Some Considerations Regarding the Presence of Heavy Metals in Soil and the Human Body

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Authors’ contributions

This work was carried out in collaboration among all authors. Authors SA and BVC designed the study, performed the literature searches and wrote the first draft of the manuscript. Author MC managed the entire study analyses. All authors read and approved the final manuscript.

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ABSTRACT

Until now, there have been laborious researches regarding the presence of heavy metals in environmental factors but their effects have been studied less in the bio-geo-chemical circuits, respectively within the local trophic chains and the regional trophic networks. Naturally, the metals existing in the earth's crust enter the bio-geo-chemical cycles. In the cells of higher organisms, as we know, there is a fragile balance between the amounts of metals needed for catalytic processes and toxic doses to organisms. However, this balance is dependent not only on the concentration and variety of metals in the Earth's crust but also on the microbiological activity of environmental factors, responsible for the transformation of these metals into complex chemical substances that affect more or less the organisms, respectively their enzymatic activity. The vital-necessary, but also the non-vital mineral substances in their mobile forms, which may at one time be toxic to

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organisms, are significantly pushed out by anthropic activities into trophic chains. They are present in environmental factors such as soil, air, water, reach the body of plants and the body of animals. Plants and animals can bioaccumulate and concentrate in their bodies several chemical elements in the environment, regardless of their origin, which is then easily transferred through food circuits into the human body. Thus, through local trophic chains, respectively through regional trophic networks, contamination of the human body takes place. This requires the need for a measure of most likely high complexity to mitigate the effects with a strong impact on the health status, including that of the human psychic. In severe cases of contamination, behavioral manifestations, especially among the vulnerable population, are proven.

**Keywords:** Chemical substances; food webs; heavy metals; soil contamination.

**1. INTRODUCTION**

During recent decades the stirring up of the processes of globalization, practically in all spheres of society, has aggravated and brought numerous problems resulting from Human-Environment Interactions (HEI). To overcome these problems, it is necessary to develop and adopt new concepts and techniques to study, evaluate, and manage the changes occurring on the Earth's ecosystem [1]. In this context, the protection of our environment (including all the environment factors) remains one of the greatest challenges in all kinds of industrialized societies or communities. This challenge is addressing politics, economy, sociology, as well as technology, informatics, and research [2].

State and dynamics of the environment (air, water, soil, biodiversity, etc) are described by biological, physical, chemical, geological, meteorological, and finally by the social-economic data [3]. In soil, for example, heavy metals are naturally found and become concentrated as a result of different human activities [4]. In their natural concentrations, metals play an essential role in many biochemical processes in the body, but any concentration that exceeds that of the background can become toxic [5]. Heavy metals are an important category of stable toxic pollutants [6]. Heavy metal pollution is recognized as a significant problem, because it represents a major risk to the environment, on the ecosystems and regarding life quality and health of the peoples living in or near the affected areas [7].

The current state of pollution in the Baia Mare depression is the result of the mining and metallurgical activities carried out during over 150 years [4], a period in which the production technologies used have directly and excessively polluted all the environmental factors and as a result, have had the human communities in the vicinity suffered. The assessment of the effects of heavy metals on different categories of consumers can be done by researching their transfer ways from their storage compartments to the human population and researching the effects on human populations.

The literature presents general data on the risk of heavy metals on human health, but detailed research is needed for each area affected and long affected. Heavy metal toxicity is a less common but clinically significant medical condition. The type of affected organ and the severity of the damage varies with the metal involved, the age of the individual, and the level of toxicity. If not properly recognized and treated, it can lead to significant morbidity and mortality. European Environment Agency (EEA) Report no. 19/2018, provides an overview of the progress made by the European Union (EU) to achieve 29 environmental policy objectives. These are relevant to the achievement of the 7th Environment Action Program (WFP) three key priority objectives: Natural capital, resource efficiency, and low carbon emissions, human health, and well-being. Urban expansion, bioenergy, and food production all compete for finite land resources and put pressure on biodiversity, drinking water and health status. The heavy metals in the environment come from different sources: Industrial activities, transport, fossil fuels, agriculture, urbanization, and other human activities. The release of large quantities of heavy metals into the natural environment creates problems due to their persistence. These can accumulate in the food chain presenting a significant danger to human health [8].

Bioaccumulation is a frequent topic recently addressed in the field of research and analysis of environmental risk because it represents the body's exposure to various pollutants in the environment. a prerequisite for highlighting
adverse effects at the species and individuals level [9]. As such, heavy metals are the term that is generally used for metals with a density greater than 5 kg/dm³ and are generally toxic, their residues causing environmental pollution. Heavy metals are non-ferrous metals. Common sources are mining and industrial waste, car emissions, aluminum, acid, fertilizers, petrochemical refining [6].

Metals are divided into the following categories: alkaline, alkaline-earthy, transitional, metalloid. Examples of metals that are more relevant to the environment in terms of toxic effects are the following: cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), tin (Sn), vanadium (V), zinc (Zn). Arsenic is also considered a dangerous metal, although chemically it is a semi-metal.

2. MATERIALS AND METHODS

The heavy metals pollution is a term commonly met for several human impact activities affecting in a significant way the environment. However, although it may seem a little out of place, the concept of pollution with heavy metals is increasingly making its presence felt in today's society, most often, lately, as a source of different illegal human activities. Thus, there are more and more followers who have chosen to study, understand, and manage this issue, based on the scientific literature already consecrated all over the world. On a similar note, our interest was also to emphasize some general aspects regarding the pollution itself with heavy metals from a limiting perspective, but for all environmental factors.

3. RESULTS AND DISCUSSION

3.1 The Occurrence and Dispersion of Heavy Metals Ions in Nature

Heavy metals are natural compounds of the Earth's crust. They cannot be broken down or destroyed. They reach our bodies in a very small amount, with food, drinking water, and air. As essential elements, some heavy metals such as ficupium, selenium, zinc are vital in maintaining the metabolism of the human body. However, in high concentrations, they can be toxic. The negative effect of heavy metals can be seen through contaminated drinking water (lead pipes), high levels of air concentration around emitting sources, or assimilation through the food chain.

Heavy metals are dangerous because they tend to accumulate. Bioaccumulation means the increase in time, in biological organisms, of the concentration of the substance in an amount compared to the concentration of the substance in the environment. Compounds accumulate in living organisms when assimilated and stored at a higher rate than they are destroyed (metabolized) or eliminated. However, food poisoning with heavy metals is very rare and in most cases occurs only after environmental pollution.

Many metals are of interest due to their toxic properties or because they are essential for the health and survival of humans, animals, and vegetation. It is important to know that pollution and toxicity are most often given [10,11]. Metals that play an important role in the life of organisms can be in large quantities: K, Mg, Ca, Na or only some traces (below 1 mg/kg tissue): Cu, Fe, Mn, Zn, Se, Co, Mb, Cr, Ni, Si, V, As [12].

Heavy metals are the term that is generally used for metals with a density greater than 5 kg/dm³ and are generally toxic, their residues causing environmental pollution. Heavy metals are non-ferrous metals. Their level in the aquatic environment and industrialized societies is 3 times higher than the preindustrial one. Satisfying European demands for food, water, energy, and housing exerts major pressure on the environment, indirectly affecting human health and well-being.

3.2 The Presence and Spill of Heavy (Critical) Metals in Air

Annually, millions of tons of toxic pollutants are released into the air, both from natural sources, but especially from anthropogenic ones. There are four categories of emission sources: stationary (industrial processes, industrial and domestic combustion), mobile (car traffic), natural (volcanic eruptions, forest fires), and accidental pollution (spills, industrial fires). Air pollution has experienced a great extent with the increase of industrial production, intensification of road traffic, incineration, household waste.

The pollutants were initially organic and readily biodegraded by bacteria and fungi. As the industrial development and demographic explosion appeared, non-biodegradable waste appeared, for which there was no natural enzyme capable of decomposing them. Artificial pollution is of nature: Physical (sound,
radioactive, thermal), chemical, biological pathogens (viruses, bacteria, fungi).

Heavy metals are found in the environment naturally or over-added from artificial sources - which derive mainly from the following activities: thermal power plants and other solid and liquid fuel combustion plants, road circulation through exhaust gases, evaporation of gasoline or as a result of gasoline. improper handling, coal combustion, oil, non-ferrous metal production, steel, and iron production, cement production, etc.

3.3 The Presence and Spill of Heavy (Critical) Metals in Soil

Heavy metals naturally exist in the Earth's crust, but they are also found due to artificial sources. Some metals are micronutrients needed in the plant development process (e.g. Zn, Cu, Mn, Ni, and Co) while other metals are not involved in the physiological processes of plants (e.g. Cd, Pb, Hg). The most common metal contaminants are Cd, Cr, Cu, Hg, Pb, Zn.

The sources of metals in the soil can be the use of fertilizers, pesticides containing metals (fungicides containing mercury, copper, arsenic, zinc, etc.). Of course, depending on soil type and geographical location, it contains high quantities of heavy metals (in Romania at Baia Mare, Copşa Mică). The high content of heavy metals in the soil presents a direct risk of soil pollution and therefore affects the plants that absorb them, the animals that consume those plants and implicitly on humans. If not properly recognized and treated, heavy metal toxicity can cause morbidity and mortality. The periodic table of the elements contains 118 elements, of which 80 are considered metals, and of these, for about 30 metals toxic effects have been discovered in humans.

Some heavy metals are essential in different biochemical processes (Co, Cu, Fe, Mn, Mo, Ni, V, and Zn are required in small amounts for the body but become toxic to it in large quantities). Other heavy metals, such as Pb, Cd, Hg, and Ca (a metalloid, but generally referred to as heavy metal), have no beneficial effect on organisms and are therefore considered as "major threats" because they are very harmful to both plants as well as animals.

Anthropogenic activities as forms of impact on the environment represent an important source that almost entirely influences the current general level of the abundance of heavy metals in the soil. The quantitative presence of heavy metals in the soil is dependent on their concentration in burnt coal, combustion temperature, volatilization temperature of metals and meteorological factors such as wind direction, speed, atmospheric pressure, etc. This is why the consumption of leafy vegetables grown in the area of large industrial outlets is contraindicated. Factors that have an obvious effect on the accessibility of heavy metals for plants are soil texture, organic matter content, cation exchange capacity and drainage.

Whether they are biologically essential or not, excess heavy metals are harmful (phytotoxic). While cadmium, lead, and mercury are considered harmful to plants, others, such as copper, zinc, and manganese are harmful in high concentrations but essential in low concentrations. Considering the importance of plants in most food networks, more and more studies are directed to the study of the accumulation of heavy metals in soil and plants as well as the measures to reduce them in the living environments.

3.4 The Presence and Spill of Heavy (Critical) Metals in Water

Today, the ecological importance of water is considered as a fundamental necessity throughout the world. The primitive requirement for human livelihoods is water. The serious environmental burden is increasing due to water contamination and water shortage, and its limited availability is increasing nowadays due to the destruction of the natural water supports.

In recent decades, the elimination of highly polluted wastewater has increased due to certain actions, such as urbanization, industrialization, and agricultural practices. But the release of untreated wastewater from industry is the main source of water pollution. The tributary from industries containing a different concentration of pollutants is discharged into rivers or other water resources. During the initial discharge, the wastewater may incorporate a high concentration of organic and inorganic pollutants.

Wastewater generated from industries is due to the manufacturing process, paper and cellulose processes, textile products, chemicals and different flows such as cooling tower, boiler, and production line, etc. Contaminants from industrial
wastewater moving in the environment are pesticides, dyes, aromatic hydrocarbons, oils, heavy metals. Accumulation of metals in marine sediments is a risk to the ecosystem, and the concentrations of heavy metals in these can provide historical information on the pollution of an area. Unlike many organic pollutants, metals do not degrade but remain in the environment.

According to environmental reports, in recent years increased levels of contaminants have produced drastic changes in aquatic ecosystems. Due to these, attention has been paid to the areas that study the accumulation and toxic effects of contaminants on aquatic organisms and the taking/accumulation of contaminants in marine resources for human consumption. Over the past decade, it has been shown that bioaccumulation and amplification of chemicals, via the food chain or food chain, maybe a necessary condition for highlighting adverse effects on species and individuals.

3.5 Danger of Heavy Metals Stored in The Human Body

Heavy metals are natural chemical elements existing in the lithosphere. They reach our body in a very small amount, with food, water, air, or even some medicines (it is known that some vaccines contain mercury). The presence of heavy metals in the body leads, depending on their plasma concentration and the degree of toxicity, necessarily, to the development and occurrence of particularly serious symptoms/conditions, which in turn denote the presence of a possible medical condition with a high potential for lethality, spontaneous or gradual.

Some heavy metals, such as iron, copper and zinc, at oligomeric doses, are considered harmless, they even play a vital role in the functioning of the body, because they act as catalysts - they speed up or slow down a chemical reaction - and not only, although at high doses they become toxic and endanger life.

The human body, like other organisms, needs cations of metals, which ensure the development of many processes of vital importance. From the nutritional point of view, the metals found in food products are also divided into two categories:

- Metals with a well-defined physiological role called essential or biometal. The lack or even just their insufficiency in human nutrition causes, after some time, disorders of the metabolic processes and the appearance of deficient diseases. Of this category belong: Na, K, Ca, Mg, Fe, Cu, Zn, Mn, Mo, Co, Se;
- Metals that, until today, are not necessary for life, called non-essentials. Such elements are Pb, Hg, Al, Sn, Ag, Au, Ni, Cr, others and their resistance to food appears as contamination. When the daily ingested amounts of these metals are smaller than the normal possibilities of elimination through urine, digestive juices, bile, flaking cells, and other pathways, they behave as chemical impurities, which cross the body without causing biochemical disturbances.

Once penetrated the body, the metal will be accumulated and/or excreted. Accumulation can occur as a result of physiological mechanisms in the case of essential metals, which are directed to tissues to perform metabolic functions. As scientists put some unknown diseases on the account of heavy metals, people realized that pollution was turning against them through the heavy metals present in food. These accumulate in the body and affect the vital organs. By definition, heavy metals are chemical elements that have a specific weight of at least 5 times greater than that of water. Water has a specific weight 1, arsenic 5.7, cadmium 8.6, iron 7.9, lead 11.3 and mercury 13.5.

However, as far as heavy metals are concerned, the body cannot eliminate them by the usual methods. They remain in the solid-state in the body and accumulate in the kidneys, liver, bones, nails, brain, and hair, causing various kidney diseases, developmental problems such as autism, Parkinson's, Alzheimer's, cancer, and in some cases causing body death. In small quantities, certain heavy metals are essential in carrying out metabolic processes. These are iron, copper, magnesium, and zinc and are naturally found in foods, fruits and vegetables, and various nutritional supplements.

Due to their solubility in water and their bioaccumulative tendency in different environmental matrices, some heavy metals are extremely toxic even at low levels of exposure and can be transported into the food chain. Toxic minerals have negative effects even in extremely low concentrations, but the effects vary depending on the mode and duration of exposure and the metabolism and detoxification
capacity of each individual. The mechanisms of toxicity are multiple and include: Enzymatic or cofactor inhibition, enzymatic potentiation, membrane damage, and impaired transport processes, decreased neuronal functioning, and nerve conduction. Some of these effects are synergistic with other minerals or toxic chemicals.

The level of toxicity of these elements and the corresponding adverse effects vary from individual to individual. Subacute or chronic exposure can lead to subtle or frank symptoms, prolonged in some individuals, and especially in children. Especially lead and mercury have negative effects on children, due in part to their accelerated growth rate and small body mass. Toxic minerals interfere with the different enzymatic and neurological processes gradually and progressively. The following are some of the relationships that exist between the toxic minerals and the different dysfunctions and disorders.

There are numerous cases and studies in the literature concerning the connection between the interference of aluminum accumulations with normal neurological functions. Dyslexic children have been shown to exist. Aluminum (Al) is ubiquitous, being the most common heavy metal in the earth's crust. The most common source of non-occupational exposure is drinking water (especially from areas exposed to acid rain).

Mercury (Hg) at high concentrations causes liver damage and neurological symptoms [13]. Regarding the neurological pathology, some data show that the increased intake of mercury from poor freshwater fish and the subsequent accumulation of mercury in the body leads to increased mortality due to vascular causes. This correlation was presumed to be due to the promotion of lipid peroxidation by mercury [14].

Lately, there has been increased interest in the possible harmful effect of mercury released from dental fillings from amalgam as well as the consumption of fish contaminated with mercury [15]. A study that looked at the dental floss, of many dental hygienists in the UK, showed a 2-3 fold increase in Hg compared to the unexposed lot [16].

Lead (Pb) is the most common metal found in chronic exposure to toxic minerals in low concentrations. Studies show that lead poisoning is associated with children with central nervous system functional deficits that may persist into adolescence [17]. A recent study of 227 school children showed severe effects of Pb on learning and behavior. There was a close connection (p<0.0001) between the Pb of the hair and the scores on the questionnaires regarding the ability to concentrate and to fulfill the tasks, which indicated a very marked deficit [18]. Another Pb study showed a 7-fold increase in the incidence of high school graduation failures [19]. The accepted level of risk of lead neurotoxicity in children has steadily decreased over the last decade, as more sophisticated studies have shown the harmful effects of even low levels of Pb.

Cadmium (Cd) is a metal that enters into the composition of numerous industrial compounds (cadmium acetate, fluoroborate, carbonate, nitrate, oxide, stearate, sulfate and sulfide). Cadmium contamination of the environment has caused in Japan a disease called "Itai-Itai" manifested by severe arthralgia and osteomalacia in people with low calcium and vitamin D.

The cadmium sources are mainly derived from human activities

- Contaminated food (rice), contaminated soil or contaminated cigarettes;
- Combustion of petroleum products (refineries);
- The manufacturing process of nickel-cadmium batteries;
- Pigments used in the manufacture of plastic, ceramic and glass products;
- Manufacture of welding metals and alloys.
- Toxicokinetic and toxicodynamic.

Cadmium (metal or in the form of salts) has a low volatility and is found in the air as fine particles. Absorption occurs mainly in the lung alveoli, with 25% of the inhaled cadmium being absorbed. The absorption in cigarettes seems to be higher compared to that in aerosols, probably due to the smaller dimensions of the cadmium particles in the cigarette, favoring their "penetration" up to the alveolar level. Only 5% of the ingested cadmium is absorbed, its absorption being favored by the deficiency of iron or calcium or by the diets high in fat. Cadmium does not absorb transdermally. Once absorbed, cadmium is distributed throughout the body, predominantly in the liver and kidney.
Neurological effects consist of peripheral neuropathy (decreasing nerve conduction velocity), impaired balance, and disabilities in the concentration process. Serum cadmium levels in exposed workers fall in the range of 10-100 mg/l. Levels above 0.7 µg/dl indicate severe exposure. Serum cadmium level assessment can be used to evaluate recent exposure. Tubular dysfunction caused by cadmium is irreversible and can be evaluated by dosing urinary α1-microglobulin. If the urinary excretion of cadmium is below 2 mg/day, the risk of renal impairment remains low. The most faithful procedure for evaluating cadmium poisoning remains atomic absorption spectroscopy and emission spectroscopy.

It is not yet known in the medical literature whether cadmium is metabolized by alkylation, oxidation, or reduction in the body. Once deposited in the kidneys, the half-life of cadmium is 6-38 years, and for the one deposited in the liver of 4-19 years. After a single exposure to cadmium in a large but nonlethal dose, lung function may be impaired for years. It is described in the case of a worker who was exposed to cadmium for 1 hour during welding with electrodes containing cadmium, and the lung function was affected for more than 4 years. Cumulative deposition of cadmium and other minerals in both the human body and the environment may pose a significant risk [20]. Trace element reference values in tissues from inhabitants of the European community V: a review of trace elements in blood, serum, and urine, and critical evaluation of reference values for the Danish population.

4. CONCLUSION

We consider that the bi-unequivocal human-environmental relationship still has many neglected or still unexplored aspects, all these aspects contributing to what we call the quality of our life. Before reaching the treatment of the toxic effects of heavy metals on living organisms, a careful analysis of the causes is also preferable, as the advanced technology allows the use of measuring and control tools specific to the research fields.

Testing patients to detect mineral deficits, excesses, and imbalances are becoming more and more important, due to a large number of toxic metals in the environment and the mineral imbalances widely encountered in modern humans. Both pollution and nutrition begin to speak its way into mental illness. Tissue mineral analysis (AMT) is an effective and faithful method for determining long-term exposure to toxic minerals and nutrient deficiencies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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