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Arsenic and cadmium solubilization in soil as affected by alternate submergence/drainage and water percolation rates.

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Arsenic (As) concetration in the soil solution of paddy fields is known to increase upon reduction of arsenate (As(V)) to arsenite (Ar(III)) under reductive conditions. Contrastingly, reductive condition leads to insolubilization of cadmium (Cd), which in turn is solubilized under oxidative conditions produced by drainage of the soil. For minimizing uptake of these toxic elements by rice plants, As and Cd concentrations in the soil solution should be kept as low as possible. Here, we conducted a series of column experiments to investigate the effects of different submergence/ drainage treatments and water percolation rate on the development of oxidative-reductive conditions, and arsenic and cadmium concentrations in the soil solution.

A Gray Lowland soil taken from the topsoil of a paddy field, with 1 M HCl-extractable As of 7.9 mg/kg and 0.1 M HCl-extractable Cd of 0.22 mg/kg, was repacked into cylindrical columns with an inside diameter of 20 cm to a thickness of 15 cm. A series of column experiments was conducted which differed in the submergence/drainage treatments (i.e., "conventional", "prolonged ponding", and "intermittent irrigation") and in the water percolation rate. During the submerged periods, 0.5 mM $CaCl_2$was infiltrated into the soil columns with a ponding depth of 5 cm. The oxidation-reduction potential (Eh), pH, air-filled porosity (estimated from the volumetric water content measured with TDR), dissolved oxygen concentration were continuously measured at 2.5 cm, 7.5 cm and 12.5 cm depths. Soil solution was collected at the same depths every three to four days and, after filtrating through a 0.20-um PTFE filter, analyzed for dissolved As, Cd and Fe (II). The conventional submergence/drainage treatment comprised a sequence of 32-day ponding, 17-day drainage, 32-day ponding followed by the final drainage for 19 days. The prolonged ponding treatment consisted of 50-day ponding and 20-day drainage. The intermittent irrigation treatment comprised 35-day ponding, 21-day drainage followed by alternate 5-day ponding and 5-day drainage. The average water percolation rates in the prolonged ponding and intermittent irrigation treatments were 1.6 and 11.7 mm/d, respectively, whereas those in the conventional treatment were 7.8 mm/d in the first ponding period and 14.5 mm/d in the second ponding period.

In all the treatments, total As concentration in the soil solution increased with the development of reductive conditions during the submergence period, with the maximum concentrations of 522 ug/ L, 340 ug/L and 264 ug/L in the prolonged ponding, conventional, and intermittent irrigation treatments, respectively. Arsenic solubilization at different depths started at a similar Eh of +100 mV. There was no consistent difference in the total As concentration observed between the different depths. The dissolved As was mostly As(III).

Upon drainage, invasion of oxygen from the soil surface induced Eh increase, decrease in the As concentration, and increase in the Cd concentration in the soil solution. While the increase in the Cd concentration was preceded by the decrease in the As concentration at any depth, slow drainage at the deeper depth temporarily produced a condition in which the soil at 2.5 cm depth was oxidative while that at 12.5 cm depth remained reductive. Thus, in the conventional treatment

column 5-9 days after drainage, the Cd concentration at 2.5 cm depth had increased to 10 to 19 ug /L whereas the As concentration at 12.5 cm depth was still as high as 287 ug/L. Such concurrent presence of Cd in the upper part and As in the lower part of the topsoil was most typically observed when the soil drying was slow and the Eh increase was delayed in the deeper part of the soil. In the intermittent irrigation, both the As and Cd concentrations were kept minimal during the alternate ponding and drainage periods. Further study is required on the solubilization processes of As and Cd during intermittent flooding.

Keywords: Arsenic, Cadmium, Irrigation, Paddy