LEACHING RATES OF HEAVY METAL IONS IN FOREST SOIL

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Abstract. The leachability of Mn, Zn, Cd, Ni, V, Cu, Cr, and Pb was studied in two purely organic spruce forest soils: one control soil and one similar soil heavily polluted by Cu and Zn from a brass foundry in southern Sweden. Artificial rainwater, acidified to pH 4.2, 3.2, and 2.8 was used in the experiment. The 10% residence times, estimated from the experimental data, varied from 3 yr (Mn) to 70 to 90 yr (Pb) in the control soil and from 2 yr (V) to >200 yr (Pb) in the polluted soil with a precipitation water of pH 4.2. Residence times for most elements studied (except V and Cr) decreased with pH of precipitation water.

1. Introduction

A wealth of information is available on the distribution of heavy metal elements, in particular Pb, in the terrestrial environment. Many industrialized areas are characterized by a high degree of metal pollution and an increase in recent decades of the deposition rate has been demonstrated on a regional scale.

The residence time of heavy metals in soil is a question of great concern in environmental science. Much speculation is characteristic of the debate in this field, as few applied studies have been devoted to the question. Evidence for a high degree of retention of certain heavy metals in the topsoil has been displayed by, e.g., studies conducted in connection with application of sewage sludge to agricultural soils.

The high degree of retention in mosses and lichens of deposited Pb, Cu and many other metal elements is well known and seems to be valid also for different types of plant litter. Concerning residence times in forest soils, however, virtually nothing seems to be known, but the nature and amount of certain heavy metals in soil solution have been studied in different types of soil. It is a well-known fact that the extractability of most metal elements in soils is greatly dependent on the acidity of the system. Lowering of the pH of the extractant increases the exchange. As the pH of precipitation water in northern and western Europe has decreased markedly during the last two decades, the possibility cannot be ignored that this acidification has affected the leaching and residence time of many metal elements in the soil. And the possibility is even greater that a further pH decrease will have this effect.

Therefore it should be of importance as the basis of future empirical studies, to assess the influence of varying pH of precipitation water on the leachability of heavy metals in soils. In this paper the purely organic mor horizons from two spruce forest soils, developed on Archaean till in southeastern Sweden, have been studied. One of the soils is normal to the area with respect to chemical properties and visible characteristics. The other soil was sampled in originally similar spruce forest sites in

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the close vicinity of a brass foundry. It has a very high metal content, mainly of Cu and Zn, due to atmospheric deposition of the foundry emissions.

The main objectives of this paper are to (a) describe the differences in leachability between eight heavy metal elements in mor soils at various pH-levels of artificial precipitation water used as leaching solution, (b) describe the differences in leachability of these elements between unpolluted and heavily polluted soil, and (c) predict the residence times of the elements in the two soils at the present pH of precipitation water and after a further increase of the acidity.

The regional pH of precipitation in southern Sweden during 1961–1970 was 4.5 (arithmetic mean of monthly pH values from the two IHD-stations of this area). Canopy throughfall in spruce forest usually has a lower pH-value than open field precipitation (Nihlgård, 1970). Furthermore it is probable that the increase of the regional acidity of precipitation has continued after 1970. A reasonable estimate of the current mean pH of precipitation reaching the ground in the spruce forests of southern Sweden is 4.2. This estimate has been used as the starting-point of the experiment.

2. Materials and Methods

Samples of the purely organic needle mor layer from ten spruce forest sites surrounding a brass-mill in southeastern Sweden were combined to a composite sample by sifting (mesh 5 mm) and careful mixing. Corresponding samples from ten unpolluted sites at a distance of 20 to 30 km from the mill were treated similarly. In the following text these materials are called 'polluted soil' and 'control soil', respectively. From each of these two materials five sub-samples at field moisture, corresponding to 200 g dry weight, were taken for the leaching experiment. Each subsample was evenly distributed and loosely packed in a plastic cylinder (100 mm, basal area 464 cm²), closed at the lower end by a nylon net (mesh 1 mm). The mean thickness of the leaching bed thus formed was ca. 40 mm, being a normal thickness of the mor horizon of the sample area.

The experiment was performed at room temperature. Above the cylinder a leaching apparatus was installed, composed of an almost cylindrical plastic vessel, the bottom of which was pierced by 50 evenly distributed perforations and covered by two filtering papers (Munktell OOH), kept in place by a plexiglass cylinder of a slightly smaller diameter. Artificial rainwater, prepared in distilled, deionized water from p.a. chemicals to resemble the composition of macroconstituents in the rainwater of southern Sweden and acidified by H₂SO₄ to different pH-levels (Table I) was added to the apparatus; 2 l every second day. Percolation of 90% of this volume was completed within 2 h. The percolate was sampled for pH and metal ion analysis after a volume of 4, 8, 14, 24, 37, 55, 75, 103, and 125 l had passed the leaching bed. pH was determined electrometrically directly in an aliquot of the percolate and