficient metal removal, high reagent and energy requirements, and the production of hazardous sludge or other waste products that must be disposed of.

Heavy metals like lead, zinc, and chromium are used in a variety of products, including basic steel, paper and pulp, leather tanning, organo-chemicals, petrochemicals, fertilizers, and more. Vehicles and battery manufacturers are the biggest contributors of lead pollution. Zinc and chromium are primarily utilized in fertilizers and tanning leather, respectively [6]. The number of heavy metal ions released into the environment has increased as a result of industrial operations and technological advances.

Furthermore, indiscriminate dumping has been a source of worldwide worry for many years due to its toxicity, accumulation in the food chain, permanence in nature, and concentration by organisms. Heavy metals are non-biodegradable and accumulate in living beings, resulting in a variety of diseases and ailments. As a result, it's critical to lower harmful metal levels in wastewaters or entirely eliminate them before they're released into the environment. Then there's the reduction and assessment of dangerous substances in the environment like lead (Pb) and uranium (U). Heavy metals are non-biodegradable and accumulate in living beings, causing a wide range of diseases and problems.

As a result, it's vital to cut harmful metal levels in waste waters or eliminate them entirely before they're released into the environment. The reduction and assessment of dangerous contaminants such as lead (Pb) and uranium (U) in the environment are also crucial from an environmental standpoint [7]. Carbonaceous materials, such as activated carbon (AC), bio-char, and carbon nanotubes, have lately been used in adsorption. Activated carbon has demonstrated tremendous potential for the removal of various inorganic and organic contaminants as well as radionuclides due to qualities such as wide surface area, microporous structure, and high adsorption capacity. Due to its unique physical and chemical properties, powdered activated charcoal continues to attract a lot of attention as a promising candidate among nanostructured carbon materials. Chemical functionalization of activated carbon, in particular, can alter its physical and chemical properties, improving performance in a range of applications. Through surface morphological alterations with certain functional groups, AC activation is recognized to play a key role in enhancing adsorption efficiency [7].

The use of biological materials for heavy metal removal and recovery technologies (Biosorption), which has gained substantial respect in recent years due to its excellent performance and low cost, has focused on the quest for alternative and creative treatment strategies [8]. The natural affinity of biological molecules for metallic elements may assist in lowering the cost of removing heavy metals from wastewater [9]. Metal-binding capacities of microorganisms (bacteria, yeasts, fungus, and algae) and some plants are particularly intriguing among the different resources in biological wastes.

The utilisation of dead biomass reduces both the toxicity concern and the cost of fertilizer delivery and culture upkeep. A thorough evaluation of metal biosorption utilizing nonliving biomass was undertaken by [10]. An affordable, naturally accessible plant biomass can be employed as a material for the removal of harmful heavy metal ions from synthetic solutions and industrial effluents as an alternative to conventional technologies [11]-[14].

II. Biomass Scope

Wood, vegetables, seaweed, and animal waste are all examples of biomass that can be used as an energy source. Biomass is most likely our earliest source of energy after the sun. For thousands of years, people have used wood to heat their houses and cook their food. Biomass receives its energy from the sun. Sun-stored energy can be found in all organic stuff. Photosynthesis is the process by which plants transform water and carbon dioxide into oxygen and carbohydrates using the energy provided by sunlight. Carbohydrates are sugars that supply energy to plants and animals that eat plants. Carbohydrate-rich diets provide the human body with a good source of energy. Biomass is a renewable energy source since its sources are not limited.

From a biochemical aspect, biomass is the mass of living organisms such as plants, animals, and microbes, as well as cellulose, lignin, carbohydrates, lipids, and proteins. Plant tissues such as leaves, twigs, branches, and boles, as well as tree roots and grass rhizomes, are all included in biomass. Biomass is commonly quantified in dry weight and reported as a mass per unit area (g m or Mg ha) (water removed by drying). Unless otherwise stated, biomass is made up entirely of living organisms. Although the fact that soils contain biomass in the form of bacteria, fungus, and meiofauna, neither deadwood nor organic soil debris are termed biomass. Soil biomass (both living and dead microbes) accounts for approximately 5% of soil organic matter [15].

III. Available Biomass in Nigeria

A. *Wood and Agricultural Wastes*

All materials originating from biological sources, including both plants and animals, are referred to as biomass. Nigeria has an abundance of biomass products from the forestry and agriculture industries. Agro-residues such as rice husks, crushed nut shells, corn curbs, sugar cane trash, coconut shells, and sorghum stalks are among the many raw materials available. Forest residues, on the other hand, are made up of tree branches, sawdust, wood shavings, offcuts, and other byproducts of the timber harvesting process. Wood and wood waste are used to generate electricity.

B. *Agricultural Residues*

Agricultural-based industries generate a massive amount of residues every year. If these residues are not properly disposed of, they may pollute the environment and have a negative impact on human and animal health. Because most agro-industrial wastes are untreated and underutilized, they are typically disposed of by burning, dumping, or unplanned landfilling. By increasing the amount of greenhouse gases in the atmosphere, these untreated wastes contribute to climate change. Agriculture residues are further divided into two types: field residues and process residues. After crops have been harvested, field residues are residues that remain in the field.

Leaves, stalks, seed pods, and stems are examples of field residues, whereas process residues are those that remain after the crop has been processed into another useful resource.

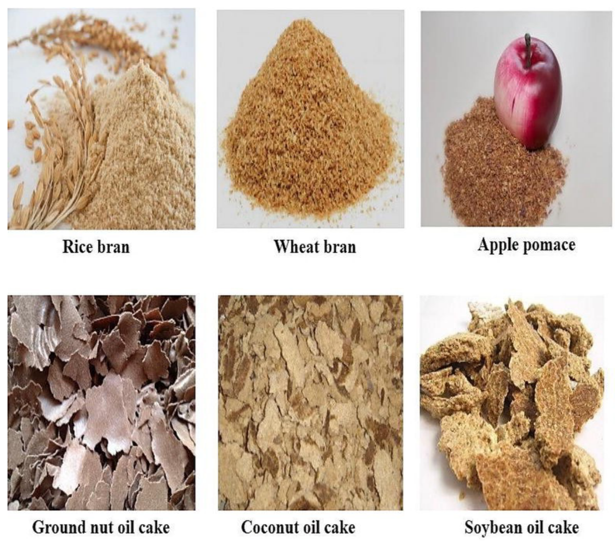

Fig. 1. Images of various Agricultural wastes.

C. Forest Residues

Timber harvesting operations produces a large quantity of waste in the form of tree offcuts, branches, and tops as a result of harvesting, pruning, or thinning of timber. Sawmilling, the largest sector of the timber industry, has sustained an upward growth trend, whereas potential downstream pulp, paper, and board industries have either ceased or are declining as a result of the economic downturn [16]. As a result, demand for sawmill waste is less than the amount produced.

Fig. 2. Heap of biomass sawdust.

IV. Biomass Components, Conversion and Uses

Normally, we burn wood and use the energy it produces to heat our homes. However, burning biomass energy is not the only way to convert it into usable energy. There are four major approaches: Biomass can be burned in special equipment to generate steam for the generation of electricity, or it can be burned to provide heat for industries and homes. Bacteria consume dead plants and animals, releasing methane. This is a natural process that occurs when waste decomposes.

Methane is identical to natural gas, which is sold by natural gas utilities. When yeast is added to biomass, it produces an alcohol known as ethanol. This is the method used to make wine, beer, and liquor. Wine is essentially fermented grape juice. Biomass can be converted into gas or liquid fuels using chemicals or heat. Animal manure is converted to methane gas and used to generate electricity. Methane gas can also be used to produce methanol, a liquid form of methane. Using bio-refining, we can convert sustainable biomass into marketable products.

Various intermediates (such as carbohydrates, sugars, proteins, oils, and fiber) can be extracted depending on the type of biomass and conversion methods used.

To convert biomass (plants and waste streams from agriculture and the food industry) into intermediates, a variety of conversion processes can be applied, including mechanical, chemical, biochemical, and thermochemical. Biomass components that can be isolated include fiber, sugars, carbohydrates, oils, proteins, and lignin. Chemically and biochemically, these components or intermediate products are subsequently transformed into high-value end products in our laboratories or with industry partners. End products include energy, materials, chemicals, food, and animal feed. Intermediates are essential in the manufacturing of finished items. Biomass is increasingly being hailed as a renewable resource rather than an organic solid waste since it can be turned into a variety of chemicals, biofuels, and solid bio-char utilizing modern technology. In recent years, pyrolysis has gained prominence as a promising and diverse platform for turning biomass into valuable resources. However, an efficient and selective conversion process remains difficult to achieve due to the complicated nature of biomass, which often complicates the outputs. Additionally, many pollutants and inorganic elements inherent in biomass (e.g., heavy metals, nitrogen, phosphorus, sulfur, and chlorine) may be transported into pyrolysis products or released into the environment, raising environmental issues. Understanding how they behave in biomass pyrolysis is critical for optimizing the pyrolysis process for efficient resource recovery and lower pollution. However, a comprehensive review of the fates of chemical elements in biomass during pyrolysis has yet to be completed.

Recent advances in research on the emission, transformation, and distribution of elements in biomass pyrolysis are presented, along with challenges for resource-oriented conversion and pollution abatement, emphasizing the importance of understanding the fate of elements during pyrolysis. Biomass is composed of three major components. Biomass is mostly made up of cellulose, a homo-polymer of glucose units (hemicellulose, a homo-polymer of xylose units), and lignin, a biopolymer made up of aromatic monomeric units (here depicted as hardwood lignin).

V. Biomass Absorption Processes

Photosynthesis allows plants to absorb the sun's energy and convert carbon dioxide and water into nutrients, which are then stored in biomass (carbohydrates). Biomass can be directly burned to generate heat, converted to electricity, or processed into biofuel (indirect).

A. Biomass Absorption Mechanism

Bringing solid materials into contact with gases in order to generate specific reactions is one of the challenges that chemical engineers face. A fluidised bed, which consists of a vertical cylinder with a perforated plate inside through which solid particles are introduced, using pressurised air, is one option. As a result, the solid particles are suspended and behave in the same way that boiling water does. The air stream's speed is critical in achieving the desired behavior of solids behaving like liquids. The particles do not move when there is insufficient air, but when there is too much, the air stream carries them away. Fluidised beds have environmental benefits since they enable the gasification of biomass to produce energy. That is, using crushed biomass to produce fuel gas, which may subsequently be utilized to generate electricity. Using fluidised beds as chemical reactors, according to one of the study's authors, Mercedes de Vega of the UC3Department M's of Thermal and Fluid Engineering, provides for more effective conversion by reaching high mixing degrees and high mass and heat exchange rates.

B. Advantages of Biomass Resources

Bioenergy pathway offer important opportunities for reducing greenhouse gas emissions due to their immense potential to replace fossil fuels in energy production. Because short-rotation crops or forests established on abandoned agricultural land accumulate carbon in the soil, biomass reduces emissions while increasing carbon sequestration. Bio-energy typically has an irreversible mitigation effect by reducing carbon dioxide at the source, but it may emit more carbon per unit of energy than fossil fuels unless biomass fuels are produced in an unsustainable manner.

By utilizing thermo-chemical conversion technologies, biomass has the potential to significantly reduce reliance on fossil fuels. Furthermore, increased use of biomass-based fuels will help to protect the environment, create new job opportunities, and improve rural health.

The development of more effective biomass handling technology, the improvement of agroforestry systems, and the installation of small and large-scale biomass-based power plants can all help rural development.

Biomass energy may also contribute to the modernization of the agricultural industry.

Biomass power facilities, in comparison to wind and solar energy, can provide critical, dependable base load supply. Biomass plants provide a variety of fuel sources, protecting societies from the volatile nature of fossil fuels. Biomass energy minimizes our dependency on foreign energy sources and promotes national energy security since it uses fuels generated in the United States.

Energy is expended significantly in the cultivation and processing of crops such as sugarcane, coconut, and rice, which can be offset by utilizing energy-rich residues for electricity generation. The incorporation of biomass-fueled gasifiers into coal-fired power plants would provide increased flexibility in response to fluctuations in biomass availability as well as lower investment costs. Increasing the emphasis on green power marketing can also help to grow the bioenergy industry.

VI. Heavy Metal: Sources, Processing and Characteristics

Although there is no precise definition of a heavy metal, it has been defined in the literature as a naturally occurring element with a high atomic weight and a density five times that of water. Because of their toxic nature, heavy metals have received the most attention from environmental chemists of all pollutants. Heavy metals are commonly found in trace amounts in natural waters, but many of them are toxic even at very low concentrations. Even in trace amounts, metals such as arsenic, lead, cadmium, nickel, mercury, chromium, cobalt, zinc, and selenium are highly toxic.

The increasing amount of heavy metals in our resources is currently a source of concern, especially since many industries discharge metal-containing effluents into fresh water without adequate treatment. When heavy metals are not metabolized by the body and accumulate in soft tissues, they become toxic. When they come into contact with humans in agriculture, manufacturing, pharmaceutical, industrial, or residential settings, they may enter the human body through food, water, air, or absorption through the skin. A common route of exposure for adults is industrial exposure. In children, the most common route of exposure is through ingestion. Natural and human activities pollute the environment and its resources, releasing more than the environment can handle.

A heavy metal is a dense metal that is toxic at low concentrations (usually). Although the term "heavy metal" is widely used, there is no standard definition that classifies metals as heavy metals. Heavy metals can be produced by both natural and anthropogenic processes, and they can end up in various environmental compartments (soil, water, air and their interface).

Many studies have been conducted to identify various natural sources of heavy metals. Natural heavy metal emissions occur under various and specific environmental conditions. Volcanic eruptions, sea-salt sprays, forest fires, rock weathering, biogenic sources, and wind-borne soil particles are examples of such emissions. Natural weathering processes can cause metals to be released from their endemic spheres and into different environmental compartments. Heavy metals can be found as hydroxides, oxides, sulfides, sulphates, phosphates, silicates, and organic compounds. Lead (Pb), nickel (Ni), chromium (Cr), cadmium (Cd), arsenic (As), mercury (Hg), zinc (Zn), and copper are the most common heavy metals (Cu). Although traces of the aforementioned heavy metals can be found, they still pose serious health risks to humans and other mammals. [17].

TABLE I: LIST OF SOME SELECTED HEAVY METALS, THEIR SYMBOL AND ATOMIC NUMBER

Element	Symbol	Atomic number
Mercury	Hg	80
Lead	Pd	82
Cadmium	Cd	48
Arsenic	As	33
Copper	Cu	29
Manganese	Mn	25

A. Characteristics of Heavy Metals

Some lighter metals and metalloids are toxic and thus classified as heavy metals, though some heavy metals, such as gold, are not typically toxic. The vast majority of heavy metals have a high atomic number, atomic weight, and specific gravity greater than 5.0. Some metalloids, transition metals, basic metals, lanthanides, and actinides are heavy metals. Although some metals meet certain criteria while others do not, most people would agree that mercury, bismuth, and lead are toxic metals with a sufficiently high density. Heavy metals include lead, mercury, cadmium, and, in some cases, chromium. Metals such as iron, copper, zinc, aluminum, beryllium, cobalt, manganese, and arsenic are less commonly considered heavy metals.

B. Anthropogenic Processes

Pollutants are released into the environment through industries, agriculture, wastewater, mining and metallurgical processes, and runoffs. Anthropogenic heavy metal processes have been observed to exceed natural fluxes for some metals. The vast majority of metals naturally emitted in wind-blown dusts originate in industrial areas. Automobile exhaust, which emits lead; smelting, which emits arsenic, copper, and zinc; insecticides, which emit arsenic; and fossil fuel combustion, which emits nickel, vanadium, mercury, selenium, and tin, are all major anthropogenic sources of heavy metal contamination in the environment. Human activities have been discovered to contribute more to environmental pollution as a result of the daily manufacturing of goods to meet the demands of a large population [17].

VII. Environmental Benefit of Biomass

A. Biomass is a Renewable Energy Source

The greatest evident advantage of biomass energy is that it is a renewable energy source that, unlike fossil fuels, does not decline with time. Plants are the primary source of biomass, and they are necessary for life on Earth to exist. This means biomass will be available as a renewable energy source as long as plants persist on Earth.

B. Biomass Helps in Climate Change by Reducing Greenhouse Gas Emissions

In fact, biomass aids in the reduction of greenhouse gas discharges that contribute to worldwide warming and microclimate change. The fact that biomass produces some emissions; they are significantly lower than that of fossil fuels. In terms of carbon emissions, the main difference between biomass and fossil fuels is that during biomass energy production, all of the CO2 absorbed by plants for growth is returned to the atmosphere, whereas CO2 produced by fossil fuels is only released into the atmosphere, where it contributes to global warming by increasing the Earth's greenhouse effect. In comparison to biomass, fossil fuels emit not only CO2, but also sulfur dioxide and lead oxide, both of which are extremely toxic substances.

C. Cleaner Environment

The third key benefit of biomass energy is that it may assist in environmental cleanup.

As the world's population grows, so does the amount of rubbish that needs to be disposed of properly. Numerous amount of trash end up in rivers, streams, and oceans, damaging local ecosystems and posing a health risk to humans. Rather than damaging our earth with all of this trash, we might use it to generate electricity, which would help to clear our environment of a number of toxins.

D. Biomass is Widely Available Source of Energy

The challengers of biomass admit that it is a readily obtainable energy source. One of the most important benefits of biomass energy over fossil fuels is its availability. Equally we all know that fossil fuels are limited, and when exhausted, the world will require a relatively cheap, readily available energy source, which is where biomass can help. When the economic and environmental features of energy sources are considered, many energy experts feel that biomass will emerge as one of the finest energy sources.

VIII. Conclusion and Recommendation

Biomass as a possible remedial natural material cannot be exaggerated based on the use of biomass waste to treat or resolve environmental problems. This approach can be used to recover metals from treated effluents and/or polish them. The potential of plant biomass as a heavy metal absorber from polluted soil has been established, and recycling heavy metal-bearing residues could allow for the eradication of pollution and the transfer of effluents.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

References

[1] Aderhold D, Williams CJ, Edyvean RGJ. The Removal of Heavy Metal Ions by Seaweed and Their Derivatives. *Bioresour Technol.* 1996; 58(1): 1-6.

[2] Blanco A, Sanz B, Llama MJ, Serra JL. Biosorption of Heavy Metals to Immobilised Phormidium laminosum Biomass. *Journal of Biotechnology*. 1999; 69: 227.

[3] Lee HS, Suh JH. Continuous Biosorption of Heavy Metal Ions by Ca-loaded Laminaria japonica in Fixed Bed Column. *Korean J. Chem. Eng.* 2000; 17: 477.

[4] Eccles H. Removal of Heavy Metals from Effluent Streams - Why Select a Biological Process. *International Biodeterioration & Biodegradation*. 1995; 35(5): 5.

[5] Rich G, Cherry K. *Hazardous waste treatment technologies.* Pudvan Publishers, New York. 2000.

[6] Trivedi RK. *Pollution Management in Industries*. Environmental Publications, Karad, New Delhi. 1989.

[7] Neoki K. Adsorption of Heavy Metals onto the Material Prepare by Biomass. *Biomass Production and Uses.*

[8] Scott CD. Removal of dissolved metals by plant tissues. *Biotechnol Bioeng.* 1992; 39(5): 1064-1068.

[9] Gadd GM. Accumulation of metals by microorganisms and algae. *Biotechnology.* 1988; 6b: 401 – 433.

[10] Modak JM, Natarajan KA. Biosorption of metals using nonliving biomass—a review. *Min Metall Proc*. 1995; 12: 189 – 195.

[11] Reddy BR, Mirghaffari N, Gaballah I. Removal and recycling of copper from aqueous solutions using treated Indian barks. *Resource Conservation Recycle.* 1997*;* 21: 227 – 245.

[12] Gaballah I, Goy D, Alliain E, Kilbertus G, Thauront J. Recovery of copper through decontamination of synthetic solution using modified barks. *Metal Trans.* 1997; 28: 13 – 23.

[13] Tiwari D, Mishra SP, Mishra M, Dube RS. Biosorption behaviour of mango (Mangifera indica) and neem (Azardiracta indica) barks for Hg +2, Cr +3 and Cd +2 toxic ions from aqueous solutions. *Appl Radiat Isotopes.* 1999; 50(4): 631 – 642.

[14] Villaescusa I, Martinez M, Miraes N. Heavy metal uptake from aqueous solutions by cork and yohimbebark wastes. *J Chem Technol Biotechnol*. 2000; 75(9): 812 – 816.

[15] Houghton RA. Carbon flux to the atmosphere from land-use changes: 1850–2005. [Internet] 2001 Available from: https://www.researchgate.net/publication/234748221_A_model-based_constraint_on_CO2_fertilisation

[16] Bailis R, Baka J. Constructing Sustainable Biofuels: Governance of the Emerging Biofuel Economy. *Amm Asoc Am Geogr.* 2011; 101(4): 827-838.

[17] Vhahangwele M, Khathutshelo LM. Environmental Contamin ation by Heavy Metals. 2018.