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CONNECTION BETWEEN THE CONTENT OF CHEMICAL ELEMENTS IN RAW MATERIALS AND THE DEBYE TEMPERATURE

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Abstract. The connection between the heavy metals content in plant raw material and such an important integral physical parameter as the Debye temperature of a metallic element was considered. This was confirmed by the high values of the correlation coefficient. This parameter was calculated for cadmium, lead, copper, manganese, nickel, chromium and zinc ions.

The graphical dependence of the heavy metals accumulation coefficient k from the soil for the wild grassy plants of the Lower Don was presented. Ambrosia of the wormwood (*Ambrosia artemisiifolia* L.), tansy ordinary (*Tanacetum vulgare* L.), Austrian wormwood (Artemisia austriaca Pall. ExWilld.), Cedar grass (*Elytrigia repens* (L.)) were studied in the research. Samples were taken at a distance of 1 km from Novocherkasskaya GRPS.

The value of the mobilization factor (the factor of technogenic enrichment) EF is described as the ratio of the technogenic flow of a chemical element to a natural one, in the transfer of metallic elements. Dependences of the mobilization factor (EF) on the metal Debye temperature were presented.

The dependence of the heavy metals content in the soil-vegetation-invertebrate animals system in steppe biogeocenoses on the Debye temperature of the metal was characterized. This will allow to predict the possible mechanism of the heavy metals transfer in nature.

Keywords: *Debye temperature, metals accumulation coefficient, heavy metals content in plants, mobilization factor EF, correlation coefficient.*

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1. Introduction

The accumulation of heavy metals by plants is a serious problem for the environment. This is one of the possible mechanisms of the heavy metals transfer in nature. The accumulation of elements by a plant occurs as a result of the cell walls sorption processes and it is considered as a multifactorial process. The elements content in the soil plays an important role in this process. The accumulation of elements in plants can occur from the atmosphere through the surface of foliage and from the soil through the root system.

To understand the mechanism of the metals accumulation in plants, it is important to identify the physical parameter that is responsible for the accumulation of the elements, such as the Debye temperature of a metal (Shachneva, 2012; Chaplygin, 2010; Vinogradova *et al*., 2010; Zozulin & Fedyaeva, 1985; Kizilshteyn & Sobornikova, 1990; Chaplygin, 2014).

2. Experimental

Research methods

Plant samples were taken along with the root part and dug out of the ground at various points of the monitoring site (SS 27262-87). A combined sample from plants belonging to the same species was formed. The combined sample of plants weighted 1,5 kg and consisted of 8-10 point samples. After selection the plants were dried to air-dry condition and crushed. Before grinding the root part was preliminarily cleaned of soil particles in order to avoid their entering the sample (Ilyin & Syso, 2012).

The mineralization of the plant samples was carried out by the method of dry ashing (SS 26657-85). To determine the heavy metals content 1 g weighed on an analytical balance of a ground air-dry plants sample was taken. The sample was pre-ashed on the electric stove for 10-15 minutes until the smoke emission finished. The crucibles with samples were covered with a watch glass in order to prevent burning and associated with this process loss of compounds part that should be taken into account in the analysis. Then, the samples were ashed in a muffle furnace at a temperature of 450°C for 3 hours, cooled in a desiccator and weighed to determine the ash content (Guidelines for the determination of heavy metals in soils of farmland and plant products).

Acidic extraction of heavy metals from the ash was carried out by dissolving it in a 20%-solution of hydrochloric acid followed by determination on an atomic absorption spectrophotometer. All of the above analyzes were performed on the basis of the laboratories of the Department of Soil Science and Land Resources Assessment, the laboratory of special analyzes of FSI SCAS “Rostovsky” and JSC “Yuzhgeologiya”. The experimental part was processed by the method of dispersive, correlation and multiple regression analysis with the exception of insignificant members of the regression equations (Dospehov, 1985). The reliability of the multiple regression equations parameters was checked by dispersive analysis and the Student's criterion.

3. Discussion

In proof to the connection indicated in the title the dependence of the heavy metals accumulation coefficient k from the soil by the ambrosia of the wormwood (Chaplygin, 2014) as a function of the Debye temperature of metals is presented (Kittel, 1996) (Fig. 1). As described earlier the samples for the research were taken at a distance of 1 km from Novocherkasskaya GRPS (Kizilshteyn & Sobornikova, 1990; Chaplygin, 2014).

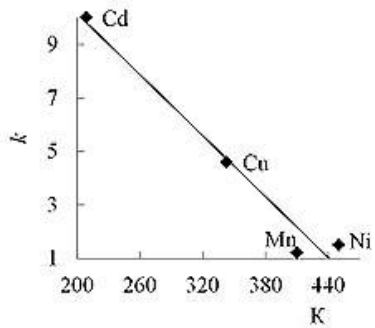

Fig. 1. The dependence of the heavy metals accumulation coefficient k from the soil by the ambrosia of the wormwood as a function of Debye temperature. Correlation coefficient is 0,983

Figure 2 shows the dependence of the heavy metals accumulation coefficient k from the soil by tansy ordinary plants (Chaplygin, 2014) as a function of the Debye temperature. Samples were taken at a distance of 1 km from Novocherkasskaya GRPS.

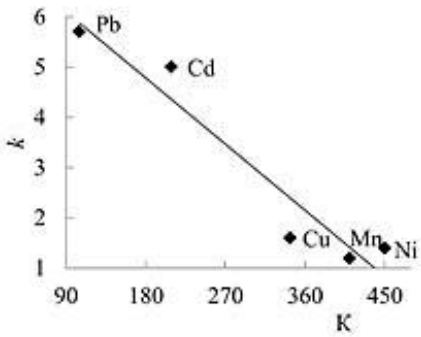

Fig. 2. The dependence of the heavy metals accumulation coefficient k from the soil by tansy ordinary plants as a function of Debye temperature. Correlation coefficient is 0,961

Figure 3 shows the dependence of the heavy metals accumulation coefficient k from the soil by Austrian wormwood (Chaplygin, 2014) on the Debye temperature.

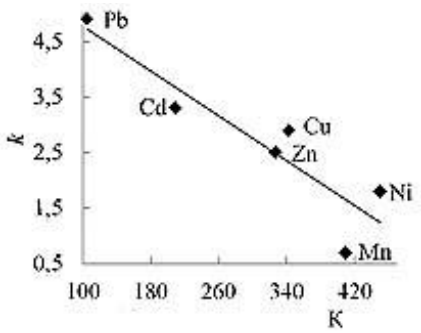

Fig. 3. The dependence of the heavy metals accumulation coefficient k from the soil by Austrian wormwood on the Debye temperature. Correlation coefficient is 0,911

It should be noted that the content of heavy metals in plants of cedar grass m (Chaplygin, 2014) is also depended on the Debye temperature (Fig. 4).

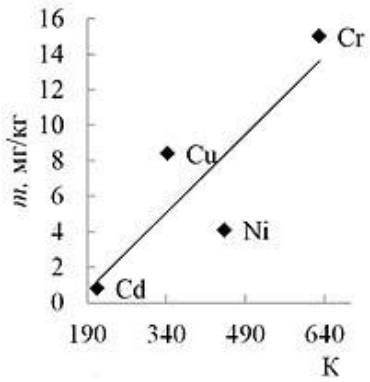

Fig. 4. The dependence of the heavy metals content in plants of cedar grass m on the Debye temperature. Correlation coefficient is 0,855

It is important to note that the high values of the correlation coefficients indicate the reliability of the established dependencies. However, in each case there are metals that do not fit the specified dependencies. This may be due to the specific features of the metals accumulation in plants and require special research.

In the transfer of metal elements, an important role is played by the mobilization factor (factor of technogenic enrichment) EF, which is understood as the ratio of the technogenic flow of the chemical element to the natural one (Korolev & Panin, 2010). Fig. 5 and 6 show the dependences of the mobilization factor (EF) on the Debye temperature of the metal. All the above elements are divided into two dependencies. This may be due to the size of the particles involved in the transfer of substances. Particles of small sizes that can be compared to the size of molecules can be presented in a dissolved state.

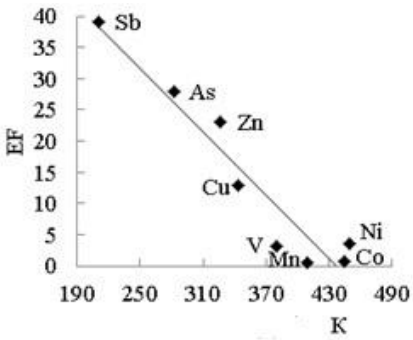

Fig. 5. The dependence of the mobilization factor EF on the Debye temperature. Correlation coefficient is 0,957

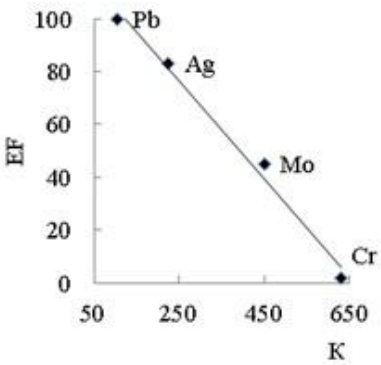

Fig. 6. The dependence of the mobilization factor EF on the Debye temperature. Correlation coefficient is 0,994

The heavy metals content in the “soil – vegetation – invertebrate animals” system is a matter of particular interest in connection with the problem of the heavy elements transfer in nature. Fig. 7 demonstrates the dependence of the heavy metals content in the system “soil-vegetation-invertebrate animals” in steppe biogeocenoses on the Debye temperature of the metal.

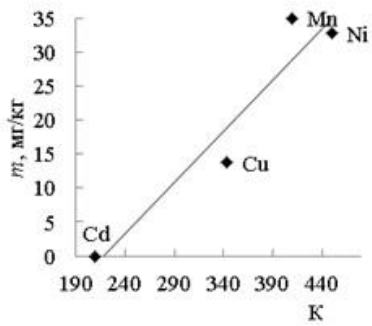

Fig. 7. The dependence of the heavy metals content m in the system "soil-vegetation-invertebrate animals" on the Debye temperature. Correlation coefficient is 0,956

4. Conclusion

Thus, the connection between the content of metal elements in plant raw material and the important physical parameter of a solid, the Debye temperature of a chemical element, is stated. It should be noted that different types of wild herbaceous plants are differed in the accumulation and distribution of heavy metals in the aerial and root parts. For example, the values of the accumulation coefficient of heavy metals in natural grass vegetation, depending on the Debye temperature, can be arranged in the following row: Cd> Cr> Pb> Zn> Cu> Ni> Mn. The plants that accumulated in their composition the most amount of cadmium and lead ions are Ambrosia of the wormwood, Austrian wormwood, and tansy ordinary. Manganese and zinc ions have the lowest accumulation factor. Such a high capacity for phytomediation suggests that the described plants do not require special care and are able to adapt to the environmental conditions.

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