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EFFECT OF HEAVY METALS ON ECOSYSTEMS

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Environmental pollution is one of the most serious problems in the sphere of ecology. Rapid industrialization, discovery and development of new oil fields, modern agricultural practices, and other types of anthropogenic activities contribute substantial amounts of toxic heavy metals to the environment. Heavy metals are some of the prominent substances that pollute soil, water, and air. Pollution by heavy metals is constantly rising, producing serious toxic effect on all forms of living organisms, and altering properties of soil and its biological activity. Excessive accumulation of heavy metals in plant products can have serious adverse effect on the quality and safety of food. Consumption of such products poses a potential risk to global food security and healthy lifestyle. This article examines the effect of heavy metals on plants and their enzymatic and metabolic processes, which ultimately leads to a decrease in overall productivity of plants.
Keywords: *heavy metals, pollution, plants, productivity, ecology, environment.*

In the process of production, transportation, and refining of oil, heavy metals may find their way into the environment. When associated petroleum gases are burned in flare stacks, heavy metals as a constituent of soot also precipitate in and pollute the adjoining area. Moreover, rapid development of agriculture and industry,

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fast urbanization, increase in production of useful minerals, growth of transportation, and rise in level of solid waste generation also indisputably cause environmental pollution.

Heavy metals account for a significant proportion of the substances polluting the environment. They are highly toxic for living organisms, including plants. The term "heavy metals" gained wide popularity in recent time and encompasses a wide group of pollutants. However, in various basic and applied research works, the authors interpret this concept differently. As a result, the number of elements that could be assigned to the group of heavy metals varies in a wide range.

At present, in works devoted to the problem of ecological monitoring and environmental pollution, more than 40 metals of D. I. Mendeleev's Periodic Table, whose atomic mass exceeds 50 atomic units, are referred as heavy metals. Such metals could be V, Mo, Fe, Sn, Hg, Cr, Ni, Co, Mn, Pb, Zn, etc. There is, however, another view, according to which this group includes metals having a density above 5 g/cm^3 or having an atomic number above 20 [1, 2]. A list of chemical substances, including heavy metals, like Pb, Cd, Hg, As, etc., which need to be determined in natural environments at base stations of biospheric preserves is included in Yu. A. Israel's works [3].

Literature analysis showed that about two tens of various directions, along which search is being pursued currently, can be identified among numerous and diversely planned investigations within the scope of this subject. In particular, much attention is being paid to the study of the main physiological processes and productivity of plants and to the mechanisms of absorption of heavy metals by the root and their transport through the plant, to the determination of the effect of heavy metals on microbiological processes in soil, to the investigation of the mechanisms of metal resistance of plants that operate at different levels of organization, especially at the cellular and molecular levels. In terms of risk level, heavy metals cede only to pesticides. Their phytotoxicity depends on the chemical properties of a specific metal, such as ionic radius, valence, etc. Most heavy metals and their compounds, besides toxic action, produce mutagenic and carcinogenic effect.

Heavy metals feature among the main environmental pollutants, especially in regions with a high anthropogenic level [4, 5]. The primary sources of their admission into the environment are the industry, boilers and garbage incinerators, road transport, and agriculture. The results of the investigations where the quality of environmental objects was assessed indicate steady increase of pollutants in soil, water, plant organisms, etc. [5]. Here, the main victim of pollution is soil. Because of pollution its quality declines and the value of the agricultural land diminishes. The substances entering the soil and their transformation products are absorbed by the plants and accumulate in them in concentrations that are unsafe for human and animal health, which is one of the most serious aspects of this problem [7].

Soil quality is a subject of heightened attention of scientists. In the world, more than 90% of human food products are grown in soil. The sources of admission of heavy metals into soil were studied in detail and the gross content of a multitude of metals was analyzed in the works [8-10]. The main heavy metals polluting soil are Cu, Ni, Cd, Zn, Cr, and Pb. Lead (Pb) is the most widespread toxic element in soil. High lead concentration in soil reduces its productivity [11].

Investigations carried out in oil well drilling sites showed high risk of pollution by heavy metals of oil origin. Particularly hazardous is migration of heavy metals from polluted soils to surface and ground waters, which may get into human organism with drinking water. A direct correlation between contents of oil in water and Hg, Zn, Pb, and Cd was established in works of several scientists [4, 6, 12, 13]. Accumulation and migration of heavy metals in soils depend on the type of soil formation. Thus, most often higher concentrations of heavy metals accumulate in soils with a heavy grain composition than in sandy and sandy loam soils. It was shown that roughly 50% of the whole amount of heavy metals occurring in the solid phase of the soil is in the form of

iron hydroxide. A fraction of them is strongly bound with argillaceous materials. At the same time, the bulky forms associated with both organic matter and minerals constitute a small fraction of the whole mass of heavy metals in the soil profile [12, 14]. The acid-base properties of the soil also exert a considerable effect. Special investigations revealed adverse effect of heavy metals of soils and acid rains on the ecosystem. In [15] it was found that acidification of soils alters the buffer capacity and cation exchange saturation of (Ca + Mg), Al, and (Fe + H) and that Pb and Cu accumulate in top layers of the soil. Heavy metals produce toxic effect on soil microorganisms, which leads to a considerable decrease in population of soil microorganisms, a change in their species composition, and overall activity of soil microbial communities [16, 17]. Accumulation of heavy metals adversely affects food safety, marketability, yield of agricultural products, their phytotoxicity, and ecological health of soil organisms. Transfer of heavy metals from soil to plant is one of the key components of the effect of metals on human beings via the food chain.

Absorption and accumulation of heavy metals in plants affect their metabolic activity. This stems from geological and biological redistribution of heavy metals in major polluted media, temperature, humidity, organic matters, pH, and availability of nutrients [18]. The effect of heavy metals on plants is being studied by scientists of various countries over several decades. Numerous vegetational, laboratory, and field experiments indicate that heavy metals cause a wide variety of changes in plants. Their action on plant organisms causes disruption of metabolism, growth lag. chlorosis, poor assimilation of nutrients, reduced crop yield, etc. [19, 20].

Heavy metals, such as Co, Cu, Fe, Mn, Mo, Ni, and Zn, occurring in soil in trace concentrations, become enzyme activators performing stimulating functions in metabolic processes. Plants are capable of controlling ingress of these metals with the aid their root system. Plants need them in a limited quantity [21]. However, in unusually high concentrations heavy metals become toxic for plants which hinders their growth and development, stops enzymatic and metabolic processes, and ultimately reduces overall productivity of plants [22].

It was demonstrated by numerous investigations that under the influence of excessive concentration of heavy metals in plants accumulation of biomass decreases and length of roots and shoots shortens. The largest number of investigations in this direction is devoted to the effect on the plants of cadmium as it is one of the most toxic heavy metals, and such metals as copper, nickel, zinc, and lead were studied to a lesser extent [13]. Accumulation of heavy metals in roots is accompanied by a decrease in size and biomass of the root system, drop in the number of lateral roots, and death of root hairs.

Such heavy metals as copper, cobalt, nickel, and zinc affect the growth of plants and soil microflora. It was established that in higher plants excess of the first three suppresses germination of seeds and growth of green mass and excess of the last one (Zn) suppresses the root system as well. The effect of nickel and cobalt also suppresses tuber formation and reduces chlorophyll content in leaves [7, 23, 24].

Heavy metals produce a strong toxic effect on productive processes, delaying them thereby [25, 26]. In general, higher concentrations of heavy metals retard growth of shoots more than the growth of roots. As a result, the height of shoots and the size of leaf blades diminish and the biomass of above-ground organs and, in addition, the length of internodes of grasses decreases. The results of investigations by scientists indicate adverse effect of both shortage and excess of such heavy metals as Fe, Mn, Co, and Ni on plants. Upon action of these metals on plant organisms the chlorophyll content and the concentration of sugar, protein, amino acids, starch, etc. diminish. All these processes exert adverse effect on the yield and quality of the products [27, 28].

The capacity of heavy metals to suppress morphophysiological development of plants is confirmed by the investigation results. Heavy metals (Cu, Zn, Fe, Mn, Pb, Cd, etc.) reduce germination of seeds in biogenic

soil by as much as 50%. They affected the root system of plants most, whereas the above-ground part of the plants was depressed to a lesser extent [29, 30]. The investigation results revealed a correlation between increase of cadmium concentration in the root zone and shortening of height of the main shoot and reduction of biomass of the above-ground organs of barley and oat. It was also found that, in terms of the studied indices of the seed product, oat was less resistant to pollution by cadmium than barley [31]. In wheat (Triticum sp.), excess of cadmium reduces germination of seed, nutrient content in plants, and length of shoots and roots [32]. In corn (Zea mays), it reduces shoot growth and inhibits root growth [33]. The size of racemes as well as the mass of fruits and seeds decrease much less in the presence of metals because their content in these organs is commonly minimal and the adverse effect on their generative organs is rather indirect. Increase of heavy metal concentration in the environment retards plant growth and onset of regular phenological phases, which often leads to prolongation of the vegetative period and, in some cases, plants do not at all pass onto generative growth in spite of fully favorable natural-climatic conditions [34].

Study of accumulation and distribution of heavy metals in soils and plants is of definite interest. Heightened concentrations of metals in soil lead to their accumulation in flora growing wild and in agricultural crops, which is accompanied by contamination of food chains. Heavy metals cause diverse changes in plants, including in physiological processes. It was found that heavy metals not only retard plant growth and development, but also causes a multitude of structural-functional changes in photosynthesis apparatus, disruption of respiration processes, transpiration, transport of substances, etc. As a result, productivity of individual plants and entire phytocenoses decreases and at times the plant community even suffers complete destruction.

Yet another problem characterized by scientific urgency and practical importance is resistance of plants to heavy metals. The problem of cleaning of soils polluted by heavy metals in regions associated with oil and gas complexes can be solved by phytoextraction, i.e., by sowing and growing in polluted soils specially chosen species of agricultural plants which will extract heavy metals by their root system and accumulate them in the over-ground biomass which is utilized subsequently. In this context, the need for conducting ecological monitoring of the content of heavy metals in air, water, and soil for development of methods and selection of species of plants for their cleaning and decontamination in ecosystems is indisputable.

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