BIOAVAILABILITY, TOXICITY AND MICROBIAL VOLATILISATION OF ARSENIC IN SOILS FROM CATTLE DIP SITES

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Abstract

Arsenic (As) and DDT have been intensively used in the dipping liquid to control cattle tick (*Boophilus microplus*) in northern New South Wales, Australia. Concentrations of total As and hexane extractable DDT in the surface (0-10 cm) soils from 11 dip sites ranged from 34 to 2941 mg As kg^{-1} and 2.9-7673.2 mg DDT kg^{-1} soils, respectively.

High residual levels of As and DDT from such cattle dipping operations may have adverse impact on soil microbes which are important for maintaining soil fertility and in assisting soil remediation. Long-term effects of mixed As and DDT contaminants upon soil microbial properties were examined by comparing polluted and unpolluted soils. Microbial studies included the measurement of bacterial and fungal populations as well as microbial biomass C and soil respiration. There was a highly significant difference between the microbial properties of polluted and unpolluted sites ($p \leq 0.001$). In comparison to unpolluted soils, fungal counts, microbial biomass C and respiration were dramatically reduced ($p \leq 0.05$) in polluted soils. Generally, however the bacterial populations between polluted and unpolluted soils were not different ($p \leq 0.05$). The combined effects of As and DDT contaminants resulted in an increased stress on soil microorganisms than a single compound. The results of this study suggest that long-term contamination by As and DDT of soils adjacent to former cattle dipping soils adversely affects soil microbial properties and alters the microbial characteristics as shown by a reduction in fungal abundance and development of selected resistant bacterial population.

Microbial conversion of As plays an essential role in the distribution and mobilisation of As in soils and these mechanisms may remove As from polluted soils. Recently, it has

been reported that microbial methylation of As with subsequent As volatilisation could potentially be developed as a remediation strategy for As contaminated soils. Many studies have investigated As volatilisation by microbes in As polluted soils, but no work has examined this microbial transformation in soils containing additional contaminants of DDT. This study was conducted to assess whether the addition of exogenous nutrients and augmentation of arsenic (As) methylating organisms were able to accelerate the rates of As volatilisation in soils containing mixed contaminants of As and DDT. Results showed that the rates of As loss in long-term contaminated dip soils was stimulated by cow manure amendments and basic environmental optimisation that favours aerobic microbial processes. A minor rate of As loss was observed in control soils either in autoclaved or unautoclaved (without nutrient addition) soils, indicating the process was mediated predominantly by microorganisms. Increasing manure levels added resulted in a greater amount of As release in contaminated soils, following the order: 30% > 15% > 5% (w/w) of manure > cow urine amendment. Soil moisture affected the rates of As loss ($p \leq 0.05$) and the yield was optimised at 75% of field capacity. The supplement of 30% (w/w) of manure at 75% of field capacity soils exerted the greatest reduction of As concentrations (8.3% loss of initial total As concentration) in a contaminated dip soil containing 1390 mg As kg^{-1} and 194 mg DDT kg^{-1} in 5 months. The rates of As loss and microbial respiration (CO_2 production) were correlated with added nutrient levels ($p \leq 0.05$).

Screening of As and DDT resistant fungi for As methylating ability shows that 2 fungal isolates (*Penicillium* and *Ulocladium* sp.) were the most active arsine producers yielding 0.32 and 0.40 μg of arsine, respectively in 7 days. These 2 fungal cultures were observed to be able to grow on the contaminated environment of dip soils as indicated by

distribution of fungal mycelia on the entire surface soil in the flask. The augmentation of both fungi enhanced the arsine evolution rates either in field contaminated soils or freshly As-added soils. The amounts of arsine dissipated in contaminated soils and As-spiked soils were 3.7 and 8.3 fold respectively when compared to uninoculated soils. Moreover, an algal species (*Stichococcus* sp.) isolated from As contaminated dip soils was shown to be capable of generating arsine on various As levels substrates. The algal culture produced arsine on the media amended with 25, 50 and 100 μg As mL^{-1} which yielded 0.08, 0.14 and 0.11 μg of arsine, respectively over 7 days. No arsine was trapped on the media added with 200 μg As mL^{-1}. The inoculation of this alga to either polluted or As-amended soils was able to accelerate the rates of As volatilisation. Similar to fungal observation, a greater arsine evolution rate was noticed in uncontaminated soils (spiked with 50 mg As kg^{-1}) than in polluted soils. The results suggest that the presence of DDT in contaminated dip soils possibly limits the As volatilisation rates by microbes.

Statement

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or tertiary institution. To the best of the author's knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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