Transfer of Heavy Metals from Soil to Vegetables in a Polluted Area: Background and Main Issue

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Abstract: *The world is in continuous state of development, but for good and healthy development to be possible, a clean-living environment is also needed. Throughout its evolution, mankind has realized that the industries whose purpose is that of extraction, much needed to be sure, have the most significant impact on life on our planet. Therefore, the industrial pollution produced for over a century has seriously damaged the Romania natural heritage as well. Among the categories of pollutants resulting from anthropogenic activities, heavy metals are stable and have long-term toxicity. Heavy metal pollution resulting from obtaining non-ferrous metals in the Baia Mare area represents a danger for the community even after a decade since the ceasing of mining activities and useful minerals processing in the area. Thus, in the Ferneziu district of the Baia Mare city, an area heavily polluted but also carefully monitored, soil samples and 6-point culture plants were taken. The concentrations of Pb, Cu, Zn and Cd were thus determined. The obtained results show the concentration levels of heavy metals, which are micronutrients, but also pollutants in the soil. That level extends, of course, also in the cultivation plants most commonly used for daily consumption by the locals.*

Keywords: *Heavy metal pollution, soil-plant transfer, polluted area, Enviromatics approach.*

1. Introduction

The actual world - as a dynamic expression of the Knowledge-based Society, is in continuous state of development, but for good and healthy community development to be possible, a clean-living habitat is also needed. In this context, the environmental data, Environmental Information Systems (EISs) and Environmental Informatics (EI) relative to the environmental quality play an important role in decision-making, being closely and intimate linked with the community requirements in time [1, 3, 4, 9, 10].

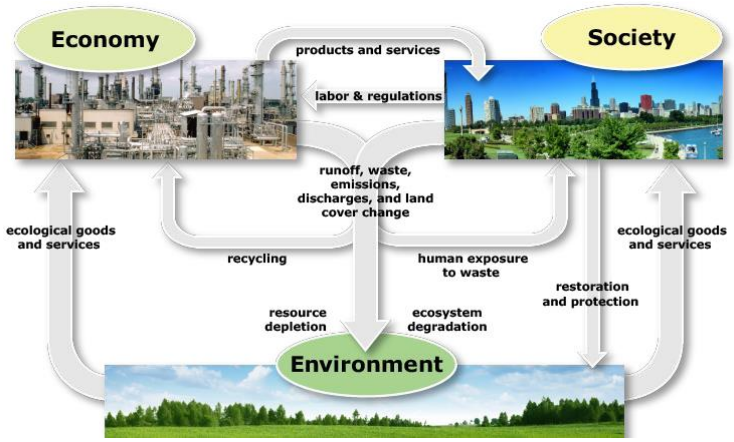

Fig. 1. The Human-Environment Interaction view as a sustainability framework

Pollution is one of the most important ways of deteriorating the natural capital [2, 13]. Of the pollutant categories, the chemically stable and highly toxic ones raise the biggest problems for the environment and the community, and heavy metals are part of this category.

In order to substantiate the decisions regarding the management of the zones and of the vegetal crops contaminated with heavy metals, it is necessary to evaluate their effects, both on the components of the natural capital and on the socio-ecological systems (as shown in Fig. 1). The first step is to characterize their distribution in the compartments of these systems.
In particular, if we are interested in evaluating the effects of heavy metals on human populations in contaminated areas, we must characterize their transfer pathways from storage compartments (soil and plant) to the human population. One of the most important such transfer routes is through the consumption of plant and animal foods produced in the contaminated area. This transfer path plays an important role especially where the source of pollution is placed near rural socio-economic systems (Fig. 2) characterized by subsistence agriculture.
In Romania there are some critical areas in terms of pollution with heavy metals (Baia Mare, Zlatna, Copșa Mică, etc.). Of these, the Baia Mare area presents a higher risk of interception of heavy metals through locally produced local food, due to the large abundance of agrosystems in the structure of socio-ecological complexes.

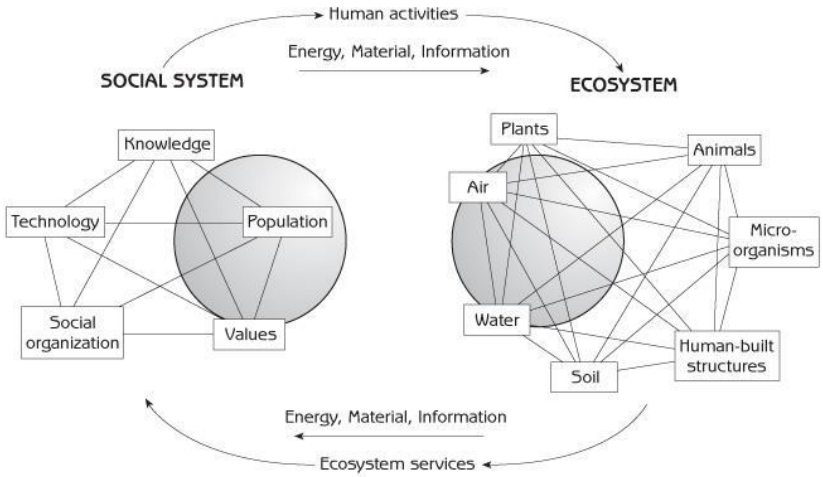

Fig. 2. Interaction of the Human Social System with the Ecosystem

In this context, the problem of assessing the risk of using contaminated land for agricultural crops and beyond is raised. Risk assessment requires the characterization of the space-time distribution of metals, but also of the exposure of the human population and of the populations from the natural capital structure to metals. This work is specifically addressed to one single stage of the ones that must be taken to evaluate the exposure of human populations in the area adjacent to the municipality of Baia Mare (respectively Ferneziu) to the heavy metals, namely their biocumulation from the soil in the crop plants most representative for the respective systems.

2. Materials and methods

Throughout its evolution, mankind has realized that the industries whose purpose is that of extraction, much needed to be sure, have the most significant impact on life on our planet. Therefore, the industrial pollution produced for over a century has seriously damaged the Romania natural heritage as well.
Among the categories of pollutants resulting from anthropogenic activities, heavy metals are stable and have long-term toxicity. Heavy metal pollution resulting from obtaining non-ferrous metals in the Baia Mare area represents a danger for the community even after a decade since the ceasing of mining activities and useful minerals processing in the area.
Thus, in the Ferneziu district of the Baia Mare city, an area heavily polluted but also carefully monitored, soil samples and 6-point culture plants were taken. The concentrations of Pb, Cu, Zn and Cd were thus determined. The obtained results show the concentration levels of heavy metals, which are micronutrients, but also pollutants in the soil. That level extends, of course, also in the cultivation plants most commonly used for daily consumption by the locals.

3. Results and discussions

The analysis of the behavior of a chemical compound in ecosystem is a complex problem [12], because its distribution is performed in both abiotic and biotic compartments (in this case in plants – as shown in Fig. 3) [7, 11].

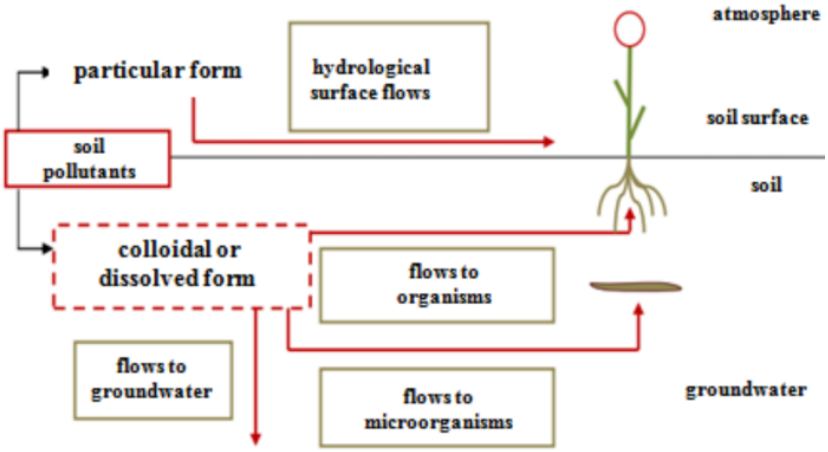

Fig. 3. The schematic presentation of the pollutants transfer to soil and plants

The processes of transport of chemical compounds can be carried out within the same compartment (water, air, soil) or between compartments through advection and/or dispersion mechanisms. Once entered the ecosystem complex for a sufficiently long period of time metals may be distributed by transfer to other abiotic compartments of the complex ecosystems or to biotic compartments of the complex ecosystems, or to other ecosystems within the complex through passive mobility populations or activate.
The transport and destination of heavy metals at large spatial scales is in causal relation with the physico-chemical properties of the metal, of the crossed environment and of the storage surface. At the ground level the metals are distributed, according to the chemical state in which, through surface flows, the hydrological flows of infiltration to the groundwater and of the fluxes to the organisms that take trophic substances from the soil, all of which can be represented by software. dedicated computers [5, 6].
Existing metals in ecological systems are available for the acquisition process in a certain proportion of the amount of metal in soil, sediment, water, atmosphere [8]. The fraction of available metal represents the amount of metal that exists at one point in a system and has the potential to come into contact or be ingested by organisms [8]. Plants easily take from the soil metals that are dissolved in the soil solution, either in ionic form, chelated or complexed.
The main features of the absorption process can be summarized as follows:

- it is carried out at very low concentrations in the solution;
- depends, in general, on the concentrations in the solution, especially on short distances;
- the adsorption rate depends decisively on the presence of H+ and other ions;
- the adsorption intensity varies depending on the species and the development stage;
- the process is influenced by certain soil parameters such as temperature, aeration and redox potential;
- may be selective for a particular ion;
- the accumulation of ions can also occur against the concentration gradient.

The absorption through the roots is the main way of transferring the metals to the plant. The ability of plants to take up metals from the growing medium is evaluated by the ratio between the concentration of the element in the plant and the concentration of the element in the soil called biological absorption coefficient, bioaccumulation index or transfer factor. The ability of plants to take up chemical elements varies across a wide range. Elements like Br, Ca, B, Cs, Rb are very easy to pick up while elements like Ba, Ti, Zr, Sc, Bi, Ga, Fe, are less available, but these aspects change depending on the particularities of the system. the soil-plant. The uptake by plants with different efficiency is also due to the different bioavailability of the metal ions.

4. Conclusions

The potential for accumulation of chemicals that can cause adverse effects and their transfer along the food chain is one of the current challenges and concerns in the field of ecotoxicology. The processes accompanying the accumulation and the transfer have been studied mainly in the aquatic systems, the situation in the case of the terrestrial systems being precariously described in terms of data consistency.
Scientific studies, which have been related to terrestrial systems, have focused mainly on the problem of transfer to the terminal levels of the food chain, especially of the transfer to mammals and birds whose food resource is in aquatic systems.
The transfer of heavy metals in the sequence of trophic levels is of importance recognized by several researchers due to the need to integrate the principles of transfer and bioaccumulation of metals in the trophic network with the establishment of toxicity and effects. Starting from the accumulation of metals in the soil, the risk of contamination occurs in the plant and animal organisms that take metals directly or indirectly, and subsequently in the organisms that meet them, through trophic relationships, via the transfer through the food chain.

References

[1] Avouris, N.M., and B. Page. *Environmental Informatics: Methodology and Applications of Environmental Information Processing*. Dordrecht, Boston, Kluwer Academic, 1995.
[2] Botnariuc, N., and A. Vădineanu. *Ecology / Ecologie*. Bucharest, Didactic and Pedagogical Publishing House, 1982.
[3] Cioruța, B., and M. Coman. "Evolution, definition and role of Environmental Information Systems in the development of strategies for environmental protection / Evoluția, definirea și rolul Sistemelor Informatice de Mediu în dezvoltarea strategiilor pentru protecția mediului." *Journal of Environmental Research and Protection (ECOTERRA®)*, no. 27 (2011): 11-14.
[4] Cioruța, B., and M. Coman. "Foray into modern scientific research of the environment. From Environmental Information Systems to Environmental Informatics / Incursiune în cercetarea științifică modernă a mediului înconjurător. De la Sistemele Informatice de Mediu la Informatica Mediului." *Journal of Environmental Research and Protection (ECOTERRA®)*, no. 29 (2011): 17-20.
[5] Cioruța, B., and M. Coman. "Innovative possibilities to represent the Baia Mare Urban System soils pollution with heavy metals using G.S. Surfer." Paper presented at International Conference "Scientific Research and Education in the Air Force", Brașov, Romania, May 28-30, 2015.
[6] Cioruţa, B., M. Coman, and V. Mateșan. "Modeling Possibilities of the Heavy Metals Concentration in Baia Mare Urban System Soils with G.S. Surfer." *Journal of Documentation, Research and Professional Training (ProEnvironment®)* 6, no. 14 (2013): 479-485.
[7] Coman, M., L. Muntean, and B. Cioruța. "Regarding the eco-models in the characterization of soil pollution with heavy metals." Paper presented at the 40th International Conference on Mechanics of Solids, Acoustics and Vibrations & The 6th International Conference on "Advanced Composite Materials Engineering", COMAT&ICMSAV, Brașov, Romania, November 24-25, 2016.
[8] Fairbrother, A., R. Wenstel, K. Sappington, and W. Wood. "Framework for Metal Risk Assesssment." *Ecotoxicology and Environmental Safety* 68 (2007): 145-227.
[9] Günter, O. *Environmental Information Systems*. Berlin, Springer, 1998.
[10] Hilty, L.M., B. Page, F.J. Radermacher, and W.F. Riekert. "*Environmental Informatics as a new Discipline of Applied Computer Science*." In Avouris, N., and B. Page. *Environmental Informatics – Methodology and Applications of Environmental Information Processing*. Dordrecht, 1995.
[11] Hreniuc, M., B. Cioruța, and M. Coman. "An insight into the history of scientific concerns about soil pollution in Maramures County." *Journal of Documentation, Research and Professional Training (ProEnvironment®)* 12, no. 38 (2019): 142-149.
[12] Iordache, V. *Ecotoxicology of heavy metals / Ecotoxicologia metalelor grele.* Bucharest, Ars Docendi Publishing House, 2000.
[13] Vădineanu, A. *Sustainable development - Theory and practice / Dezvoltare durabilă - Teorie și practică*. Bucharest, University of Bucharest Publishing House, 1998.