Effects of pH and Pyrolysis Temperature on Adsorption of Lead (Pb) by Biochar

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ABSTRACT

Elevated level of lead (Pb) in water is a health concern that can cause reproductive and immunological defects. Pyrolyzed carbon-rich material (biochar) has been reported to be effective in removing Pb in aqueous media. Since biochar feedstock and pyrolysis temperature determine the adsorption of heavy metals, the aim of the current work was to check the effects of pH (2, 4, 6, 8, 10 & 12) and temperature (400, 600 & 800 °C) on the adsorption of Pb, using three biomasses of biochar (avocado seeds, aspen bedding & palm tree) in comparison to a commercially available biochar (AquaTech activated carbon). The study was conducted by preparing 50 mg/L of Pb solution and the solution pH was adjusted using either nitric acid or sodium hydroxide. The biochar materials were ground and passed through a 0.5-mm sieve size. Afterwards, 0.05g of the biochar was agitated with 0.10 mL of Pb for 24 h, and duplicate samples were tested. The filtrate, after agitation, was divided into two subsamples to see the precipitation of lead in high pH. First set of samples was further subjected to pH adjustment less than 2 while pH of the second samples was not further adjusted after filtration. Both the pH adjusted, and non-adjusted samples were analyzed with a PinAAcle 900T Atomic Absorption Spectrometry. Overall, there was a decreased Pb adsorption in low pH (pH 2-4) and the Pb adsorption increased with pH up to 8.0. The results showed that palm tree at 600°C and aspen bedding at 800°C performed the best with 97–100% Pb removal rate at the pH range between 4 and 6, suggesting that they have a high potential for removing Pb from contaminated water.

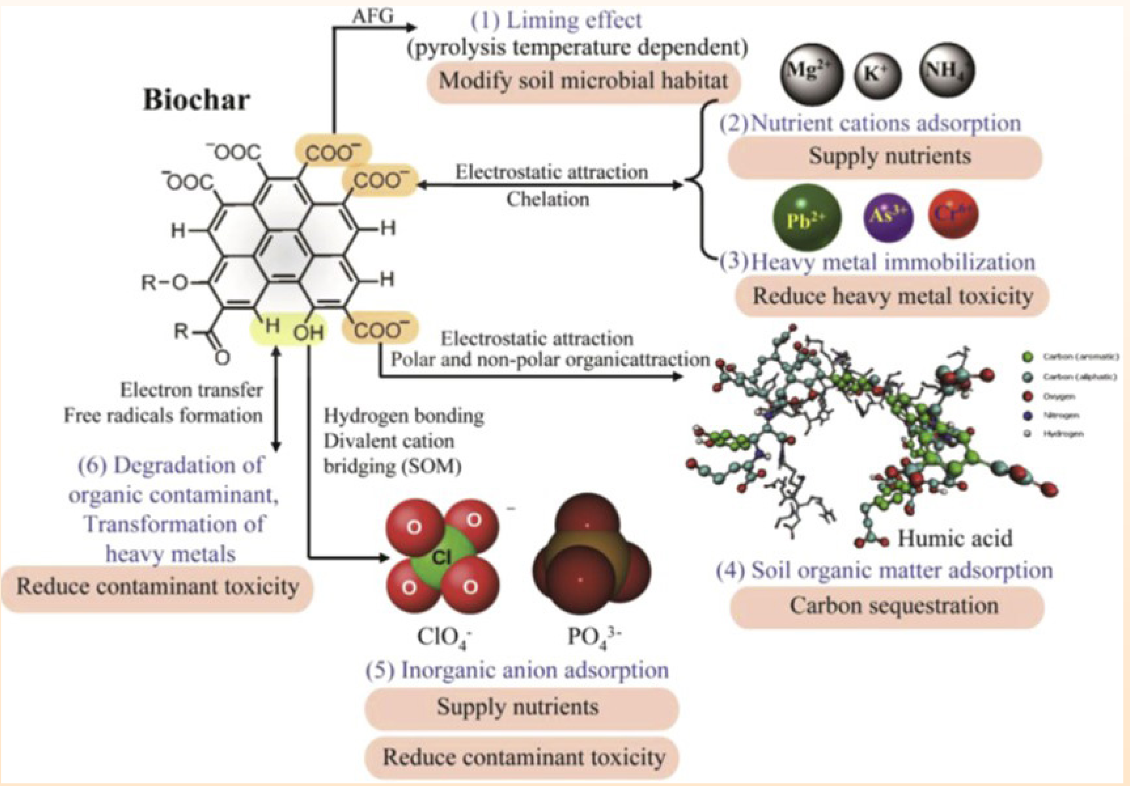

Figure 1. Functional groups of biochar. Zhu *et al.* (2017)

INTRODUCTION

- Biochar is a carbon-rich solid that is produced from the pyrolysis of organic materials, and scholars have noted carbon sequestration, soil improvement, water remediation, bioremediation of hydrocarbons as some of its numerous applications.
- Biochar has demonstrated to be effective in remediating toxic contaminants due to its specific properties such as a large surface area, a porous structure, surface-enriched functional groups, and the presence of some mineral components (Li, et al., 2017; Ding et al., 2016). Ahmad et al. (2014) opined that feedstock type and pyrolysis parameters are the predominant biochar functional group indicator. In a similar study, Zhu et al. (2017) observed a higher specific surface area and increased pH for wood biochar as pyrolysis temperature increased.
- According to Ahmad et al., (2014), biochar yield and volatiles increases as temperature drops, while ash content and surface area tend to have a positive relationship with pyrolysis temperature.
- Figure 1 shows the interaction between biochar functional groups and organic and inorganic compounds, where the negatively charged biochar surfaces and cations (Ahmad et al., 2014) combine to supply nutrients to soil microbes and immobilize heavy metals.
- The adsorption of Pb by biochar is affected by solution pH with maximum adsorption capacity achieved at pH 6, as documented by Mireles et al. (2019). The current study investigated the effect of pH and pyrolysis on Pb adsorption, using three feedstocks of biochar.

MATERIALS AND METHODS

The experimental procedure is as follows.

- Three feedstock types (AB, BE, and PT) were collected from restaurants, sawmills, and residential areas. The feedstocks were soaked and then watched multiple times, followed by oven-drying at 110 °C for 24 h. The three biochars (AB, BE, and PT) were produced individually in the absence of oxygen at a temperature of 400–800 °C for 2 h.
- The produced biochars were named as follows; AB400, AB600, AB800, BE400, BE600, BE800, PT400, PT600, and PT800 to reflect the three different pyrolysis temperatures (400 °C, 600 °C, and 800 °C). After production, the biochar was ground and sieved through a 0.5-mm mesh, and rewashed multiple times to eliminate unwanted particles. Once again, the oven-drying process was repeated overnight for the washed biochar.
- A 50 mg Pb L^{-1} solution was prepared in separate containers, and pH was adjusted to pH 2, 4, 6, 8, 10, and 12 using either nitric acid or sodium hydroxide solution. Batch adsorption as performed by mixing 0.05 g of biochar with 10-mL aliquot of 50 mg Pb L^{-1} in a 20-mL plastic vial, from pH 2 to 12. The biochar–Pb^{2+} mixtures were shaken for a 24 h period. After shaking, the solutions were filtered using a single-use filter cartridge.
- The supernatants were collected, and pH was adjusted a second time to pH 2, using a 1M nitric acid solution, and analyzed for Pb^{2+} with a PinAAcle 900T Atomic Absorption Spectrometry. The adsorption capacity (q) and percent removal of Pb^{2+} ions (Re%) by biochar were calculated by the formula: $q = (C_0V–CV)/M$ and $Re\% = [(C_0–C)/C_0]x100$ where C_0 and C are the initial and final amount of Pb^{2+} in solution (mg L^{-1}), V is the volume of liquid used (V), and M is the weight of the dry mass of biochar (g).

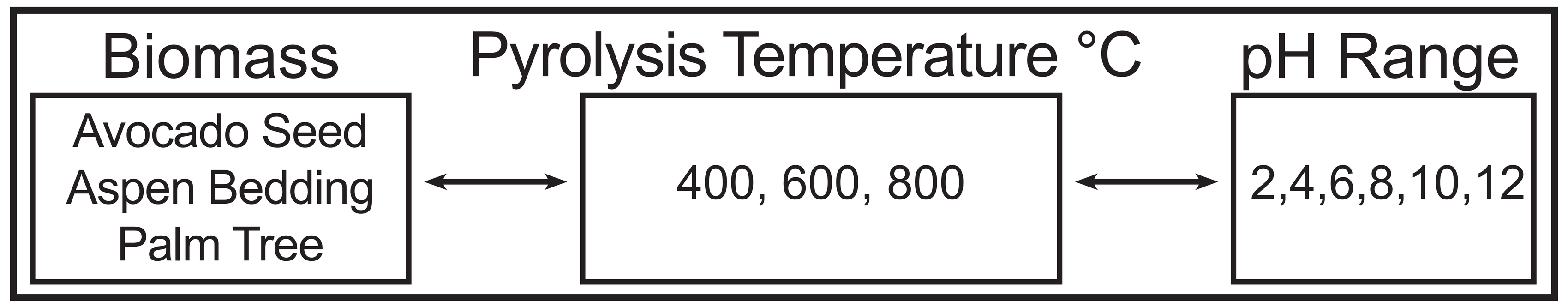

Figure 2. Schematic showing biomass, pyrolysis and pH range

Figure 3. Raw ground biomass

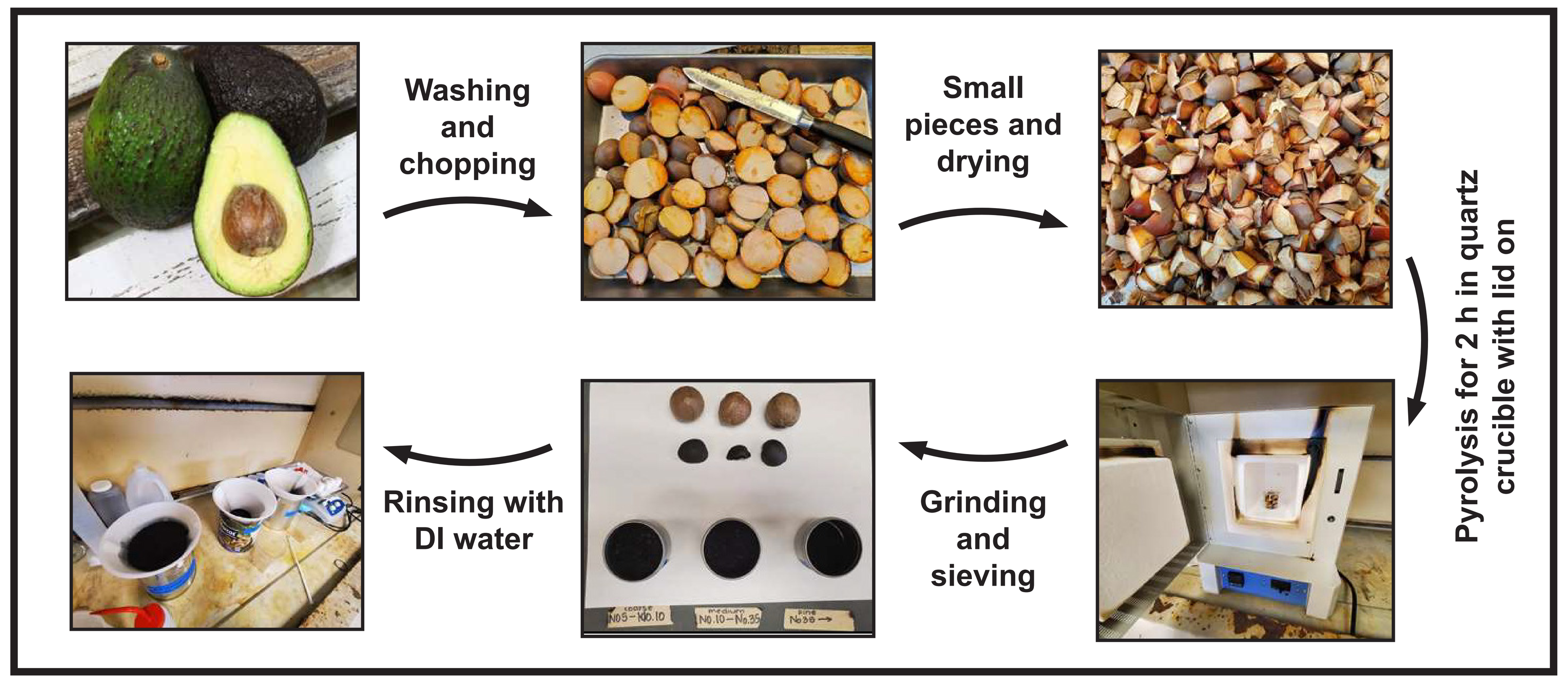

Figure 4. Schematic showing biochar production procedures

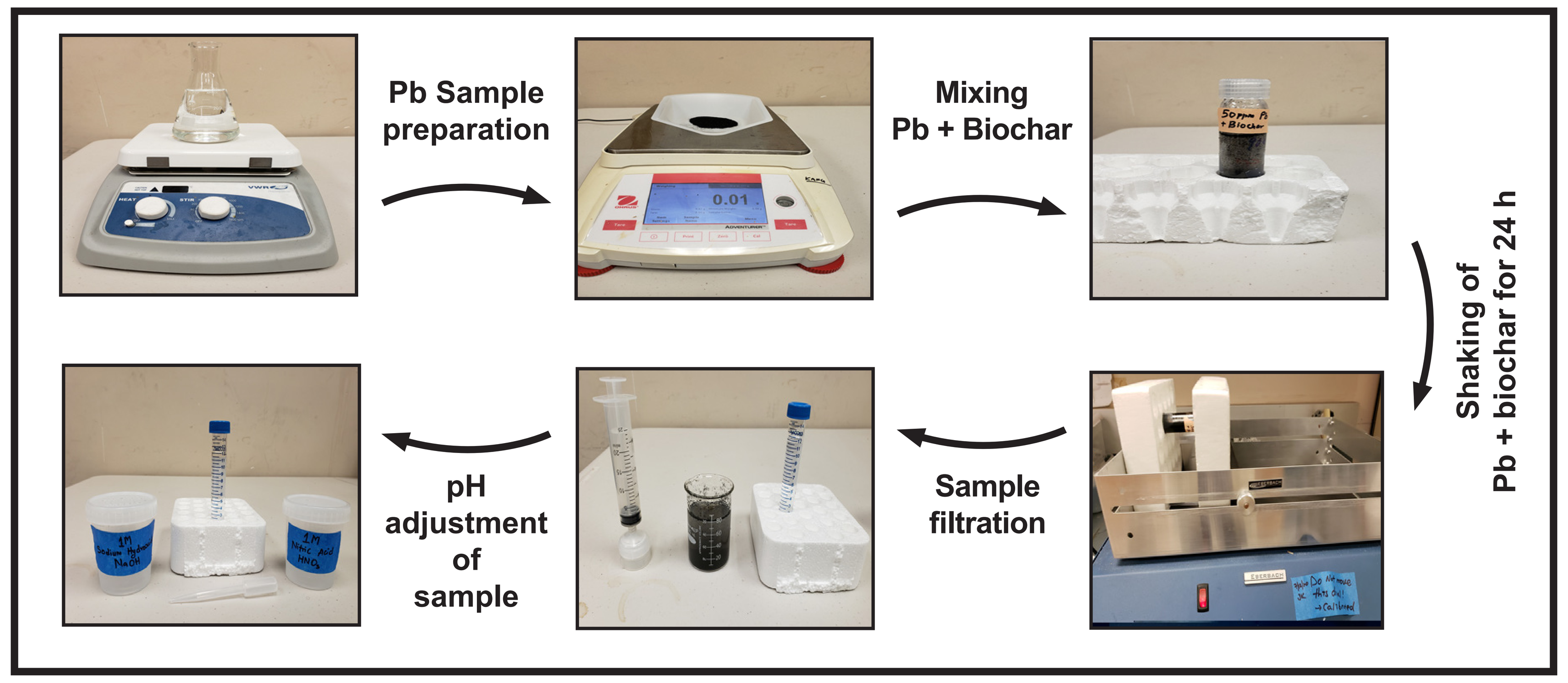

Figure 5. Schematic showing absorption procedures

RESULTS AND DISCUSSION

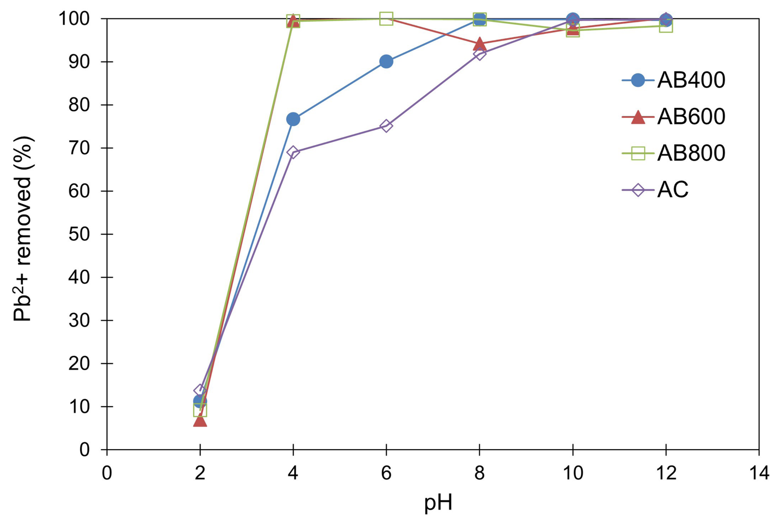

Figure 6. Effect of pH on lead (Pb^{2+}) adsorption

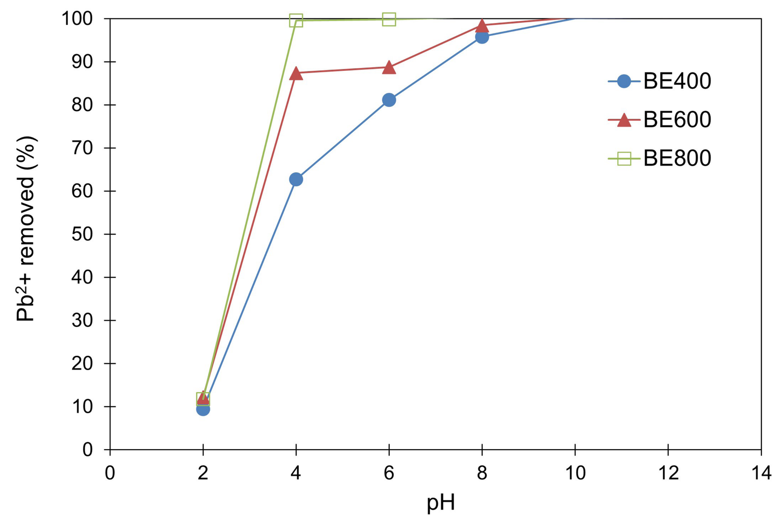

Figure 7. Effect of pH on lead (Pb^{2+}) adsorption

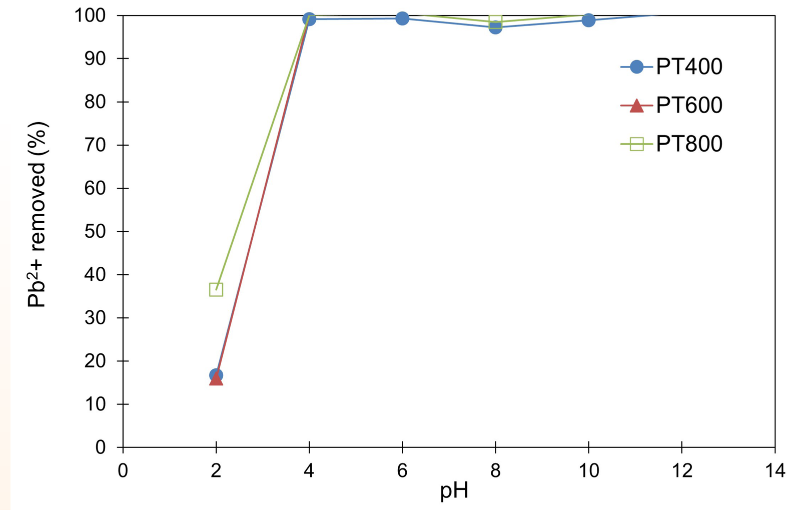

Figure 8. Effect of pH on lead (Pb^{2+}) adsorption

- Figures 6–8 summarizes the preliminary results from this study. Similar to the findings of Mireles et al. (2019), AB600, AB800, BE800, PT600, and PT800 attained a maximum adsorption capacity at pH 6 while AB600 and AB800 had variations after pH 6.
- A higher pH above 6 may not be considered due to the possible precipitation of $Pb(OH)_2$ from solution (Mireles et al., 2019). The results were compared with AC, a commercially available biochar with unknown pyrolysis temperature. It was observed that AC did not reach maximum adsorption at pH 6 like most of the biochar samples, this could be a function of its pyrolysis temperature.
- The recorded data suggests that at less than pH 6 and lower temperatures, the adsorption capacity of biochar diminishes. The adsorption capacity of biochar at pH 6 and high temperatures (600 – 800°C) agrees with Ahmad et al. (2014) that improved biochar surface area is a function of high pyrolysis temperature.

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