STUDY OF HEAVY METAL LEACHING IN THE SOIL

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Abstract
A long-term field experiment was established with different doses of some heavy metals (As, Cr, Cd, Cu, Hg, Pb, Zn) to study their behaviour in the soil-plant system. The soil of the experimental site was characterized by pH (H_2O) 6.2, pH (KCl) 5.4, soil organic matter content 3%, and clay mineral content 30-35%. To check the vertical movement of the studied elements, two years after application soil samples were taken from the 0-30, 30-60 and 60-90 cm layers of plots treated with the highest heavy metal load (270 kg element/ha). Both total (cc.HNO_3+H_2O_2 extractable) and available (NH_4-acetate+EDTA extractable) element content was determined using the ICP-MS technique. Vertical movement of Cr (VI) was detected in the full soil profile. Therefore Cr contamination of the soil profile suggest a significant risk for the quality of ground-water. Arsenic and Pb remained mostly in the 0-30 cm layer. There was only a slight contamination in the 30-60 cm layer. Cadmium, Hg, Cu and Zn were fixed in the plough layer. Both total content and available fraction of these elements were detected in the upper 0-30 cm layer. These contaminants seem to be resistant to leaching.

Additional Keywords: soil, toxic metals, element leaching

Introduction

Environmental pollution is placing an ever-increasing load on the various resources of our environment, including soil. Tests and experiments involving heavy metals and other toxic elements play a very important role in our environmental research programs. Soils polluted with heavy metals can be found near industrial areas, metropolises, along major transportation routes, roads, and areas treated with waste-water sludge, but soils can also be "polluted" geologically. Soils are able to accumulate heavy metals for many years without the obvious signs of their acute toxic effect. However, the filtering/purifying capacity of soils is finite and, above a certain level, soils are no longer able to absorb these elements and become sources of pollution themselves. Toxic elements are released into water, absorbed by cultivated crops and plants; they are assimilated into vegetative and generative organs, and enter the food-chain where they cause long-term harm.

The system of relations between heavy metals-soils-plants can be accurately and reliably studied in targeted field experiments. The Ministry of Environment and the Soil Research Institute of the Hungarian Academy of Science launched a research program in 1991, titled "Heavy metal loading of the environment". The goal of the research program is to study the effect of certain heavy metals and other potentially toxic elements in the soil-plant system and in the food chain. The study is carried out in long-term field experiments in major soil types (carbonate-loam, carbonate-sand, acidic-loam, acidic-sand). The aim of the present scientific paper is to examine (a) which of the heavy metals that are dispersed over the soil accumulate in the upper (tilled) strata/horizons? and (b) Are the heavy metals that are dispersed over the soil, leached into deeper horizons and as a result, do these elements endanger ground water?

Material and Methods

A field experiment was set up at the K.R. College Farm in 1994, to study the effect of 8 heavy metals (Al, As, Cd, Cr, Cu, Hg, Pb, Zn) at three dosage levels (0/30, 90 and 270 kg ha^{-1} of each element). These were repeated three times on 35 m^2 plots (Table 1).

Table 1. Field experiments with heavy metal load Gyöngyös, 1994

Element	Load levels kg of element/ha			Form of salts applied
	1	2	3	
Al	0	90	270	$Al(NO_3)_3 \cdot 9H_2O$
As	30	90	270	$NaAsO_2$
Cd	30	90	270	$3CdSO_4 \cdot 8H_2O$
Cr	30	90	270	K_2CrO_4
Cu	30	90	270	$CuSO_4 \cdot 5H_2O$
Hg	30	90	270	$HgCl_2$
Pb	30	90	270	$Pb(NO_3)_2$
Zn	30	90	270	$ZnSO_4 \cdot 7H_2O$

The soil type used for the experiment is mildly acidic chernozyom brown forest soil formed on alkaline sediment (andesite, andesite tuff). Key soil parameters are the following: $pH(H_2O)=6.4$; $pH(KCl)=5.4$, $y_1= 9.5$; $CaCO_3\%=0$; humus%=3; KA=45; L%=70; hy=4.8. Particle size of the soil is dominated by clay and silt fraction. The textural type is clay-loam with a bulk density of 1.20 g/cm^3. Soil surface is slightly sloping, elevation is 150 m above sea level. Water table depth is 10 m, therefore the probability of pollution through surface leaching is minimal. The soil has good water absorption, conduction and storage capability. In the event of heavy rainfall, rill erosion occurs on tilled surfaces.

The soil in the plots was examined and tested each year. Samples were taken from the following strata of the plots treated with the maximum dosage (270 kg ha^{-1}): 0-30, 30-60, 60-90 cm. Samples were taken from bored holes in cartridges. In each plot, 5 bores were made at each depth range to obtain at an average sample. The samples were dried, ground and homogenized before determining the "total" element content estimated with the cc.HNO_3+cc.H_2O_2 extraction and the available element content with the Lakanen-Erviö (1971) method. The analysis of samples for elements was carried out by the ICP laboratory at the Soil Research Institute (TAKI) of the Hungarian Academy of Science, for 25 elements, using the ICP-AES method.

Results and Discussion

Arsenic was predominantly present in the upper stratum (0-30 cm) in the 2nd year of the experiment (Figure 1). The 0-60 cm stratum was also polluted as shown in the figure by the "total" and available element content. Enrichment/accumulation in deeper soil horizons/strata is not significant, with respect to the tolerance of sampling, it is practically negligible. Leaching, and the extent and dynamics of leaching cannot be determined from this data.

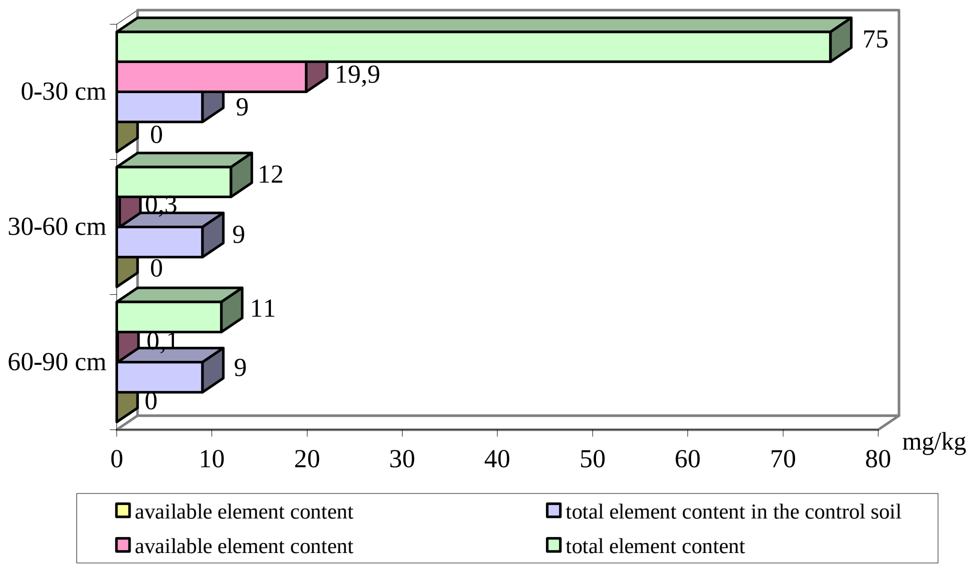

Figure 1. The effect of 270 kg/ha arsenic load on the arsenic content of the soil profile. (Chernozyom brown forest soil, Gyöngyös, 1996)

Figure 2. shows that Cd also is concentrated in the upper, tilled stratum of soil. Both "total" and available content is present in the place of input, deeper horizons show no sign of accumulation. It seems that this extremely toxic element is highly resistant to leaching in loamy soils in the initial years. According to literature, Cd is highly mobile in the soil-plant system (Lehoczky *et al*., 1996; 1996a; 1999; Zanders, 1999).

The mobility of Cr(VI) is unambiguously evident (Figure 3). In comparison, with unpolluted control soil, accumulation in the deeper strata between 30-60 and 60-90 cm is obvious, both in terms of "total" and available content. Heavy rainfall in 1995 and 1996 may also have contributed to leaching. It is also true that the available Cr content of the deeper strata is one magnitude less than the values measured at the input point. The fact that Cr pollution was, although more moderately, apparent between 60-90 cm after the second year draws attention to the importance of examining the mobility of Cr(VI) in the horizons beyond 1 m depth. We will need to monitor the limits of Cr leaching in the future with deeper test bores.

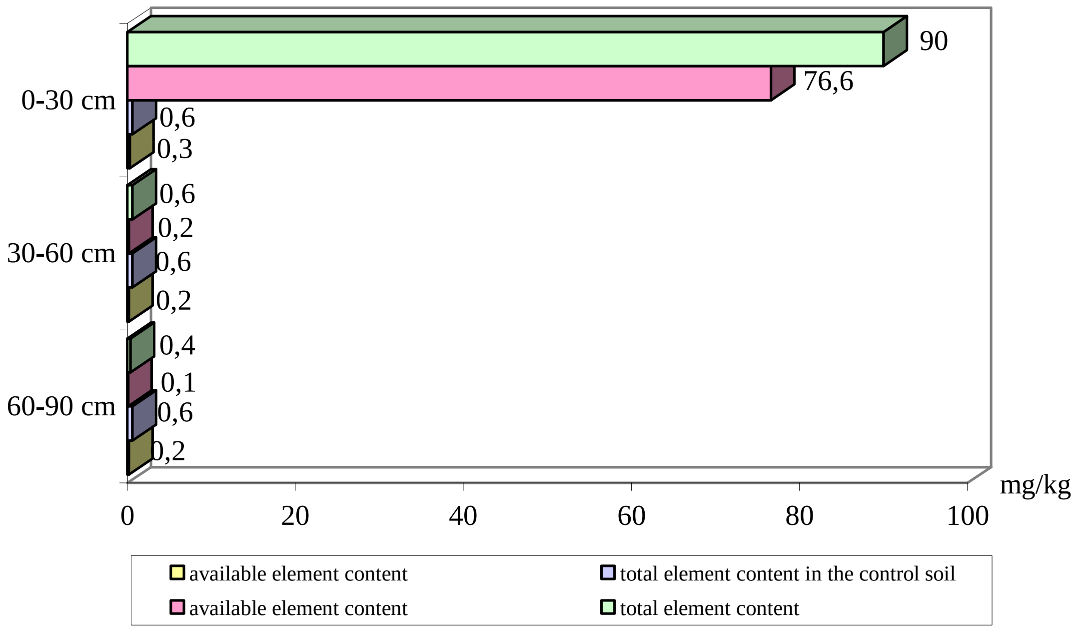

Figure 2. The effect of 270 kg/ha cadmium load on the cadmium content of the soil profile. (Chernozyom brown forest soil, Gyöngyös, 1996)

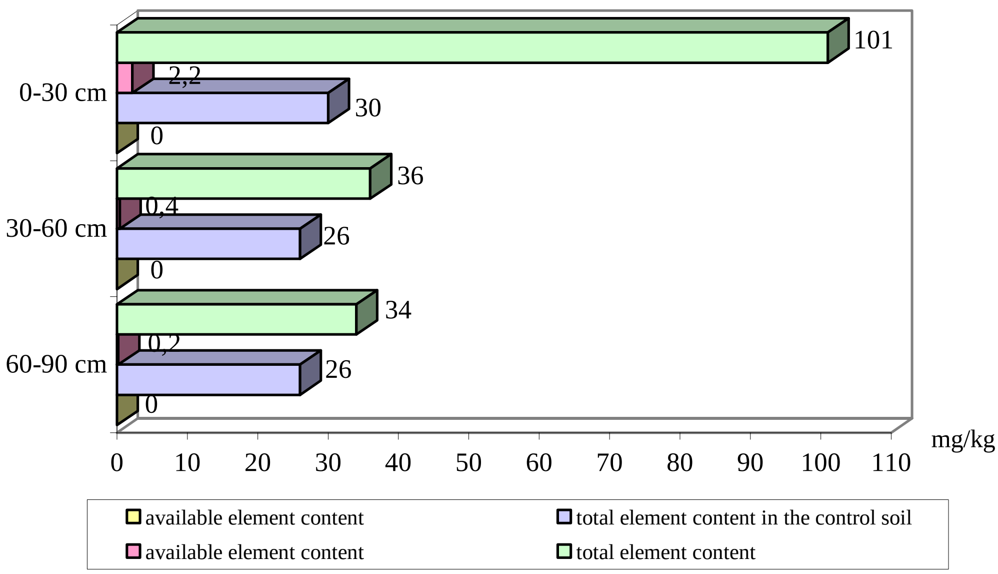

Figure 3. The effect of 270 kg/ha chromium load on the chromium content of the soil profile. (Chernozyom brown forest soil, Gyöngyös, 1996)

The majority of Pb remained at the point of input, however it is not realistic to assume that this element will remain completely immobilised in acidic forest soils. Hence Pb may pose a moderate danger to soil water and the food chain. According to the results of soil examinations, Hg is not leached. Literature shows that $HgCl_2$ is rapidly bonded by organic matter and clay fractions or precipitated in the form of insoluble salts. Solubility may increase under acidic conditions, thereby Hg in soils may become mobilised. Cu and Zn are bonded in the tilled horizon, mobility was not experienced.

Conclusion

1. The rate of transformation and immobilisation of toxic pollutants in soils varied according to elements. A clear distinction can be made between elements that are mobile pollutants in soils (Cd, Zn, Pb, Cu) and those that transform rapidly into insoluble forms and become bonded (As, Hg, Cr).

2. Heavy metals and other pollutants that are spread over soils accumulate in the tilled soil horizons where root mass is highest. Cd, Cu, Pb, Hg and Zn are bonded in the tilled horizons, while As moderately polluted the deeper horizons between 30-60 cm.
3. The leaching of Cr input into soils in the form of chromate is a rapid process in mildly acidic brown forest soils, the element was detected at depths of 60-90 cm after 2 years. Subterranean water sources are endangered by this element as a result of rapid leaching.

References

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