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Effects of sulfate-fertilization and water management on toxicant and micronutrient accumulation in rice

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Rice is an important staple food and source of micronutrients in low-income countries but also known to accumulate Arsenic (As) when grown in flooded paddy fields due to reductive dissolution of As bearing iron-(oxy)hydroxides. For consumer safety, food guidelines limiting the As concentration of rice grains were established in many countries and paddy field management was optimized on harvesting low As-rice. Among the most widely used managements strategies are sulfur (S)-fertilization and alternate-wetting and drying (AWD) water supply, however, the effects of different paddy field managements on the interactions of contaminants (As, Cd, Sb, Pb) and micronutrients (Zn, Mn, Cu) were rarely studied so far.

Here we show, how S-fertilization and water-management and the combination of both treatments influenced the pore-water and grain concentrations of contaminants and micronutrients in 2-year mesocosm experiments using two different Italian paddy soils. While S-fertilization generally showed the beneficial effect of decreasing the accumulation of contaminants in the rice grains, it also decreased the uptake of essential micronutrients. The opposite effect was observed for AWD management, which increased micronutrient and lowered As concentrations, however, increased Cd accumulation up to 9 times. Combining S-fertilization and AWD, no further improvements on the rice grain quality were found. Not only the beneficial uptake of micronutrients was lower than in the AWD treatment, but also the accumulation of Cd was still higher than in the control and the As accumulation was not further decreased compared to the single S or AWD treatment. None of the treatments had significant effects on the accumulation of Sb or Pb in the rice grains.

Just considering As accumulation in rice grains, S-fertilization, AWD, and the combination of both treatments would seem favorable, however, we could show that considering Cd and micronutrient uptake, S-fertilization has the most beneficial effect on reducing contaminants. Nevertheless, the decrease of micronutrients after S-fertilization should be further evaluated and taken into consideration when rice is consumed as the main staple food and in regions where the population is affected by micronutrient malnutrition.