Chemical Considerations in the Interpretation of Toxicity of Metals in Soil

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INTRODUCTION

The bioavailability and toxicity of metals in soil is controlled by a number of soil properties and processes. Some of these such as pH, adsorption/desorption and competition with beneficial cations have been extensively studied. Yet, they are not always taken into consideration when ecotoxicological studies are designed. Also, the effects of aging (or natural attenuation) and of co-toxicants, such as Al and Mn, have major implications for the interpretation of ecotox results but have not been thoroughly investigated.

Here we discuss the importance of some soil chemical characteristics in controlling metal toxicity and discuss how the design of ecotoxicological studies may modify these soil characteristics before or during biological testing.

FACTORS CONTROLLING METAL TOXICITY IN SOIL

To be relevant to real world conditions, terrestrial ecotoxicity tests need to take into account the fact that soil chemistry modifies chemical toxicity and that there is a wide range of different soil types with very different chemistry. Among the various soil characteristics controlling toxicity and bioavailability of metals pH, organic matter content and mineralogy play a dominant role. It is generally accepted that the solubility and free ion activity of metals increases with decreasing pH. However, the apparent solubility of metals may increase at high pH due to the enhanced presence of colloids in soil solution. Also, at equivalent free ion activities, the toxicity of metal ions in solution is generally lower at acidic pH due to competition between metal ions and protons for the biological receptors.

Organic matter provides a major sink for metals in soil and therefore it generally decreases their toxicity. However, dissolved organic matter may increase the solubility of metals through complexation reactions, and if this decreases diffusional limitations to transport, may enhance metal availability.

The contact time between the contaminant and the soil also plays a significant role in metal bioavailability. When a soluble metal enters the soil, its concentration in solution rapidly decreases due to adsorption and precipitation reactions. After this rapid initial reaction phase, the bioavailabity and toxicity continues to decrease over time with a slower rate due to ageing reaction (Fig. 1). The rate and extent of these aging reactions are determined by a range of factors including soil mineralogy, pH, organic matter and temperature.

EXPERIMENTAL ARTEFACTS

The most common approach to test the toxicity of metals in soil is based on the measurement of a biological response when an organism is exposed to a range of concentrations of the toxicant. In order to obtain this concentration range, soils are generally spiked with soluble forms of the metals (metal salts). This process has significant consequences on the chemistry of soil:

(1) pH decreases with increasing concentrations of the spiked metal due to metal hydrolysis and to metal adsorption by soils and the consequent release of protons into soil solution (Speir et al., 1999).

(2) The ionic strength (IS) of the soil solution increases markedly due to the displacement of cations from the solid phase. The increased (IS) decreases the adsorption of the metal and increases the amount of competing cations (Ca^{2+}; Mg^{2+}) present in solution.

(3) When metals are added as salts, the response of the biological endpoint may be influenced by an increase in osmotic pressure (causing salt stress) and by the counter ion (Cl^{-}, NO^{3-} or SO_4^{2-}) added. Stevens et al. (2003) suggested that Hence if the anion associated with the metal is not leached from the soil, direct salinity responses may lead to significant overestimation of the EC50 for those metals.

In addition, if the organism tested is supplemented with a source of food during testing, the soil chemistry may be altered by this addition. For instance, Van der Zee et al. (2004) reported that yeast, added during a Cu ecotox study using *Folsomia candida*, could effectively compete for Cu adsorption.

Finally, as mentioned above, metal toxicity can also decrease with time following addition of soluble metals to soils. This decrease is generally more pronounced immediately after spiking. Therefore, standard laboratory protocols, which test toxicity shortly after addition of soluble metals, are likely to be influenced by the ageing process. It can be expected that metal bioavailability between the beginning and the end of the trial could be significantly different due to aging processes. Also, in the case of microbial tests, acclimation/adaptation of the microbial population during testing is likely to be time dependant and provide a confounding factor in metal ecotox studies (Fig. 1).

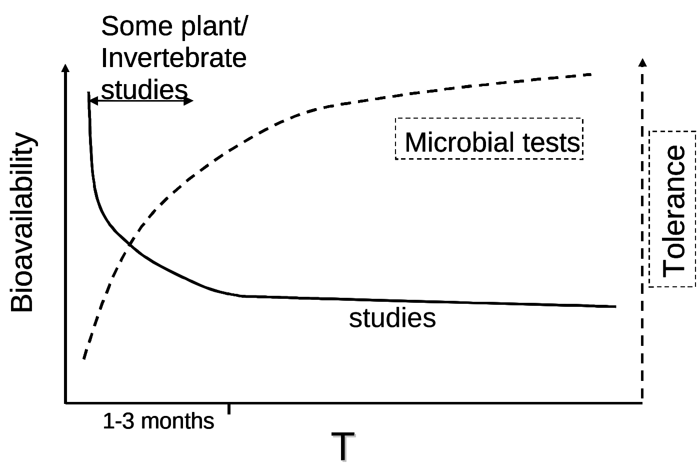

Fig. 1. Relationship between changes in bioavilability and tolerance and time.

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