CHARACTERISATION OF ADSORBENTS PRODUCED FROM HYDROTHERMAL CARBONISATION OF VARIOUS BIOMASS WASTES

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ABSTRACT

Utilizing biomass wastes for the removal of environmental contaminants such as heavy metals from wastewater has gain research interests in recent times as a means of proffering a sustainable solution to water pollution. In order to understand the kinetics of heavy metal adsorption onto biomass wastes, an intrinsic knowledge about the microstructural properties, elemental chemical composition and particle size analysis of each adsorbent is necessary. The main objective of this study was to use Hydrothermal Carbonisation (HTC) to produce hydrochars from different biomass wastes, and to investigate their sorption potential for heavy metals (Cr, Cu, Fe, Pb) adsorption, as compared with a commercially available activated bone char. The biomass wastes used in this study were lemon peel, rice husk, coco peat and chicken eggshell. These were carbonised at 200^{o}C for 20 hours, and the biomass produced hydrochars were then characterised for their micro-structure; elemental composition; surface area, pore size and volume; as well as particle size using a scanning electron microscopy (SEM); energy dispersive spectroscopy (EDS); Brunauer, Emmett and Teller (BET); and a Mastersizer, respectively. The results showed a very high surface area for the activated bone char (99.70 m^2/g), while lower surface areas were obtained for hydrochars from the biomass, which were approximately 2.14 m^2/g for the coco-peat, 0.50 m^2/g for the eggshell, 15.74 m^2/g for the rice husk, and 6.89 m^2/g for the lemon peels. However, the corresponding surface areas of the un-carbonised biomass were measured as: 1.23 m^2/g for coco-peat, 0.09 m^2/g for eggshell, 0.46 m^2/g for rice husk and 0.05 m^2/g for lemon peel. In conclusion, the hydrochars had increased porosity with crispy and flaky as well as micro and meso-porous structures and cavities, indicating active sites on the adsorbents signifying high affinity for heavy metal binding.

Keywords**:** Adsorption, biomass, hydrochar, SEM, EDS, particle size distribution

1. INTRODUCTION

In recent years, the search for novel technology for the treatment of wastewater containing heavy metals has gain research interests with a view of reducing the concentration of micro pollutants in the environments (Bortoluz, et al., 2016). Over the years, regulatory bodies such as World Health Organization (WHO), Food and Agriculture Organization (FAO), have issued sets of risk-based reduction strategies to limit the proliferation of contaminants into the environmental media for instance air, soil, and waterbodies (FAO/WHO, 2006). These measures were taken to reduce the pervasive consequences of the micro pollutants on both flora (crops) and fauna (humans and animals) at concentrations above their thresholds.

Several studies have described various conventional methods for heavy metal removal from industrial wastewaters. These methods include chemical precipitation, ionic exchange, electro dialysis, reverse osmosis, and adsorption using activated carbon (Zhao et al., 2016). Although, these methods have been proven to be very useful till date, their applications are inimical and limited by high operational and maintenance costs, generation of secondary toxic waste which requires additional cost of treatment, and ineffectiveness in removing metal ions even at much lower concentrations (Azouaou et al., 2013). Activated carbon, which is effective for removing heavy metals at lower concentrations require high temperatures (up to 800^{o}C), and high cost of production (Lima et al., 2008).

The limitations of the conventional wastewater treatment methods have raised the environmental awareness to the development of new, eco-friendly and economical technologies for wastewater purification. Therefore, nowadays, most studies have focused on the utilisation of biomass for removing metal contaminants from wastewater. A number of agricultural residues have been tested as low cost sorbents of heavy metals from wastewaters (Azouaou et al., 2013). However, for all raw biosorbents, a major disadvantage is the release of organics that cause secondary pollution and oxygen reduction in water (Liu and Zhang, 2009). Hydrothermal carbonisation (HTC) has been proposed as a potential technique of overcoming this issue (Libra et al., 2011).

HTC is a thermochemical pathway, in which the biomass is heated between 180–300°C in a closed vessel at a self-increasing pressure to produce carbonaceous solids, called 'hydrochar'(Funke and Ziegler, 2010). The advantages of HTC over other conventional thermal processes such as pyrolysis is that, HTC is not limited to biomass with low moisture content, hence, it is open to a variety of biomass materials. Also, compared to pyrolysis, HTC is cheap, as it does not require pre-drying of the biomass feedstock and it is operated at a relatively moderate temperatures (Libra et al., 2011). Apart from the solids (hydrochar), HTC generates a larger amount of water and fewer gaseous phase (Funke and Ziegler, 2010). Unlike raw biomass, majority of the organic components are transferred to the liquid (Danso-Boateng et al., 2015).

The objective of this study therefore is to examine the sorption characteristics of hydrochar biosorbents from different biomass in terms of (i) surface morphology; (ii) elemental composition; (iii) surface area, porosity, pore volume and (vi) particle size distribution.

2. MATERIALS AND METHODS

The wastes considered in this study include eggshell, rice husk, coco-peat, lemon peels, and a commercially available activated carbon (bone char) used as a standard. The choice of these materials was based essentially on the fact that they are locally sourced, relatively abundant, and cheap. The method that would be used for characterisations of these biosorbents include (i) Scanning Electron Microscopy (SEM) for surface morphology; (ii) Energy Dispersive Spectroscopy (EDS) for elemental composition; (iii) Brunauer, Emmett and Teller (BET) for determining surface area, porosity, and pore volumes; and (vi) Mastersizer-2000 for particle size distribution.

3. RESULTS

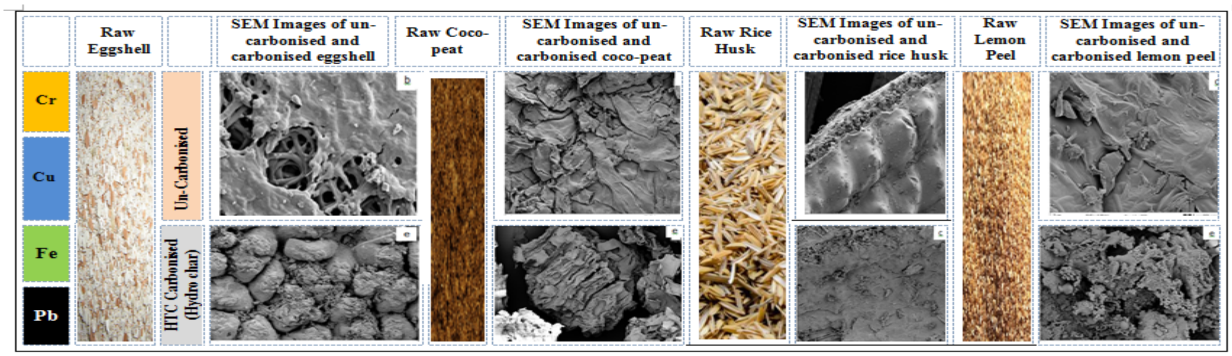

Figure 1. illustrate raw adsorbents and scanned images of un-carbonised and carbonised biomass wastes

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