A bioavailability insight into the risk assessment of a trace metal contaminated soil following long-term application of organic wastes

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The processes driving the bioavailability of trace metals in agricultural soils amended with organic wastes have been investigated for long time. Researches were however largely focused on laboratory-scale and short-term (< 5 years) studies. Current regulations thus remain largely based on thresholds given as total metal burden rather than on bioavailability indicators. For example, French regulations and standards imposed total metal concentrations in soil over which sewage sludge spreading is forbidden or maximal flux of total metal supplied to the soil by organic amendments. Consequently, it is today very hazardous for decision-makers, risk assessors, and stakeholders to operationally assess the risk related to trace metal bioavailability in soil contaminated by the long-term application of organic wastes.

To tackle this issue, we monitored over 10 years (17 cropping cycles) the biogeochemistry of copper (Cu), nickel (Ni), and zinc (Zn) in a field trial of market-gardening crops fed with mineral or organic (poultry litter compost or pig slurry compost) fertilizers. Total concentrations of trace metals in fertilizers, plants and soil were monitored for 10 years. During the three last cropping cycles, bulk soil and rhizosphere were collected and the soil solution was recovered. Dissolved organic carbon (DOC) concentration, pH, total concentration of trace metals and Cu speciation were determined in soil solution.

The total metal concentration in soil remained stable overtime whatever the fertilizers applied for Ni, but only when mineral fertilizers were applied for Cu and Zn. The mass-balance modelling of Cu and Zn cycles in the soil-plant system confirmed that the 25% build-up in total Cu and Zn concentration in soil was due to organic fertilizer applications. In comparison with soil amended with mineral fertilizers, organic fertilizers generated an increased in pH and DOC concentration. The chemical changes observed in soil amended with organic fertilizers induced in soil solution an increase in total Cu concentration up to one order of magnitude but a decrease in free Cu activity up to two orders of magnitude. Plants further alkalinized the rhizosphere by 0.5 pH unit in average and increased both the concentration and the binding properties of DOC in the rhizosphere compared to the bulk soil. These alterations of rhizosphere chemistry further decreased free Cu activity in soil solution. The results were finally consistent with trace metal concentration in plants that tended to be lower in plants fed with mineral fertilizers than in plants fed with organic fertilizers.

This case study is consequently a striking illustration that risk assessment based on the consideration of bioavailability can reach opposite conclusions in comparison with risk assessment based on total metal burden. The concept of bioavailability and its operational application should be consequently better accounted for the risk assessment of trace metal contaminated soils following long-term application of organic wastes.