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Interactions of Arsenic and the Dissolved Substances Derived from Turf Soils

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Monosodium methanearsonate (MSMA) is frequently used as an herbicide for the control of weeds in turf grasses at golf courses in Florida. There are concerns about arsenic (As) contamination of local shallow groundwater from the application of MSMA. The distinction between "free" As and colloid-bound/complexed As in soil solution is important for understanding the mobility and bioavailability of As in the environment. In this study, the equilibrium membrane (500 and 3500 Da) dialysis method was employed to determine the "free" and "bound" As in water extracts of five types of golf-course soils containing coated and uncoated sands in various proportions with peat. All samples were evaluated for arsenic species (arsenite, As^{III} and arsenate, As^{V}), dissolved organic matter, and additional constituents (iron, aluminum, and calcium). The impacts of microbial growth were evaluated by conducting experiments with and without the addition of sodium azide for one particular soil type. Results indicate that (1) the presence of peat in the soils plays a significant role in the distribution of As in the dissolved phase of soil solutions; (2) the majority of As present in the soil extracts from soils containing peat was associated with substances of molecular weight (MW) between 500 and 3500 Da; (3) the association of As and dissolved organic matter (DOM) in the soil solution strongly affected As bioavailability, thus determining As transformations via microorganism-mediated processes; and (4) the presence of peat greatly enhanced the release of iron, aluminum, and calcium from soil. Amendment of sand with peat is a common practice at Florida golf courses. However, the addition of peat will alter the properties of the soils, which in turn could affect As transport and transformation. The results of this study are useful for understanding the factors controlling As trapping and transport within porous soil media and in developing comprehensive plans for managing and remediating As contaminated environments, such as golf courses.

I. Introduction

Health problems associated with exposure to toxic As species have drawn attention worldwide (*1*) and the use of arsenical pesticides may contribute to the arsenic burden of the environment thereby increasing the likelihood of human exposures. It was found that about 96% of Florida golf courses use herbicides containing the active ingredient monosodium methylarsonate (MSMA) 2−3 times every year at an application rate of ∼0.224 g/m^2 (*2*). Due to the local shallow groundwater, significant migration of MSMA and arsenate out of the vadose zone and into the water table has been found after MSMA application (*3*). A laboratory study on As mobility in the soils collected from some golf courses (*4*) demonstrated that As present in these soils was relatively mobile, suggesting potential for As leaching. Recently, a field study was conducted to evaluate the influence of substrate composition on As retention and species conversion after application of MSMA (*5*). The results indicated that substrate composition significantly influenced As mobility and As species transformation in the percolate water. Arsenic species transformation occurred in soil, resulting in co-occurrence of four As species, arsenite (As^{III}), arsenate (As^{V}), monomethylarsonic acid (MMA), and dimethylarsinic acid (DMA) in percolate water.

It is widely accepted that a large portion of toxic chemicals is associated with inorganic or organic colloids in aquatic systems (*6, 7*). Studies of these associations based on molecular size distribution in soil and sediment pore waters have attracted much attention in recent years since these associations were found to be an important factor controlling the fate and bioavailability of these toxic chemicals (*8*). However, very little work has been done on the association of As with colloids and DOM and the facilitated transport of As in soil. Arsenic distributes between the two phases in the soil−water system, liquid soil solution, and solid soil substrate. In the liquid solution, As species may exist in "free" form and/or in association with the DOM or colloids derived from the soil. With regard to the As in golf courses, it is expected that the interactions between As and the colloidal materials would play an important role in As fate and transport in the soils based on the fact that the soils used in the golf courses are usually composed of sand and are often amended with organic matter (peat) to improve nutrient and water retention. The large amount of colloidal materials derived from frequent watering could move rapidly through the soil components. The potential As movement accompanying the colloids could have potential negative impacts on the surrounding environment.

The technique based on the separation of the smaller "free" molecules from the larger complexes by means of a dialysis membrane has been used successfully in several studies of the binding of metals to DOM in natural systems (*9, 10*). Very few studies, however, have dealt with the metalloid As (*11*). The purpose of this study was to investigate As distribution in soil solutions and association with dissolved substances derived from several well-characterized soils used in Florida golf courses. Since large amounts of inorganic arsenate have been observed in percolate water a few weeks after MSMA application in a prior field study (*5*), we decided

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