ABSTRACT

Most heavy metal contamination is found in Asian and African nations, and late water filtration methods rely heavily on electricity. Also, a good population living in rural Asian and African countries consumes heavy metal contaminated water due to the lack of electricity. Additionally, heavy metal pollution in groundwater is a significant concern for human health in the Indo-Gangetic Plain of India. Moreover, due to a lack of economically and sustainable rice straw waste management options for rice straw utilization, around 84 Mt of rice straw is burned on the field in India. We aim to transform rice straw waste into biochar and utilize it remove heavy metals from groundwater. Therefore, in this study, biochar was produced from rice straw at different temperatures (300-600 ℃) through pyrolysis. The result indicated an increase in process temperature led to the decreased biochar yield (57.87 – 35.63%), while the yield of bio-oil (30.22-39.6%) and syngas (11.91-26.16%) increased. Moreover, pH (8.28-11.4), fixed carbon (43.91-57.63%), pore-volume (0.0087-0.059 $cm^3\ g^{-1}$), surface area (12.78-83.06 $m^2\ g^{-1}$), and HHV (17.63-20.13 MJ kg^{-1}) of biochar increased. The energy (76.7-82.39%) and exergy efficiency (63.97-81.57%) of the pyrolysis system increased with process temperature, and the thermodynamic optimization was achieved at 600 ℃.

The single-step physical activation (CO_2 and H_2O) of rice straw was planned and optimized the activation process parameters to get better biochar yield and surface area. The biochar activation parameters were optimized using the central composite design method. The CO_2 activated biochar has an optimum surface area and product yield of 399.99 $m^2\ g^{-1}$ and 26.79 %, whereas H_2O activated biochar has an optimum product yield and surface area of 31.53 % and 300 $m^2\ g^{-1}$. The SEM analysis shows that CO_2 activated biochar has a more uniform porous structure compared to H_2O

activated biochar. Cost analysis revealed that CO_2 and H_2O activated biochar had a manufacturing cost of 1.287 and 1.672 U.S. \$ kg^{-1}, respectively.

Biochar derived at 600 ℃ had a higher surface area (78.17 m^2 g^{-1}) and adsorption capacity for As (4.51 mg g^{-1}) and Mn (3.61 mg g^{-1}) in a binary metal system. The PSO kinetics (R^2: 0.97) and Langmuir isotherms (R^2: 0.94) model batter explained the adsorption of As and Mn. The adsorption was facilitated by electrostatic attraction between metalloids and oxygenated (-COOH and -O.H.) surface functional groups. Health risk assessment indicated that field water (50 ml) treated with 0.1 g biochar had the highest As and Mn removal efficiency (>85 %) and hence lowered the cancer risk in the community. The cost of biochar produced at 600 ℃ (0.913 U.S. \$) is comparable with other adsorbents. Furthermore, CO_2-activated biochar was used to study the comparative analysis of As and Mn adsorption in a single and binary metal approach. Findings showed that the maximal sorption capacity of As and Mn in single metal systems was 18.26 and 12.18 mg g^{-1} and 8.51 and 5.42 mg g^{-1} in binary metal systems. The highest removal efficiency of As (99.53 %) and Mn (96.23 %) was achieved in naturally contaminated water (Sahibganj, district of Jharkhand, India). Health risk assessment indicates chances of cancer (CR> 1×10^{-4} and HQ>1) in humans due to the high concentration of As (192 μg L^{-1}). Water treated with 0.1 g activated biochar had lower CR and HQ values, and metal concentration was below the WHO safe drinking water standard.

Apart from this, silver and copper impregnated CO_2 activated biochar was produced and studied its efficacy in removing heavy metals as well as microbial contaminants from groundwater. Results indicated that silver-impregnated activated (As: 87.29% and Mn: 99%) biochar had higher metal removal efficiency than copper-impregnated activated biochar (As: 84.38% and Mn: 99%). The antibacterial rate of silver-impregnated activated (92.74%) biochar was higher than copper-impregnated

activated biochar (76.70%). The concentration of As and Mn ions in the field water after adsorption by silver and copper-impregnated activated biochar was found in the range of the BIS safe drinking water guidelines.