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Editorial

Special Issue on Heavy Metals in the Environment—Causes and Consequences

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1. Introduction

The modification of the chemical composition of environment components, including the concentration of heavy metals, is one of the consequences of the development of human societies. Human impact is manifested in the formation of new pathways of element migration, release of elements that would not be in circulation under natural conditions, e.g., Pb, Zn, and Cd, and a considerable acceleration of the circulation rate [1–3]. The first changes of air, water, and soil properties under anthropogenic pressure occurred with the emergence of Neolithic sedentary agricultural societies. However, it was the industrial revolution in the 18th century that triggered irreversible changes, often of a global character, that reached their peak in the years 1960–1970 [4–6]. However, these emissions remain high in developing countries. Heavy metals are found in the air we breathe, the water we drink, and the food we eat. This contributes to an increased incidence of many diseases.

The anthropogenic enrichment of the environment with elements and their compounds can be a result of various forms of human activity, namely industry, transport, agriculture, and settlement activity. The scale and spatial range of these effects varies. Human activity can impact the geochemical environment directly through the enrichment and delivery of elements and chemical compounds introduced with fertilizers, sewage, exhaust fumes, as well as industrial and municipal waste. The most significant geochemical changes are related to mining, industrial, and transport activity. Even in areas free from a clear anthropogenic geochemical impact, it is difficult to regard the environment as natural in chemical terms [3,5,6].

Therefore, it is extremely important to determine the contemporary levels of heavy metal pollution of air, water, soil, and sediments, trends in concentration changes, determinants of these processes, and threats to living organisms associated with increased levels in the environment. It is particularly crucial to investigate elements that are toxic to humans, such as lead, cadmium, and mercury. Topics of special significance include the assessment of the pollution level and the associated health risk, determining the main sources of heavy metal emissions into the environment, spatial conditions for the diversity of their concentration in the environment, contemporary trends in content changes, methods for reducing the environmental risk associated with these elements, and remediation of contaminated components.

Topics related to heavy metals in the environment are often addressed by researchers. An analysis of the Web of Science database indicates that, during the last 20 years, more than 26,000 articles have been published on topics related to the contamination of the natural environment with heavy metals (this phrase appears in the titles). The number of publications per year has risen from 500 in 2001 to more than 2500 in 2021.

2. Heavy Metals in the Environment

The papers included in this issue present a broad spectrum of studies on the contamination of the environment with heavy metals and on the determinants and effects of their increased concentrations. These studies are concerned with the content of heavy metals

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in all components of the environment, i.e., the air, water, soil, and living organisms. The investigations have been conducted on land, in urban and rural areas, as well as in seas. In most cases, these studies have a practical dimension because, apart from determining specific heavy metal content, the authors have also indicated the health-related consequences of pollution, as well as ways of mitigating the negative effects.

The study by Moldovan et al. [7] demonstrates a very strong Pb, Fe, and Mn contamination of the Aries river (eastern Romania) that drains former mining areas. This takes place despite the fact that industrial activity has been discontinued in that area. The pollution necessitates a special treatment of the water before it is used, as well as appropriate management of water resources in the catchment to prevent adverse health effects. The investigations conducted indicate that the pollutants occurring in former mining areas pose a serious threat to the environment and require special attention.

Strzebońska et al. [8] have investigated the geochemistry of water coming from rooftops in the city of Kraków (southern Poland). Water runoff from the city, including water from the roofs, is an important factor affecting the quality of surface water. In chemical terms, the pollution of water runoff from roofs is not considerable, even though non-carcinogenic risk values indicate the existence of health hazards. Carcinogenic risk occurs in the case of Pb. Microbiological pollution has also been found in water under study. This indicates that the quality of water runoff from the roofs should be taken into account when identifying health and environmental risk in urban areas.

Latosińska et al. [9] have studied heavy metal levels in sewage sludge, which can potentially be used as fertilizer, originating from three wastewater treatment plants located in Świętokrzyskie Province (central Poland). It is particularly important because heavy metals that leach into the soil can enter the food chain and thus pose a health risk to people consuming contaminated food. The form in which the metals occur is particularly significant, as it influences their mobility in the environment. The studies conducted have shown that, despite increased heavy metal levels in sewage sludge (Zn in particular), using them as fertilizer does not pose a high health risk.

Increased heavy metal concentrations in marine organisms are a major problem in many places around the world because they can enter the human food chain. Fierro et al. [10] have studied heavy metal levels in water and in juvenile fish occurring at the estuary of the Valdivia river (Chile). While no pollution of marine water has been detected, very clear differences occur in heavy metal concentration depending on the fish species: it was clearly greater in puyes (*Galaxias maculatus*) than in silversides (*Odontesthes regia*). For some elements (Zn, Pb, and Cd), greater concentrations have been found in larger (older) specimens. Heavy metal levels in the bodies of the fish under study have been found to be higher than those reported in the literature so far. In the case of puyes, Pb and Cd concentrations are above the permitted limits and thus pose a health risk if the fish is consumed by people.

Zgłobicki and Telecka [11] have investigated heavy metal content in street dust collected from the streets in Lublin (eastern Poland). The dust, resulting from the interaction of air, water, soil, and direct anthropogenic delivery, is a good indicator of the quality of the environment in the city. At the same time, the resuspension of street dust can cause air pollution in areas frequented and inhabited by people. Despite the clearly increased heavy metal levels, they do not pose a risk to human health in terms of non-carcinogenic effects. However, increased cancer risk values have been found for metals such as Cd, Cr, and Ni, which poses a health hazard particularly in the case of children.

Dong et al. [12] have analyzed the impact of landscape structure on the propagation of heavy metal pollution related to road traffic in the tropical areas of south-eastern China. It has been found that the contamination level of soils used for agricultural purposes is impacted by the distance from roads, the type of land cover, topography, and soil properties. In natural soils, on the other hand, the distance from roads does not influence the level of pollution with heavy metals. A road's place in the road hierarchy (and the resulting traffic intensity) does not impact the concentration of pollutants.

The amount of heavy metals accumulating on the leaves of coniferous trees can be used to assess the level of air pollution in urban areas. Liu et al. [13] have assessed the impact of the leaf rinsing method on results of studies on concentration of metals. It has been found that the commonly employed rinsing of needles with water can conceal the actual contamination due to its rather low efficacy (5–50%).

Aleksander-Kwaterczak and Ciszewski [14] have studied the variation of heavy metal levels in soil profiles within a waste heap of a Zn-Pb mine decommissioned more than 200 years ago. The study objective was to determine the intensity of the vertical migration of heavy metals in soil profiles. This process can pose a threat to groundwater. It has been established that, until now, the most mobile elements, such as Cd and, to a lesser extent, Zn, have migrated several dozen centimeters down the soil profiles. This occurs primarily in acidic soils that are poor in organic matter. The authors conclude that spontaneous reforestation is a good way of stabilizing the heap material and limiting the contamination of groundwater. Long-term monitoring of such sites is necessary, however.

In the case of soils, immobilizing heavy metals that penetrated into the soil as a result of human activity is a major challenge. While conducting experimental research, Correia et al. [15] have analyzed the impact of various additives (carbon nanotubes, clay, and Portland cement) on the mobility of Pb, Cu, Ni, and Zn in contaminated soils. Their findings indicate that these additives increase the soil's natural capacity to bind and retain heavy metals. Therefore, they can be used for the remediation of soils contaminated with heavy metals.

Phytoextraction is the topic of a study by Danelli et al. [16] who have conducted quantitative research on the possibility of removing heavy metals through the cultivation and harvesting of *Arundo donax* L. grass. It has been found that 3.8 kg/ha Zn, 2.1 kg/ha Cu, and 0.007 kg/ha Cd can be removed (third year of cultivation). At the same time, according to the authors, the harvested grass can be used for power generation. This indicates the prospects of improving the condition of the environment by removing contaminants while reducing the consumption of fossil fuels and thus reducing the emissions of harmful substances.

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