World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:14, No:03, 2020

In situ Stabilization of Arsenic in Soils with Birnessite and Goethite

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Abstract : Over the last century, rapid urbanization, industrial emissions, and mining activities have resulted in widespread contamination of the environment by heavy metal(loid)s. Arsenic (As) is a toxic metalloid belonging to group 15 of the periodic table, which occurs naturally at low concentrations in soils and the earth's crust, although concentrations can be significantly elevated in natural systems as a result of dispersion from anthropogenic sources, e.g., mining activities. Bioavailability is the fraction of a contaminant in soils that is available for uptake by plants, food chains, and humans and therefore presents the greatest risk to terrestrial ecosystems. Numerous attempts have been made to establish in situ and ex-situ technologies of remedial action for remediation of arsenic-contaminated soils. In situ stabilization techniques are based on deactivation or chemical immobilization of metalloid(s) in soil by means of soil amendments, which consequently reduce the bioavailability (for biota) and bioaccessibility (for humans) of metalloids due to the formation of low-solubility products or precipitates. This study investigated the effectiveness of two different types of synthetic manganese and iron oxides (birnessite and goethite) for stabilization of As in a soil spiked with 1000 mg kg^{-1} of As and treated with 10% dosages of soil amendments. Birnessite was made using HCl and $KMnO_4$, and goethite was synthesized by the dropwise addition of KOH into $Fe(NO_3)$ solution. The resulting contaminated soils were subjected to a series of chemical extraction studies including sequential extraction (BCR method), single-step extraction with distilled (DI) water, 2M HNO_3 and simplified bioaccessibility extraction tests (SBET) for estimation of bioaccessible fractions of As in two different soil fractions (< 250 µm and < 2 mm). Concentrations of As in samples were measured using inductively coupled plasma mass spectrometry (ICP-MS). The results showed that soil with birnessite reduced bioaccessibility of As by up to 92% in both soil fractions. Furthermore, the results of single-step extractions revealed that the application of both birnessite and Goethite reduced DI water and HNO_3 extractable amounts of arsenic by 75, 75, 91, and 57%, respectively. Moreover, the results of the sequential extraction studies showed that both birnessite and goethite dramatically reduced the exchangeable fraction of As in soils. However, the amounts of recalcitrant fractions were higher in birnessite, and Goethite amended soils. The results revealed that the application of both birnessite and goethite significantly reduced bioavailability and the exchangeable fraction of As in contaminated soils, and therefore birnessite and Goethite amendments might be considered as promising adsorbents for stabilization and remediation of As contaminated soils.

Keywords : arsenic, bioavailability, in situ stabilisation, metalloid(s) contaminated soils
Conference Title : ICEPC 2020 : International Conference on Environmental Pollution Control
Conference Location : Paris, France
Conference Dates : March 26-27, 2020