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Influence factors in soil-fertilizer accumulation of heavy metals in plants

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ABSTRACT

The problem of environmental pollution with heavy metals present in Poland locally and relates primarily to industrial areas, but in some areas, in the vicinity of the former or current sources of emissions, water, soil and sometimes show a considerable degree of contamination. Heavy metals in soils may be a potential source of danger to plants and groundwater, and consequently - can be incorporated into the food chain [Karczewska et al. 2008 Kabata-Pendias 1993]. Downloading trace elements from contaminated soils by plants often exceeds their physiological needs, with the result that an excess of these elements in the soil can act phytotoxic.

Keywords**:** heavy metals; soil; plant; arable lands; Police district

1. INTRODUCTION

The factors determining soil fertility should morphology - morphological characteristics of the soil profile, soil thickness and level of humus, physical properties - granulometric composition, structure and texture, porosity-pore system, thermal properties, water and air (water and air, as factors antagonistic), chemical and physicochemical properties - abundance of nutrients and other.

All these components interact, complement and comprehensively affect the state of soil fertility. Knowing the value of these factors in cultivated soil is possible to apply the appropriate fertilizer or agricultural treatments appropriate to obtain high yields, while ill human activity - farming without soil analysis may lead to its complete degradation, often impossible to remove.

2. SOIL FACTORS

Of the physico-chemical properties of the soil influence the amount of heavy metal forms decisive role played by soil type, particle size distribution, organic matter content, sorption, pH and redox potential (Kabata-Pendias and Pendias 1999 Gębski 1998).

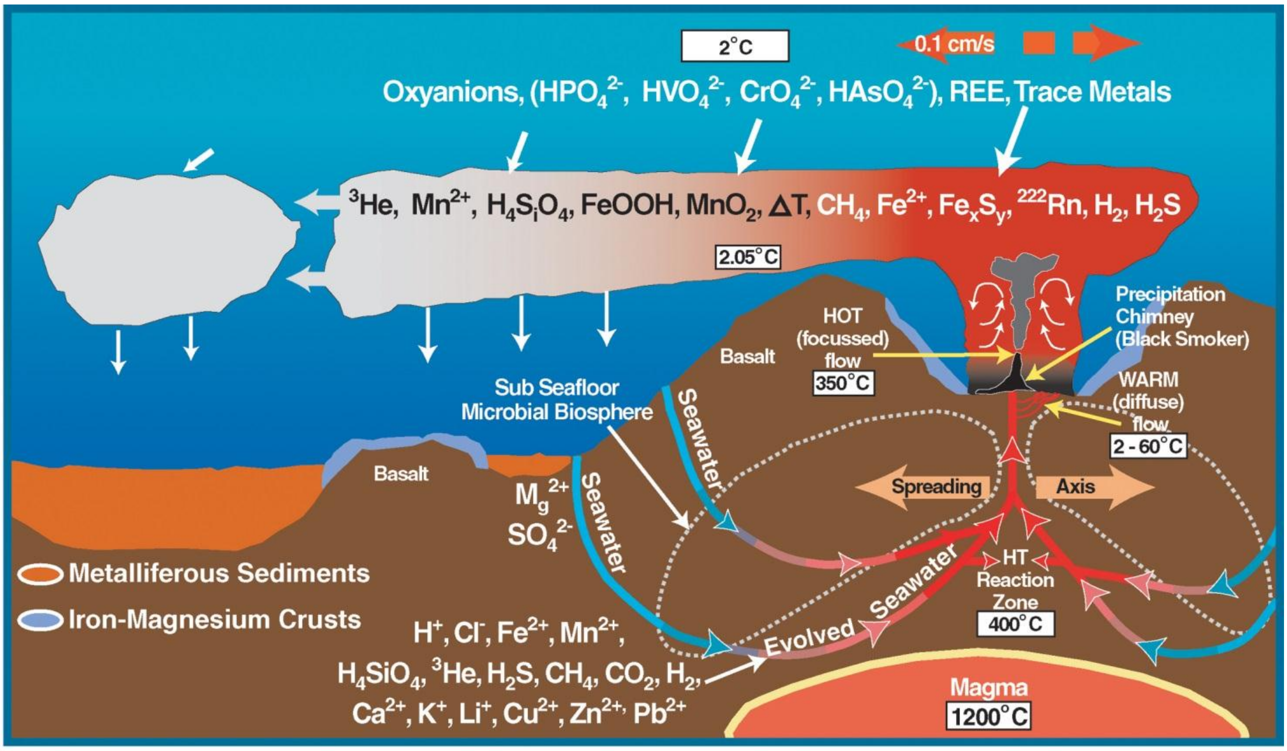
3. SOIL TYPE AND THE SIZE DISTRIBUTION

The total content of heavy metals in the soil depends primarily on the type of host rock and soil formation factors, the amount of these elements in the soil (in particular its level) is changed by the action of anthropogenic and climatic factors (Hajduk, 1998, Kabat-Pendias and Pendias 1999 Strączyńska and Strączyński 2000). As reported by Kabat-Pendias and Pendias (1999) for most soils, regardless of their type, heavy metals are primarily the clay fraction. Trelak and Pietruch (2000), after examining 48,590 soil samples from different regions of Polish found a relatively weak relationship between the amount of Cd in soils and the general content of clay fractions in them (R2 = 10.49%) and colloidal fraction (R2 = 8.02%). Piotrowska and Trelak (1997), Strączyńska and Strączyński (2000) and Właśniewski (2000) found no relationship between the content of cadmium and granulometric composition of soils. The different results obtained in this field Lipinski (2000). The analysis of 60 soil samples showed that light soils characterized by lower concentrations of Cd than medium and heavy soil. This relationship resulted in cadmium content of the potatoes grown in these soils. Potato tubers with light soils accumulate less Cd than those growing on medium to heavy soils. Different results were obtained by different authors into the relationship between the content and the amount of clay fractions of heavy metals may be a consequence of the use of different methodologies extraction of these elements from the soil. It seems that to get rid of fraction in the soil can strongly affect the amount of heavy metal forms than on their total content in the soils and thus affect the collection and accumulation of these elements in plants.

4. ORGANIC SUBSTANCE

Occurring in the soil the organic matter in the form of humus compounds and is introduced into the soil (ground) together with the manure, organic organic-mineral, helps to reduce the amount available to plants of heavy metals forms and thus yield a crop having reduced the contents of these elements (Gawęda 1995 Curyło and Jasiewicz 1998 Zaniewicz-Bajkowska 1998 b, c, 2000 a, b).

The organic matter in the soil affects the force with which the acidity of the soil affects the solubility of heavy metals. However, this effect depends on the particle size of organic matter, the quantity of humic structural, soil pH, type and concentration of metal in the soil (Kabat-Pendias et al. 1993, Mercik and Kubik 1995). Soils enriched in organic matter (e.g.. Manure, peat, composts, brown coal) decreases gradually forms available to plants of heavy metals, thus decreasing their toxicity to plants (Mercik and Kubik 1995 Gębski 1998). As reported Łabętowicz and Rutkowska (2001), organic matter, heavy metals bound specifically to compounds insoluble or sparingly soluble in water limits their desorption in the soil solution, and thus their mobility in soil. In contrast, the durability of complex connections-metal organic matter increases with increasing degree of decomposition, as well as raising the soil pH.



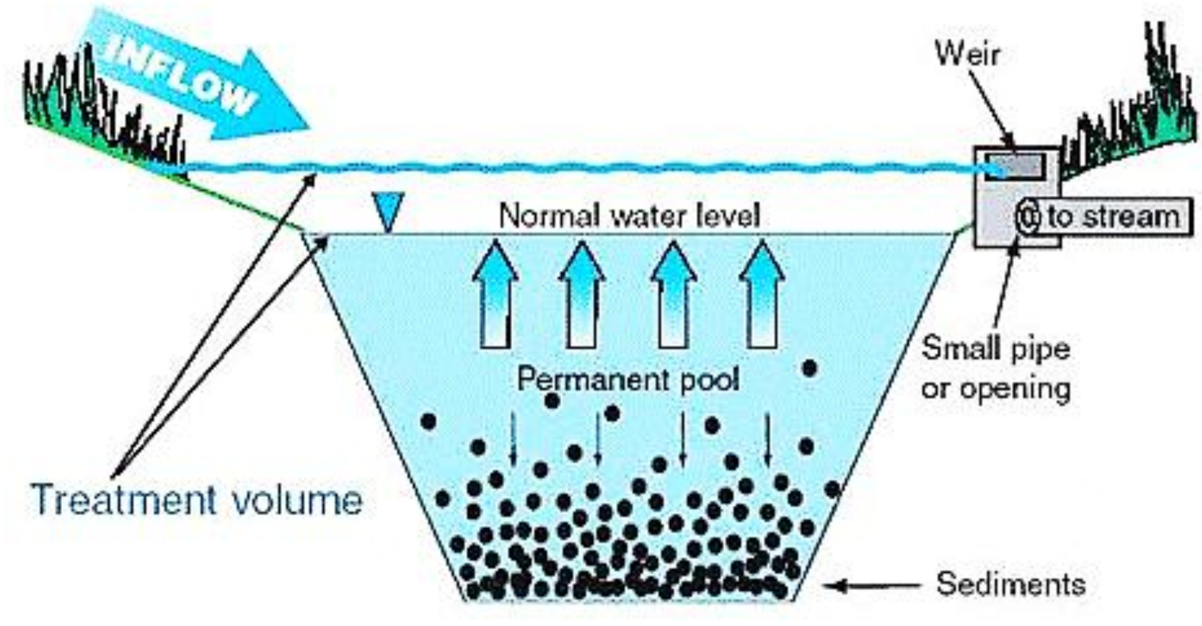
5. SORPTION PROPERTIES

Heavy metals after getting into the soil are adsorbed by the sorption complex interchangeably, as well as subject to a process of biological sorption - microbial immobilization. Furthermore, heavy metals can also be precipitated as insoluble compounds. These processes lead to the reduction of available forms of heavy metals in the soil environment (Chłopecka 1994 Łabętowicz and Rutkowska 2001 Majewska and Cock 2002). The content of clay minerals (clay fractions of the soil) has little effect on the overall amount of heavy metals in soil (Piotrowska and Trelak 1997 Trelak and Pietruch 2000).

However, these minerals by their sorption properties will affect the reduction in the solubility of heavy metals (number of motile forms), and thus the availability to plants of these elements in the soil (Gębski 1998 Majewska and Cock, 2002). Gambuś (1993) reports that the higher the total cationic capacity of the soil, the higher can be the heavy metal content, for which the yield can be obtained characterized by an acceptable level of accumulation of the group of elements.

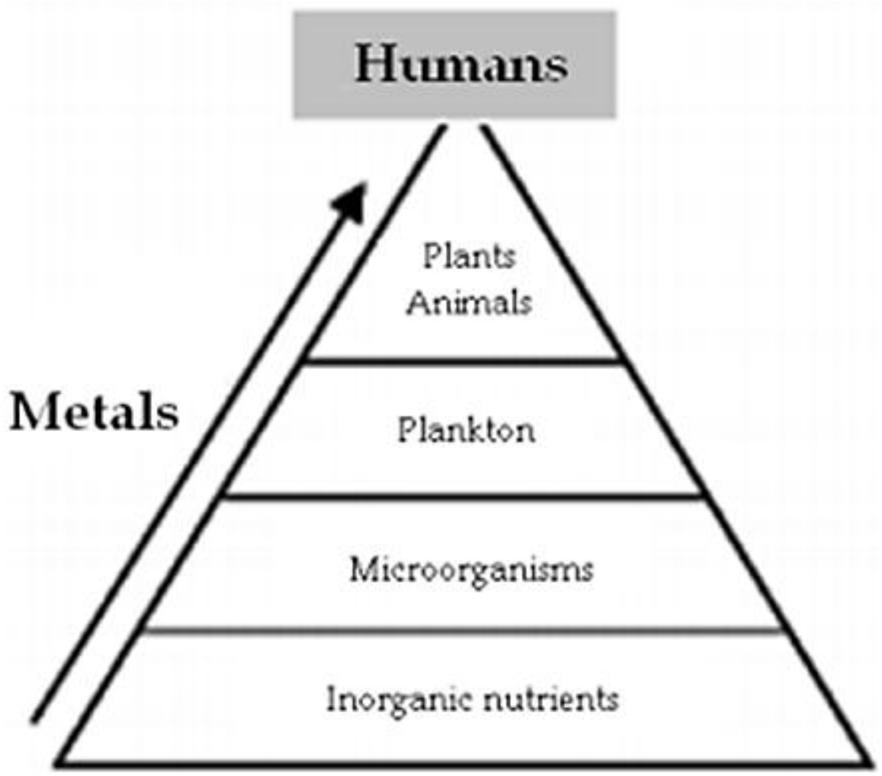
This is confirmed by the results of the carrots grown in various positions soil, in which the smallest content of cadmium (< 0.02 mg Cd kg^{-1} • S.M) was obtained in roots carrots grown on soils characterizing the erythrocyte pH KCl > 7.0; Ca content of > 2920 mg • dm^{-3}, Mg > 105 mg • dm^{-3}, and the saturation of the sorption complex elements of a basic over V > 98% (Sady et al., 1999, Sady et al. 2000 b, Orchards and Horn 2002). Metals vary the force with which are bound by the sorption complex. A number of individual metals enter the sorption complex is as follows Pb > Cu > Zn ≥ Cr > Ni > Co > Cd - sandy soil, and Pb > Cu > Cr > Zn > Ni > Co > Cd - loess soil (Gąszczyk et al., 2000). The ease with which Cd^{2+} is released from the sorption complex causes that even in soils with low content thereof (at the so-called geochemical background), may easily download an excessive amount of this element by the plants.

Therefore sought ways designed to reduce the amount of Cd format and other heavy metals in the soil in order to yield products characterized by a low rate of accumulation. Introduction to soil substances that can increase the sorption capacity of soils (diatoms and other compounds exhibiting sorption) reduces the amount of heavy metals in soil (Gworek 1992 Gębski 1998 Sady et al. 2000 a). However, this property is most evident at acidic, because with decreasing soil pH increases the concentration of soluble forms of heavy metals in the soil solution (Gębski 1998). In a pot experiment has shown that the use of diatomite soil alleviated Cd accumulation in roots of carrots grown in modern buildings with natural content of Cd in the soil (0.37 mg • kg^{-1}) and on soils contaminated with the element (from 0.87 to 1.37 mg • kg^{-1}). However, the enrichment of the soil substances of sorption is very expensive. In addition, under varying conditions of soil and climate, this treatment is not always effective in limiting the amount forms of heavy metals in the soil.



6. SOIL REACTION

Reaction is considered to be one of the main factors affecting the form in which heavy metals are present in the soil environment and their availability to plants (Chłopecka 1994 Gębski 1998 Kabata-Pendias and Pendias 1999). Lowering the soil pH to slightly acidic and the acid causes an increase in the concentration in the soil solution, available to plants, moving heavy metal forms, and thus reinforce its rate of accumulation in plants (Chłopecka 1994 Gębski 1998). This is due to the increase in the solubility of the chemical combination of these elements, as well as a reduced absorption of soil colloids with low soil pH. Gębski (1998) reported that the most susceptible to change in pH values of Cd and Zn. Their mobility is growing with a drop below pH 6-6.5, while the Cu and Pb have the property that only at pH < 5.0. Tyler and Olsson (2001) found two high levels of concentration of Cu and Pb in the soil solution. One at a pH of 5,2-6,5, while the second at pH 7.5-7.8. This is probably because Cu and Pb in soil produce stable complexes with various ligands whose solubility is related to the solubility of the organic substance.



Cu and Pb were included in the group of elements whose concentrations in the soil solution is "seemingly casual" associated with the erythrocyte. The Blake and Goulding (2002) report that the activity of Cd and Mn increases at pH 6,0-5,5, and Zn, Ni, Cu at pH 5,5-5,0, and Pb at pH < 4.5. Nowak and Wojtasik study (1997) showed that the accumulation of Cd and Ni in the yield of carrots was higher on light soil acidic (pH 4,2-4,7) than on heavy soil with a pH neutral (pH 7.0-7.5) despite the fact that heavy soil contained twice the content of Cd and Ni six times higher than the light soil.

Therefore, a low light soil pH had a huge impact on the increase in the concentration of these metals fito - forms in the soil environment. As indicated by the results of Zaniewicz-Bajkowski (1998 a, b, c, 2000 a, b) liming treatment caused a reduction in the soil content of plant available forms of Cd and Pb with respect to the soil niewapnowanej, with the result that there has been a reduction in the accumulation of Cd and Pb yield of cabbage, beetroot and lettuce grown in succession at first, second and third year after liming.

However, raising the soil pH is not always decreased fitod - forms of heavy metals in soil. How to inform Kabat-Pendias et al. (1993) in terms of the alkaline pH of the soil may increase the mobility of heavy metals, most likely due to the busy formation of organometallic complexes of heavy metals from soil finely divided organic substance (Gębski 1998 Majewska and Cock, 2002).

These connections (metal and organic matter) are easily absorbed by plants. The dependence of this study seem to support Tyler and Olson (2001). Thus, on soils rich in organic substances liming treatment may cause temporary increase in the amount available for the plant fraction of heavy metals in the soil.

7. REDOX POTENTIAL

Fito-accessibility heavy metals depends to some extent on changes in soil redox reaction. They can occur spontaneously in the soil - if the pace is very slow. Redox potential depends largely on the activities of soil microflora (Łabętowicz and Rutkowska 2001, Majewska and Cock 2002). On the rate of oxidation and reduction processes also affect the physicochemical properties of the soil, such as pH or moisture condition. The use of organic fertilizer at low potential redox soil can lead to increased levels of soluble forms of heavy metals in the soil environment. Under these conditions the organic substance with a wide C: N ratio can sequester heavy metal ions, increasing their mobility (Gębski 1998 Majewska and Cock, 2002). Chłopecka (1994) reports that heavy metal oxide forms at low potential redox soil become readily available to plants.

8. MINERAL FERTILIZATION

The impact of mineral fertilization on the content of heavy metal forms fito - from one side that fertilization mono-, di-, and multi interact with a number of physicochemical and biological properties of the soil, resulting in an increase or decrease in the amount of fito - forms of heavy metals in soil. On the other hand, these fertilizers contain certain amounts of heavy metals, which, if introduced into the soil increase in the concentration of these elements fitod forms (Nowak and Wojtasik 1997 Gębski 1998 Orchards and Horn 2002). Mineral fertilizers most polluted with heavy metals are successively phosphoric > Calcium > Potassium > nitrogen. It should be emphasized that the greatest impact on the degree of contamination with heavy metals mineral fertilizers is the raw material from which they are made and the technological process in which they arise (Kabata-Pendias and Piotrowska 1987 Jarosz and Nowińska 1992 Gorlach and Gambuś 1997). Nowak and Wojtasik (1997) reported that the level of accumulation of Cd and Ni in carrot roots in the most affected by the type of the compound used, and to a lesser extent, its dose. Seem to confirm the results obtained by Sadego and cones (2001).

9. NITROGEN FERTILIZATION

From previous studies, the effect of nitrogen fertilization on the amount fito - forms of heavy metals depends on the type of nitrogen fertilizer, the dose and timing of fertilizer application. As reported Gębski and Mercik (1997) and Gębski (1998) use a physiologically basic nitrogenous fertilizers (calcium nitrate, sodium nitrate) limits the intake of heavy metals by plants. However, Maier et al. (2002) have shown that the use of calcium nitrate increased the concentration of Cd in potato tubers as compared to the fertilized object $(NH_4)_2SO_4$ is not used when calcium carbonate to adjust the pH of the soil. In the case of fertilization reduced fertilizers containing nitrogen form - ammonium sulfate, urea (fertilizer physiologically acid) - there is an increase content fito forms of heavy metals in soil due to reduction of the acidity.

This contributes to an increase in the accumulation of these elements in plants (Gębski and Mercik 1997 Gębski 1998). Uher test results (1995) indicate that increasing the dosage of nitrogen (in the range of 40-200 kg N • ha^{-1}) resulted in an increased accumulation of Cd, Zn and Ni, but had no impact on the levels of Pb and Cu in the yield of carrot. The same author has not found significant differences in the content of cadmium in the roots of carrots grown on the premises of nitrogen fertilization. In contrast, the fertilizer had a significant effect on the accumulation of lead in carrot roots, wherein depend on the type of fertilizer used.

10. PHOSPHORUS FERTILIZATION

Phosphatic fertilizers used can be a significant source of soil contamination with heavy metals, especially cadmium. The average content of trace elements in phosphate fertilizers are arranged in the following order of Cd < Cu < Pb < Ni < Zn, with significant variation in the level of their content depending on the form of fertilizer (Gorlach and Gambuś 1997). Different is the degree of solubility and availability to plants of heavy metals in phosphate fertilizers. He and Singh (1994) showed a higher coefficient of cadmium transfer into plants superphosphate (and the NPK) than clay phosphates. At higher contents of readily soluble phosphorus in the soil may precipitate sparingly soluble zinc phosphates, copper, cadmium and lead (Brümmer et al. 1986 Japony and Young 1994), which may lead to a beneficial effect on the phosphoric fertilize reducing accumulation of heavy metals in the plants. But the tale (1998) found no significant effect of phosphorus fertilization to 50, 200 and 800 mg P • kg^{-1} soil compactness Pb spinach and lettuce, radishes, and the bosses of carrot roots. The Gorlach and Gambuś (1991) reported that fertilization reduces the accumulation of phosphate Cu, Cd, Ni, Pb and Zn in oats and corn but to a much lesser extent as compared to the liming treatment.

11. POTASSIUM FERTILIZATION

Depending on the form of potassium fertilizer, may increase or decrease the amount of plant available forms of heavy metals in the soil, wherein it depends on the type of metal and the physicochemical properties of the soils. Heavy metals of anthropogenic origin are retained in the surface layer of the soil, their movement in the soil is very slow (Kabata - Pendias et al. 1993). According to research Gębski and Sommer (1997) and Gębski (1997), the use of KCl results in a higher leaching of Cd, Cu, Pb and Al in the soil compared to potassium fertilization in the form of sulphate (K_2SO_4). Thus, K_2SO_4 fertilization can reduce desorption of heavy metals (mainly Cd) in the soil and thus reduce their accumulation in plants as compared to KCl fertilization. However, Bednarek and Lipinski (1997) found no significant effect of these two potassium salts of the amount available to plants Cd and Ni in the soil.

12. CONCLUSIONS

Under natural conditions, content of heavy metals in soils depends on their concentration in the rock from which the soil formed. Soil is not contaminated with natural contents of heavy metals may be used in all crops including gardening. Heavy metals pose a threat to crop production mostly in industrialized countries. Along with the flue gas, sewage or industrial dust get into the soil where the plants are collected and incorporated into the food chain. Plants may undergo not only the contamination of the soil, but also by the aerial parts, easy to stop on its surface metals from polluted air.

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