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Toxic and nontoxic elemental enrichment in biochar at different production temperatures

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ABSTRACT

The major impediment to the use of biochar for soil amendment is the presence of toxic elements; however, it is not known how variations in production temperature affect the enrichment behaviour of toxic elements as identified by mass loss and whether the level of nontoxic elements compromises biochar quality. These goals require an understanding of the solid phase which constitutes the tar and ash fractions that harbour majority of the Cation exchange capacity (CEC) and functional groups of biochars and the possible mechanisms through which these metals interact with the solid phase. Results showed that the enrichment behaviour of individual toxic and nontoxic elements at low production temperatures of 350 and 450 °C was significantly different ($p < 0.005$) to that of high production temperature of 650 °C. The concentration of individual toxic elements revealed maximum enrichment of 193,957 ± 36,881 μg kg^{-1} and 1650 ± 203 μg kg^{-1} for Na and B respectively at the 450 °C. While the concentrations of individual nontoxic elements, exhibited maximum enrichment of 665,187 ± 119,715 μg kg^{-1}, 58,335 ± 13,985 μg kg^{-1}, 8858 ± 3574 μg kg^{-1} and 4907 ± 1174 μg kg^{-1} for K, Mg, Si and Al respectively at the 450 °C. Conversely, As was the only toxic element that exhibited maximum enrichment of 21 ± 9 μg kg^{-1}, at the 650 °C. Total toxic elemental concentrations indicated strong relationship with percentage mass loss ($r^2 = 0.998$, $p < 0.05$), which was greatest at 450 °C, but indicated strong negative relationship with percentage ash content ($r^2 = -0.946$, $p < 0.210$), which was greatest at 650 °C. Therefore, the 650 °C was effective in reducing both the toxic and nontoxic elements in biochar and thus, presented a quality biochar, due to its pi electrons which can result in dual benefits such as stronger binding of inorganic and organic elements to biochar in soils.

1. Introduction

Despite the fact that coconut shell (CS) accounts for about 1/5th of the biomass reported to be globally available for the production of low-cost sorbent (Smith et al., 2009), but studies focusing on the toxic elemental assessment in CS biochar are not available in the literature. It has also been reported that there is a lack of sufficient data with regards to non-toxic elemental content in biochar (Chan and Xu, 2009). In the past, researches were mainly focused on CS Activated Carbon (AC), which was used for the treatment of waste water (Daud and Ali, 2004; Xie et al., 2011). Similarly, the use of AC and presently carbon nanotubes of varying feedstock, in waste water treatment is on the increase (Gupta et al., 2011a, 1998, 2004, 1997, 2011b, 2012a, 2012b, 2013; Gupta and Nayak, 2012; Gupta and Ali, 2001; Jain et al., 2003; Karthikeyan et al., 2012; Khani et al., 2010; Mittal et al., 2009, 2010; Saleh et al., 2011; Saleh and Gupta, 2012a,b). However, the risks that may be posed by the presence of toxicants in the resulting sorbents were not considered prior to utilization. Presently, the International-Biochar-Initiative (2015)-(IBI) had recommended toxicant assessment in biochar.

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