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CONTENT OF Cu, Zn AND Mn IN THE ERODED SOILS OF A SMALL ARABLE-FOREST CATCHMENT OF WEST POMERANIA (THE CHOJNA DISTRICT)

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A b s t r a c t. The aim of this paper was to assess differentiation in the total content of Cu, Zn and Mn under the influence of water erosion. The present author investigated parent material, eroded soils and delluvial sediments of a small arable-forest catchment of the moraine zone in West Pomerania.

The average content of heavy metals in the parent rock (boulder light loam) were assumed as geochemical backgrounds of Cu, Zn and Mn. It was found out that erosion process caused differentiation in heavy metals. Zinc was the most mobile in this transportation; Mn was not sensitive to it. Delluvial sediments from arable (drainage) depressions had a clearly lower content of Cu and Zn than the parent material. It was also noted that Cu and Zn content in the forest area was lower than in the arable area of a similar relief and soil composition. Mn content was always higher in the arable soils. Soil-forming processes influenced differentiation of heavy metals in the vertical soil profile. The humus and Bt horizons (accumulation of silicate clay) were enriched with heavy metals. A decrease of heavy metal content was noticed in the eluvial horizon (Eet – outwash of silicate clay). The humus horizon of the investigated soil had, a natural (not increased) content of Cu, Zn and Mn.

K e y w o r d s: heavy metals, geochemical background, catchment water erosion, West Pomerania.

INTRODUCTION

Heavy metals are kept mainly in the humus horizon; their dislocation in the soil profile is often very slow [3] and this is why, it can be expected that erosion processes, especially runoff, can cause differentiation in the heavy metal content in the eroded area.

The aim of this work was to determine the influence of erosion processes on the Cu, Zn and Mn content in the eroded soils and delluvial sediments of the moraine zone of West Pomerania, Poland.

METHODS

The present investigations were carried out in the slightly eroded arable-forest catchment of the Stream Jelenin (a left tributary of the Rurzyca River, near Chojna). This catchment is in the area of end-moraines of the latest glacial – the Baltic Glacial. The absolute heights are in the range of 17.8-114.1 m a.s.l. [2].

Soil profiles were selected for the characteristic elements of relief: mounts, convex and concave slopes and feet of the slopes (delluvial depressions) in the chosen arable and forest objects. Soil samples were taken from genetic horizons of the soil profiles.

Samples of parent material (boulder material) from bore-holes at the depth below 1.5 m or even to 6 m were taken. This boulder material was to show natural heavy metal content in the investigated area for the determination of the geochemical background of heavy metals. Delluvial material was taken from the boreholes made in delluvial depressions (feet of slopes) to the depth of 5 m.

In the soil material, the following chemical and physical properties were determined: pH reaction, carbon organic content (C org.), sum of alkaline cations (S), hydrolytic acidity (Hh), grain size distribution. Volumetric density was determined for the genetic horizons of soil profiles. These analyses were made according to the generally used methods of soil science.

Total content of Cu, Zn and Mn were determined in the soil extract with an atomic absorption spectrophotometer (AAS) after mineralization of the soil with HNO_3 and $HClO_4$ acids in the 1:1 ratio.

RESULTS

Content of Cu, Zn and Mn in the boulder (parent) material = geochemical background of heavy metals

Boulder material – parent material of the investigated soils is most often light (sandy) loam. It contained the following average quantities of heavy metals: Cu – 15.2; Zn – 42.8, and Mn – 213.6 mg/kg of dry soil mass. These average values were accepted as geochemical backgrounds of Cu, Zn and Mn in the present investigation. These values were suitable for comparisons of changes in the heavy metal content: (1) in the superficial layer of an eroded and delluvial area (surface differentiation); (2) in the soil profiles (vertical differentiation).

These comparisons were necessary to assess the influence of soil-forming and erosion processes on the differentiation of heavy metal content in the investigated catchment.

Content of Cu, Zn and Mn in the light loam of the Baltic Glacial were higher than their content in the light loam of the Middle-Polish Glacial (Riss) [1].

Content of Cu, Zn and Mn in delluvial sediments

It was surprising that delluvial material had lower Cu and Zn content than the boulder (parent) material with the same content of soil fractions. Probably, it may have been caused by the draining properties of delluvial depressions (feet of slopes). Such a drainage characteristics can cause superficial outflow of rain water to water-courses. Migration of the finest soil particles and soluble substances can be related to this rainwater transportation. It shows the power of erosion process, as it can transport chemical elements such as heavy metals that are hardly soluble in water.

Differentiation of Cu, Zn and Mn content under the influence of soil-forming processes

Brown podzolic soils (lessive soils) and delluvial soils dominated in the investigated area. The soils of the brown podzolic type were divided into two subtypes: typic and epigleyed.

Following the above hypothesis, the highest content of Cu and Zn was noticed in the enrichment horizon (accumulation of silicate clay – Bt) but the lowest content of these elements was found in the eluvial horizon (eluvial outwash of silicate clay – Eet). Changes in the heavy metal content caused by the transportation of silicate clay in the soil profile were more clear for Cu content than for the Zn content.

Genetic horizons of lessive typic soils had similar Mn content. In these soils, Mn content was close to the level of geochemical background for Mn (content in the parent rock).

Genetic horizons of lessive epigleyed soils had more differentiated Mn content. The eluvial horizon of these soils had higher Mn content than the level of geochemical background. This situation may have been caused by the soil enrichment in this element, however it may also indicate a significant influence of gley processes (redox processes) on Mn migration in the soil profile.

Delluvial soils were divided into two subtypes: typic and humose. The investigated delluvial typic soils originated from sediment deposits in the drainage depressions. For that reason, these sediments contained lower content of clay fraction and humus (components associated with heavy metals).

The investigated delluvial humose soils were formed in the forest non-drainage depressions and accumulated the soil with the finest particles (mineral and organic). These soils were formed in wet places, rich in turf plants. Turf plants delivered organic matter that caused an increase of heavy metals sorption. In the delluvial typic soils, Cu and Zn content were lower than their content in parent rock (geochemical background), in the case of Cu – 1.5 times, for Zn – 1.8 times lower. Delluvial typic soils had also a lower content of Cu (0.5 times) and Zn (4.0 times) than delluvial humose soils. Delluvial humose soils had higher Cu and Zn content even in relation to their levels of geochemical background: for Cu – 1.5 times and in the case of Zn – 2.2 times higher.

The Mn content in delluvial typic and humose soils was similar. It showed that the Mn content was not so strongly related to delluvial sediment (namely the clay fraction and humus content of delluvial sediment). The Mn content in all the investigated delluvial soils was higher in relation to the geochemical background of this element.

Comparison of Cu, Zn and Mn content in the arable and forest objects with similar relief and soil profile structure

This comparison was to show the influence of erosion processes on the differentiation of heavy metal content in both areas with similar relief (similar decline) and similar soil matrix but with different land use.

Two objects with different land use: "Forest I" and former arable (now fallow) object "Brwice" were chosen for the comparison. The soil profiles were located on the characteristic and common elements of relief in both objects: mounts, concave slopes and depressions. Additionally, for the "Brwice" object, the lower part of depression was investigated. This part of depression does not exist in the forest conditions.

Cu, Zn and Mn content was calculated (in grams) for every genetic horizon distinguished in a given soil. Then they were summed up to obtain the content of metals in the whole soil profile (Table 1).

It was found that all forest soils (on each element of the relief) had higher Cu and Zn content than arable soils (Table 1). The highest content of Cu, Zn and Mn were noted in the forest depression. Probably, it was a non-drainage depression that accumulated colloid particles and humus. High content of heavy metals in the forest depression was related to acidic reaction that made heavy metals mobility. Even the

Table 1. Total content of Cu, Zn and Mn (in g/m^2 in 1.5 m deep profile) in the forest and arable soil profiles of the chosen relief elements

Object	Mount			Concave slope			Upper part of depression			Lower part of depression		
	Cu	Zn	Mn	Cu	Zn	Mn	Cu	Zn	Mn	Cu	Zn	Mn
Forest I (F)	37.0	130.8	604.1	13.6	133.7	538.7	53.4	294.8	536.3	-	-	-
Arable Brwice (A)	22.0	70.3	712.1	9.5	49.8	586.1	11.2	46.1	692.1	31.4	114.8	324.2
Difference (F-A)	15.1	60.5	-108.0	4.2	83.9	-47.3	42.2	248.7	-155.8	-	-	-

content of heavy metals in the lower part of the arable depression was lower than in the forest depression. These components were transported with the finest soil particles to water-courses.

Table 2 shows the sum of total Cu, Zn and Mn content in grams for forest and arable objects calculated from all the soil profiles of individual relief elements. Data from Table 2 showed that Cu and Zn content in the forest soils was higher, for Cu by about 28.8%, for Zn by about 49.8% in relation to arable soils.

This comparison showed that forest was richer in Cu and Zn than the arable area with similar soil profile structure and relief. Mn content was always higher in the arable soils.

Table 2. Sum of the total Cu, Zn and Mn content (in grams) for the forest and arable objects calculated from their content in all the soil profiles

Object	Cu	Zn	Mn
Forest I (F)	104.0	559.3	1679.1
Arable - Brwice (A)	74.1	281.0	2314.4
Difference (F-A)	29.9	278.3	-635.3

These results showed that Cu and Zn accumulation did not exist in the arable soils. A decrease in the Cu and Zn content may have been caused by the erosion process or by lack of mineral fertilization (fallow).

Comparison of Cu, Zn and Mn content in the arable and forest objects with differentiated relief and soil profile structure

The above comparison was to show the influence of erosion processes of various intensity (related not only to land use but also to different relief parameters, such as slope inclination and length and soil profile structure) on heavy metal content. The group of compared soils included the soils that never eroded and the soils with different degrees of erosion.

Table 3. Total content of Cu, Zn and Mn (in g/m^2 in 1.5 m deep profile) in forest and arable soil profiles of the chosen relief elements

Object	Mount			Concave slope			Upper part of depression			Lower part of depression		
	Cu	Zn	Mn	Cu	Zn	Mn	Cu	Zn	Mn	Cu	Zn	Mn
Forest II	35.7	137.2	817.9	27.7	120.6	467.5	51.4	99.1	242.7	-	-	-
Forest III	37.0	130.8	604.1	28.7	122.9	543.0	53.4	294.8	536.3	-	-	-
Arable Brwice	275.2	69.4	653.9	91.7	77.9	636.4	42.9	61.4	650.4	346.9	76.2	472.6
Arable Czartoryja	35.2	127.0	738.6	40.7	140.8	840.0	41.2	62.7	594.9	-	-	-

Table 4. Sum of Cu, Zn and Mn total content (in grams) for forest and arable objects calculated from their content in all soil profiles

Object	Cu	Zn	Mn
Forest II	114.8	356.9	1528.1
Forest III	118.6	538.5	1683.4
Arable-Brwice	756.7	284.9	2413.3
Arable-Czartoryja	117.1	330.5	2173.5

Similarly, as in the previous comparison, calculations of Cu, Zn and Mn content in grams for all the compared soil profiles were made (Table 3). Data from Table 3 showed that the soils of mounts and convex slopes from the objects “Forest II”, ”Forest III” and the arable object “Czartoryja” had similar Cu and Zn content. The arable soils of mount and convex slopes in the object “Brwice” had a higher Cu content and lower Zn content.

The soils of forest depressions always had a higher Cu and Zn content than delluvial soils of arable depressions. Probably, these forest depressions had a non-drainage character as compared to the drainage character of arable depressions. Delluvial soils of arable depressions had similar content of Cu, Zn and Mn that was sometimes lower than in the soils of mounts and convex slopes of these objects. Content of Mn was always higher in the arable soils than in the forest soils.

Table 4 showed the sum of total Cu, Zn and Mn content in grams for the compared forest and arable objects calculated for all the soil profiles of individual relief elements. The comparisons showed that forest soils do not always contain higher Cu and Zn content than arable soils.

Eroded arable soils showed high differentiation in the heavy metal content. This differentiation may have been caused by different intensity of erosion processes. Various relief elements (decline and length of slopes) and different physical and chemical properties of soils resulted in the differentiated intensity of erosion processes.

The compared forest soils had similar Cu and Mn content, but different content of Zn. Arable soils had similar Zn and Mn content but different content of Cu. All the arable soils had higher Mn content than forest soils.

Erosion processes in the arable area resulted in changes that were more pronounced than in the forest area. They can change structure of the soil profile, for instance by removing the loose Eet horizon (outwash of silicate clay fraction). Then, the Bt horizon rich in heavy metals (accumulation of silicate clay) can fall into the soil surface and it can enrich lower parts of the area (depressions) and even water-courses as a result of runoff.

It was also found that delluvial sediments rich in mineral colloids accumulated all the investigated heavy metals (in forest depressions). Delluvial sediments rich in humus, accumulated mainly copper.

CONCLUSIONS

1. The parent material of the investigated soils – boulder light (sandy) loam of the Baltic Glacial had an average content of heavy metals as follows: Cu – 15.2; Zn – 42.8 and Mn – 213.6 mg/kg of dry soil mass. These values were accepted as geochemical backgrounds of heavy metals.

2. Soil forming processes caused differentiation in the heavy metal content in the vertical system of soil profiles. The humus horizon and Bt horizon (accumulation of silicate clay) were enriched with heavy metals. A decrease in the heavy metals content was noticed in the eluvial horizon (Eet – outwash of silicate clay).

3. Water erosion caused differentiation in the Cu, Zn and Mn content. Zinc was most mobile in the erosion transport, and the content of Mn was less dependent on it.

4. Delluvial sediments of arable depressions had lower heavy metal content than boulder material. It may have been caused by the drainage depression character.

5. The humus horizon of the investigated soils had a natural (not increased) heavy metal content, according to IUNG criteria.

6. The content of Cu and Zn in the forest was higher than in the arable area with a similar physiographic conditions and soil profile structure.

7. The content of Mn in the arable soils was always higher than in the forest soils.

REFERENCES

1. **Czarnowska K.:** Ogólna zawartość metali ciężkich w skałach macierzystych jako tło geochemiczne gleb. Rocz. Glebozn., XLVII Suppl., 43-50, Warszawa, 1996.

2. **Józefaciuk A., Józefaciuk C.**: Erozja agroekosystemów. PIOŚ, Bibl. Monitoringu Środ., Warszawa, 1995.
3. **Kabata-Pendias A., Piotrowska M., Witek T.**: Ocena jakości i możliwości rolniczego użytkowania gleb zanieczyszczonych metalami ciężkimi. [In:] Ocena stopnia zanieczyszczenia gleb i roślin metalami ciężkimi i siarką. IUNG, Puławy, 1993.
4. **Kabata-Pendias A., Piotrowska M., Motowicka-Terelak T., Maliszewska-Kordybach B., Filipiak K., Krakowiak A., Pietruch C.**: Podstawy oceny chemicznego zanieczyszczenia gleb. Metale ciężkie, siarka i WWA. PIOŚ, IUNG, Bibl. Monitoringu Środowiska, Warszawa, 1995.