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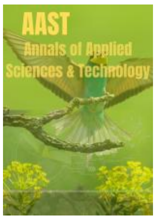

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Arsenic Mitigation Potential of Biochar in Soil and Wastewater; A Review

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Abstract: Arsenic (As) is a metalloid abundant in the earth crust and released by anthropogenic activities. It is a potent carcinogen that leads to serious health problems. Mitigation strategies for cost-effective amputation of this metalloid from soil and groundwater need to be developed. Several treatment approaches for eliminating arsenic from water and soil like sorption, ion exchange, phytoremediation, and membrane filtration were evaluated. Biochar, a form of charcoal pyrolyzed under low conditions of oxygen, is known as a multifunctional sorbent for removing contaminants from wastewater and soils. Biochar is capable of retaining arsenic from contaminated media including soil and water. Certain functional groups, porosity, and increased surface area are mechanisms for that retention. The biochar's potential to mitigate heavy metals in wastewater and soil is discussed in the current review.

Keywords: Arsenic, biochar, functional groups, sorption

1. Introduction

The Industrial Revolution of the 1830s, which included the metals use in different industries, led to increased heavy metal emissions. Heavy metals (HMs) are non-biodegradable and can accumulate in soil (Tangahu et al., 2011). HMs typically found at polluted sites are a category of dangerous inorganic chemicals that include lead, arsenic, cadmium, and copper. Soils are the primary sink released into the atmosphere for heavy metals, and most are not degraded chemically and microbially (Wuana and Okieimen, 2011). In recent years more soil is reported to be polluted with different kind of pollutants owing to increased global industrial waste pollution, wastewater irrigation, mining, and insufficient management of chemicals and pesticides in agro-activities (Bolan et al., 2004). Soil contaminants are detrimental to natural habitats and agricultural land and cause a major threat to public health. Contamination of heavy metal soil can pose vulnerabilities to human beings and the environment through eating or interacting with polluted soil or food chain, consuming polluted water, reducing food value via phytotoxicity, and reducing agricultural land usability leading to food timidity, and land tenancy issues (McLaughlin et al., 2000a). Major efforts must be made to address contaminated/polluted soil through physical or chemical methods, integrated treatment technologies, and bioremediation (Lee et al., 2008).

Metals are capable of transferring waste/sludge from industry to soil and then into groundwater, which is the main hazard connected with the use of metal waste (McBride et al. 1997). Soil is a crucial element of the ecosystem that participates directly/indirectly to quality of life (Ajmone-Marsan and Biasioli, 2010; Mahmood et al., 2011). Metals can damage the biosphere and reduce farm productivity, affecting both the flora and fauna and humans (Leela et al., 2010). Weathering and volcanic activity can be natural causes of the existence of HMs in certain soils, while in some other cases high heavy metals levels are responsible for anthropogenic activities including smelting, mining, pesticide use, sewage sludge, and fertilisers (Paz-Ferreiro et al., 2014). Soils are key sinks for releasing heavy metals to environment due to anthropogenic activities. Exposure to HMs like arsenic, lead, mercury and cadmium is a key intimidation to human health (Hina et al., 2019a). These metals have been expansively premeditated and regularly reviewed for their properties on human health. Man used heavy metals for millennia. Though numerous harmful health impacts of HMs have long been noted, heavy metal contact lingers (Järup, 2003). Copper, lead, mercury, cadmium and nickel are one of toxic metals which pose severe health and environmental and ecosystem problems through consumption or contact with contaminated soil (Inyang et al., 2011). Consequently, the food chain (soil-plant-humans and soil-animal-plant-humans) will be affected, water quality contaminated, food safety degraded through phytototoxicity, and agricultural land usability reduced (Wang et al. 2016).

The dangerous environmental consequences of HMs, in particular As, are having global attention recently due to groundwater pollution and wastewater pollution caused by industrial waste and chemical use. Sludge, sediments and As contaminated soils are the main reasons of its presence in groundwater, drinking water, and the food chain (Gonzaga et al., 2006). Arsenic, a highly toxic component, is the twentieth widespread in the earth surface (Rehman et al., 2021). It is also available as a response to several environmentally based anthropogenic activities. Arsenic is a metalloid belonging to group V-A. Different oxidation states, such as 0 (arsenic), + III (arsenite), -III (arsenate), and + V (arsenate), exist in nature. Arsenic compounds in the aqueous solution are present in the oxidation states + III and + V as arsenic acid (As(V)), arsenic acid (As (III)), and their salts. Inorganic arsenic compounds tend to mix yeasts, fungi, and methyl group bacteria into organic substances such as dimethyl arsenic acid (DMA), monomethyl arsenic acid (MMA), and arsine gaseous derivatives (Bissen and Frimmel, 2003). These methylated arsenic compounds are exist as little components in soil (Huang and Matzner, 2006), but may increase their levels (Abedin et al., 2002), and are more lethal than organic arsenic compounds (Meharg and Hartley, 2002). The bioavailability of arsenic in flooded environments is significantly increased and transported from soil to plants via roots such as rice (Wang et al., 2016). Rice accumulates more arsenic in its grain relative to cereals (Awasthi et al., 2017). To safeguard the value and security of the food, mitigation strategies are required to remedy polluted soils and water.

2. Sources of arsenic in soils and groundwater

The quantity of As in the environment is linked to natural sources such as local geology, aquifer geochemistry, hydrogeology and climate of the area, as well as anthropogenic activities such as insecticides, herbicides , pesticides, biosolids and manures, phosphate fertilizers, processes of metal mining and milling, and industrial processes (McLaughlin et al., 2000b). Some of arsenic's natural and anthropogenic sources are discussed here below.

2.1. Natural sources:

Arsenic is a indigenous noxious element, widely dispersed in ecosystems. Little of As is virtually widespread. More than 99 percent of the total As is reported to be exist in rocky environment (Bhumbla and Keefer, 1994). The frequently reported minerals are orpiment (As2S3), realgar (AsS) and mispickel (FeAsS) (Niragu and Azcue, 1994). The corrosion and weathering of these overstrain materials has been an important foundation for the starter of As into the environment (Bhumbla and Keefer, 1994). Naturally, it is present in different soil minerals and/or sediments (Smedley and Kinniburgh, 2002; Wuana and Okieimen, 2011). Several studies recorded an annual average of 6mg of As kg-1 for the upper earth crust (Matschullat, 2000). A lot of geochemical and natural processes are responsible for liberating As into groundwater from soil and residues. The natural causes include the geochemical cycle, arsenic that is co-precipitated or adsorbed on iron oxides and arsenic-containing sulphides. In certain instances, these natural sources of As may be responsible for pollution of groundwater that is used for irrigation and drinking water.

2.2. Anthropogenic sources:

There are several anthropogenic factors which contribute to the water and soil contamination of As. The major sources include the application of phosphate fertilizers, herbicides, insecticides, coal burning, production progressions, mining, smelting, timber preservers, etc. These human activities can contribute to the contamination of drinking water, groundwater, marine, and freshwater environments, as well as soil with arsenic. Several studies were conducted in Pakistan to determine the arsenic levels in drinking water in Manchar Lake (Arain et al., 2008), Jamshoro (Baig et al., 2009), Muzaffargarh district (Nickson et al., 2005), Lahore (Farooqi et al., 2007), and Tharparkar, Sindh (Brahman et al., 2013). These studies concluded that as is contaminated by surface and groundwater due to anthropogenic activities and some natural factors. Also investigated for contamination were the surface soils and sediments about 40-45 km south of Lahore, Punjab, Pakistan (Farooqi et al., 2009; Baig et al., 2012). This study established that the main sources of arsenic pollution in these soils are combusted coal, fertilizers, and industrial waste, and the highest concentration of 35 mg As kg-1 was appeared in surface soil samples. The study also showed that other potential sources of As availability can be soil adsorption under oxidizing conditions during mineral weathering, affecting reserves of local potable water. Also, meat and vegetables are sources of human exposure. Table 1 lists the recommended limits of As in food products. The main path for As movement in the food chain is from soils, plants, and groundwater to humans and other living biota (Figure 1). Several strategies for the reclamation of contaminated soils and waters are reported to provide good quality water and food for humans, society and the ecosystem. Bioremediation, nanotechnology, and filtration treatments are among the techniques involved. Biochar is an emerging sorbent for treating contaminants and metals in soil and water, among the various filtration techniques. Usually, it's an economical and environmentally friendly alternative, but cost and performance vary depending on feedstock and preparation technology availability (Mishra et al., 2023).

Table 1. Concentration of As in various food products and their permissible limits (European Food Safety Authority, 2014).

Food item	As concentration (µgkg^{-1}) against permissible limit (1 mgkg^{-1})
Wheat	22.0
Rice	153.1
Oat	27.3
Corn	49.3
Pulses	1300
Chicken meat	286
Fish	3000

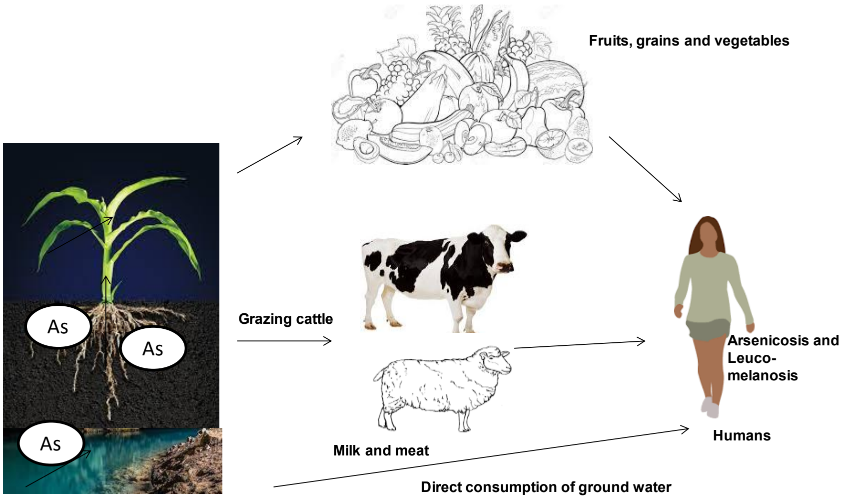

Figure 1. Schematic diagram of arsenic uptake through the plant to humans.

3. Risks Associated with Arsenic Contamination

The acceptable limit for As in drinking water is 0.01 mgL-1 according to WHO guidelines. Depending on its exposure rate, organic As is less noxious than inorganic As. Inorganic As is more hazardous to human health, causing negative effects on the body's various functions causing gastrointestinal symptoms, cardiovascular problems and death-induced effects on the nervous system. It is found in the compound, in the trivalent form (Bhatti, 2013).

4. Guideline and standards for arsenic in drinking water

Because of severe human health problems, WHO provided guidelines in 1993 to reduce arsenic intake to a safe drinking water limit of 10-50 µgL-1. Many developed countries, including Japan, Jordan, Laos, Namibia, Syria, the EU and the USA, adopt the limit set by WHO as their national standard. Those countries where this guideline value is not implemented, i.e. 10µgL-1, and where up to 50µgL-1 is retained, face health problems e.g. Bangladesh and India, where it reports many cases. Similar problems exist in countries such as Bolivia, Bahrain, China, Egypt, Oman, Indonesia, Saudi Arabia, Philippines and Sri Lanka (World Health Organization, 2004).

Table 2. Data regarding arsenic concentration in irrigation water worldwide (Bhatti, 2013).

Region	Arsenic concentration in irrigation water (µgL^{-1})
Bangladesh	<1.0 to 267
India	5.9$\pm$0.2 mg L^{-1}
Pakistan	5.4 to 8.2
Pakistan	Near to 100 mg L^{-1}
Spain	38 to 136
Italy	19 to 104

5. Arsenic effects on human health

Researches have presented that risks to human health relate to arsenic-contaminated groundwater drinking in various arsenic-contaminated areas (Phan et al., 2010). Various consequences of As on public health have been calculated in west Bengal (India). Arsenic dermatosis, melanosis and keratosis have been found in the affected populations and the source of pollution was drinking arsenic contaminated groundwater (Maity et al., 2012). Around 150 million people suffer from health risks related to arsenic. Among them, 110 million people come from ten South-East and South Asian countries: Pakistan, India, Bangladesh, Myanmar, China, Cambodia, Nepal, Vietnam Laos, and Taiwan (Ravenscroft et al., 2011). Another pathway for human consumption of arsenic is the use of arsenic-enriched groundwater for irrigation of various vegetables and crops (Chatterjee et al., 2010; Samal et al., 2011) (table 2). The bulk of polluted irrigation water from crop contamination occurs in West Bengal, Bangladesh, and India (Alam et al., 2003). Particular responsiveness has been remunerated recently to the irrigation of food crops like rice, which require high water system, was proposed (Pal et al., 2014). A cross flow nano filtration, followed by a pre-oxidation step to transform trivalent arsenic into pentavalent form, could remove both As (III) and As (V) under optimum conditions a high degree of arsenic removal efficiency was achieved through a solid calcium and sodium matrix.

7.3. Electrochemical arsenic removal:

Electrochemical technology has demonstrated efficacy in eliminating As from water (Kumar et al., 2011; Hansen et al., 2006). In this method, anode materials are generated in-situ coagulant as a result of electrolytic oxidation. Compared to ferric coagulation, electrocoagulation has good efficiency for removing arsenic (As (III) and As (V)). Arsenic (V) is easier and faster removed compared to As (III), but arsenic removal was slow in this process at an elevated initial arsenic level and at high pH (Wan et al., 2011), making it pH-reliant (Lakshmanan et al., 2010).

7.4. Oxidation: Oxidation is the conversion of soluble As (III) to higher valence As (V), afterward precipitation and then precipitation of As (V). This arsenic removal technology is indispensable for the treatment of anaerobic groundwater because As (III) is the main form in the neutral pH solution. As (III) is present due to anaerobic soil settings, for example, in paddy fields, and is more readily dissolved in soil (Xu et al., 2008). As a result, plants easily adsorb it. To increase treatment efficiency, the process may be required before adsorption, coagulation, or membrane filtration. Several conventional chemical oxidants are stated for As(III) to As(V) oxidation in various research, including ozone (O_3), chlorine (Cl_2), hydrogen peroxide (H_2O_2), chlorine dioxide (ClO_2), permanganate (MnO^{4-}), chloroamine (NH_2Cl), and ferrate (FeO_4^{2-}) (Sharma, 2007). The selection of the proper oxidant, however, depends on the construction of oxidation by products, the remaining concentration and the prospect of oxidation of other water ingredients (Jekel and Amy, 2006).

7.5. Phytoremediation: Phytoremediation is an economical, environmentally friendly technology used by microbes and plants to remediate arsenic polluted soil and groundwater (Behera, 2014; Dickinson et al., 2009), which may be a suitable method of use in less developed countries (Yang et al., 2012). It is an efficient, ecologically based method and is characterized as a green technology. It can be smeared using methods both *ex situ* and *in situ*. For example, the *Pteris vittata* plant is recognized as an arsenic hyperaccumulator (Ma et al., 2001) and has the capability to captivate arsenic by roots and translocate it to the soil above when cultivated in arsenic-contaminated soil (Zhao et al., 2009). Phytofiltration is also a very low cost alternative technology and is carried out for the removal of As by multiple sea plants (Favas et al., 2012). The following plants found maximum arsenic concentrations (354-2346 μgg-1); *Callitriche stagnalis, Azolla caroliniana, Callitriche lusitanica, Callitriche brutia, Lemna minor, Fontinalis antipyretica* and *Ranunculus trichophyllus*. Green filamentous *Cladophora* tends to survive at 6 mgL^{-1} arsenic (Jasrotia et al., 2014).

Also plant biomass is used to eliminate arsenic from contaminated water e.g. biomass (powdered) from the Acacia nilotica shooting was used to remediate As contaminated water (Baig et al., 2010). Vidali (2001) explains the techniques of phytoremediation (hyperaccumulator plant extraction of contaminants) and is classified as phytotransformation, phytostimulation, phytovolatilization, phytodegradation, phytostabilization, phytodegradation, and rhizofiltration.

7.6. Adsorption: Heavy metals have a dire role in soil and water pollution, and are very commonly found near industrial sites in the groundwater. Different processes can be applied to remove the HMs but can be very expensive. Processes of adsorption may also be used to eliminate pollutants from water, soil or gaseous solution. Adsorption methods have been known for more than a century and have appealed the responsiveness of researchers due to many advantages such as cost-effectiveness (Zhang et al., 2007), ease of handling (Jang et al., 2008; Ghani et al., 2022), small quantities of chemicals required, and minimal by-product and sludge generation. Substantial research has been conceded out on the development of new arsenic adsorption materials using various materials such as activated alumina (Han et al., 2013; Singh and Pant, 2004), iron oxides (Sun et al., 2013; Giménez et al., 2010), clay minerals (Su et al., 2011), zeolites (Swarnkar and Tomar, 2012), amended fungal biomass (Pokhrel and Viraraghavan, 2006). This procedure is contingent on several aspects such as the coexisting ions, for instance calcium (Ca^{2+}), bicarbonates (HCO^{3-}), silicates, and phosphates, as they can reduce the arsenic removal, pH, and arsenic speciation adsorption sites. Activated carbon is considered an ideal filter for eliminating pollutants but it is more expensive than other materials such as biochar. The adsorbents mostly used include activated carbon, silica gel and aluminum oxide. Biochar can also be an useful adsorbent for metals owing to its large surface area, permeability and cation exchange capability. Heavy metals are the non-degradable and accumulate when consuming metal contaminated drinking water in living systems (Zhu et al., 2013). Wood waste has a tendency to be used as a biochar to manage water pollution. The concentration of As in soil relies on different physico-chemical soil properties and thus affects the processes of adsorption and desorption. Arsenic is reported to be highly affine in pure systems for oxide surfaces. Oxide reactivity is known to depend on a number of features, such as competing cations, pH and density of charge. Also, nano technology (i.e. nano oxides) is an emerging option for arsenic immobilization in soils and water. The nano particles of iron and manganese oxide are used as a potent arsenic-retaining sorbent in soil media. Adsorption is usually considered to be the major path included in the removal of contaminants by nano technology. Bhatti et al. (2013) experiment on horticultural crops reported that the adsorption phenomenon was responsible for the retention of arsenic on soils. The Freundlich isotherm model fit the adsorption performance of designated soils very well. Soils also showed higher affinity to As V than As III, as shown by the high bonding energy and maximum adsorption. In another biochar study it was used as a soil modification to check the bioavailability of As in spinach leaves (Bhatti et al., 2013). The results presented that the adding biochar in retaining As in soil and on biochar surfaces was not promising. In the presence of biochar, the As in the leaves was reported higher than in control. The reason behind this might be the type of conditions of biochar, feedstock, and pyrolysis that are responsible for determining properties of cation retention.

Working with farm effluents, the researchers reported that NH^{4+} retention augmented from unprocessed bark to smoked bark (alkaline material to increase exchange sites) and zeolite (clinoptilolite) (Bolan et al., 2004). The NH^{4+} removal capacity of zeolites depends on the type of wastewater, flow rate of wastewater loading, particle size and time of interaction between the wastewater and zeolite particles. Ammonium retention was also found to depend on the existence in the aqueous phase of other cations and the primary concentration of NH^{4+} (Demir et al., 2007). The NH^{4+} removal method is deemed feasible for treating wastewater if it can reduce the NH^{4+} cation concentration from 20-60 mgL^{-1} to 5 mgL^{-1} (Bernd et al., 2013). Similarly, filters can be found which can be the best sorbents for the wastewater treatment.

7.8. Biochar: Biochar is rich in condensed aromatic carbon which has studied as a tool for soil modification and for carbon sequestration. A definite level of organic C-form called fused aromatic ringed structures is an crucial defining property of the biochar, analogous to charcoals. These structures, which are essential to the mineralization or adsorption of biochar's characteristics, are created during pyrolysis. Biochar is therefore typically impoverish in C, and even more in writing full or other metal such as writing full and writing full and sometimes even Nitrogen. In addition to removing contaminants from wastewater, biochar also acts as a fertilizer, soil modification and has increased the properties of sorption capacity in soil (Bernd et al. 2013). Biochar is essentially organic matter produced from pyrolysis of various feedstocks, such as; pine wood, pine bark, oak bark and oak wood (Mohan et al., 2012a, b), corn straw char, hard wood char (Deb et al., 2013), rice husk (table 3 presented As adsorption capacity), orange waste, compost, buffalo weed biochar (Yakkala et al., 2013), dried olive pomace (Pellera et al., 2012), rice straw biochar (Han et al., 2013). The pine needle biochar is revealed to be a efficient adsorbent for various pollutant types, such as nitrobenzene and naphthalene (Chen, 2009). Dairy-manure biochar efficiently removed atrazine and lead at the same time as having little effect on competition (Cao et al., 2009). However, there are currently no potential studies available with a comparison of biochar's adsorption properties to other adsorbents presently used to treat wastewater. In addition, the impact of particle size of biochar on the efficacy of wastewater treatments in unknown. With its high surface area and increased cation exchange capacity, the biochar can hold nutrients and pollutants in the soil (Beesley and Marmiroli, 2011). Biochar alteration in soil caused significant decreases ($P<0.01$) in soil DDT (Dichlorodiphenyltrichloroethane) levels (Gregory et al., 2015). the application of biochar described to decrease the as concentration in tomatoes (Beesley et al., 2013). Because of biochar application, microbial activity was stimulated in contaminated soil with arsenic and resulted in significant degradation of organochlorides (Gregory et al., 2015).

There are several sorbents available to remove metal ions from wastewater and contaminated soils, but sorption of these ions on biochar has been shown to be a more effective and less expensive method especially in developing countries (Hina, 2013; Toosi et al., 2012). Biochar is capable of absorbing organic substances, hydrocarbons, and inorganic metal ions (Mohan et al., 2011; Hale et al., 2012). Biochar is reportedly retaining As from metal contaminated leachate solution (Beesley and Marmiroli, 2011). The mechanism behind this retention could relate to chemical or physical interactions between the surface of the biochar and As. In biochars with high surface areas prepared at higher temperatures the adsorption of organic compounds is considered to be superior. The thermal decarboxylation in biochars also leads to a decrease in functional groups containing OH^-. Carboxyl and phenolic OH^- groups are typically known to be responsible in biochars for the sorptive processes. The FTIR (Fourier Transform Infrared Spectroscopy) wave numbers (cm^{-1}) found in various biochars were at 3300, 1600 and 1750 cm^{-1} representing H bonded OH groups, $C = C$ and $C = O$ functional groups, respectively (Hina, 2013). These bands are known in the biochars for their power to exchange cations.

Table 3. As adsorption capacity by biochars

Biochar	Pyrolysis temperature (°C)	Initial concentration of As (mgL-1)	Adsorbent dose (gL-1)	Adsorption capacity (mg g-1)	Reference
Rice husk	550	0.101- 0.9	0.4	0.0987	Cope et al., 2014
Rice husk	700	1-10	2	0.0733	Cuong et al., 2021
Pinewood	600	7.8-55.5	2.5	0.0781	Wang et al. 2015b
Oak wood	450	0.075	10	0.0612	Mohan et al., 2007
Peanut shell	450	5	0.6	5.5	Sattar et al., 2019
Sewage sludge	550	1	10	0.07	Taveres et al., 2012
Pine cone	500	0.05-0.2	0.01-0.1	0.0057	Van Vinh et al., 2015

8. Studies on the sorption efficacy of Biochar from water

Several studies have been reported to find the application of biochar to remove heavy metal from aqueous solution/groundwater. Biochars have proven effective in addressing water contamination issues with many benefits such as economical, wide availability and good physiochemical properties on the surface. Researchers studied the adsorption capability of three crop straw biochars (peanut, canola straw and soybean) for removing Cu (II) from an aqueous solution (Tong et al., 2011). The crop straw biochars were prepared at 400°C and investigated their adsorption at pH range from 3.5-6. These biochars used the Langmuir equation to define the adsorption of the metal ion. Biochars' adsorption capacity followed the order that is to say canola straw char< soybean straw char<peanut straw char. The negative surface charge on the canola straw biochar resulted in more Cu(II) electrostatic adsorption compared to the two other biochars in the study. Aqueous solution has been investigated for the adsorption of Cu (II) by agrarian by-products, such as orange waste, olive pomace, rice husk, and compost (Pellera et al., 2012). The potential adsorption aqueous solution of fresh, hydrothermally treated (300°C) and paralyzed agricultural by-products at 3000°C (P300) and 600°C (P600) was assessed at different adsorbent dose, pH, initial Cu (II) concentration and batch interaction time. After hydrothermal treatment (at 300oC) pinewood biochar was reported to have more stable carbon–oxygen complex and activated sites for adsorption compared to raw pinewood (Xu et al., 2013).

Aluminum adsorption by biochars from rice straw and cattle manure has been studied (Qian and Chen, 2013). These were biochars produced for Al adsorption at three temperatures of 100, 400 and 700°C (A100, A400, A700), to check the dual behavior of biochar. The Langmuir model fits in well with the isothermic Al adsorption. The findings presented that the silicate particles and organic components present in the biochars helped in the process of adsorption. It found maximum adsorption at pH 4.5. Biochar made from milk manure has proved to be very operative in the absorption of metal ion Pb (II) from aqueous solution (Chen and Chung, 2006). At 200°C and 350°C the biochar samples were primed by pyrolysis and untreated manure was used for comparison. The samples were observed using infrared spectroscopy and X-ray diffraction from the Fourier transform.

The removal of lead from the water was also determined by the use in a batch sorption experiment of fresh sugarcane bagasse and anaerobically processed sugarcane biochar (Inyang et al., 2011). In addition, X-ray diffraction and scanning electron microscope suggested that the main mechanisms of sorption of lead onto the digested sugarcane bagasse biochar and raw sugarcane bagasse biochar, respectively, were surface adsorption and precipitation. Deb et al. (2013) studied the properties of corn straw and hardwood char for removing aqueous solution from Zn (II) and Cu (II). The chars were formed and characterized by pyrolysis at 450°C (hardwood) and 600°C (corn straw). The data for adsorption was well patterned with the Langmuir equation.

To remove As (III), Pb (II), and Cd (II) from drinking water, various biochar from by-products such as oak bark char, pone bark char, oak wood char, and pine wood char, produced from rapid pyrolysis in an auger-fed reactor at 400 and 450°C, were used (Fendorf et al., 2010). These chars were characterized by the bark and wood. After this, batch-mode sorption studies were conducted at various pH levels, solid-to-liquid ratios, and temperatures. Maximum adsorption was achieved for As (III) at pH range 3-4 and for Pb (II) and Cd (II) at 4-5.

9. Studies on the sorption efficacy of Biochar from soil

Biochar alteration in soil is receiving considerable attention for the remediation of contaminated sites e.g. cotton seed hulls were used at five temperatures (200, 350, 500, 650, and 800°C) to produce biochar via pyrolysis, and then characterized (Zhang et al., 2007). This research group demonstrated the special effects on soil heavy metal concentration of ten biochars primed at 350°C and 700°C temperatures from paved feedlot manure, milky manure, separated pork solids, poultry litter, and turkey litter. They determined that biochars with pyrolytic temperatures of 700°C were more stabilizing heavy metals Cu and Pb, whereas soil stabilization of Ni and Cd depends more on the type of biochar smeared in the soil. Similarly, heavy metals were less efficient in immobilizing manures with low phosphorous and ash content. Cotton stalk biochar has been demonstrated to reduce the accessibility of Cd in soil through co-precipitation or adsorption (Zhou et al., 2008). In a pot experiment (Beesley et al., 2013) with tomato test plant (Solanum lycopersicum L.) plantlets, an arsenic concentration in plant tissues, soil pore water, and soil were estimated. Biochar has increased significantly as concentrations in pore water (500 μgL^{-1}-2000 μgL^{-1}) while shoot and root concentrations have decreased significantly related to the control treatment without biochar. Arsenic fruit levels were very low (<3 μgkg^{-1}), representing nominal toxicity and the risk of transferring food chains. Arsenic availability has been reported to be reduced in the presence of biochar in various research studies (Beesley et al., 2013; Namgay et al., 2010). Definite functional groups, surface area, and structural porosity are found to be different mechanisms for its reduction (Hina, 2013).

10. Conclusion

Arsenic and other heavy metals are not degradable and are extremely persistent for long periods in the climate. Arsenic pollution in soil and water poses a danger and causes problems for the environment and public health worldwide, especially in less developed countries. Owing to its harmful impacts on humans and other living things, ecological risk must be minimized by improving environmentally sustainable methods and techniques for handling polluted water and soil. A relatively recent, but promising, arsenic mitigation technique is the use of biochar as a soil alteration or water filter to extract the metalloid from polluted products. The mechanism of contaminant retention on the biochar is understood to be the existence of functional groups, increased surface area, and porosity. Over an extended period, the cations sorbed on biochar are found to have low availability. Nevertheless, further research is required to improve biochar efficacy as an arsenic contamination treatment. This research should concentrate on identifying more forms of biochar, such as hydrochar, and various pyrolysis conditions, such as temperature, feedstock, and heating time, to find biochar with qualities that can prove to be an effective arsenic removal mitigation tool.

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