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Altering the Solid Phase Speciation of Arsenic in Paddy Soil: An Approach to Reduce Rice Grain Arsenic Uptake

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Abstract : Fates of Arsenic (As) on the soil-plant environment belong to the critical emerging issue, which in turn to appraises the threatening implications of a human health risk — assessing the dynamics of As in soil solid components are likely to impose its potential availability towards plant uptake. In the present context, we introduced an improved Sequential Extraction Procedure (SEP) questioning to identify solid-phase speciation of As in paddy soil under variable soil environmental conditions during two consecutive seasons of rice cultivation practices. We coupled gradients of water management practices with the addition of fertilizer amendments to assess the changes in a partition of As through a field experimental study during monsoon and post-monsoon season using two rice cultivars. Water management regimes were varied based on the methods of cultivation of rice by Conventional (waterlogged) vis-a-vis System of Rice Intensification-SRI (saturated). Fertilizer amendment through the nutrient treatment of absolute control, NPK-RD, NPK-RD + Calcium silicate, NPK-RD + Ferrous sulfate, Farmyard manure (FYM), FYM + Calcium silicate, FYM + Ferrous sulfate, Vermicompost (VC), VC + Calcium silicate, VC + Ferrous sulfate were selected to construct the study. After harvest, soil samples were sequentially extracted to estimate partition of As among the different fractions such as: exchangeable (F1), specifically sorbed (F2), As bound to amorphous Fe oxides (F3), crystalline Fe oxides (F4), organic matter (F5) and residual phase (F6). Results showed that the major proportions of As were found in F3, F4 and F6, whereas F1 exhibited the lowest proportion of total soil As. Among the nutrient treatment mediated changes on As fractions, the application of organic manure and ferrous sulfate were significantly found to restrict the release of As from exchangeable phase. Meanwhile, conventional practice produced much higher release of As from F1 as compared to SRI, which may substantially increase the environmental risk. In contrast, SRI practice was found to retain a significantly higher proportion of As in F2, F3, and F4 phase resulting restricted mobilization of As. This was critically reflected towards rice grain As bioavailability where the reduction in grain As concentration of 33% and 55% in SRI concerning conventional treatment ($p < 0.05$) during monsoon and post-monsoon season respectively. Also, prediction assay for rice grain As bioavailability based on the linear regression model was performed. Results demonstrated that rice grain As concentration was positively correlated with As concentration in F1 and negatively correlated with F2, F3, and F4 with a satisfactory level of variation being explained ($p < 0.001$). Finally, we conclude that F1, F2, F3 and F4 are the major soil. As fractions critically may govern the potential availability of As in soil and suggest that rice cultivation with the SRI treatment is particularly at less risk of As availability in soil. Such exhaustive information may be useful for adopting certain management practices for rice grown in contaminated soil concerning to the environmental issues in particular.

Keywords : arsenic, fractionation, paddy soil, potential availability
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