

Microorganisms and Technogenic Pollution of Agroecosystem

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Abstract: This paper deals with the reactions of the soil microbial community to the effects of agrochemicals (pesticides, heavy metals), oil pollution and other possible xenobiotics.

Pesticides and heavy metals change the physicochemical properties of the soil and lead to a distribution in the qualitative composition of the soil microbial community, which is characterized by a wide range of phenomena (stimulation, repression, resistant species). Some compounds of S, N and Cl cause soil and groundwater acidification, which results in Ca, Mg and K losses, higher content and greater activity of Al, Fe and Mo as well as in the activation of toxic elements Hg, Pb and Cd, which reduce the number of bacteria and actinomycetes and enhance the presence of bacilli and fungi in the soil. Low oil pollution level may cause fluctuating changes in the soil microbial cenosis, whereas a higher one may result in serious disorders of the microbial community and even in its completely restrained activity.

Key words: microorganisms, oil, pesticides, heavy metals, pollution

Modern world progress contributes to the well-being of mankind, on the one hand and increases the ecological damage to the biosphere - the soil, natural and artificial water basins, rivers, the atmosphere, living organisms etc. - on the other. Harmful anthropogenic, particularly technogenic effects on the environment are highly pronounced. They often include the use of chemicals in agriculture. Modern agriculture, however, is not possible without the use of chemicals, especially mineral fertilizers. The problem can neither be solved by an attempt to nourish the increasing world population by feeding it with high-quality food products, which are produced as the result of a transition to biological or bioorganic farming.

Therefore, agricultural principles based on dialectic ties between agrochemistry, biotechnology and environmental protection need to be followed. Highly productive agriculture cannot be achieved without the resolution of contradictions between the use of chemicals in agriculture and their impact on the biosphere, i.e. without the use of those agricultural product processing technologies that increase the soil fertility, improve the product quality and meet the demands of the environmental protection from pollution. There are plenty of similar and effective methods and technologies in agronomical sciences.

The use of chemicals in agriculture involves the use of mineral fertilizers and pesticides. These chemicals can be used for many different purposes and they have a great variety of impacts on the environment. Pesticides are lethal to all living organisms and their use is necessary mostly when other agrotechnical measures and biological substances cannot protect yield from pests, diseases and weeds.

Fertilizers are the material basis of both quantity and quality of the obtained plant production and a source of biogenic elements for plants. A scientifically based system of the use of agrochemical substances helps solve the following problems: provision of an expanded soil fertility reproduction, non-deficient or positive balance of biogenic elements and humus within the soil-plant-fertilizer system; obtainment of plant products with well-balanced chemical composition and nutritional value; higher profitability of agricultural production; better ecological situation in agriculture. At the same time, fertilizers affect the environment very actively. The presence of different toxic ingredients in mineral fertilizers, their low quality and possible disturbances of the technology of their use may lead to serious negative effects. High rates of mineral fertilizers are used in industrially developed countries and their effect on the biosphere assumes increasingly dangerous characteristics on a broad level.

The struggle for the ecological safety of our planet is, therefore, considered to be one of the most important and humane tasks of the whole mankind. A knowledgeable and conscientious approach of every man to nature should be cherished from early childhood - in the family, at school and college and in direct production, too. Environmental protection is one of the major tasks of farmers. Every farmer, within his domain, keeps order in nature, as its major protector. Rational land management is a precondition of its flourishing.

We shall consider some ecological aspects of the use of agrochemical substances (pesticides; heavy metals; sulfur, nitrogen, chlor and other compounds; oil and its products), primarily the basic ways of soil and other chains of the biosphere pollution, as well as the negative effects of their use.

Pesticides. More than ten thousand chemicals are used today against weeds and pests that seriously affect plants and cause agricultural products to decay as well as against parasites and vectors of dangerous human and animal diseases (Meljnikov, 1974; Merenjok, 1984; Djukic, Stamenkovic, 1992).

As chemicals not pertinent to the biosphere, pesticides are referred to as "xenobiotics", while in the role of chemical pollutants of the environment, they are recognized as pollutants. Regardless of the method of the use of pesticides, the basic mass of pesticides reaches the soil, as their specific depot and becomes a source of pollution (with pesticides) of other environments - water, air, plants

(Goncaruk, 1977; Kruglov, 1982; Neistejn, 1982). They are able to circulate in the environment for quite a long time - up to 40 years, thus causing a wide range of disturbances of the natural balance of matter (Barik, 1984).

Depending on the chemical properties of chemicals, their ability to dissolve in water, their shape, the way of their application and the dosage rate itself (tab. 1), soil type and soil properties, characteristics of the hydrothermic regime, modern agricultural measures, the character of plant cover, etc., pesticides may have different kinds of effects on soil organisms, their number, diversity and living activity (Voevodin, 1986; Govedarica, Mrkovacki, 1993; Jarak et al., 1994; Mandic, Djukic, 1995; Djukic, Mandic, 1995; Mandic, Djukic, 1996; Mandic et al., 1996 a, b).

Tab. 1. Maximum permitted dosage rates of pesticides for different regional conditions (by Goncaruk et al., 1982)

Pesticides	Rate kg/ha	MPC in soil mg/kg	MPC kg/ha	
			Chernozem zone	Non-chernozem zone
Hardona	0.6-3.0	1.4	2.6	2.0
Heptachlor	0.18-0.4*	0.05	0.4	0.3
Dilor	0.2-4.0	0.5	3.2	2.1
Kelthane	0.2-1.2	1.0	12.0	7.2
Propamide	3-9	1.5	5.0	-
Zineb	0.4-6.4	1.8	8.3	6.5

*permitted only for disinfection of small grains seeds in concentration of 0.4-2.2 kg/t

Based on published data, pesticides in recommended dosage rates generally do not affect soil microorganisms. Their increased dosage rates cause regrouping in the microbial cenoses within some time: a short period of depression is replaced by the creation of resistant mutant forms (Zarasov, 1982; Akopjan et al., 1986; Voevodin, 1986; Visnjakova, 1988).

Tab. 2. Average number of ammonifiers of ($10^6/1,0$ g-absolute dry soil) in soil in correlation of applied herbicides (A) base type (B) and vegetation period (C)

Chemical (A)		Control		Simazine		Paraquate		Napropamide		$\bar{X}$ for period
Stock (B)		M9	MM106	M9	MM106	M9	MM106	M9	MM106	
Periods (C)	I	41	50	29	28	42	93	26	29	42.25
	II	293	298	287	290	300	342	107	191	263.5
	III	134	136	130	152	190	211	58	170	147.6
	IV	260	275	158	294	318	334	214	285	267.2
$\bar{X}$ - chemical		185.87		171.00		228.75		135.00		180.1
$\bar{X}$ - stock		M 9			161.69					
		MM 106			198.63					
$l \quad s \quad d$										
lsd	A	B	C	AxB		AxC		BxC		AxBxC
0.05	4.75	3.37	4.75	6.70		9.50		6.70		13.46
0.01	6.29	4.45	6.29	8.91		12.58		8.91		17.82

The effect of pesticides on microorganisms and on microbiological processes in the soil is selective. Thus, for example, atrazine, monuron and carbathion prevent the development of microscopic algae; basudin is toxic for fungi and TMTD for fungi and actinomycetes, while rogor inhibits the nitrification process (Kruglov, 1982). From the point of view of dehydrogenation, atrazine is the least poisonous (Iljinskaja et al., 1985). A longer use of herbicides may significantly reduce the number of ammonifiers (tab. 2), amylolytic microorganisms (tab. 3), azotobacter (tab. 4), oligonitrophiles, nitrifiers and particularly denitrifiers in the soil, which increases $N = NO_3$ in the soil (Halaim et al., 1985).

Tab. 3. Average Number of amilolytic microorganisms of (10^5 /1g-absolute dry soil) in Soil in Correlation of Applied Herbicides (A) Stock type (B) and Vegetation Period (C)

Chemical (A)		Control		Simazine		Paraquate		Napropamide		$\bar{X}$ for
Stock (B)		M9	MM106	M9	MM106	M9	MM106	M9	MM106	period
Periods (C)	I	88.3	87.3	46.3	43.3	47.3	52.3	74.0	53.0	61.63
	II	98.3	103.0	88.0	82.0	91.0	108.0	64.0	50.0	85.50
	III	95.6	98.6	56.3	71.6	101.3	109.0	60.0	109.3	87.75
	IV	131.3	160.0	60.0	156.0	184.0	183.0	100.0	158.0	141.50
$\bar{X}$ - chemical		107.83		75.58		109.50		83.54		
$\bar{X}$ - stock		M 9 MM 106				86.63 101.60				
$I \quad s \quad d$										
lsd	A	B	C	A×B		A×C		B×C		A×B×C
0.05	3.56	2.50	3.56	5.03		7.10		5.03		10.10
0.01	4.72	3.33	4.72	6.65		9.40		6.65		13,30

Table. 4. Average Number of azotobacters of (10^2 /1g-absolute dry soil) in Soil in Correlation of Applied Herbicides (A) Stock type (B) and Vegetation Period (C)

Chemical (A)		Control		Simazine		Paraquate		Napropamide		$\bar{X}$ for
Stock (B)		M9	MM106	M9	MM106	M9	MM106	M9	MM106	period
Periods (C)	I	30.0	20.0	16.5	12.0	42.0	21.0	48.0	24.0	26.69
	II	35.0	23.0	30.0	15.0	16.0	16.0	20.0	7.5	20.31
	III	15.5	10.5	15.0	11.0	13.0	7.5	11.5	8.0	11.50
	IV	31.6	24.0	0.20	6.50	26.0	19.0	19.0	35.0	20.17
$\bar{X}$ - chemical		27.71		13.27		20.06		21.63		19.67
$\bar{X}$ - stock			M 9			23.09				
			MM 106			16.25				
<i>I s d</i>										
lsd	A	B	C	A×B		A×C		B×C	A×B×C	
0.05	1.45	1.03	1.45	2.04		2.89		2.04	4.08	
0.01	1.90	1.36	1.90	2.70		3.83		2.70	5.40	

Azoplant in the dosage rate of 2.5 kg reduces the number of bacteria and dehydrogenation activity as well (Mahula et al., 1987). A longer use of atrazine and monuron causes the death of the most sensitive forms of algae - blue-green, green and diatoms (Kruglov, Mihajlova, 1977). One-time use of herbicides (2-4-L, of dalapon and atrazine) does not cause negative changes of the agrochemical properties of sandy illuvial-ferric podzols (Fedorec, Leontjeva, 1985). When tested in pure form, THA and dalapon inhibit the activity of protease, amylase and phosphatase. When immobilized on humus compounds, these enzymes are 1.4 - 2.7 times more resistant (Masko et al., 1982).

The increasing dosage rates of ridomil destroy fungi and actinomycetes, but do not affect the nitrogen-fixing microorganisms of the *Azotobacter* and *Rhizobium* genera. Among the latter, *R. japonicum* is the most sensitive, when fungicides are used at maximum dosages. Ridomil also controls the development of cellulolytic microorganisms and some biological processes - the soil nitrification and "respiration" (Golovleva, Filjkenstejn, 1988).

Based on the total reduction of the number of bacteria and fungi, simazine and zeazine control the development of oligonitrophiles, whereas dalapon controls that of ammonifiers (Visnjakova, 1988). At the same time, according to some other data, a great number of pesticides do not have any noticeable effects on the living activity of soil microorganisms (Kuzmina, Musikaev, 1982; Golovleva et al., 1987; Mandic, Djukic, 1995; Djukic et al. 1997). Garlo 3a has a small toxic effect on bacteria, actinomycetes, fungi and azotobacter, but it controls soil "respiration" even up to two years' time (Sapundzijeve, 1987). Setoxidin has a similar effect (Roslycky, 1986) and it also, in 1000 mg/g-of soil concentration, stimulates the bacteria and actinomycetes development on the basis of the fungi quantity reduction.

In some researchers' opinion, dehydrogenation and the soil "respiration" process are the most sensitive to pesticides (Iljinskaja et al. 1985; Tjurjukanova et al., 1988). The use of fungicides (thiuram and its products, captan, mancozeb), even in recommended dosage rates, reduces the number of microscopic fungi, nitrifying bacteria and sometimes the number of actinomycetes. At the same time, it increases the total number of bacteria, ammonifiers and amylolytic microorganisms, as well as the number of bacteria and fungi which have the ability to decompose phosphates and cellulose (Miljto et al., 1984; Djukic et al., 1996; Mandic, Djukic, 1998).

The emulsion of sulfur carbon (a fumigant used in viticulture for phylloxera control) has a short preventive effect (lasting 10 to 20 days) on basic tropho-ecological groups of microorganisms in the chernozem soil with some humus content; it was only in the case of cellulolytic microorganisms that the preventive effect lasted three months (Janover et al., 1982).

What is interesting is that free nodular bacteria are not sensitive to the presence of herbicides in production dosage rates, but in symbiosis with leguminous plants, they are very sensitive. Herbicides have an indirect effect in that case - through plants, stopping the photosynthesis and reducing the nitrogen exchange, which influences the nodule formation and symbiotrophic nitrogen fixation processes (Miljto et al., 1984).

Most of the pesticides belong to highly active organic compounds. If the compounds in question are basically lipophilic ones, they dissolve quite well in the cell membrane lipids and easily diffuse into cells. Mineral pesticides penetrate into cells in the form of ions or nondissociated molecules. The greater the ability of pesticides to dissolve, the faster and easier their entry into cells. Large molecular compounds reach cytoplasm, probably through pinocytosis.

When once they reach a living cell, pesticides change the physicochemical properties of cytoplasm, decompose the membrane of cell organelles, alter the reaction of the environment and disturb the conditions of a normal functioning of cell proteins. Enzymes - cell biocatalysts - are particularly sensitive to the effect of pesticides. The enzyme blocking, which takes part in an important process of metabolism, has a preventive and sometimes a lethal effect on an organism.

Regardless of that, the microbial community formation in the soil has been proved possible. Microbial communities efficiently decompose many xenobiotics - carbamates, acetamides, anilides, organophosphates and other herbicides, insecticides, nematocides and fungicides (Golovleva, 1987; Speedie et al., 1987/1988). How fast pesticides will disappear from the soil depends on many factors: granulomatous soil composition, humus content, climatic conditions, fertilizers etc. and it may vary from several weeks to several years.

The pesticide transformation mechanism consists in the following basic reactions: dehalogenation, dealkylation, amide or ether hydrolysis, oxidation, reduction, the ether bond severing and the aromatic ring hydroxylation and breaking.

Heavy metals. In many regions of the world, soils are polluted by heavy metals. Basic sources of the pollution are: industrial firms and motor transportation aerosol waste materials, which reach the atmosphere in the form of oxides and sulfides; solid industrial waste; industrial and public wastewaters; mineral fertilizers, pesticides and other chemicals; metal deposits, etc.

Here are some examples. $250 \cdot 10^3$ t of metal in dissolved form and more than $120 \cdot 10^3$ t in the form of deposits are removed by ground waters from the territory of natural manganese deposits each year (Koneva, Tjurjukanova, 1980). Industrial wastewaters may contain (mg/l): Ca 0.015; Cu 0.35; Cr 0.4; Pb 0.3; Zn 0.8 (Fowler, 1979; Djukic, Mandic, 1997). In the Mescer valley region, 14 g/ha of copper, 585 g/ha of manganese, 260 g/ha of zinc and 80 g/ha of boron, together with industrial dust, reach the soil each year. In some Valdaj highland regions, the Zn content in the 0 - 50 cm depth of layer ranges from 110 - 130 to 190 - 290 kg/ha, depending on the mechanical composition (Migracija, 1980).

In natural conditions, heavy metals are in a dispersed (diffused) state, but they are able to build up local accumulations in which their concentration is a hundred and thousand times higher.

A great number of heavy metals (Mn, Co, Cu, Zn, Mo etc.) are recognized as microelements, which occur in the soil in micro quantities and are necessary for a normal life of plants, animals and man. However, owing to the anthropogenic activity, it was noticed that they are able to accumulate in the soil in such amounts that disturb the normal course of natural processes that has been established through centuries and endanger the health of the living organisms. In Kovda's opinion (Kovda, 1975), "neogeochemical anomalies", caused by the anthropogenic environmental pollution, can now be investigated on time.

When they once reach the soil, heavy metals place themselves on horizons according to their migratory ability and accumulate mostly in the humus and alluvial horizons (Zolotarev, Skripnicenko, 1983; Kosinova, 1985; Naplekova, Bulavko, 1985). They are, however, mostly in the upper layer gravitating towards the root (Iljin, 1988). Thus, humus participates in the depositing of a number of heavy metals from 6 to 85 percent in a local situation (tab. 5). Such a range of changes is, therefore, connected to the ability of metals to form complexes. The basic Zn mass reaches the soil probably in the form of compounds dissolved with difficulty and Cu - in the form of chemically active compounds, which are able to interrelate with humus acids.

Heavy metals participate in different reactions in the soil: oxidation-reduction, complex formation, dissolution, photochemical reactions etc. Owing to those reactions, they connect in the soil and convert into other forms, so that plants can accept them. When in water, they gradually convert into a colloidal and ionic state (Migracija, 1980; Jones, Jarvis, 1981; Tinsli, 1982; Kosinova, 1985). All of that affects the level of their toxicity to a certain extent as regards soil microorganisms. It was noticed that heavy metals are more mobile in the acid environment than in the alcaline one and in appropriate (suitable) conditions, they fix more or less firmly to the soil. Lead is, for example, less mobile than cadmium, copper or (and) nickel (Ribalkina, 1957; Kosinova, 1985).

Tab. 5. The actual participation of polluted soil humus in the accumulation of heavy metals (*Iljin*, 1988)

Metal	Metal content		Humus participation in accumulation of heavy metals, %
	total, mg/kg	in humus*, mg	
Zinc	14125	865	6.1
Lead	649	89.4	13.8
Copper	220	187.5	85.2
Cobalt	12	2.2	18.3
Nickel	59	6.5	11.0

*Humus content in the soil 10,9%

Accumulating in the soil, heavy metals change its physicochemical properties: soil aggregation and porosity decrease suddenly; the mobility of clayey fraction mobility increases; the exchangeable Ca and Mg content is decreased; carbonate, iron hydroxide and gypsum neoplasms decompose; the quantitative humus composition changes - the humin acids mobility is increased and optic density is reduced. (Vazenina, 1985; Zikina, Cuginova, 1987).

Researchers proved a long time ago that metals in microdoses, i. e. as microelements, have a stimulating effect on the number and different living activities of soil microorganisms (Bersova, 1976). That can be, as a rule, observed in soils that are far from the sources of pollution by heavy metals. With a gradual decrease of the distance from the pollution source, the concentration of heavy metals increases so much that it reduces the number and biomass of

microorganisms and impoverishes the composition of their species (Babjeva et al, 1980; Stefurak, 1981; Bulavko, 1982; Klevenskaja, 1985; Rodinjuk, 1985). The mycelium content in the zone of high-level pollution with heavy metals can be reduced 2-3 times in comparison to control soils (Marfenina, 1987). Based on the fungi biomass reduction, the bacteria biomass reduces far more quickly and, as a result of that, the ratio between those indicators grows with the pollution increase (Letunova et al., 1982). According to the results obtained by Djukic et al. (1996), with the heavy metal concentration increase (Cu, Pb, Cd, Hg), the total number of bacteria, actinomycetes and fungi in the soil becomes reduced (graphs 1, 2, 3, 4).

Fig. 1. Effect of diverse concentrations Pb on the total number of bacteria ($10^6/1g$ absolutely dry soil), number of fungi and actinomycetes ($10^5/1g$ absolutely dry soil) - Djukic i sar., 1996.

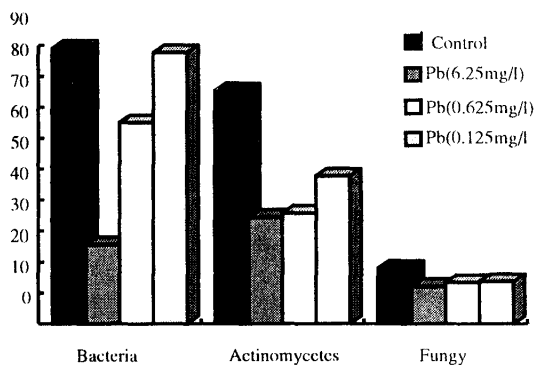


Fig. 2. Effect of diverse concentrations Cu on the total number of bacteria ($10^6/1g$ absolutely dry soil), number of fungi and actinomycetes ($10^5/1g$ absolutely dry soil) - Djukić i sar., 1996.

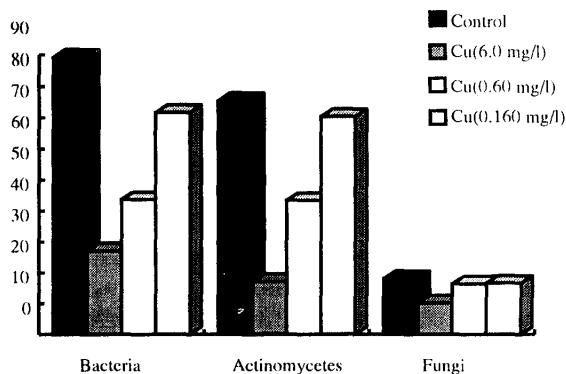


Fig. 3. Effect of diverse concentrations Cd on the total number of bacteria (10^6 /1g absolutely dry soil), number of fungi and actinomycetes (10^5 /1g absolutely dry soil) - Djukic i sar., 1996.

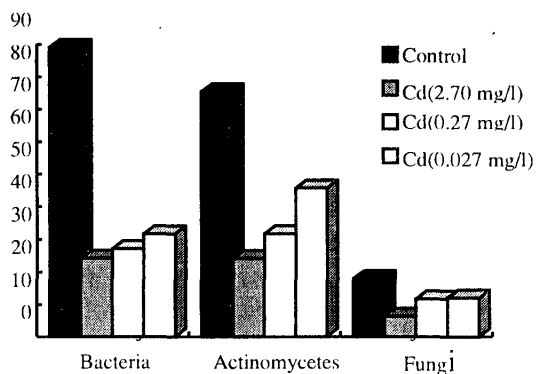
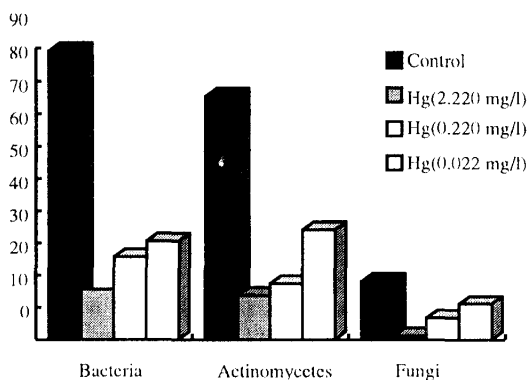


Fig. 4. Effect of diverse concentrations Hg on the total number of bacteria (10^6 /1g absolutely dry soil), number of fungi and actinomycetes (10^5 /1g absolutely dry soil) - Djukic i sar., 1996.



High concentrations of heavy metals in the environment act as a selective factor, which selects only adaptable microorganisms. As a rule, only the metal-resistant species remain in the microorganism communities. For example, in the clumpy-podzolic soil, polluted with lead, the following microorganisms are metal-resistant - *Bacillus mycoides*, among bacilli; *Penicillium lilacinum*, *P. flavum*, *P. meleagrinum*, *Mucor rammanianus*, *Aspergillus niger*, *Fusarium oxysporum*, *Gymnoascus setosus*, among fungi; and *Actinomyces albus*, *A. griseus* (Naple-kova, Bulavko, 1985), among actinomycetes. *Cladosporium elegantulum* and *Penicillium janthinellum* are predominant in the microbial soil community with an increased copper and zinc content (Alekseeva, 1986).

It is well known that micromycetes are most resistant to the pollution with heavy metals (Bulavko, 1982; Evdokimova, 1982; Letunova et al., 1982; Naplekova, Bulavko, 1985; Alekseeva, 1986; Zikina, Cugunova, 1987). Sanitary indicators and pathogenic microorganisms are resistant to high rates of heavy metals (Pereligin et al., 1978).

The resistance of a great number of microorganisms to high concentrations of heavy metals can be explained by their ability to accumulate those elements in their cells. For example, some representatives of micromycetes, singled out from the soil with an increased copper and zinc content, may accumulate up to 13,4 percent of copper and up to 16,8 percent of zinc from their initial content in the environment (Alekseeva, 1986), while *Penicillium* and *Trichoderma* genera representatives can extract 70-80 percent of copper from the solution (Evdokimova, 1982). Besides micromycetes, *Bacillus megatherium*, *B. cereus*, *B. meseatericus*, *Azotobacter chroococcum*, *Pseudomonas* sp., *Mycobacterium album* and *Streptomyces indigocolor* have the ability to accumulate different metals (Zn and Pb) into cells (Nijazova, 1982). On the whole, based upon published data, actinomycetes, azotobacter, yeasts of the *Lipomyces* genus and nodular soybean bacteria show the highest sensitivity to superfluous amounts of heavy metals (Huang et al., 1974; Pereligin et al., 1978; Babjeva et al., 1980; Naplekova, Bulavko, 1985).

With the increase of the content of metals in the soil, their surplus becomes the main ecological factor, which determines the level of different processes carried out by microorganisms. The reduction of the intensity of the basic transformation processes of the N and C compounds - ammonification, nitrification, denitrification, cellulolysis and humification - is noticed very often in such conditions (Umarov, Azieva, 1980; Vazenina, 1985; Kleverskaja, 1985; Letunova et al., 1985; Naplekova, 1985; Rodinjuk, 1985).

The disturbance of these processes decreases the content of free amino acids and the amount of organic matter and it causes the accumulation of the sufficient amount of NO_2 - up to 1.75 mg N/kg of soil (Evdokimova, 1982; McKenny, Vriesacker, 1985; Grišina et al., 1987).

The effect of metals is weaker in the soils of heavy mechanical composition with high humus content than in light and impoverished soils, which can be explained by the ability of clayey minerals and organic matter to convert the metals from free to bonded state (Umarov, Azieva, 1980; Kosinova, 1985).

What is the effect of heavy metals on a microbe cell like? According to Avakjan's results (1973), high concentrations of metals coagulate proteins and cause immediate death of cells; while in sublethal dosage rates, they affect certain biochemical blocks. The nitrogen adoption block is very sensitive, compared to the blocks related to respiratory processes, which are less sensitive. The latter can be explained by different metabolic ways of CO_2 formation. The inhibition of the activity of a great number of enzymes - phosphatase, protease, dehydrogenase, invertase etc - is the basis of the control of the biochemical activity of microorganisms (Tyler, 1974; Pereligin et al., 1978; Evdokimova, 1982; Raskova et al., 1983; Kosinova, 1985; Jevleeva et al., 1986; Mateos, Carcedo, 1988).

The toxic effect of heavy metals (e.g. of Cd and Pb) is also noticed on the symbiosis system formation and functioning levels. It can be examined on the basis of the reduction in the number of formed nodules and the reduction or

absence of nitrogenase activity. The nitrogen fixation activity is far more sensitive than the photosynthesis, leaf respiration or the chlorophyll content (Rodinjuk, 1985).

A physiological adaptation plays a certain role in the gradual increase of the heavy metal concentration - a bond sensitive to a certain metal is disconnected from the cell metabolism or the cell cover experiences some changes.

The increased content of heavy metals in the soil causes some changes of the morphofunctional properties of soil micromycetes: the spore germination is stopped, the mycelium and sporogenesis growth speed is reduced and mycelium becomes thinner (Marfenina, 1987).

Modelling the soil pollution with heavy metals (with Pb and Cd), Guzev et al. (1985) determined a four-level microbial community reaction to the pollutant concentration gradient: the homeostasis, stress, resistance and repression zones. The pollution in the homeostasis zone does not cause qualitative changes in the functioning of the microbial soil system. The roles of special populations of microorganisms become distributed in the stress zone and they carry out certain microbiological processes in the soil. During the high-level pollution, characteristic of the resistance zone, disorders are such that active microorganisms become transformed into a non-active state and atypical pollutant-resistant organisms are mainly formed. The negative effect of a pollutant in the microbial soil system repression zone shows itself through the general sterilization effect.

The sulfur, nitrogen, chlor and other compounds. Besides the oxides of heavy metals, the industrial waste also contains large amounts of the sulfur, nitrogen, chlor, phenol, hydrocarbon (methanol, ethylene glycol, paraxylol etc.) compounds and other organic compounds. Many are carcinogenic (e.g. benzo-pyren). All of them are deposited in the soil in the form of dry (dusts) and water sediments and they enter the natural circulation of matter.

Sediments containing chlorides, sulfides and nitrogen oxides etc. incite a sudden soil acidification. "Acid" rains fall very often and especially in densely populated industrial zones although, due to the movement of air masses, they may cause soil acidification of other regions as well (Antonenko, 1985; Maranyi, 1986; Rjabinin et al., 1987).

The soil acidification phenomenon is a world problem. This phenomenon was observed in Germany, Switzerland, Canada, in the north of the USA, the Ukraine, etc. According to the results obtained by the Scandinavian researchers, the pH atmospheric deposits value has reduced from 5.5 - 6.0 to 4.0, often to 3.0 and sometimes even to 2.8 in recent years. Soil, as well as ground waters acidification causes the growth in Ca, Mg and K losses and the increase of Al, Fe and Mn content and activity. The reduction of the pH value activates the toxic effects of mercury, lead and cadmium (Kovda, 1975).

Besides "acid" rains, fertilizers, especially ammoniac fertilizers may also incite soil acidification (Bonneau et al., 1987). In the soil on the grounds of a factory emitting different nitrogen oxides into the atmosphere, the content of ammoniac, nitrate and nitrite nitrogen forms is increased, sulfur accumulates in surface levels of soil and the content of fulvo acids is reduced (Antonenko, 1985; Rjabinin et al., 1987; Dolgova et al., 1988). The presence of high dosage rates of

sulfurous anhydrides in the soil (ten times above the MPC) causes long-term changes in the microbial community structure: the amount of bacteria and actinomycetes is reduced, the relative bacilli and fungi content is increased (Antonenko, 1985; Rjabinin et al., 1987). Microorganisms revive in time. Different puferic soil systems play a great role in it - carbonate, silicate, clayey and other systems, which start to act in reaction to the pollution of soil with any type of compound (Vedeneev, 1983; Bonneau et al., 1987).

The products of the polyether lavsan fibre chemical production, as well as the compounds of organic nature, can represent additional sources of growth and energy of microorganisms, mostly bacteria. In the presence of these matters, the bacteria biomass in the soil is increased 1.5 to 2 times in comparison to the control soil. Microscopic fungi are, on the other hand, very sensitive to this kind of pollution (Efremov, 1986).

The number of micromycetes, sporogenic bacteria and actinomycetes suddenly increases in the soils polluted with 3.4 of benzopyren (100 μ g/kg); the *Escherichia coli* content is increased 2.5 times (Tonkopij, 1978).

Oil and its products. Among the different organic compounds causing the high-level environmental pollution, oil products have a very important role. Regardless of the precautionary measures, taken during the production, storage and transportation processes, soil pollution with oil and its products is inevitable. The physicochemical properties of the soil, first of all, change under its effect. The aerial regime of the soil is particularly disrupted; entering the soil particles, oil pushes air out of the pores; significant amounts of microzon with limited O₂ access are formed in soil aggregates. Na and Cl concentrations increase in the soils with an increased content of oil products, which may lead to salinization; the mobile P₂O₅ content is reduced; total nitrogen and K₂O amounts, as well as the pH value, do not change (Ismailov, 1983; Demurdzan et al., 1985; Oborin et al., 1987).

The disturbance of the living conditions of soil microorganisms affects their living activity. Regardless of the fact that microorganisms play the leading role in oil and oil product degradation in natural conditions (Birsseher, 1957), the soil pollution with these compounds affects, in a specific way, the balance of the microbial cenosis as a biological system.

Fluctuating changes of the microbial cenosis, caused by the low oil pollution level, are followed by more serious disorders and even by the complete restraint of the soil microbial community activity - when the soil pollution with oil is high (Oborin et al., 1987). Based on the reduction of the total number of bacteria and algae in microbial communities, the content of azotobacter, actinomycetes and fungi is decreased; the activity of hydrolysis and oxidation-reduction enzymes is also reduced (Demurdzan et al., 1985; Beradze, Osakmasvili, 1987; Haziiev et al., 1988).

In many researchers' opinion, the reaction of nitrification microorganisms to the oil-saturated soil is the most sensitive. Based on the sudden reduction of the nitratoreductasis activity (15 times in very polluted soil), denitrifiers develop very suddenly and, naturally, the denitrification process is increased; the number of microorganisms involved in the nitrogen fixation and ammonification processes is also increased; the aerobic microorganisms oxidizing hydrocarbons actively develop, too (Ismailov, 1983; Beradze, Osakmasvili, 1987; Djukic, Mandic, 1997 - fig. 1.)

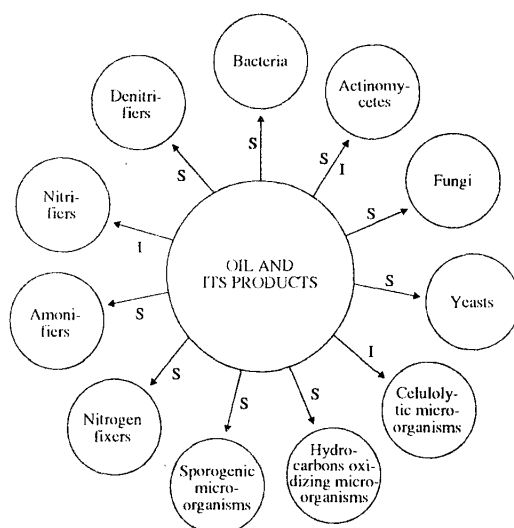


Fig. 1. Effect of oil and its products on soil microorganism complexes (s-stimulation; i-inhibition)

Actinomycetes are also sensitive to oil pollution. Their number in the polluted soil of field experiment is reduced 2-2,5 times, whereas in the vegetative soil - 10-12 times in comparison to the control soil. At the same time, the number of bacteria and fungi is increased (Ribak et al., 1984). Some researchers have found out that the living activity of micromycetes stops in the soil two years after the pollution and the number of microorganisms using the mineral nitrogen as well as the number of sporogenic microorganisms is increased (Anderson et al., 1980). Oil also controls the development of all types of soil algae (Stina, 1985). Yellow-green and blue-green (cyanobacteria) algae have shown a specific sensitivity.

The characteristics of oil pollution and the degree of its effect on soil microorganisms depend on the oil composition and its amount, on climatic conditions, physicochemical properties and type of soil and agrochemical measures. For example, the use of fertilizers in soils polluted with oil and its products reduces their negative effect to a certain extent: the "respiration" intensity is increased, the mineralization coefficient grows, dehydrogenase and urease are activated, the oil hydrocarbon oxidation process is intensified (Ribak et al., 1984; Haziev et al., 1988; Djukic, Mandic, 1997) - figures 2, 3.

Along with microorganisms that are sensitive to oil pollution, bacteria using oil hydrocarbons exist as simple components of microbial cenoses. Soils polluted with oil products are characterized by the presence of specialized species of microorganisms: species oxidizing gaseous hydrocarbons, solid paraffins, aromatic hydrocarbons etc. They are mostly representatives of the *Bacillus*, *Pseudomonas*, *Nocardia*, *Candida*, *Rhodotorula* and other genera (Kvasnikov, Kljušnikova, 1981).

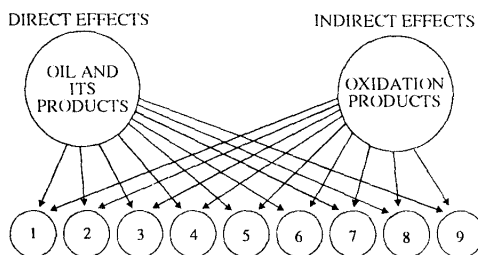


Fig. 2. Effect of oil pollution on the enzyme system in soil
 1-respiration; 2-dehydrogenase; 3-protease; 4-urease; 5-catalase;
 6-phosphatase; 7-invertase; 8-nitratoreductase; 9-poliphenoloxidase

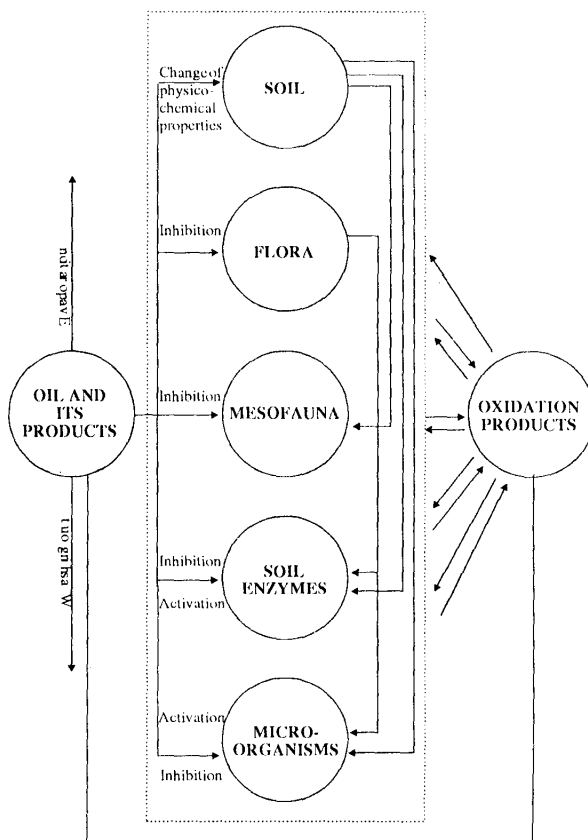


Fig. 3. Effect of oil and its products on soil biocenosis

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MIKROORGANIZMI I TEHNOGENO ZAGAĐENJE AGROEKOSISTEMA

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Rezime

U ovom radu se razmatraju ekološke posledice primene agrohemijskih i drugih potencijalnih i stvarnih ksenobiotika, a posebno reakcija zemljišne mikrobne zajednice.

U zavisnosti od vrste pesticida, primenjene koncentracije i doze, tipa zemljišta i sprovedenih agrotehničkih i drugih mera, njihovo dejstvo se može okarakterisati širokim spektrom pojava - od stimulacije, preko represije, do pojave otpornih mutančnih vrsta zemljišnih mikroorganizama, pa čak i mikroorganizama koji ih efikasno razgrađuju, učestvujući u autopurifikaciji zemljišta. Ipak, može se konstatovati da pesticidi smanjuju brojnost zemljišnih mikroorganizama (bakterija, aktinomiceta, gljiva i algi) i njihovu aktivnost (proteinaza, amilaza, dehidrogenaza, celulaza, "disanje" zemljišta, nitrifikacija).

Teški metali menjaju fizičko-hemijska svojstva zemljišta (smanjujući agregiranost i šupljikavost, sadržaj Ca i Mg; povećavaju pokretljivost glinaste frakcije i mobilnost humusnih kiselina; razgrađuju se neoplazme karbonata i hidroksida gvožđa i gipsa). Kao mikroelementi deluju stimulatивно na brojnost i aktivnost zemljišnih mikroorganizama. U povećanim dozama teški metali smanjuju ukupnu brojnost i biomasu bakterija, aktinomiceta i gljiva; dovode do preraspodele u kvalitativnom sastavu zemljišne mikrobne zajednice, pojave otpornih oblika (sa patogenim svojstvima) sa povećanom sposobnošću akumulacije metala i i četvorostepene reakcije zemljišne mikrobne zajednice (zona homeostaze, stresa, rezistentnosti i represije).

Suvi i vodeni talozi jedinjenja S, N i Cl izazivaju zakiseljavanje zemljišta i podzemnih voda, što uslovljava gubitke u Ca, Mg i K, povećanje sadržaja i aktivnosti Al, Fe i Mo i aktiviranje toksičnih efekata Hg, Pb i Cd.

Naftno zagađenje izaziva promene fizičko-hemijskih svojstava zemljišta (remecenje vazdušnog režima; povećanje koncentracije Na i Cl; smanjenje sadržaja mobilnog P_2O_5 ; količine ukupnog N i K_2O , kao i pH se ne menjaju), smanjenje ukupne brojnosti bakterija i algi, azotobaktera, aktinomiceta i gljiva, kao i aktivnosti hidroliznih i oksido-redukcionih enzima.