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BACHELOR THESIS

(EXPLANATORY NOTE)

SPECIALTY 101 "ECOLOGY",
EDUCATIONAL AND PROFESSIONAL PROGRAM:
"ECOLOGY AND ENVIRONMENT PROTECTION"

Theme: «Study of the impact of chemical soil pollution on the vital activity of microorganisms»

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МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

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ОПП «ЕКОЛОГІЯ ТА ОХОРОНА НАВКОЛИШНЬОГО СЕРЕДОВИЩА»

Тема: ««Вивчення впливу хімічного забруднення ґрунту на життєдіяльність мікроорганізмів»»

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NATIONAL AVIATION UNIVERSITY

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Specialty, Educational and Professional Program: specialty 101 “Ecology”, Educational and Professional Program: “Ecology and Environment Protection”

(code, name)

APPROVED

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«____» _________ 2023

BACHELOR THESIS ASSIGNMENT

Veronika V. Petroshchuk

1. Theme: «Study of the impact of chemical soil pollution on the vital activity of microorganisms» approved by the Rector on April 19, 2023, № 529/ст.

2. Duration of work: from 05.05.2022 to 22.06.2023.

3. Output work (project) : studying the impact of chemical soil pollution on the vital activity of microorganisms and understanding the consequences of this impact on the ecosystem.

4. Content of explanatory note(list of issues) : to environmental role of soil, to research methodology, to effects of soil pollution on microorganisms.

5. The list of mandatory graphic (illustrated materials): tables, figures, graphs.

6. Schedule of thesis fulfillment

№ з/п	Task	Term	Advisor's signature
1	Setting up the experiment	05.05.2022 – 06.05.2022	
2	Collection and analysis of the experiment	10.11.2022 – 25.02.2023	
3	Justification of the goal, object and subject of research	29.05.2023 – 04.06.2023	
4	Review of literary sources	01.06.2023 – 08.06.2023	
5	Collection and analysis of materials	01.06.2023 – 10.06.2023	
6	Writing chapters I of the thesis	02.06.2023 – 05.06.2023	
7	Writing chapters II of the thesis	05.06.2023 – 12.06.2023	
8	Writing chapters III of the thesis	09.06.2023 – 12.06.2023	
9	Issuance of an explanatory note	13.04.2023 – 20.06.2023	
10	Defense of the thesis	19.06.2023	

7. Date of task issue: «_19_» April 2023

Diploma (project) advisor: _______________ Petroshchuk V.V.

(advisor's signature) (S.N.P.)

Task is taken to perform: _______________ Radomska M.M.

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ABSTRACT

Explanatory note to thesis «Study of the impact of chemical soil pollution on the vital activity of microorganisms» 49 pages, 6 figures, 3 tables, 19 references.

Object of research: effect of pollution on living organisms.

Subject: changes in living activity of soil microorganisms under the influence of selected pollutants

Aim of the research: studying the impact of chemical soil pollution on the vital activity of microorganisms and understanding the consequences of this impact on the ecosystem.

Methods of research: data analysis, experiment, statistical methods.

MICROORGANISMS, CHEMICAL SOIL POLLUTION, LIVING ACTIVITY, POLLUTANT, SOIL BIOCENOSIS

INTRODUCTION

Relevance of work. Nowadays, the problem of soil contamination with chemical substances is urgent and has wide consequences for the environment and human health. Chemical substances used in industries, agriculture, households, and other sectors can accumulate in the soil through improper application, illegal waste disposal, or natural processes such as weathering or decay.

This contamination can have a negative impact on the vital activity of microorganisms in the soil. Microorganisms, including bacteria, fungi, and algae, play a crucial role in soil biological processes, including organic matter decomposition, nitrification, nitrogen fixation, and regulation of soil chemical composition.

Chemical pollution can lead to a reduction in the diversity and abundance of microorganisms, disrupting their functioning and interaction with other components of the ecosystem. This can affect soil fertility, its structure, and resistance to erosion. Moreover, some chemical substances can be toxic to microorganisms, causing their extinction or changes in genetic structure.

The consequences of soil contamination with chemical substances also extend to plants, animals, and humans. Contaminated soils can supply harmful substances to plants, which can then enter the food chain. This can result in a decrease in the quality of food products and pose a threat to human health, including poisoning or chronic illnesses.

Aim and tasks of the diploma work

Aim of the work – studying the impact of chemical soil pollution on the vital activity of microorganisms and understanding the consequences of this impact on the ecosystem.

Tasks of the work:

1. Overview of literature about the role of living organisms and microorganisms in particular in the soil formation and functioning;

2. Generalization of available research data on the effects of pollutants on soil biota;

3. Designing and performance of experiment to demonstrate the changes in soil microorganisms activity under the influence of pollutants;

4. Formulation of recommendations about the appropriate methods of soil remediation after pollution.

Object of research is effect of pollution on living organisms.

Subject of research is changes in living activity of soil microorganisms under the influence of selected pollutants

Methods of research: data analysis, experiment, statistical methods.

Personal contribution of the graduate: search and analysis of information, performance of the experiment and analysis of the obtained data.

Approbation of the results:

1. Radomska M., Petroschuk V. The resilience of natural communities under the combined pressure of climate changes and military actions // Environment Recovery and Reconstruction: War Context 2022: Proceedings of the International Conference, Poltava, November 17-18, 2022.

2. Петрощук В.В., Радомська М.М. Оцінювання наслідків техногенних аварій в умовах недостатності вихідних даних // Екологічна і техногенна безпека. Охорона водного і повітряного басейнів. Утилізація відходів: тези доп. Міжнар. наук. конф., (19-20 квітня 2023 р.). – Харків: Харківський національний університет міського господарства імені О.М. Бекетова, 2023.

CHAPTER 1
ENVIRONMENTAL ROLE OF SOILS

Soil is a complex and dynamic natural system. The definition of soil varies widely as it is determined by its uses and how we perceive it as a society that provides services, food, shelter and enjoyment, but these functions are related to soil health and It is related to quality and essential.

The established definition of soil is a medium containing minerals, organic matter, myriad organisms, liquids and gases that support life on Earth through a variety of functions.

Soil is the loose surface layer of the earth's crust (lithosphere), which is a complex complex of organic and mineral compounds and is characterized by fertility. Soil is a product of the combined effects of time, climate, vegetation, animals and microorganisms. In it, the synthesis and decomposition of organic matter, the cycle of elements of ash and nitrogen nutrition of plants, absorption and detoxification of various pollutants take place continuously. The soil cover of the Earth is considered as a component of the biosphere, which plays a complex global role in the accumulation and redistribution of energy, in maintaining the cycle of chemical elements vital to organisms.

The soil organizes all flows of substances in the biosphere, is a connecting link and regulating mechanism in the processes of biological and geological circulation of elements, regulates the composition of the atmosphere and hydrosphere. As a result of the constant exchange between the soil and the atmosphere, various gases are transformed into the air pool.

The most important global function of the soil is the ability to accumulate in the surface part of the earth's weathering crust - in the soil horizons - a specific organic substance - humus and the energy associated with it. The processes of biogenic accumulation, transformation and redistribution of energy coming to the Earth from the Sun take place continuously in the soil. Potential biogenic energy accumulates mainly in the form of plant roots, biomass of microorganisms and humus.

The soil is a regulator of living organisms, performs the functions of creating and preserving biological diversity. As a habitat for many organisms, it limits the activity of some and promotes the activity of others. In addition, the soil is the main natural receiver and absorber of various wastes.

Soils affect the climate (microclimate) of the area, the development of vegetation, the state of certain branches of the national economy; their fertility is taken into account when building and planning settlements, improvement and operation of the latter.

Therefore, the soil is the most valuable and irreplaceable natural resource, a global accumulator of solar energy, the basis of plant, animal and human life, the most important element of the external environment, the basic component of the ecosystem,

connecting link of cycles of elements, the main natural receiver and absorber of various wastes, etc.

All soils consist of solid, liquid and gaseous phases, which are interconnected.

Changes in one of them inevitably lead to changes in others. Soil fertility is determined by a complex of factors, primarily the quantitative content and qualitative indicators of organic and mineral matter.

1.1. Soil structure and formation

Soil formation is a complex process, the basis of which is the biological cycle of substances. The development of the soil-forming process is greatly influenced by basic factors such as climate, vegetation and animal life, parent breeds, topography, and soil age. Later, scientists added two more factors to this system: the relative age of the soil and human economic activity.

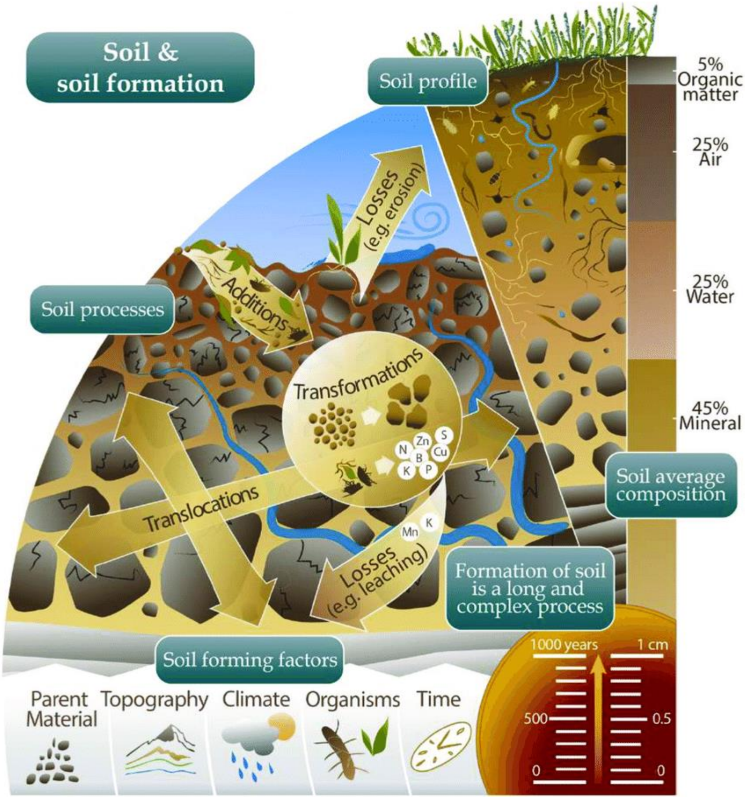

Fig. 1.1 Soil formation

Climatic factors - heat, light, precipitation have a significant impact on the growth and spread of plants. The climate in different parts of the globe is different. According to climatic conditions, tundra, forest, forest-steppe, meadow-steppe, dry-steppe, desert and tropical vegetation zones arose. The amount of organic matter produced by different plant communities is not the same, and depends on climate conditions and increases from north to south; at the same time, the nature, speed and duration of the biological cycle and the type of soil formation process change.

The most important factor in soil formation is vegetation. Green plants, using the energy of the sun's rays, carbon dioxide, water and mineral salts, are able to form organic matter, involving a huge number of nutrients in the biological cycle. Annually, 232.5 billion tons of organic matter are created in the life process of plants on earth. At the same time, they use 90.1 billion tons of carbon, 5.3 billion tons of nitrogen, about 20 billion tons of minerals (K, Ca, P, etc.).

Parent or soil-forming rocks have a significant impact on the process of soil formation, since soils retain their chemical and water-physical properties, as well as mineralogical and mechanical composition for a long time. More fertile soils are formed on rocks containing a large amount of chemical elements necessary for plant nutrition. The richest soils develop, for example, on carbonate loams, while on sands they are poorer, but often turn out to be better aerated, warmer. Depending on the parent species, the composition of the vegetation changes. So, pine trees form on sandy soils, and grassy meadow-steppe vegetation forms on loamy soils; the type of soil formation also changes.

The relief has a significant impact on climatic conditions, the life of plants, animals, microorganisms, the nature of the formation and decomposition of organic substances, and on the soil-forming process as a whole. The mountainous terrain determines the formation of vertical climatic and vegetation zones. The meso-relief affects the redistribution of moisture, the transformation of surface runoff into ground runoff, the formation of the water regime and associated vegetation cover. Depending on the exposure of the slopes, the amount of heat entering the soil changes. Northern slopes receive it less, southern slopes more. The redistribution of heat and moisture affects the composition and quantitative characteristics of the plant cover. Microrelief changes the amount of moisture, significantly affecting the depth of soil wetting, salt regime and species composition of herbaceous vegetation.

The absolute age of soils is calculated from the beginning of the development of the soil-forming process, which causes the gradual formation of the soil profile. For most of the territory of the East European plain, the age of the soil is determined by the time of retreat of the glaciers. Therefore, the age of the soils of the chernozem zone, which avoided glaciation, is higher than the age of the tundra and forest soils, and the age of the elevated areas, somewhat earlier freed from the ice cover, is slightly older than the age of the soils of the lower areas in the same area.

The term "relative soil age" shows that with the same absolute age of the territory, the soils can be evolutionarily different, that is, they can be at different stages of development: some are in the initial stages, while others are significantly developed. Differences in the evolution of soils are interconnected with differences in the vegetation cover of parent rocks, relief and other local conditions that affect soil formation.

Human activity is a specific, very powerful factor affecting the soil. In the conditions of intensification of agricultural production, man acts on the soil with the help of machines, fertilizers, land reclamation, pesticides, and industrial waste, leading to changes in natural ecosystems. Intensive cultivation, systematic application of fertilizers lead to changes in the soil profile. In many cases, the soil is cultivated: the humus content increases, the water, air and nutrient regimes improve.

At the same time, significant areas of soil degrade and lose their original fertility. The factors of soil degradation are very diverse and can be of both natural and anthropogenic origin:

- extreme weather phenomena (droughts, floods);
- deforestation;
- active agricultural activity;
- surface storage and burial of industrial and household waste;
- use of agrochemicals;
- incorrect melioration technology;
- waste water discharge;
- forest fire
- geological phenomena (landslides, erosion, volcanic eruptions).

All these factors significantly change the chemical and biological processes taking place in soils, destroy their structure and lead to the transformation of soils into less form products - saline, waterlogged, structureless, toxic, and in some cases to the complete loss of soils due to desertification.

To effectively prevent degradation processes, it is necessary to study the processes of soil functioning in detail and understand the role of all factors in this complex system.

1.2. Functions of soils

- Food production (agriculture and forestry)

The soil functions as a medium to support the plants that we use to produce food, fiber, and bio-energy materials. It serves as a physical support and protective environment for plant roots. It provides a reservoir of available water and nutrients for plant growth. Plant growth is a direct result of photosynthetic activity (absorbing sunlight) to produce plant material and energy.

Plant material decays in the soil due to the activity of microorganisms, which use it for their energy and growth.

There are approximately 550 billion tons of plant animal, and microbial biomass on Earth Plants, including crops and forests, make up 450 billion tons, or 82% of the total biomass on Earth.

- Circulation of matter and energy

The soil provides a large geological and small biological cycle of substances on the earth's surface. Biogenic elements accumulate in the soil, it accumulates them and prevents their rapid removal into the hydrosphere. the soil regulates the chemical composition of the atmosphere and hydrosphere.Filtering and storing water

The soil is a vast reserve for water storage across the world. The texture of a soil (i.e., the content of sand, silt, and clay particles), as well as the density with which it is compacted, affects the rate at which water moves through the soil. Sandy soils generally allow water to move more rapidly, while ones containing greater amounts of clay can store more water for plants. Microorganisms living in the spaces between soil particles use water and nutrients just as plants do.

The movement of water and the transformation of nutrients and organic residues serve as a vast filtering and detoxification system for precipitation (e.g., rain and snow) around the world.

Although less than 1% of the world's supply is stored at any given time in rivers, lakes, and soil, the passage of water through these systems provides an invaluable service in improving its quality for drinking and irrigation.

- Reservoir for genetic biodiversity and for species habitat.

Soil provides a habitat for the greatest diversity of microorganism species than any other environment on the planet, and can be considered its own micro-ecosystem.

In fact, there are more individual microorganisms in a spoonful of soil than there are people on this earth.

- Physical environment for humanity and its culture

In areas where the soil or climate hinders adequate food production or water availability, resources such as food and water must be transported in from far away.

They provide a foundational support for all buildings we live and work in as well as support the parks and natural areas we recreate in as well.

It is a landscaping and engineering medium to be dealt with when planning and building transportation systems such as highways and railroads.

Soils are also used as a medium for the concealment and disposal of vast amounts of refuse. In Texas, we deal with special ones that shrink when dry and swell when wet.

The cracking and heaving caused by this behavior demands special consideration when building structures on these soils.[11]

- Source of raw materials for industries and buildings

Soils provide many raw material deposits. Sands may be collected for building.

Clays may be used for ceramics. Some clay minerals are also used in variety of industrial products. One example is bentonite clay used as drilling fluid by oil industry.

Texas also mines a large amount of raw materials for limestone and cement.

- Carbon storage

Carbon is the basis for all life on Earth. It exists in many forms, including the carbon dioxide (CO_2) that makes up a small portion of our atmosphere (~ 0.041%).

In soils, carbon may be part of the inorganic mineral complex. It may also be part of living organisms or of decaying organic tissue.

This form of carbon is called soil organic carbon (SOC). There is more carbon in and under the Earth's soil than is contained in all the plants that grow above its surface.

There remains a high potential for increased carbon storage in soils that can have a positive effect on both biomass production and the regulation of atmospheric CO_2 balances.

- Geologic and archeological heritage archive

When we gaze across the surface of the landscape, we may forget that the soil has a history that is often linked with the history of human activity.

Soils often conceal and protect paleontological and archeological treasures of considerable value towards better understanding the history of our planet and ourselves.

They may also be considered a reservoir for much more recently placed information for use in forensic investigations of crime scenes.

1.3. Soil biotic complex

First of all, it should be understood that the soil is a living world with its own rules and laws. All processes in the soil are closely interconnected. A complex and at the same time very stable ecosystem, a biocenosis, is created. Soil is the lowest part of the biocenosis, the most inhabited and alive, which processes huge objects of organic matter. Up to 80% of all solar energy stored by plants is absorbed by the soil.

Biota (pedobiota) is the entire set of organisms (microorganisms) that jointly inhabits the material (environment) regardless of the functional connections between them. The biotic component of soils includes various organisms for which soils serve as a temporary or permanent habitat. The area of existence of living organisms within the lithosphere is called lithobiosphere, which is part of the biosphere. The upper limit of the lithobiosphere is the daytime surface of the earth, and the lower limit is determined by the depth of penetration of life into rocks. But the most active processes involving microorganisms occur precisely in the surface layer - up to a depth of 80 cm [10].

Soil fauna plays an exceptional role in shaping soil fertility. About 500 kg of living organisms live on one hectare of land (microbes, algae, crustaceans, mushrooms, worms, etc.). All organisms of the soil complex consume up to 10 kg of plants per 1 m2 per season. According to the research data of B. Grzymek, in a layer of soil 30 cm deep on one square meter of the steppe lives:

- up to 2 kg of bacteria, actinomycetes and fungi;
- up to 100 g of ciliates and other protozoa;
- up to 50 g of nematodes, ticks, roundworms;
- up to 100 g of mollusks, woodlice, spiders, millipedes and other insects;
- up to 500 g of worms and vertebrates.

All of them perform special functions in the soil:

1. Plants are primary producers, the root system of which affects the physical and

chemical properties of the soil and its biological activity.

2. Soil algae are producers that affect the oxygen regime, nitrogen accumulation and soil structure. Can be bioindicators.

3. Soil animals are consumers that affect the chemistry, structure,

biological activity and soil fertility, formation of humus.

4. Mammals - rodents, insectivores, hares, exert mechanical influence on

soil, participate in mineralization and humification of organic matter.

5. Soil fungi are reducers.

6. Lichens.

7. Bacteria are reducers.

8. Viruses and phages are parasites

Without a huge and complex complex of creatures living in the soil, the existence of the soil itself is not possible. Nevertheless, about 75% of the composition of the soil biota is formed by microorganisms (bacteria, fungi, etc.), while the remaining 25% are representatives of macrofauna - worms, insects, mites, and others.

In the process of their vital activity, soil microorganisms ensure the gradual transformation of crop residues and other organic substances into humus. The latter for a long time accumulates the nutrients necessary for plants, which, breaking down in the soil, become available for absorption by plant roots.[3]

1.4. The role of microorganisms in soils formation

Microorganisms are of great importance for soil formation processes. They play a major role in the deep and complete destruction of organic matter, some primary and secondary minerals. Each type of soil, each soil difference has a unique profile distribution of microorganisms. At the same time, the number of microorganisms and its species composition reflect important properties of the soil. The main part of microorganisms is concentrated in the upper 20 cm of the soil layer. fungal and _ bacterial biomass in arable soil layers up to 5 t/ha. The microbiota is characterized by a very high biodiversity. According to R. Tait, 1 g of soil contains about 4,000 types of microorganisms.

Microorganisms take an active part in the process of formation of humus, which is biochemical in nature. Microorganisms have a significant influence on the composition of ground air and the cycle of nitrogen compounds. One of the key links incycle of nitrogen transformation - fixation by soil microbes. The total global production of microbial nitrogen fixation is 270-330 million t/year, of which 160-170 million t/year falls on land and 70-160 million t/year. / year delivered from the sea. Legumes with the help of nodule bacteria fix and accumulate in the soil from 60 to 300 kg of nitrogen per hectare per year.

The soil is not only the place of life of a huge number of the most diverse microorganisms, but also the product of their vital activity, in the soil microbes find all the conditions for development: moisture, nutrients, protection from the harmful effects of direct solar radiation, etc. Thanks to these favorable conditions, the number of microbes in the soil is huge - from 200 million microbes in 1 g of clay soil to five or more billion in 1 g of chernozem. Soil is the main source from which microorganisms enter the external environment - air and water.

Soil microflora is very diverse. It contains nitrifying, nitrogen-fixing, denitrifying bacteria, sulfur and iron bacteria, cellulose decomposers, various pigment bacteria, mycoplasmas, actinomycetes, fungi, algae, protozoa, etc. The quantitative and qualitative composition of the microflora of different soils varies depending on the chemical composition of the soil, its physical properties, the reaction of the environment, the content of air, moisture and nutrients in it. The composition and number of microbes in the soil are significantly influenced by climatic conditions: seasons, soil cultivation methods, the nature of the vegetation and many other factors[2].

The presence of billions of bacteria, actinomycetes, up to 1 million spores of fungi and many other microorganisms in 1 g of soil (top layer of chernozem) testifies to the high biogenicity of the soil. There is evidence that an arable layer of potting soil with an area of 1 hectare can contain 5-6 tons of microbial mass. Pathogenic bacteria are part of a diverse soil microbiota, but the soil as a whole provides a hostile environment for the survival of most pathogenic bacteria, viruses, fungi, and protozoa. Simultaneously with the mineralization of organic matter, the soil undergoes a self-purifying action of bacteria, which leads to the death of saprophytic and pathogenic bacteria that are not characteristic of the soil. The important role of microorganisms in the destruction and regeneration of minerals. This is primarily due to the microbial cycling of potassium, iron, aluminium, phosphorus, and sulfur. Mineral splitting and synthesis ensure the inclusion of elements in biological cycles and interaction with larger geological cycles of matter. Fungi and, to a lesser extent, actinomycetes and other bacteria are involved in microbial mineral degradation processes. Mechanisms underlying the degradation of minerals:

1. Dissolution with strong acids as a result of nitrification and oxidation of sulfur.

2. Action of organic acids - incomplete oxidation of carbohydrates by fermentation products and fungi.

3. Interaction with extracellular amino acids secreted by most microorganisms.

4. Destruction of plant residues by microbiological conversion.

Products - polyphenols, polyuronides, tannins, flavonoids.

5. Decomposition of by-products of microbial biosynthesis, such as polysucram.

As a result of the action of acids, alkalis, and microbial slime on minerals, either complete dissolution of the mineral occurs with the formation of amorphous decomposition products, or potassium ions, for example, are isomorphically substituted for hydrogen or sodium without destroying the crystal lattice. Extraction of chemical elements from minerals does not always occur in equivalent amounts, and this leads to the transformation of one mineral into another. For example, during the decomposition of aluminosilicates with the participation of heterotrophic microflora, there is a sequential release of first alkaline elements, then alkaline earth elements, and finally silicon and aluminum. The resistance of a mineral to microbiological decomposition is determined both by the peculiarity of the structure of the crystal lattice and the specificity of the complex of microorganisms, and as a result, the specificity of the biochemical mechanisms of action on the mineral.

The microbiota of podzolic soil has the highest capacity for mineral degradation. Microorganisms are involved not only in the distribution of elements contained in minerals, but also in their formation. In particular, microorganisms deposit aluminum around their cells and form bauxite (aluminum hydroxide), destroying aluminosilicates. In addition to aluminum, new sulfide, carbonate, phosphate, iron-bearing and silicate minerals are formed in the soil [7].

The role of microorganisms in the process of converting amorphous silica into secondary quartz is limited to the isolation of phytris from organic matter. Further crystallization is a purely chemical process. Sulfide transformed by sulfur bacteria, in particular Thiobacillus ferrooxidans. In an acidic environment, these bacteria oxidize primary sulfides and generate new secondary minerals. For example , senarmonite is formed from antimonite (Sb_2S_3) , and with the participation of Stibiobacter senarmontii it is further oxidized to Sb_2S_5. In addition, microorganisms contribute to the formation of soil structure, forming aggregates that ensure the penetration of air, water and plant root systems into the soil. It also interacts with plant roots to form symbiotic relationships such as mycorrhiza. These compounds improve the supply of nutrients to plants and their defense against pathogens[8].

Thus , microorganisms are an integral part of the process of soil formation . They influence its structure , chemical composition , physical properties , as well as ensure the decomposition of organic matter and the formation of soil substances .

1.5. Environmental role of soil microorganisms

Each group of soil microorganisms play essential roles in various soil processes and contribute to the overall health and functionality of the soil ecosystem.

Bacteria: Bacteria are the most abundant group of microorganisms in soil. They are highly diverse and perform crucial functions such as:

- Decomposition: Bacteria are key decomposers, breaking down organic matter into simpler compounds and releasing nutrients back into the soil.
- Nutrient cycling: Certain bacteria are involved in nitrogen fixation, converting atmospheric nitrogen into forms usable by plants. Others participate in nutrient transformations, such as the conversion of organic phosphorus into inorganic forms.

- Disease suppression: Some bacteria have antagonistic properties and help suppress soil-borne plant pathogens, promoting plant health.
- Plant growth promotion: Certain bacteria form mutualistic relationships with plants, enhancing nutrient uptake, producing growth-promoting substances, and improving plant resilience to stress.

Fungi: Fungi are another important group of soil microorganisms. They can be categorized into two main types:

- Decomposers: Many fungi are specialized decomposers that break down complex organic matter, including lignin and cellulose, contributing to the nutrient cycling process.
- Mycorrhizal symbionts: Mycorrhizal fungi establish mutualistic associations with plant roots, forming mycorrhizae. They facilitate nutrient uptake by extending their hyphae, increasing the root surface area, and aiding in the absorption of water and nutrients, particularly phosphorus.

Archaea: Archaea are less abundant but still present in soil ecosystems. They exhibit diverse metabolic capabilities and contribute to various functions, including:

- Methane cycling: Some archaea are involved in methane production, while others participate in methane oxidation, thus regulating the global methane cycle.
- Nutrient cycling: Certain archaea contribute to nitrogen cycling by performing nitrification, converting ammonium into nitrite and nitrate.
- Protozoa: Protozoa are single-celled eukaryotes that play important roles in the soil food web. They feed on bacteria, fungi, and other microorganisms, regulating their population sizes. Their activities influence nutrient availability and microbial community composition.
- Viruses: Soil viruses are incredibly abundant but often overlooked. They infect bacteria, fungi, and other microorganisms, impacting microbial community structure and genetic diversity.

Collectively, these soil microorganisms interact with each other and with plants, influencing nutrient availability, organic matter decomposition, disease suppression, and overall soil health. Understanding their composition and functions is crucial for sustainable land management practices and the maintenance of healthy soil ecosystems[2,6].

1.6. Role of soil biodiversity in the provision of ecosystem services by soils

Soil biodiversity plays an important role in the provision of soil ecosystem services. Ecosystem services are the benefits that humans derive from ecosystems, including soil, such as nutrient cycling, soil formation, water purification, climate regulation, and supporting the development of ecosystems. plant. Here are some specific roles of soil biodiversity in providing ecosystem services:

- Nutritional cycle:

Soil organisms, including bacteria, fungi, and invertebrates, play an important role in the nutrient cycle in the soil. They break down organic matter, releasing essential nutrients like nitrogen, phosphorus and potassium, which are then absorbed by plants. Soil biodiversity improves nutrient availability and promotes efficient nutrient cycling, which contributes to plant growth and yield.

- Soil Formation:

Soil biodiversity contributes to the process of soil formation, known as morphogenesis. Various organisms, including earthworms, termites and microorganisms, are actively involved in the breakdown of rocks and minerals, the breakdown of organic matter, and the formation of soil masses. They improve soil structure, porosity and fertility, facilitating water infiltration, root penetration and nutrient retention.

- Filter and purify water:

Soil organisms play an essential role in water filtration and purification. Diverse microbial communities, including bacteria and fungi, help filter and break down pollutants, pathogens and organic compounds in the soil, preventing their entry into groundwater or surface water. Soil biodiversity improves water quality and helps maintain clean and healthy water supplies.

- Climate regulation:

Soil biodiversity affects climate regulation through different mechanisms. Soil organisms, especially microorganisms, participate in the carbon cycle by decomposing organic matter and releasing carbon dioxide (CO_2) into the atmosphere. However, they also contribute to carbon sequestration by storing organic carbon in the soil, thereby helping to mitigate climate change. In addition, soil biodiversity affects soil moisture holding capacity, influencing local climatic conditions, including temperature and humidity.

- Plant growth and yield:

Soil biodiversity has a direct impact on crop growth and yield. Beneficial soil organisms, such as mycorrhizal fungi, form symbiotic bonds with plant roots, improving nutrient uptake, disease resistance and overall plant health. Pollinators, including insects and other soil-dwelling organisms, help plants reproduce and produce fruit, seeds, and crops.

- Pest control:

Soil biodiversity plays a role in pest control in agro- and natural ecosystems. Some soil organisms, such as some bacteria, fungi, nematodes, and predatory insects, act as natural enemies of pests and pathogens, regulating their populations and reducing the need for nutrients. chemistry card. Maintaining diverse soil communities can strengthen natural pest control mechanisms.

- Resilience and resistance to environmental stressors:

Soil biodiversity contributes to the resilience and resistance of ecosystems to environmental stressors. Diverse land communities are more resilient to disturbances such as pollution, extreme weather events, and land use change. They provide stability and functional redundancy, ensuring continuity of ecosystem services even in the face of disturbances.

Physiological process of soil microorganisms are essential for the stability of soil. At the same time Many commonly used antibiotics for human medical treatments are in fact produced by soil microorganism, while many more are yet to be undiscovered, but represent an exciting frontier for the future of human and animal health.

The conservation and promotion of soil biodiversity is essential to sustain the ecosystem services provided by the soil. Land management practices that prioritize the protection of soil organisms and their habitats, such as reducing chemical inputs, implementing organic farming methods, and conserving natural areas, is essential to maintaining the health of the soil and the benefits it provides to people and ecosystems.

1.7. Factors having influence on soil microorganisms

Among the factors that influence soil microorganisms, the following can be highlighted:

- Soil pH: Soil pH determines its acidity or alkalinity. Different microorganisms have specific pH requirements for optimal growth and activity. pH levels outside their preferred range can inhibit their growth or activity.
- Organic Matter: Soil microorganisms play a crucial role in the decomposition of organic matter. The presence of organic materials such as plant residues, compost, or manure provides a food source for microorganisms, promoting their growth and activity.
- Moisture and Water Availability: Soil moisture content affects microbial activity. Microorganisms require water to survive and carry out their metabolic processes. Water availability influences microbial growth rates, nutrient availability, and the transport of nutrients within the soil.

- Temperature: Microbial activity in soil is influenced by temperature. Different microorganisms have different temperature ranges at which they are most active. Soil temperatures outside their preferred range can limit microbial activity.
- Oxygen Availability: Soil microorganisms have varying requirements for oxygen. Some are aerobic, requiring oxygen for their metabolic processes, while others are anaerobic and can survive and function in oxygen-depleted conditions.
- Nutrient Availability: Microorganisms require essential nutrients such as nitrogen, phosphorus, potassium, and various micronutrients for their growth and metabolism. The availability and balance of these nutrients in the soil can influence microbial populations and their activity.
- Soil Texture and Structure: Soil texture, which refers to the relative proportions of sand, silt, and clay particles, can affect the availability of water and nutrients to microorganisms. Soil structure, including the arrangement of soil particles, pore spaces, and aggregates, can influence microbial habitats and the movement of air, water, and nutrients in the soil.
- Land Management Practices: Agricultural practices such as tillage, irrigation, fertilizer application, and pesticide use can impact soil microorganisms. Intensive or improper management practices can alter microbial populations and diversity, affecting soil health and fertility.
- Plant Roots and Rhizosphere: Plant roots release a variety of compounds such as sugars, organic acids, and exudates that can influence microbial communities in the rhizosphere (the soil region influenced by plant roots). Some microorganisms form beneficial associations with plant roots, such as mycorrhizal fungi, which can enhance nutrient uptake and plant growth.
- Pollution and Contaminants: Soil pollution from chemicals, heavy metals, or other contaminants can have detrimental effects on soil microorganisms. Some pollutants can inhibit microbial growth or activity, disrupt microbial communities, and reduce overall soil health.

It's important to note that these factors are interconnected, and changes in one factor can affect others, leading to complex interactions within the soil microbial community.

1.8. Conclusion to Chapter 1

Soil is a complex system that includes organic and inorganic substances, various organisms, liquids and gases that support life on Earth through many functions. The soil is a valuable natural resource and a global accumulator of solar energy, which plays an important role in the accumulation and redistribution of energy, maintaining the cycle of chemical elements and regulating the composition of the atmosphere and hydrosphere. The soil affects the climate, the development of vegetation, the state of economic industries and is important for the construction and planning of settlements.

Soil formation is a complex process that depends on many factors, such as climate, flora and fauna, parent species, topography, and soil age. Climatic conditions have a significant influence on the growth and distribution of plants, which affects the amount of organic matter produced by them and the type of soil formation process. Vegetation also affects soil formation, as plants are able to create organic matter and incorporate large amounts of nutrients into the biological cycle. Parent rocks also affect the process of soil formation, as they determine the chemical composition of the soil and plant composition. Relief has a significant influence on climatic conditions, the life of plants, animals, microorganisms, the formation and decomposition of organic substances and the process of soil formation in general. The age of the soil is determined by the beginning of the soil formation process, which gradually leads to the formation of the soil profile.

In summary, soil is an irreplaceable natural resource that performs many functions and is of great importance for sustaining life on Earth. It is formed under the influence of climate, vegetation, parent rocks, topography and time, and it has properties that depend on the quantity and quality of organic and inorganic matter. Understanding the formation and properties of soil is important for ensuring the sustainable use of this natural resource and preserving biological diversity.

CHAPTER 2
RESEARCH METHODOLOGY

2.1. Sequence of soil description

Soil description includes consideration of various aspects, ranging from general characteristics to a more detailed study of its composition and properties. The sequence of soil description includes the following stages:

1. General characteristics: The name of the type of soil, its distribution, climatic conditions and features of the area where it is found.

2. Physical characteristics: Physical properties of soil, such as texture (proportion of sand, clay, and loam), structure (size and shape of soil particles), density, porosity, and water permeability. The color of the soil and its layering.

3. Chemical properties: Chemical characteristics of the soil, such as pH (acidity or alkalinity), content of organic substances, mineral composition (content of nitrogen, phosphorus, potassium and other macro- and microelements), content of salts and other chemicals

4. Biological activity: Biological aspects of the soil, in particular the presence and distribution of microorganisms (bacteria, fungi, actinomycetes, etc.), the life cycle of soil organisms, the biological decomposition of organic substances and the biological activity of the soil as a whole.

5. Physico-chemical processes: Physico-chemical processes that occur in the soil, such as chemical reactions, dissolution of minerals, absorption and release of substances, changes in pH and other processes that can affect the chemical structure of the soil.

6. Micro- and macrostructure: Organization and relationships between soil particles at different levels.

2.2. Experimental procedure

The basis of the planning of the experiment is the organization and procedure of its implementation. Such planning depends on the purpose and conditions under which the experiment is to be conducted. A clear design of experiments is particularly useful for the study of complex systems, the output of which can be influenced by a potentially large number of factors.

When planning an experiment, it is important to ensure that the obtained results are not caused by a random combination of factors and conditions. When conducting experiments, there is a risk of incorrect assumptions about cause-and-effect relationships in the system, and therefore it is necessary to carefully determine and control all parameters of the system under study.

In this work, an experiment was carried out, which investigates the consequences of chemical contamination of soils for the vital activity of microorganisms. For this purpose, the following sequence of work was implemented:

1. Preparation of experimental surfaces:

- envelopes 10 cm * 15 cm were made of linen fabric;
- cardboard sheets of the same size were weighted;
- cardboard sheets were inserting into the envelopes;
- the envelopes were tightly sewed and fabric was stretched over them.

Fig 2.20 Envelopes 10 cm * 15 cm

2. Preparation of incubator containers: five 5 l containers were filled with soil and placed into the soil so, that the top part is located at the level of the ground.

Fig 2.21 Incubator containers

3. Sampling of soil: samples of soil were taken while digging the holes for incubation containers with minimal damage to the soil structure.

4. Placement of envelopes: one third of the soil sample was placed at the bottom of the container, the envelopes were then placed on it vertically and another portion of soil was added, ensuring that the envelope is well sealed and protected by the surrounding soil.

Fig 2.21 Incubator containers

5. Filling containers: the containers were completely filled with soil, leaving about 5 centimeters of free space up to the edges.

Fig 2.22 Incubator containers

6. Preparation of model pollutants solution: specific portions of contaminants were diluted in 1 l of water, including:

- Salt (NaCl),

- Surfactant (detergent),
- Petroleum product (gasoline),
- Heavy metal ($CuSO_4$).

Fig 2.23 Incubator containers in soil

7. Addition of pollutants: the prepared pollutants solutions were uniformly distributed over the soil surface in each container – one type of pollutant per container.

8. Control group: one container was left without adding pollutants.

9. Incubation and observation: the containers were kept at open air to keep the incubation conditions as natural as possible; they received moisture and solar energy just like the surrounding soil. The samples were incubated for 6 month during the whole vegetative period.

10. Data collection and analysis: after the end on vegetation the enveloped were extracted from the soil and prepared for analysis:

- envelopes were rinsed with water and opened to remove cardboard;

- cardboard or its fragments were also rinsed with water and dried to air-dry condition.

11. Analysis of collected data:

- the signs of microbial activity were studied on the fabric by the change of colour and formation of dark colonies;

- the area affected by bacterial activity was measured;

- cardboard was weighted and the change in mass was calculated as compared with the initial samples.

The study of the influence of chemical soil pollution on the vital activity of microorganisms using the described experimental procedure provided valuable information about the impact of pollutants on soil microbial communities. Envelopes made of cardboard and linen cloth served as an effective tool for studying the vital activity of microorganisms in soil samples.

By preparing five containers as incubators and carefully collecting soil samples without damaging their structure, we were able to create a controlled experimental setup. The insertion of shells containing part of the soil allowed us to directly observe the reaction of microorganisms to the introduced pollutants.

Addition of contaminants including salt (NaCl), surfactant (detergent), petroleum product (gasoline), and heavy metal ($CuSO_4$) diluted with water simulated chemical soil contamination scenarios. This allowed us to assess the influence of these pollutants on the activity and composition of soil microbial communities.

During the entire experimental procedure, careful monitoring and data collection was carried out to assess various parameters and metabolic processes. These measurements provided valuable information about the sensitivity of soil microorganisms to chemical pollution and their ability to adapt to or be adversely affected by different types of pollutants.

The results obtained from this study contribute to our understanding of the ecological consequences of chemical soil contamination and highlight the importance of maintaining soil health and biodiversity. The obtained data emphasize the need for sustainable soil management and the development of strategies to mitigate the negative impact of pollutants on soil microorganisms.

Overall, this study provides valuable information on the complex relationship between chemical soil contamination and microbial activity. It serves as a basis for further research and supports the development of strategies aimed at protecting soil ecosystems and ensuring sustainable use of land resources.

2.2. Results processing

The data obtained after the experiment were processed using standard statistical approaches. The following statistical parameters were calculated:

- mean arithmetic value ($\bar{x}$)
- error of mean arithmetic (m)
- standard deviation (Sx)
- index of variation (V, %)

$$\bar{x} = \frac{\sum x_i}{n};\ S_x = \sqrt{\frac{\sum \left(x_i - \bar{x}\right)^2}{n-1}};\ m = \frac{S_x}{\sqrt{n}};\ V = \frac{S_x}{\bar{x}} \cdot 100\%,\ (1.0)$$

where x_i – measured parameter of samples (area of bacterial activity signs and mass of cardboard), n – number of measurements.

Statistically meaningful distinctions between the samples (in our case it is difference between the samples from polluted soils and control sample) is estimated with the criterion of Student (t). If the obtained actual value (t_a) is higher, than standard theoretical (t_{st}), the samples are different.

$$t_a = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{m_1^2 + m_2^2}},(1.1)$$

where $\bar{x}_1$ - mean arithmetic value of parameters (samples from polluted soils and control sample), $\bar{x}_2$ - mean arithmetic value of parameter (samples from polluted soils and control sample), m_1 and m_2 – error of mean arithmetic parameter (samples from polluted soils and control sample).

The values of t_{st} are resulted in Table 1.

Variance of samples is defined as $k = (n_1 + n_2) - 2$

The obtained values of t_a must be compared with standard values t_{st} for all three levels of statistical significance – 5%, 1% and 0,1%.

Table 1

Values of t-criterion by Student at the different levels of significance a, %

Number of degrees of freedom				**Number of degrees of freedom**			
Variance	a			Variance	a		
	5	**1**	**0,1**		**5**	**1**	**0,1**
1	12,71	63,66	64,60	18	2,10	2,88	3,92
2	4,30	9,92	31,60	19	2,09	2,86	3,88
3	3,18	5,84	12,92	20	2,09	2,85	3,85
4	2,78	4,60	8,61	21	2,08	2,83	3,82
5	2,57	4,03	6,87	22	2,07	2,82	3,79
6	2,45	3,71	5,96	23	2,07	2,81	3,77
7	2,37	3,50	5,41	24	2,06	2,80	3,75
8	2,31	3,36	5,04	25	2,06	2,79	3,73
9	2,26	3,25	4,78	26	2,06	2,78	3,71
10	2,23	3,17	4,59	27	2,05	2,77	3,69
11	2,20	3,11	4,44	28	2,05	2,76	3,67
12	2,18	3,05	4,32	29	2,05	2,76	3,66
13	2,16	3,01	4,22	30	2,04	2,75	3,65
14	2,14	2,98	4,14	40	2,02	2,70	3,55
15	2,13	2,95	4,07	60	2,00	2,66	3,46
16	2,12	2,92	4,02	120	1,98	2,62	3,37
17	2,11	2,90	3,97	∞	1,96	2,58	3,29
P	0,05	0,01	0,001	–	0,05	0,01	0,001

The graphs, which represent difference between samples from polluted soils and control sample, were developed.

2.3. Conclusion to Chapter 2

This section examines the sequence of soil description and the experimental procedure used to study the effect of chemical soil contamination on the life activity of microorganisms. With the help of a carefully planned experiment and data processing using statistical methods, valuable information about the impact of pollutants on soil microbial communities was obtained.

Initially, a description of the general characteristics of the soil, physical and chemical properties, biological activity and physicochemical processes occurring in the soil was carried out. The experimental procedure included sample preparation, addition of contaminants, sample incubation, data collection and analysis.

The obtained results were processed using statistical approaches, including the calculation of the arithmetic mean value, the error of the arithmetic mean, the standard deviation and the index of variation. Student's test was applied to determine statistically significant differences between the contaminated soil samples and the control sample.

The obtained results indicate the importance of maintaining soil health and biodiversity. They emphasize the need for sustainable soil management and the development of strategies to reduce the negative impact of pollutants on soil microorganisms. This serves as a basis for further research and supports the development of strategies aimed at protecting soil ecosystems and ensuring the sustainable use of land resources.

CHAPTER 3
EFFECTS OF SOIL POLLUTION ON MICROORGANISMS

Microorganisms inhabit all types of soils, including the diversity of soil environments. They can be found in chernozems, gray soils, sandy soils, clay soils, peat soils, and others. The total mass of microorganisms in soils is enormous. It is challenging to provide exact numbers as their concentration can vary significantly depending on the soil type, environmental conditions, and other factors.

The species composition of microorganisms in soils is highly diverse. They include bacteria, fungi, viruses, archaea, protists, and other microorganisms. Each species performs its unique functions in the soil ecosystem. At the same time they are highly vulnerable to the change of environmental parameters, which often happens under the influence of human activity. Soil pollution and degradation are the most serious challenges, faced by soil biota, and microorganisms in particular.

3.1. Soil pollution

Soil pollution has a significant impact on microorganisms, which are important components of soil biota. Microorganisms such as bacteria, fungi, and algae play an important role in maintaining soil health and ecosystem functioning.

One of the main effects of environmental pollution on microorganisms is changes in the physical and chemical properties of the soil. For example, pollutants can alter soil pH, causing changes in the composition of microbial communities. The consequences of pollution can also manifest themselves in the form of changes in the nutrients available to microorganisms and the formation of toxic compounds that inhibit the activity and reproduction of microbes.

Soil contamination can also directly affect microbial processes. For example, some pollutants can have a toxic effect on microorganisms, inhibiting their activity or causing their death. Other contaminants can alter the metabolism of microorganisms and affect the production of important biological substances such as enzymes, amino acids and vitamins.

Microorganisms in the soil can be particularly affected by the following types of pollution:

1. Chemical pollution: For example, heavy metals, pesticides, mercury and petroleum products. These compounds have a toxic effect on microorganisms and can reduce their activity and reproduction.
2. Organic pollution: For example, a variety of chemicals, including pharmaceuticals, animal waste, and other organics. These substances can affect the composition and functions of the microbial community, as well as promote the development of opportunistic microorganisms.
3. Waste and excess fertilizer pollution: Excessive use of fertilizers and uncontrolled dumping of waste can lead to soil pollution with various substances such as nitrates, phosphates, ammonium, organic matter, etc. This can lead to changes in the composition and activity of microorganisms, as well as contribute to the development of eutrophication and pollution of water resources.

Understanding the impact of pollution on soil microorganisms is of great importance for maintaining the health of soil biota and the functioning of ecosystems. This will help to develop effective strategies for the conservation and restoration of soil resources, and will also contribute to the creation of sustainable and ecologically balanced agricultural and industrial practices.

The most common types of soil pollution in Ukraine is salination, pollution with petroleum products and heavy metals. They all have specific effect on soil microorganisms[19].

3.1.1. Microorganisms in salty soils

Soil salinization is a process of localized accumulation of soluble salts. This phenomenon is now unanimously considered a major threat to agricultural land as it directly undermines the value and quality of the soil.It is estimated that worldwide 20% of all cultivated and 33% of irrigated agricultural land suffer from soil salinity [4,5]

The number of microorganism is higher in soils with normal content of salts for given climate, but there are still organisms, which can thrive in this environment. Microorganisms in the soil in salty soils show special adaptations to extreme conditions, associated with high salts. For example, they actively accumulate salts in their cells, ensuring stable osmotic equanimity. There are other mechanisms that protect cells from different salts. However, dramatic increase in salinity of soil environment may cause considerable damage to microbial community not possessing these metabolic mechanisms.

3.1.2. Microorganisms reaction to heavy metals

Heavy metals are potentially toxic to soil microorganisms and can affect their vitality and function. This group of metals include such elements as cadmium (Cd), lead (Pb), mercury (Hg), chromium (Cr), nickel (Ni), zinc (Zn), copper (Cu) and others.

Important metals can be introduced into the soil and then consumed as a result of industrial activities, pesticides and fertilizers, runoff from the outputs and other dzherel. At high concentrations, important metals become toxic to microorganisms, damaging their cells, enzymes and biological processes.

Effect of metals on microorganism can be different. Some metals in minor quantities can promote the growth and activity of microorganism, reduce their diversity and biological activity, as well as disrupt biogeochemical cycles and ecological functions of the soil

Studies have shown that heavy metal pollution causes a change in microbial species, with tolerant micro-organisms replacing more susceptible micro-organisms and increasing their numbers. Many heavy metal/metalloid resistant microorganisms can remove heavy metals from contaminated soil or convert them to less toxic forms[9].

3.1.3. Effect of oil products on soil microorganisms

Petroleum products such as kerosene, gasoline, diesel, and other petroleum substances have potentially harmful effects on soil microorganisms. These pollutants can enter the soil as a result of oil spills, fuel spills, careless use of machinery and equipment containing petroleum products.

Petroleum products can suppress the growth and activity of microorganisms, change the composition and diversity of the microbial community, disrupt biological processes such as the decomposition of organic substances and nitrification, and also affect the functioning of the soil ecosystem.

A common feature of all oil-contaminated soils is a change in the number and limitation of species diversity of pedobionts (soil meso- and microfauna and microflora). The types of reactions in response of different groups of pedobionts to pollution are ambiguous:

- There is a mass death of soil mesofauna: three days after the accident, most species of soil animals completely disappear or make up no more than 1% of the control: even light oil fractions are toxic to them.

- After short-term inhibition, the complex of soil microorganisms responds to oil pollution by increasing the gross number and increasing activity. First of all, this refers to hydrocarbon-oxidizing bacteria, the number of which increases sharply relative to uncontaminated soils. The so-called "specialized" groups are developing, participating at various stages in the utilization of hydrocarbons[14].

- The maximum number of microorganisms corresponds to the fermentation horizons and decreases in them according to the soil profile as the hydrocarbon concentrations decrease. The main "explosion" of microbiological activity occurs during the second stage of natural oil degradation.

- In the process of decomposition of oil in the soil, the total number of microorganisms approaches background values, but the number of oil-oxidizing bacteria exceeds similar groups in uncontaminated soil for a long time.

Some microorganisms may have the ability to biodegrade petroleum products, meaning they can break down these substances into less toxic components and utilize them as a source of nutrients. However, this process can be slow and depends on soil conditions, type of microorganisms and characteristics of petroleum products[16,17].

3.2. Soil description

Both the diversity of soil microorganisms and their number depend on the type of soil. In the given research the grey forest soils were used. Gray soils are a common type of soil in the Volyn region of Ukraine. They refer to the type of soils that are formed under the influence of climatic conditions, mountain wind and various weather processes. These soils arise from eroded rock and have specific characteristics.

The main components of gray soils are mineral particles, organic matter, air and water. They have a medium structure, characterized by small granules and a feathery structure. This allows them to store water and nutrients, preventing them from being carried away by rapid runoff. The color of gray soils can vary from light gray to dark gray.

Gray soils have moderate fertility. They contain a sufficient amount of macro- and microelements necessary for plant growth. The organic matter contained in these soils contributes to the nutrition of microorganisms and provides a good soil structure. As a result, gray soils are able to maintain high fertility and promote plant growth.

One of the characteristic features of gray soils is their water-meadow regime. They are able to retain moisture well, which is especially important in dry periods. Due to its water storage properties, gray soils can be used for irrigation and ensuring regular watering of plants.

In general, gray soils are an important resource for agricultural production and land use. They provide high fertility, good structure and ability to retain moisture, which contributes to successful plant growth.

3.3. Results of experiments

The samples were studied after 6 month of incubation in soil. The activity of microorganisms was measured by two living processes: area of exposure, and intensity of digestion.

The area of propagation was measured as the physical area of the textile samples affected by microbial activity. The activity of microorganisms is expressed in discoloration of textile or its darkening. The area was measured in cm^2 using the palette method.

Intensity of digestion is also revealed by the share of textile with changed color, but a more profound result is decomposition of cupboard inside each textile pocket. The mass of the cardboard was defined before the start of experiment and the residues were weighted after the end of experiments.

The results by both parameters were compared with control and the statistical reliability of the difference was defined.

3.3.1. Area of microbial exposure

The signs of microbial activity on textile samples occupied different area, depending on the type of impact factor (Table 3.1). The general appearance of the traces of microbial activity was also different in terms of the shape and pattern.

Table 3.1

Area and pattern of microbial activity on samples

Sample number	Impact Factor	Area of microbial exposure, cm^2	Area of microbial exposure, %	Description
1	n/a (control)	207	69.0	Almost whole sample is discolored with few areas of color, closer to the initial. The dark sports are distributed over the whole area, forming zones. The textile is softer than before the experiment.
2	Salt (NaCl)	145	48.3	The darkening demonstrates speckled pattern and is located inside the discolored areas. The textile is softer than before the experiment.
3	Surfactant (detergent)	114	38.0	Few parches of darkening have oval shape and the rest of textile is of the initial color, but is softer then before exposure
4	Petroleum product (petrol)	145	45.0	Most of the textile hasn't change its initial properties, rounded areas of microbial traces are dark at the

				periphery and light in the center.
5	Heavy metal ($CuSO_4$)	83,5	27.8	Most of the textile hasn't changed its initial properties; there are 11 dark spots of microbial activity with very clear borders.

In particular, control sample has the biggest are inhabited by microbial communities. The least level of damage to microcenosis was defined on the salted sample, which is softened and discolored by almost a half of its area. The moderate effect of soil salination is probably due to relative resistance of microorganisms, inhabiting agricultural soils to increased salinity.

The similar result was obtained at the sample, polluted with petroleum, which known to inhibit certain organisms, but support the intensive growth of the others. Probably, due to selective sorting the organisms, able to benefit from the hydrocarbons of petroleum were able to use digestible components of textile more efficiently in the central areas of exposure patches.

Surfactant showed its considerable negative impact on the microorganisms of soil due to intensive surface degreasing, which destroys microhabitats of these organisms.

The activity of microorganisms was suppressed the most by copper. This result causes concerns, since copper sulfate is widely used in agriculture as a fungicide. This means that soil biota is negatively affected every time this substance is applied. So, its input must be well planned and carefully calculated.

3.3.2. Intensity of digestion

The decomposition of cardboard was also not even among the sample (Table 3.2). The most efficient decomposing was demonstrated by the control sample. Moderate digestive activity was seen on the results from salted soil, while heavy metal, surfactant and petroleum have considerable and proved the potential of the given pollutants to affect the circulation of matter in the soil.

Table 3.2

Cardboard decomposition

Sample number	Impact Factor	Weight before the experiment, g	Weight after the experiment, g	Efficiency of decomposition, %
1	n/a (control)	12.2	3.851	68.434
2	Salt (NaCl)	12.2	6.624	45.705
3	Surfactant (detergent)	12.2	9.507	22.074
4	Petroleum product (petrol)	12.2	10.219	16.238
5	Heavy metal ($CuSO_4$)	12.2	11.53	5.492

To assess the reliability of he obtained results, the statistical processing was conducted, showing that in all cases the difference between the control sample and experimental sample are large enough the conclude that it was not accidental with the 95% confidence in both cases.

3.4. Recommendations

Based on the obtained results of the study of the impact of chemical pollution on soil microorganisms, the following recommendations can be formulated:

- Implementation of strict control and monitoring of the level of soil contamination by chemical substances is necessary to protect soil biodiversity. This involves regular measurements and analysis of soil quality parameters in order to identify contaminated areas and take the necessary measures.
- Development and implementation of environmentally safe methods of cleaning contaminated soil is crucial in all cases of soil pollution. Research should be aimed at finding effective technologies that would help restore biological activity and soil fertility after pollution. However, pollution with petrochemicals, salt and surfactants can be efficiently mitigated by addition of organic matter to stimulate microbial activity, while heave metals pollution needs to be addressed via remediation activities.
- It is necessary to develop agricultural methods that reduce the use of chemicals in growing crops and maintain the natural balance of soil microflora and microfauna.
- Conducting educational and informational campaigns aimed at raising public awareness of the problem of chemical soil pollution and the importance of preserving biodiversity
- Carrying out further research on the interaction of various pollutants on soil biota. This will help increase our understanding of the problem and develop effective strategies to prevent and minimize the negative impact of pollution on soil biota.

Implementation of these recommendations will contribute to the preservation of healthy and productive soils, the maintenance of biological diversity and the sustainable development of our planet.

3.5. Conclusion to Chapter 3

As a result of the study of the impact of chemical soil pollution on the vital activity of microorganisms, it was established that it has a significant impact on the composition and functions of the microbial community. The achieved results confirmed that contamination with chemical substances can lead to a decrease in the activity of microorganisms, changes in their composition and reproduction, as well as to shifts in the functioning of the soil ecosystem.

The impact of chemical pollution on soil microorganisms has a direct impact on the biological activity, fertility and stability of the soil, which can have negative consequences for human health, agricultural production and natural ecosystems.

The obtained results indicate the need to be aware of the ecological importance of the soil and its role in providing ecosystem services.

These studies emphasize the importance of understanding the factors affecting the health of soil biota and developing strategies to conserve and restore soil resources. In order to achieve sustainable development, it is necessary to implement ecologically safe land use practices, control the level of soil pollution, and develop effective methods of cleaning and rehabilitating contaminated areas.

CONCLUSIONS

1. Soil is known to be one of the most valuable natural resources, and its pollution is destructive to the environment and has negative consequences for all forms of life that come into contact with it. Soil biota, the biologically active capacity of the soil, includes an incredible variety of organisms, which represent diverse taxonomic and functional groups.

2. Microorganisms of soil are crucial components of soil formation and functioning. Their interaction with plants and larger representatives of fauna provides favourable living conditions and overall productivity of ecosystems.

3. The composition and density of soil microorganisms depends on the type of soil and climate on the one side, and on the other it is strongly affected by the land use and pollution in the soils.

4. To study the effects of soil pollution with different types of pollutants an experiment was conducted. It included formation of soil separates with textile and cardboard samples inside. These soil separates were intentionally polluted with heavy metal, detergent, oil product and salt. After the end of vegetation season (in November) textile and cardboard samples were extracted from the soil and area affected by microorganisms activity and intensity of decomposition processes were measured on all samples.

5. It was determined that heavy metal had the greatest impact on soil microorganisms among the investigated pollutants, while salt had limited effect.

6. More research in this area is of great importance for understanding the mechanisms of chemical pollution effects on soil microorganisms, developing new

cleaning technologies and restoring soil ecosystems. Implementation of effective measures to prevent chemical contamination of the soil and protect microbial diversity is the task of ensuring sustainable development and preservation of natural resources.

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