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ECOLOGICAL CONSEQUENCES OF CHEMICAL POLLUTION OF THE BIOSPHERE

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ABSTRACT

The paper discusses the basic ecological consequences of biosphere pollution - reduction of biodiversity and productivity of biogeocenoses. Technogenic pollution leads to the disappearance some of living organisms, to changes due to mutations and their disappearance. Due to the using of different agrochemicals in the agrobiocenosis due to the appearance of resistance in living organisms, there is a very rapid redistribution in the quantitative and qualitative composition of living organisms, as well as in the frequency of their finding. Mentioned pollution leads to a decrease in plant productivity and deterioration of nutritional and sensory characteristics of biomass, i.e. products.

Key words: quality, mutation, extinction, productivity, pollution.

INTRODUCTION

Human may have realized late how important, from the aspect of the modern community, it is to solve the ecological problems that he caused himself in a timely manner. The continuous growth of production is accompanied by an increase in the amount of various waste, which a huge part of humanity still does not know how to manage. Environmental pollution poses a real threat to the survival of life on the planet. The problem of chemical pollution of the environment, in that respect, has great scientific and social significance. Therefore, in this paper we will focus on the most important ecological consequences of chemical pollution of the biosphere - the reduction of biodiversity and productivity of biogeocenoses.

Decrease of biodiversity under the influence of anthropogenic activity

Biodiversity is a term that covers many aspects of biological variation. The term biodiversity is most often used to describe all types of organisms that live in a certain area. Seen from the planet's levels, biodiversity can be defined as "life on Earth". Biodiversity often includes not only living organisms and their interactions, but also their interactions with abiotic factors of the environment in which they live (Milošević et al., 2009). Therefore, biodiversity can be defined as the diversity of life on Earth at all their levels, from genes to ecosystems and as ecological and evolutionary processes that create it (www.fmoit.gov.ba). Diversity, when it comes to biodiversity, is of inestimable importance for human. Thanks to it, all species, including human, have survived, despite the changes that occurred during the development of civilization and against the destructive attitude of man towards nature. Biodiversity is an evolutionary response to the constant variability of environmental conditions (Milošević et al., 2009).

The diversity of species of organisms on the planet Earth is in line with the diversity of living conditions on it. The basic resource for the stability of the biosphere are millions of biological species (Stevanović et al., 2005; Đukić and Đorđević, 2005; Milošević et al., 2009). The composition of species of living organisms on the planet is regulated by the processes of exchange of matter and energy. In the modern systematization, it is stated that in living nature there are five higher taxons, whose representatives differ according to the type of metabolic processes and their role in nature: bacteria, protozoa, fungi, plants and animals. In each of these groups there are primitive and more complexly organized representatives. All of them are highly adapted to the conditions of the environment in which they live. The relations between producers and consumers are in accordance with the principle of organization, i.e. rentability of biological production. Plants and other producers provide biomass that is sufficient for all biotic communities. 90% of plant biomass of terrestrial ecosystems is processed by fungi and bacteria, 9% - small invertebrates and bacteria, and about 1% of the energy of primary production is obtained by large animals. Representatives of all biological species of the planet are interconnected, which is a confirmation of their belonging to the same system - the biosphere. Its persistence ensures the maintenance of the genetic fund. Under the influence of anthropogenic factors, various representatives of the living world disappear, which is manifested by a decrease in the number of certain species, their changes due to mutation and complete disappearance (Đukić et al., 2018). Biodiversity is the main criterion and property of the stability of ecosystems. The task of conserving biodiversity and the genetic fund is attributed to the reservation. It is assumed that they can fulfill their task if their surface is not less than 1/6 of the land surface of the planet.

Ecosystems are hierarchically organized and ecologists (Уиттекер, 1980) accordingly distinguish four levels of taxon diversity, which reflect the hierarchy of biological diversity. The "alpha" level is characterized by the diversity of taxons within the boundaries of a given ecosystem or habitat (diversity of species), and the "beta" level is measured by the diversity of biocenoses within the boundaries of ecosystems or biotopes. The "gama" level belongs to larger units of the landscape type (area) and is characterized by the diversity of the common complexity of the structure of sector groups. The "epsilon" level reflects regional biogeographical diversity, which refers to micro-meso-macrocombinations of ecosystems that correspond to places and landscapes. Measuring the diversity of higher level of ecosystems is a difficult task, because ecosystem boundaries are less discrete than species-level ones. The Shannon-Weaver index is most often used to determine diversity. Technogenic impacts on natural ecosystems lead to a reduction in biodiversity, impoverishment of the genetic fund and it is already reaching global proportions. There are documented testimonies on impact of human economic activity on the living world. There are about 1.3 million species of animals and 300 thousand species of higher plants on our planet. According to the International Union for Conservation of Nature, 94 species of birds and 63 species of mammals have become extinct on Earth since 1600. Even more species are threatened with extinction. Similar data can be found in other sources (Table 1).

Table 1. Loss of species diversity by some taxons since 1600 (Krasilov, 1992)

Taxon	Species extinct	Species under the threat of extinction
High plants	384 (0.15%)	18699 (7.4%)
Fishes	23 (0.12%)	320 (1.6%)
Amphibia	2 (0.05%)	48 (1.1%)
Reptiles	21 (0.33%)	1355 (21.5%)
Birds	113 (1.23%)	924 (10.0%)
Mammals	83 (1.99%)	414 (10.0%)

The trend of modern agriculture has conditioned the disappearance of numerous old varieties and races. According to the FAO, about 30% of domestic animal breeds are permanently lost in the world today. It is estimated that in the last century, due to anthropogenic activity, 27,000 species are lost annually, or 74 species per day, which is about 1,000 times more than the estimated "normal evolutionary rate" of extinction. If extinction continues at its current rate, 20% of today's species could become extinct over the next 30 years. This poses a great danger to the genetic diversity of agriculture because indigenous populations also possess an abundance of genes responsible for resistance and quality, which have disappeared in genotypes of commercial varieties and breeds (Simić et al., 2017).

In organic agriculture, in addition to wild and neglected species, local varieties are also used, adapted varieties as well as varieties created by organic breeding or varieties created on an organic basis.

According to the richness of biological diversity, Serbia is at the top in Europe. The diversity of flora and fauna is the result of a long historical development, specifics of localities and favorable climatic conditions of Serbia, which enabled the creation of a large number of indigenous populations and adaptation of numerous introduced species (Simić et al., 2017).

Agrobiological resources, which are represented through indigenous species, races and strains in Serbia, should be preserved due, above all, to economic, scientific, cultural, socio-economic and environmental needs.

The presence of 312 species of mammals has been determined on the territory of Russia, which makes about 6% of the world's fauna. In the last 200 years, 5 species have become extinct, and another 6 species have ceased to be found on the territory of Russia (Mokievskij, 1998). The data for the Moscow area show that out of 285 species of birds that lived in this area, 15 have stopped nesting in the last 100 years, and another 20 species are endangered. The causes of the decrease in the number of birds in the Sub-Moscow area are assumed to be only 12% conditioned by pollution, and that factors such as environmental degradation, harassment and destruction are of greater importance (Зубакин, 1990). Other groups of animal organisms are more sensitive to environmental pollution, which is shown at different levels of ecosystem organization.

Soil macroorganisms react sensitively to soil pollution. The reduction of microbiological circumstances (decrease in the activity of the enzymes invertase, dehydrogenesis, urease, etc.) and the total number of microorganisms (Quzev and Levin, 1987; Đukić,1996; Đukić et al., 2013) appears as diagnostic properties. The emphasized redistribution of the microbial community of the soil is evidenced by the decrease in the richness and diversity of microorganisms species. For example, in soddy subsoil, serous and alluvial soils, which are contaminated with heavy metals, there is a decrease in the number of soft microorganisms species (sensitive are the representatives of the genus Bacillus), growth of dominant species, among which a large number of micromycetes are observed (those are most often representatives of chromogenic species *Penicillium skryabin*, *P. purpurogenum* etc.) (Đukić et al., 2013;, Levin and Guzev, 2001). It was found that the diversity of the composition of epiphytic yeasts on plants grown on serous contaminated by metals decreases by 40%. At extremely high pollution, there is practically a complete disappearance of microorganisms (Levin and Streuss, 1990). The presence of increased doses of pesticides in soils causes both a reversible reduction in the diversity of the composition of the species, and more dangerous irreversible changes, i. e. extinction of some species on contaminated lands (Bizov et al., 1989).

Pollution (chemical, physical, biological) of the environment is a mechanism of direct toxic impact on biological diversity. An example is the acidification of water basins, which causes a negative impact on the respiration and reproduction of fish due to the increased concentration of free aluminum ions in the water. Water acidification was accompanied by the extinction of many species of silicate and green algae and some representatives of zooplanctons (Đukić, 1996; Monsenko, 2003).

Under the influence of pollution, the diversity of plant species decreases. Conifers (cedar, fir, pine) show increased sensitivity to atmospheric pollution with sulfur dioxide. Due to pollution, various injuries, premature decline of conifers, reduction of biomass, loss of reproductive activity, reduction of growth, reduction of lifespan and as a result of death are observed, which is expressed in the change of the composition of forest species and in the reduction of their diversity. In ecological monitoring, high sensitivity of lichens to atmospheric air pollution is the basis of efficient lichenoindication of atmospheric air. In the territory that is polluted with various pollutants (sulfur oxides, metals, hydrocarbons), the diversity of lichen species is sharply reduced (Đukić et al., 2013). Initially, the death of more sensitive, less resistant lichen species (initially shrubby, and then leafy and further crusty forms disappear) ends with their complete disappearance.

In all technogenically disturbed areas, the structure of the biocenosis changes. In the territories exposed to aerosol discharges, for example, the Severonikl plant in Russia, the four-storey biogeocenosis, which was initially presented with woody, shrubby and grassy vegetation and a cover of mosses and lichens, deprived the plant of lichens in 30 years and then fir and pine. At a distance of 20-30 km from the plant, the biogeocenosis was presented with a sparse forest with a fragmented grass-shrub cover, in the immediate vicinity of the plant, a technogenic desolation was formed.

The reduction of biological diversity at the level of the entire area is happening not only due to pollution, but also due to urbanization, agricultural expansion, deforestation, etc. For the last two decades, the steppe landscapes have been disturbed, and wetland systems are damaged from place to place.

Great damage was done to the forests. Forests of Central America, Southeast Asia and the temperate zone are devastated. For example, in Greece and England, where the area under forests is not large (about 1000 * 10^3 ha), about 65% of forests have been degraded. In Germany, Poland and Norway (with a total area under forests of 6000-8000 * 10^3 ha), at least 50% of forests have been degraded. For the last 10 years, the area under forests has been reduced to 200 * 10^6 ha. This poses a danger to the biosphere, because forest ecosystems fulfill an important function - creating an environment. Forest production and biomass is a storehouse of organic matter and energy, which preserved plants in the process of photosynthesis. The intensity of photosynthesis is determined by the rate of CO_2 uptake and O_2 release. Thus, when creating 1t of plant production, on average 1.5-1.8t of CO_2 is adopted and 1.2-1.4t of O_2 is released. Forests have high capacity of dust absorbing. Yearly they can absorb 50-60t of dust. Forest biomass purifies the air of pollutants. This is due to the deposition of dust on the surface of leaves and trees of plants, and also due to the fact that the dust contains substances that are included in the processes and that accumulate in the composition of organic matter. After the extinction of the latter, they become part of the organic matter of the soil, and after their mineralization - in the composition of other soil compounds.

Biodiversity loss is dangerous not only because of ecosystem degradation, but also because of the imbalance in the biosphere. The quality of nature can be "automatically" managed only by the living world, i.e. a collection of all living organisms on Earth. Biodiversity is the main criterion and feature of ecosystem stability. It is impossible to artificially create an environment for man. Only a system of living organisms is capable of restoring the anthropogenically disturbed state of the environment, of providing normal quality of water, air, soil and food, and only on the condition that biological diversity is ensured.

Decrease in productivity biogeocenosis

Soil pollution is dangerous not only due to the deterioration of product quality, which is caused by increasing the content of hazardous substances and/or reducing the content of valuable components in them, but also by reducing the productivity of plants. Productivity is the ability of living organisms to create, preserve and transform organic matter. Productivity is often considered as a synonym of production and is measured as the ratio of the mass of matter produced per surface (t /ha) or the mass over time (t /year).

In forest biogeocenoses, which are subject to the influence of aerosol discharges of different production companies, zones with different levels of deviation from normal development are observed. As you move away from sources of pollution, the zone of absence of vegetation (technogenic desolation) alternates with the zone of emphasized control of all representatives of the plant community, primarily sensitive species, further with the zone of medium and weak control. Disturbances often occur at a distance of several tens of kilometers, such as in the vicinity of the “Severonikl” plant. If agrocenosis soils are subjected to aerosol pollution (Đukić et al., 2008), they not only show an increase in metal and metalloid content, but also reducing the number and activity of microorganisms and other land habitants, which affect its productivity (Левин and Бабјева, 1985).

Agricultural plants suffer not only from the indirect influence of pollutants present in the soil, but also due to the direct influence of pollutants on the plants. Pollutants from aerosol discharges pollute the leaf surfaces of plants, making it difficult for them to breathe, penetrating inside the leaves, causing intracellular changes, disrupting metabolism, etc. Leaf necrosis is observed, with its specific manifestations in different types of plants, wilting of leaves and their premature decline is possible. All this is accompanied by disruption of plant growth, development, fruiting and reduction of production (Đukić et al., 2013).

The effect of pollution depends on the type of pollutant, the level and duration of its impact on plants. The content of SO_2 in the air causes necrosis with the appearance of white and brown spots on the leaves and their incomplete development. Disruption of important biochemical processes in plants is dangerous.

In plants, there is a decline in the process of photosynthesis, a decrease in the content of chlorophyll in the leaves and the ability to absorb CO_2. In connection with the injury of epidermal cells in plants, the ability to store moisture in the cells is disturbed, which reduces the resistance of plants to drought. Degradation of the protein membrane under the influence of SO_2 leads to an increase in its permeability to sugars and nutrient ions, which is accompanied by the release of protons, lowering pH levels, which in turn also disrupts the process of photosynthesis. High concentrations of SO_2 reduce the ability of plants to detoxify, which is provided in unpolluted plants by creating free amino acids with sulfur (in cells). The phytotoxic effect of SO_2 on agricultural plants is observed if its concentration in the air is 50-90 µg / m³ (Черников et al., 2000).

Pollution of the environment with heavy metals causes disturbances in the metabolism of plants. Excessive amounts of heavy metals in the tissue of mature plant leaves have been found to have toxic effects and lead to reduced productivity (Table 2).

Table 2: Orientation content of heavy metals in leaf tissues of different plant species (Kabata -Pendias, 2001)

Element	**Normal**	**Toxic**	**Element**	**Normal**	**Toxic**
Ag	0,5	5-10	Mn	20-300	300-500
As	1-1,7	5-20	Mo	0.2-1	10-50
B	10-200	50-200	Ni	0.1-5	10-100
Ba	-	500	Pb	5-10	30-300
Be	<1-7	10-50	Se	0.01-2	5-30
Cd	0.005-0.2	5-30	Sn	-	60
Co	0.02-1	15-50	Sb	7-50	150
Cr	0.1-0.5	5-30	Ti	-	50-200
Cu	5-30	20-100	Tl	-	20
F	5-30	50-500	V	0.2-1.5	5-10
Hg	-	1-3	Zn	27-150	100-400
Li	3	5-50	Zr	-	15

Physiological and biochemical changes in plants, which occur due to pollution, are largely similar to the effects caused by various pollutants (nitrogen oxides, metals, pesticides, etc.) or various stressors (drought, salinization). Stress in plants leads to a change in the activity of enzymes that contribute to increasing their resistance to a given stress. The mechanisms of plant resistance to the action of pollutants are:

a) xerophytization, which is manifested by thickening of the cuticle of plants, by increasing the hairs, which limit the access of toxicants,

b) physiological adaptability - enhancing the effect of mechanisms of disinfection and accumulation of toxic substances through their utilization in metabolism or removal from the body;

c) natural selection of individuals that are best adapted to the chemical impact (Черников et al., 2000).

Table 3. Indicators of the ecological inconvenience agroecosystem of Vinogradov, 1998

Indicator	**Norm**	**Risk**	**Catastrophe**	**Collapse**
Yield reduction, % of norm	<15	15-40	40-80	>80
Contamination, % of area	<0	10-40	40-80	>80
Pest development, % area	<10	10-20	20-50	>50
Crop death, % area	<5	5-15	15-30	>30
Projected coverage, % of norm	<80	60-80	20-50	>10
Forage yield, % of norm	<80	60-70	30-50	>20
Pastry overload, % from load-bearing load	<100	100-150	150-200	>200
Compactness of load, % of norm	<10	10-20	20-40	>40

There is a wide list of factors and indicators that adversely affect the productivity of agroecosystems. The levels of these indicators can be standardized. A stable equilibrium state is accepted as a norm, as a risk - the probability of degradation of the environment of the agroecosystem, its transition to an unstable state; a catastrophe is understood as a change in the own parameters of the agroecosystem, its transition to an unbalanced state which is accompanied by a loss of stability; a collapse means a deep disturbance of the equilibrium state of the system (Table 3).

These indicators of the state of agroecosystems also change during environmental pollution, which is reflected in the productivity of agrocenoses (Đukić et al., 2007). Table 4 presents the dependence of crop yields on aerosol complex air pollution.

Polluted agrocenosis is a real danger for the realization of the target function - ensuring the stability of agricultural production.

Table 4. Dependence of crop yields on distance from pollution sources (100kg / ha) (Balackij, 1979)

Culture	**Distance from source of pollution** 5km	2-3km
Corn	19	9
Rye	15	8
Barley	24	12
Oats	31	16
Potato	35-47	18-24
Beet	25-62	13-31
Flax	63	31
Clover	33	17
Alfalfa	38	19

CONCLUSION

Based on the insight into the very extensive material on the ecological consequences of chemical pollution of the biosphere, the following conclusions can be reported:

- Chemical pollution leads to a decrease in biodiversity, the impoverishment of the genetic fund and the extinction of many species in the entire phytogeosphere;

- Chemical pollution leads to a decrease in total number, total frequency of finding, changes in the composition of living organisms, extinction of less resistant and survival, and even multiplication of resistant species;

- Chemical pollution leads to reduced plant productivity and deterioration of nutritional and sensory characteristics of products.

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