

BIOCHAR I: A RENEWABLE AND SUSTAINABLE SOURCE FOR ENERGY

Abstract

The authors of this chapter discussed various sources of biochar as well as potential environmental problems that can be solved by using biochar. The chapter also discussed the removal of antibiotics from agricultural waste and which parameters should be investigated during the removal of antibiotics. Various sources of water pollution were discussed, as well as how and where biochar can be used to remove biochar. Organic pollutants that are harmful to aquatic ecosystems and human health, such as persistent organic pollutants (POPs), polycyclic aromatic hydrocarbons (PAHs), and others, can be removed using biochar.

Keywords: Biochar, nucleic acid, Pyrolysis, wastewater treatment, pesticides

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I. INTRODUCTION

Commensurate with 2015, there were more than 7.3 billion people in the world's population being provided with basic needs like food, clothing, shelter, and education. As the population is increasing day by day, the production of waste is also increasing along with necessities. According to the UN, 9.2 billion people may inhabit the planet by the year 2050. The minimal fundamentals like water, woods, fertile land, and fisheries might be low as the population across the world continues to increase. There is tremendous pressure on the cultivators, food industries, and animal husbandry to continuously develop new technologies to provide quality managed food and meet the same demand. The robust current handling methods point to pernicious impacts on the ecosystem. The treatment of wastewater, providing numerous treatments, and recovering water, nutrients, and energy resources will be the next worldwide challenge toward an environmentally sound future.

Furthermore, due to excessive population growth, it is unviable to produce enough food with only natural manure. Consequently, the demand for mineral fertilizers is rising. Today, we can see that many urban areas are adopting the practice of removing human waste from water estuaries as a result of urbanization. As the content of wastewater increases, the necessity of wastewater system performance also increases.

While personal care items are used for personal cleanliness to enhance daily living, pharmaceuticals are used to prevent or treat diseases in humans and animals. Contrarily, pharmaceutical and personal care products (PPCPs) cover a wide range of organic chemicals, including therapeutic medications, veterinary pharmaceuticals, perfumes, cosmetics, diagnostic agents, surfactants, and nutraceuticals. [1] According to environmental factors and octanol/water partition coefficient (K_{ow}) values, PPCPs are bioactive complex compounds that can exist as neutral, anionic, cationic, or zwitter ionic molecules. [2]

Antibiotics in wastewater have gained worldwide attention. Therefore, these emerging pollutants require adequate consciousness. Before wastewater is released into the oceans, new techniques must be developed for the effective removal of antibiotics while also considering potential risks to the ocean's biotic flora and lowering the chemical oxygen demand.

Many antibiotics have been employed to threaten all possible systemic infections caused to human beings in the current era, ultimately leading to municipal sewage waters. Besides, the rapid development of antibiotic-resistant microbes in the last 20 years has also increased the number of treatments with multiple drugs. As a result, many tertiary and quaternary classes of drugs are also found to increase in concentration in wastewater. The percolation of antibiotics in the environment, especially in water bodies, has increased antibiotic resistance in the microbial flora. As a result, they ultimately travel up the food chain and pose a risk to both human and animal health.

Besides, treating livestock with antibiotics in the feed has also added to the antibiotic water pollution. It persists in the environment through a complex and vicious cycle of transformation and bio-accumulation. Drugs from several pharmacological classes are frequently employed in animal husbandry and agricultural practices [3]. Animals are given the medications either orally (in their food and water) or topically (in skin creams containing

antibiotics in quite high doses). Antibiotics are also administered as preventive measures to significantly curb gastrointestinal tract infections. Classes of antibiotics including β -lactams, tetracyclines, Macrolides, and Quinolones, steroidal and nonsteroidal anti-inflammatory medicines, and nutraceuticals are examples of commonly used medications.

Oxytocin, ergonovine, HCG, GnRH, progesterone, and FSH are some of the estrogen hormones used to regulate animal reproduction. Excessive usage of anthelmintic medicine Dewormer also causes animals to consume more antibiotics than people do. Animal waste, which is not processed as well as human waste, is one area where the careless use of antibiotics in animal husbandry is causing greater difficulties for the environment.

Surface water, groundwater, wastewater treatment plant (WWTP) effluent, and sludge are only a few of the environmental matrices where numerous active pharmaceutical residues and compounds have been found. Bush et al, categorized the active pharmaceutical compounds into different therapeutic classes, which include (i) anti-inflammatories and analgesics (ibuprofen, paracetamol, diclofenac); (ii) antibiotics (sulfonamides, tetracyclines, penicillins, β -lactams, macrolides, fluoroquinolones, and imidazoles); (iii) antiepileptics (carbamazepine); (iv) antidepressants (benzodiazepines); (v) lipid-lowering agents (brates); (vi) antihistamines (famotidine, ranitidine); (vii) β -blockers (metoprolol, atenolol, and propranolol); and (viii) other substances (barbiturates, narcotics, and contrast media). [6] The most often found substances, followed by analgesics, were found to be antibiotics. Therefore, it is necessary to create novel techniques for effective wastewater treatment.

II. ECOLOGICAL AND ENVIRONMENTAL RISKS

Antimicrobials are chemically complex substances that are generally observed to interact with specific receptors present on cell lines. Each class of antibiotic has a distinct mode of action and mechanism, which may impede the production of proteins, nucleic acids (DNA/RNA), and cell envelopes, all of which are necessary for a variety of biological processes. Since these compounds are made to treat bacterial illnesses in both humans and livestock, it is challenging to prevent or limit the use of certain antibiotics. Numerous antibiotics have been shown to interact with receptors that are shared by organisms from lower and upper phyla in the ecosystem. [4]

Environmental microbes are more prone to non-therapeutic exposure than aquatic vertebrates, such as fish. In addition, it has been noted that the bacterial and microbial communities in frogs, fish, and rats exhibit growth abnormalities, gene expression changes, irregular protein and enzyme activities, and antibiotic resistance [7,8]. Furthermore, harmful effects from antibiotics like oxytetracycline and trimethoprim have been observed in the cyanobacterium *Anabaena flos-aquae*, the green algae *Pseudokirchneriella subcapitata*, and *Daphnia magna*. [8,9]. The pharmaceutical ingredient Diclofenac is responsible for the well-documented fall of vulture populations in Southeast Asia. [9,10]

Therefore, active pharmaceutical chemicals in the environment may have hazardous effects on a variety of environmental organisms. The elimination efficacy of various treatment procedures for antibiotic residues has increased significantly in recent years.

Because of their effective removal capabilities, advanced oxidation processes (AOPs) are a major cause for concern. [10,11]. Certain antibiotics are prohibitive and could result in harmful byproducts that are only partially effective. Adsorption and membrane technologies are effective at removing antibiotics in a suitable manner. However, these processes ultimately fall short in their attempts to break down antibiotics and suffer serious harm from other organic contaminants.

Particularly in antibiotics and drug contamination in water, treatment is generally done using adsorption to remove pollutants from the aqueous phase. There have been attempts to manufacture alternative carbon adsorbents using garbage as the raw material in an effort to reduce costs and conserve natural resources. This strategy presents a different and sustainable method for the management of residues with the goal of increasing efficiency and cost effectiveness.

Pyrolysis, a high-temperature, low-oxygen method, is used to create biochar by heating organic materials like crop waste, hay, wood waste, and manure. These carbon materials, as well as their derivatives, are found to be physically and chemically diverse. More than 80 different biochars have been examined, and it has become clear from these analyses that the type of biochar utilized must match the circumstance and the intended result. The study discovered that biochar made from grass or crops seemed to offer the optimal mixture of agricultural value and carbon stability. [12]

Biochar made from wood had a higher carbon content than biochar made from manures and food waste, which had higher nitrogen and phosphorus levels. Under the Carbon Farming Initiative (CFI), producing biochar and adding it to soil could result in reducing greenhouse gas emissions while increasing the carbon content of soil. This takes place in a number of ways: transferring carbon over a long period of time into biochar, where it would otherwise naturally disintegrate and release carbon dioxide and methane; creating syngas and bio-oil, which can be utilized as fossil fuel alternatives; and lowering nitrous oxide emissions from fertilizer application. Different pore networks, mainly micropores less than 2 nm, mesopores between 2 and 50 nm, and macropores greater than 50 nm, can be found in biochar from various sources. However, it has been suggested that the majority of the surface area and good adsorption capacity of biochar is due to micropores and small mesopores (2–20 nm) [13, 14].

Removal of various contaminants from water and wastewater by biochar derived from different feedstocks. [15]

	Biomass feedstock	Pyrolysis Method	Analyte	Removal capacity	Reference
Metals	Malt spent rootlets	at 850 °C for 1 h	Hg(II)	103 mg g ⁻¹	16
		at 300–900 °C		130 mg g ⁻¹ for MSR750	17
	Waste glue residue	ZnCl ₂ modification	Cr(VI)	325.5 mg g ⁻¹	18
	Lotus stalks	Zinc borate as flame retardant, at 300, 350, and 400 °C	Ni(II)	61.7 mg g ⁻¹ for 0.5 g ZB/g LS pyrolysis at 300 °C	19
Dyes	Bamboo cane	Phosphoric acid modification at 400, 500, and 600 °C	Lanasyn Orange and Lanasyn Gray	2.6 × 10 ³ mg g ⁻¹ for both dyes	20
	Pecan nutshell	at 800 °C for 1 h	Reactive Red 141	130 mg g ⁻¹	21
Phenols and PAHs	Sewage sludge	at 500 °C for 1 h/microwave-assisted pyrolysis at 980 W for 12 min	Hydroquinone	1,218.3 mg g ⁻¹ /1,202.1 mg g ⁻¹	22
	Malt spent rootlets	at 800 °C for 1 h	Phenanthrene	23.5 mg g ⁻¹	23
	Orange peel	at 150–700 °C for 6 h	Naphthalene and 1-naphthol	80.8 mg g ⁻¹ for naphthalene and 186.5 mg g ⁻¹ for 1-naphthol	24
Pesticides	Maize straw and pig manure	at 300, 500, and 700 °C for 4 h	Thiacloprid	About 8.1 mg g ⁻¹	25
	Almond shell	at 650 °C for 1 h with steam activation at 800 °C	Dibromochloropropane	102 mg g ⁻¹	26
	Broiler litter	at 350 and 700 °C with and without steam activation at 800 °C	Deisopropylatrazine	About 83.3 mg g ⁻¹ for BL700 with steam activation	27

III. APPLICATION OF BIOCHAR IN THE WASTEWATER TREATMENT PROCESS

In comparison to currently used low-cost procedures (such as sand filtration, solar disinfection, and chlorination), biochar wastewater treatment may have the following advantages: (1) Low-income areas can benefit from biochar because it is a cheap and

renewable adsorbent that can be created using readily available biomaterials and expertise. (2) Removal of chemical, biological, and physical contaminants is the key part of biochar. (3) While conventional techniques produce carcinogenic byproducts (such as chlorination) and/or increase chemical pollutant concentrations, biochars preserve the organoleptic qualities of water. (4) In addition to improving soil quality and crop production, biochar provides other advantages, such as providing clean energy for home heating and cooking.

Seven research hypotheses are highlighted under three categories: (1) the development and improvement of biochar wastewater treatment; (2) Risks to human health and ecotoxicology related to contamination transmission along the biochar-soil-food-human pathway, and (3) Carbon and energy footprint life cycle studies for biochar wastewater treatment systems.

Biochar could be used at different stages of wastewater treatment to improve the treatment efficiency and recovery of value-added by-products.[28]

IV. ANTIBIOTIC REMOVAL BY AGRICULTURAL WASTE BIOCHAR

Due to its simplicity, affordability, and safety, adsorption is one of the technologies that is most suitable. Chitosan, montmorillonite, and materials based on graphene have all been tested as adsorbents to adsorb LEV or TC. [29] Agricultural waste was used as a large component of the adsorbent in order to achieve a low cost, specifically maize husks. Since maize is a widely produced crop and is readily available, it is cheap and easy to obtain. It also helps to reduce antibiotic contamination and reuses the husks from the crop. Corn husks were converted into biochar in order to improve recovery and increase adsorption capacity. Magnetic and non-toxic Fe were used to modify the biochar.

V. SOURCES OF WATER POLLUTION

Major sources of water pollution are industrialization, population growth, domestic sewage, pesticides, fertilizers, urbanization, and weak management systems. [30] Deeply developed and industrial areas are responsible for the generation of organic pollutants. [31] The leaching of toxic elements into drinking water through geological composition is responsible for drinking water pollution. Some of the elements leached into drinking water are arsenic, fluoride, selenium, and a few others, such as chromium and uranium.

Mining activities are also responsible for depositing contaminants in the water and making it polluted [32, 33]. Municipal wastewater is also a source of water pollution [34]. Domestic sewage is the primary source of water pollution. Most of the domestic sewage is untreated. Domestic sewage includes toxicants, solid waste, plastic litter, and bacterial contaminants as water pollutants. Industrial effluents from industries like sugar, textiles, electroplating, pesticides, pulp, and paper cause water pollution [35]. Industrial sewages primarily cause surface water and groundwater contamination [36]. Polythene bags and plastic waste are key sources of pollution [37]. Pesticide micro pollutants cultural sectors are the direct source of water pollution. The excess content of pesticides in the water is hazardous to the ecosystem and human health [38, 39]. The presence of pharmaceutical compounds, even at trace levels in water, also causes water pollution.

Stormwater runoff is also the primary source of water pollution. Runoffs from agricultural land contain pollutants such as pesticides, fertilizers, and animal waste. Runoffs from the road and parking area include oil and gasoline as water pollutants. Industrial discharge and accidental spills are responsible for water pollution at a larger level [40].

Radioactive substances from industrial, medical, and nuclear power plants and scientific processes are also causing water pollution. Improper disposal of radioactive waste causes severe water pollution.

Four types of basic contaminants associated with water pollution are inorganic contaminants, organic contaminants, biological contaminants, and radiological contaminants [41]. The major sources of water contaminants are pesticides, domestic waste, and industrial waste [41]. Biological contaminants include living organisms, such as algae, bacteria, protozoans, or viruses [41]. Radiological contaminants include radioactive elements [41].

The various types of water pollution include chemical pollution, oxygen-depletion pollution, microbiological pollution, nutrient pollution, groundwater contamination, and surface water pollution. Generally, water pollutants are classified as organic pollutants, nutrients, and agricultural pollutants; thermal, radioactive, inorganic pollutants, pathogens, suspended solids, and other pollutants.

Sewage and industrial effluents release organic and inorganic pollutants into bodies of water. Chemical water pollution is mainly due to the infiltration of chemicals into underground water and surface water. Chemical water pollutants are usually of two types: macro pollutants and micro pollutants, depending upon their concentration in the water [42]. Agriculture waste, biological compounds, oils, and gasoline are the primary sources of micropollutants [43-45]. Heavy metals (such as Cr, Ni, Cu, Zn, Cd, Pb, Hg, U, and Pu) and metalloids are the principal types of inorganic pollutants (e.g., Se, As). Agricultural pollutants mainly include nutrients, salts, sediments, pesticides, fertilizers, pathogens, and heavy metals. Nutrients mostly contain nitrogen and phosphorus, which are present in organic fertilizers. Some of the pesticides include herbicides, insecticides, fungicides, and DDT.

Emerging pollutants (EPs) are substances that are currently unregulated yet are released into the environment; they have also been termed contaminants of emerging concern (CECs). Emerging pollutants mainly include hormones, surfactants, flame retardants, wood preservatives, food additives, and disinfectants.

VI. ORGANIC POLLUTANTS

Organic pollutants are defined as the organic chemicals released into the ecosystem that cause temporary or permanent pollution. Chemicals are harmful to the ecosystem. Organic pollutants are not indigenous to the ecosystem. Chemicals released into the ecosystem when excess to the natural concentration become a pollutant to the ecosystem.

Growing levels of organic contaminants in water bodies pose a major risk to both human health and the aquatic ecosystem. Organic pollutants in water produce toxic chemicals during the disinfection process. Organic effluent contains a large number of

suspended particles that are responsible for water pollution. Organic pollutants discharged into freshwater generally originate from domestic sewage, urban runoff, industrial (trade) effluents, and farm wastes. The discharge of organic pollutants into freshwater is responsible for eliminating the activity of microorganisms.

Environmentally friendly, renewable, and Cost-effective techniques are the need of the hour for wastewater treatment before discharging into natural water bodies [34]. Large amounts of chemical, pharmaceutical, and agricultural industries are the primary source of organic pollutants in wastewater [47, 48]. The aquatic ecology and human health are both harmed by the unrestrained and unexplained discharge of micropollutants (trace level concentration) [49–53]. The concentration of organic pollutants in sewage is low, but the volume largely makes them a primary source of organic pollutants in water.

The toxic nature, semi-volatile nature, high bioaccumulation, non-biodegradability, and lower water solubility of organic pollutants make them a more significant concern for the ecosystem as well as human health [54-56].

Phenol compounds, polycyclic aromatic hydrocarbons (PAHs), and agricultural chemicals as Organic pollutants in freshwater are responsible for critical health problems for human beings as well as for the ecosystem [57, 58]. Organic pollutants are generally placed into three general categories i) organometallic compounds, ii) hydrocarbons, and iii) oxygen, nitrogen, and phosphorus compounds.

Discharges from motor vehicles onto the road come into the water as a pollutant due to stormwater. Motor vehicles are the primary source of hydrocarbons, dioxins, and polycyclic aromatic hydrocarbons (PAHs) pollutants in the water. These compounds contain elements like hydrogen and carbon, with some containing chlorine and oxygen as well. Synthetic organic chemicals, unit process operations, and production sites are also responsible for the discharge of organic pollutants into water. Organic pollutants, including petroleum, surfactants, pesticides, humic substances, dyes, phenol compounds, and pharmaceuticals, are important pollutants in wastewater.

The dramatic increase of synthesized chemicals like pesticides, plastics, hydrocarbon fuels, soaps, detergents, and other valuable substances in the last century has increased the levels of organic pollutants in water to a great extent. Most organic contaminants come from a small number of chemical families (PCBs, HCHs, DDT, PAHs, etc.).

Waste of fresh synthetic industrial compounds and industrial releases is the prominent source of organic pollutants in the water. They are potentially dangerous to human health and the ecosystem [59-62]. Organic chemicals are important starting materials for many industries, like new chemicals, polymers, pharmaceuticals, pesticides, and paints. Because of their more significant production and use, all these industries become the primary source of organic pollutants in water.

Agrochemicals are the various chemicals that are used in the agriculture sector. This includes pesticides, fungicides, insecticides, herbicides, nematicides, synthetic fertilizers, hormones, and other chemical growth regulators. Some examples of agrochemicals widely used include chlordane, DDT, Dieldrin, Endrin, Furans, Heptachlor, Hexachlorobenzene, Mirex Polychlorinated Biphenyls (PCBs), and toxaphene. Agriculture activities are the major

source of water pollutants that are released into the environment, resulting in the contamination of water. Agrochemicals through water pollution affect aquatic life as well as human beings by largely affecting the endocrine system [63, 64].

Some organic chemicals are more harmful to the environment and human health than others due to bioaccumulation, fat solubility, and environmental persistence. These pollutants are commonly referred to as Persistent Organic Pollutants (POPs). POPs compounds commonly include DDT, PCBs, and dioxins. POPs have a significant effect on the endocrine system even at low concentrations [65-68].

The increase in POPs in water is a result of industrial, agricultural, and other anthropogenic activities. In ecosystems, POSs have a long half-life, are lipophilic, and are poisonous [69, 70]. Some of the POPs include polychlorinated biphenyls (PCBs), γ -hexachlorocyclohexane (γ -HCH), polychlorinated dibenzo-p-dioxins (PCDDs), and dibenzofurans (PCDFs) as well as the poly aromatic hydrocarbons (PAHs).

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