Untapped potential of food waste derived biochar for the removal of heavy metals from water

Muhammad Waqas¹, Asma Moureen², Naeem Khan³, Abdul Sattar Nizami⁴
Department of Environmental Sciences, Kohat University of Science and Technology 26000, Kohat-Pakistan
Department of Chemistry, Kohat University of Science and Technology 26000, Kohat-Pakistan
Sustainable Development Study Center, Government College University Lahore-Pakistan

Presenting Author: mwaqas222@gmail.com

Abstract

Problem Statement
The continuous growth of population, rapid development of urbanization and industrialization worsen the quality of our water resources. Among the inorganic contaminants, the excessive presence of heavy metals in water pose a damaging effect on human physiology and other biological systems. Different technologies have been developed to remediate heavy metals from wastewater including, chemical precipitation, gravity separation, solvent extraction, reverse osmosis, ion-exchange, electrocoagulation and electrodialysis, flotation and adsorption. Among these, adsorption technology is recognized as one of the most available option because of its low cost and high efficiency. Adsorption is a surface phenomenon and is defined as the increase in concentration of a particular component at the surface or interface between two phases. In the adsorption technology, the nature and type of adsorbent is considered as a key optimizing factor. There are various types of adsorbents that have been used to remove heavy metals from wastewater comprised of nanomaterials, metal oxides, mesoporous silicates, composites and kaolinite and montmorillonite clays. Potential use of carbonaceous materials as an adsorbent for the pollutant remediation from soil and water has been well reported in the literature. Among the carbonaceous materials, biochar is a material with a higher surface area and contains a non-carbonized fraction that interacts with the contaminants. Biochar has been recognized as an outstanding ameliorant to remediates various contaminants including heavy metals due to its unique physicochemical characteristics. For biochar production, various types of organic biomass can be subjected to thermal treatment. Among the organic biomass, food waste is the largest waste stream of municipal solid waste that is disposed of untreated in the dumpsites or landfills with no material or resource recovery. Hence the thermochemical conversion of food waste to biochar is not reported for removal of heavy metals in the literature. Hence being a low-cost feedstock and easy availability the present study is designed to convert food waste to biochar and valorize its application for the removal of heavy metals from wastewater.

Objectives
(1) To convert food waste to biochar through pyrolysis at various temperatures, (2) Explore its physiochemical properties, and (3) Potential of food waste derived biochar for removal of heavy metals from wastewater.

Methodology
Food wastes was collected from the main canteens of the Kohat University of Science & Technology (KUST), Kohat-Pakistan. After collection, the feedstock was dried at 105 °C for 24 hours to remove all the moisture and then cut to a particle size of 2-5 cm. A known quantity of the dried feedstock sample was taken in an air tight closed stainless steel cylinder and was heated in muffle furnace at different temperatures i.e., 350, 450, and 550 °C for 3 hours to produce biochar. The proximate and physiochemical analysis of the produced biochar was determined according to the standard methods. Likewise, the produced biochar was also subjected to various characterizations including XRD, FTIR, and SEM to study the variation in the properties of biochar with various temperature.

After the complete physiochemical analysis and characterizations, the adsorption potential of the food waste derived biochar was assessed for removal of selected heavy metals from wastewater. Adsorption experiments using batch technique was conducted to determine the adsorption capacity of biochar. Various adsorption parameters such as, adsorbent doses (1, 1.5, 2 and 2.5 g L-1), contact time (30, 60, 90 and 120 minutes) and pH (2, 4, 6 and 8) was studied in a batch mode of operation.

The amount of heavy metal adsorbed per unit mass of the adsorbent (qe) was calculated using the equation:

\[ q_e = \frac{(C_i - C_e)}{W} \times V \]

Likewise, the percent adsorption of the metal was calculated using the given equation:

\[ \text{Adsorption (\%) } = \frac{(C_i - C_e)}{C_i} \times 100 \]

Where Ci is the initial metal ion concentration (mg L-1), Ce is the equilibrium concentration of the metal ion (mg L-1), V is the volume of solution (L), and W is the weight of adsorbent (g).
Results
The biochar produced at various temperatures (350, 450, and 550 °C), showed a wide range of mineralogical composition, and alkaline pH, making it appropriate for the removal of selected heavy metals (lead, cadmium and chromium) from water. Results showed that all the produced biochar effectively removed the selected heavy metals from the wastewater however the highest removal capacity was observed for the biochar produced at 550 °C. The alkaline nature of biochar, negatively charged biochar active sites due to O-containing functional groups, and swelling behaviour were credited with the significant potential for heavy metal removal by biochar formed at high temperatures. The swelling of biochar at high temperatures opened the closed pores, hence increasing the adsorption capacity by increasing the interior surface area. Hence, one step conversion of FW to biochar offer the sustainable management of such waste by converting them to valuable product that could be effectively used for environmental remediation.