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Complexes and bioenergy of invertebrates in oil-polluted gray-brown soils of Absheron

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ABSTRACT

Oil pollution negatively impacts not only the physicochemical and morphogenetic parameters of soils but also the vital activity of soil biota-microorganisms and invertebrates. Studies have established that in the uncontaminated gray-brown soil of the Binagadi and Karadag massifs, the bulk of the invertebrate complex is gastropoda, insecta, tenebrionidae, and carabidae. In lightly oil-polluted biotopes, insecta, gastropoda, lithobiidae, tenebrionidae, carabidae, buprestidae, and woodlice of the genus hemilepstus occupy the leading place. The total number and biomass of invertebrates in uncontaminated biotopes of gray-brown soils of the Binagadi and Karadag massifs is 19.2 ind/m^2, respectively; 26 gr/m^2 and 20 ind/m^2; 3.64 gr/m^2. In slightly oil-contaminated biotopes, these indicators vary between 25.6 ind/m^2, respectively; 3.5 gr/m^2 and 12.8 ind/m^2; 0.84 gr/m^2. The energy accumulated in the mesofauna biomass in the slightly oil-polluted biotopes of the Karadag and Binagadi massif varies between 0.3268 gr/m^2-1418.94 cal/m^2 and 1.0468 gr/m^2-5072.20 cal/m^2, respectively. Thus, the reliability of the biogeocenoses is determined by the level and effective activity of soil organisms.

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1. INTRODUCTION

Every year, a huge amount of substances of various etiologies enter the soil surface, which are subsequently involved in the biosphere. Since the scale of such influxes continuously increases, the problem of soil pollution arises. Soil contamination with organic compounds, some also include oil and its toxic components can remain in the soil for a long time. Remaining a source of pollution, they cause a disruption in the composition of the population of biogeocenoses, changes in the complexes of invertebrate animals, and the biological activity of soils. The energy entering the soil with bioorganic substances is significantly redistributed over various microstructures and soil components. It can be assumed that the equilibrium state of biogeocenoses in nature is achieved by optimizing the circulation of substances and energy flows, and the main control mechanism for stabilizing the biogeocenotic process is placed in the soil. From this, it becomes clear that when studying biogeocenoses as open systems capable of self-regulation for a long time, special attention should be paid to the study of soil as a dynamic system that determines the duration of the functioning of biogeocenoses. The reliability of the work of biogeocenoses as a complex model of mutual relations between its links is determined by the level and effective activity of soil organisms.

Oil and various oil products are currently considered priority environmental pollutants due to the large scale of production, transportation, processing, and use. The high content of oil and oil products in the soil has a great toxic effect on its ecological state. The activity of biochemical and enzymatic reactions decreases, and the balance of processes associated with the nitrogen cycle and biophilic elements is disturbed. finally, oil pollution has a negative impact not only on the physicochemical, and morpho-genetic indicators of soils but also on the vital activity of soil biota microorganisms, and invertebrates [1]–[5]. As a result of the development of minerals, including oil production, many natural landscapes are annually polluted and destroyed, causing significant damage to flora and fauna. Anthropogenic ecosystems accumulate huge masses of organic, mineral, and industrial wastes that almost completely fall out of the world circulation of substances, polluting the environment, and disrupting the regime of the ecosystem and the entire biosphere. Unlike anthropogenic landscapes, natural ecosystems are characterized by significant stability based on the constancy of incoming solar energy, the multiplicity of populations of plant and animal species, and the biomass they create [6]–[8].

For each type of soil, its own characteristic zoo-microbiocenoses are formed, which, in the process of individual development, develop specific, adaptive mechanisms of resistance to these pollutants. The study of the vital activity of natural biogeocenoses formed in various environmental conditions is because each of them, which has a specific structural and dynamic state, is distinguished by its individual resistance to technogenic influences. Pollutants entering the soil under the influence of biotic and abiotic factors undergo complex transformations up to their complete mineralization, the rate of destruction and the time spent in the ecosystem of the constituent parts of the toxicant will depend on the physicochemical properties of the soil, the composition of flora and fauna, as well as the intensity of anthropogenic activity. Each pollutant has its own etiology and chemical structure that allows them to withstand the decomposing action of external factors. Such a state provides the pollutant with long-term preservation in the ecosystem, transforming along individual links of the ecological pyramid, and most importantly, changing the initial biotic characteristics of the soil with its toxic effect [9]–[15].

2. RESEARCH METHOD

The objects of our research were oil-contaminated gray-brown soils of Apsheron. The purpose of our research was to study the effect of low oil pollution of 2-4% on invertebrate animal complexes. Natural cenoses of uncontaminated and oil-contaminated soils of the Karadag and Binagadi massifs were chosen as the objects of study. The natural cenoses of the uncontaminated soil of the Karadag massif are covered with halophyte-grass-herbaceous vegetation, on slightly oil-contaminated soil. The main phytostructure is halophytic vegetation, the uncontaminated soil of the Binagadi massif consists of herbaceous-cereal vegetation on the soil slightly contaminated with oil, and a wormwood-herbaceous-halophytic association is formed. The sampling of invertebrates was carried out from 0-30 cm of the layer according to the method generally accepted in soil zoology [2], [16]. The energy accumulated in different groups of invertebrates was determined by burning 1 gr dry matter in a calorimetric bomb of the V-08MA brand [17], [18]. The obtained energy indicators for individual groups of invertebrates were used to calculate the total energy accumulated in their biomass. Laboratory experiments were carried out on the effect of various doses of oil on the vital activity of a native species of earthworms (*Nicodirilus Caliginosus Sav.f. trapezoids)*. Studies carried out in oil-contaminated gray-brown soils of the Karadag and Binagadi massifs revealed 16 species of mesofauna belonging to 5 classes, 6 orders, 8 families, and 15 genera [9], [19], [20]. In order to study complexes of invertebrate animals in characteristic biogeocenoses, they were sampled from 0-10 cm, 10-20 cm, 20-30 cm horizons. For the fixation of invertebrate animals, 30% formalin was used. First, the wet biomass of individual groups was determined on a torsion balance. Then, after drying in a thermostat at a temperature of 30 degrees for 5 hours, their dry biomass was weighed. The results obtained were converted to the total number per area of 1 square meter. The energy parameters of individual invertebrate species were determined by combustion in a calorimetric apparatus. Prepared tablets weighing 1 gr were placed in a calorimetric bomb and filled with oxygen in an amount of 25 atmospheres. During the combustion of the sample, the energy of the burned material was determined by the change in temperature using a metastatic thermometer. All experiments were carried out in triplicate.

3. RESULTS AND DISCUSSION

It was found that changes in the vegetation cover cause the formation of a specific complex of invertebrates. In uncontaminated gray-brown soil under grassy-grass vegetation (Binagadi), the bulk of the invertebrate complex in this area is mollusks (66.7% of the total). Other groups of invertebrates include insects (insecta), ground beetles (carabidae), and dark beetles (tenebrionidae). In the soil slightly polluted with oil under sagebrush-herbaceous-halophytic vegetation, the leading place (81.3% of the total number) is occupied by insects represented by beetles and dark beetles. Other groups include shell mollusks (gastropoda) and millipedes (lithobiidae). In heavily oiled soil near oil wells, invertebrates completely disappear, see Table 1. Some differences in the composition of invertebrates were found in slightly oil-contaminated soil under halophyte-grass-herbaceous vegetation (Lokbatan). The dominant group in oil-contaminated biotopes are insects (ınsecta) represented by dark beetles (tenebrionidae), ground beetles (carabidae), and gold beetles (buprestidae).

Table 1. Species composition of invertebrates in oil-contaminated gray-brown soil (Binagadi massif)

Invertebrate species	Uncontaminated soil under grassy-grass vegetation	Slightly oiled soil under sagebrush-herbaceous-halophytic vegetation	Heavily oiled soil devoid of vegetation
Gastropoda, Helicidae			
Helix sp	+	+	-
Xeropicta sp	+		-
Chilopoda, Lithobiidae			
Lithobius viriatus sel		+	-
Jnsecta, Coleoptera			
Carabidae, Acinopus picipes Ol	+	+	-
Broscus cephalotes semistriatus F.v		+	-
Calathus ambiguous Pk	+	+	-
Chlaenius aenecefalus dej		+	-
Tenebrionidae; Tenririya			
Striatopunctata	+	+	-

In slightly oil-contaminated soil, 20 m away from the pollution source, under halophytic vegetation, the woodlice of the genus hemilepistus are the main dominant group, see Table 2. Considering that oil pollution of gray-brown soils on Absheron lasts for a long time, it is naturally considered appropriate to study the influence of oil pollution on the biological situation and complexes of invertebrate animals of these soils. The species composition, numbers, ratios of dominant groups, and the trophic structure of invertebrate animals in the natural cenoses under study vary depending on the vegetation cover, soil conditions and the etiology of technological waste entering the ecosphere. Pollution of gray-brown soils under wormwood-ephemeral vegetation from aluminum and pipe-rolling plants with waste of various etiologies leads to changes in the composition and structures of soil invertebrates.

Table 2. Species composition of invertebrates in oil-contaminated gray-brown soil (Karadag massif)

Invertebrate species	Uncontaminated soil under grass-cereal vegetation	Slightly oiled soil under halophyte-grass herbaceous vegetation	Heavily oiled soil, devoid of vegetation
Isopoda oniscoidea			-
Hemilepistus sp	+	+	
Protracheoniseus orientalis uij	+		
Gastropoda, Helicidae			-
Xeropicta sp.	+	+	-
Chilopoda, Geophillidae			
Celinopodes sp.			
Scorpiones, Buthidae			
Brutus eupeus	+		
Insecta, Coleoptera, Carabidae			-
Acinopus picipes Ol	+		
Broscus cefalotes semistriatus F-W	+		
Pterostihus cupreus dej	+		-
Calatus ambiguous Pk	+	+	
Tenebrionidae			-
Tentiriya tessulata tausch	+	+	
Buprestidae			-
Capnodis cariosa Pall	+		-
Spenoptera sp.	+		

According to the trophic structure, invertebrates predominate in both areas phytophages, sapro-phytophages, and slight predators (ground beetles). At such a distance from the source of pollution, pioneer groups of microfauna also appear as small arthropods (ticks, springtails) [21], [22]. The total number of invertebrates in the uncontaminated gray-brown soil under grass vegetation (Binagadi) averages 19.2 ind/m^2, and the biomass is 26 gr/m^2. A significant part of the abundance and biomass of invertebrates is made up of gastropods, carbides, and darkling beetles. In slightly oil-polluted soil under sagebrush-herbaceous-halophytic vegetation, the number and biomass of invertebrates are 25.6 ind/m^2 and 3.5 gr/m^2, respectively. The dominant role in the formation of quantitative indicators of the mesofauna is assigned to insects, partially mollusks, and predatory centipedes as shown in Figure 1.

In contrast to the considered oil-contaminated gray-brown soil of Binagada, a similar gray-brown soil under the halophyte-grass-herbaceous vegetation of Lokbatan has other quantitative indicators of mesofauna. The total abundance and biomass of invertebrates are 20 ind/m^2 and 3.64 gr/m^2, respectively, which is formed by the dominant group of insects (60% of the total abundance), the remaining 40% is accounted for by woodlice, mollusks, and scorpions as shown in Figure 2. In lightly oil-contaminated gray-brown soil under halophyte vegetation, the total number and biomass of invertebrates is 12.8 ind/m^2 and 0.84 gr/m^2, respectively. The main contribution to the formation of quantitative indicators of the mesofauna is made by woodlice (62.5% of the total population), and the remaining 37.5% is accounted for by chilopods and various groups of insects (Figure 2).

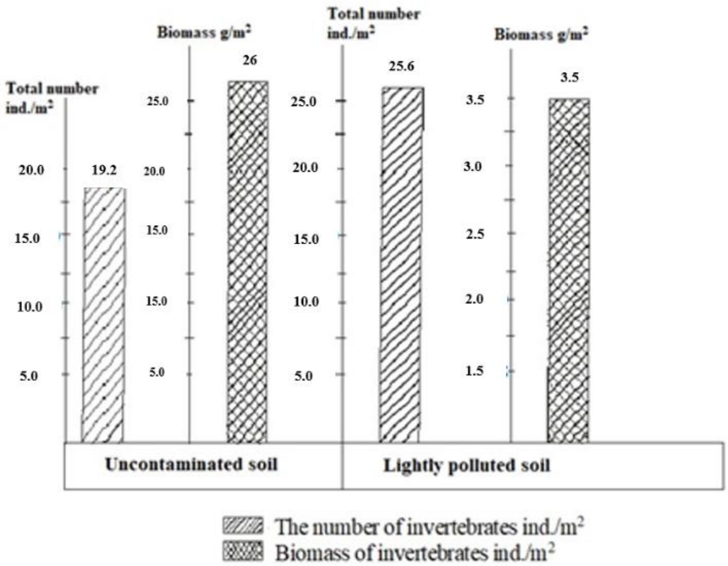

Figure 1. The number and biomass of invertebrates in unpolluted and slightly oiled gray-brown soils of natural cenoses (Binagada massif)

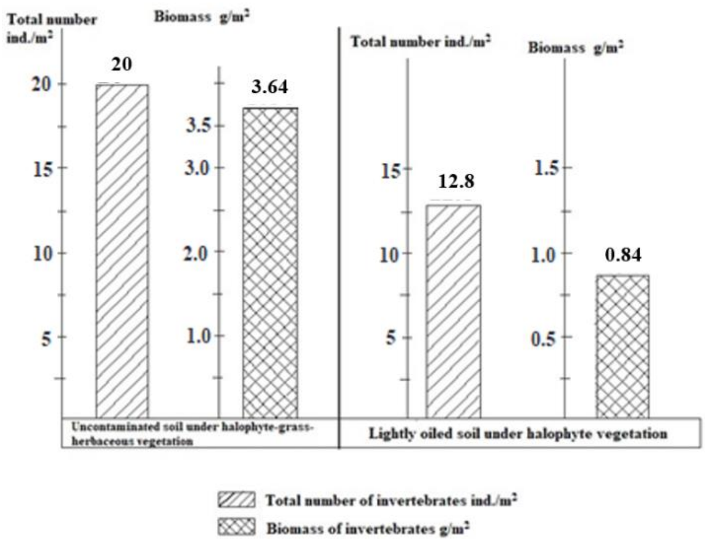

Figure 2. The number and biomass of invertebrates in uncontaminated and slightly oiled gray-brown soils of natural cenoses (Karadag massif)

The influence of various oil concentrations on the vital activity of some representatives of soil invertebrates is quite clearly manifested in the case of earthworms of the species *Nicodrilus Caliginosus Sav. f. trapezoides*. Experiments have established that the vital activity of worms in gray-brown soil at an oil concentration of 2-4% was quite high, which manifested itself in the stable utilization of plant residues in the preservation of the activity of oxidative (catalase) and hydrolytic (invertase) enzymes in the processing of soil in the form of deposited coprolites at full preservation of the vital activity of the experimental animals. As the oil concentration increases to 6-8%, the activity of earthworms decreases significantly, but their weak vital activity remains. this marks the mass death of animals [23]–[25]. Oil pollution significantly affects the formation of the community of invertebrates, their quantitative and qualitative indicators, and, consequently, the energy capabilities of certain dominant groups of pedobionts.

Therefore, we approached the problem of the influence of oil pollution on individual representatives of invertebrates from the standpoint of bioenergetics, determining the amount of energy accumulated in the biomass of characteristic groups of soil pedobionts. In the example of slightly oil-contaminated gray-brown soils of the Karadag and Binagadi massifs, a diverse energy transformation was revealed for individual groups of invertebrates. In natural biotopes under the halophytic vegetation of the Karadag massif, the energy accumulated in the biomass of 0.3268 t4 gr/m^2 of invertebrates is 1418.94 cal/m^2.

The total energy accumulated in the total biomass of recorded invertebrates is scanned in three dominant groups of pedobionts: isopods (isopoda) 902 cal/m^2, chilopods (chilopoda) 26.3 cal/m^2, and insects (insecta) 485.6 cal/m^2. In turn, the energy accumulated in insects is concentrated in two main families: carabides (carabidae) 144.2 cal/m^2 and darklings (tenebrionidae) 341.5 cal/m^2. As can be seen from these data, the largest amount of energy is stored in the isopads 63.79% and in the insects 34.35%, the least energy is contained in the predatory centipedes approximately 1.86% (Figure 3). In natural biotopes under the wormwood-herbaceous-halophytic vegetation of the Binagadi massif, the energy accumulated in the biomass of 1,418 gr/m^2 of invertebrates increases to 5072.20 cal/m^2 compared to the previous cenoses. And in this case, the total energy of invertebrates is accumulated in three main groups: gastropods (gastropoda) 757.6 cal/m^2, chilopods (chilopoda) 31.8 cal/m^2 and insects (insecta) 4,283 cal/m^2. The energy accumulated in insects is distributed over two families: carabids (carabidae) 2,778 cal/m^2 and darklings (tenebrionidae) 1,505 cal/m^2 (Figure 4).

Comparing the data obtained, it can be seen that the largest amount of energy i.e. 84.44% is found in insects, a much smaller amount i.e. 14.94% is concentrated in mollusks and the smallest amount of energy is stored in chilopods, approximately 0.62%. In heavily oil-contaminated (10-22%) gray-brown soils, the vital activity of all groups of invertebrates is completely suppressed. The study of invertebrate animal complexes makes it possible to use them in biodiagnostics and bioindication of contaminated soils, and to involve certain species that are resistant to oil pollution in the bioregeneration of oil-contaminated biotopes. Invertebrates formed under wormwood-herbaceous halophytic and halophytic-herbaceous vegetation revealed characteristic groups of biotopes adapted to these conditions, and plant remains that serve as energy resources for them.

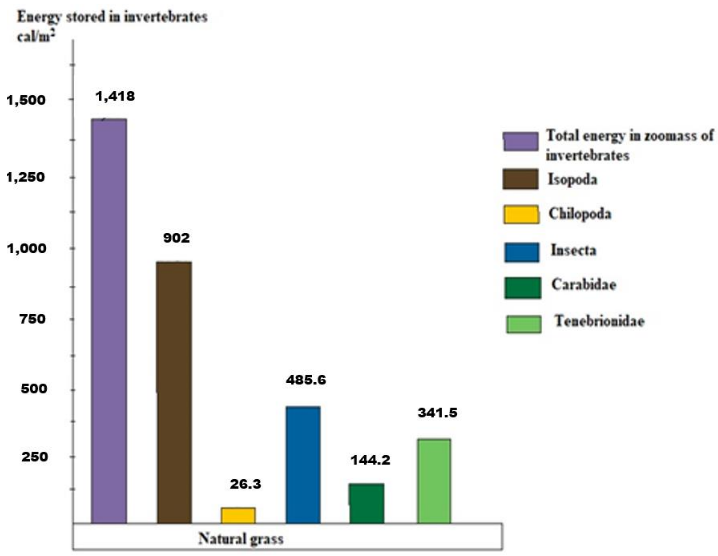

Figure 3. Energy accumulated in invertebrates of slightly oil-contaminated gray-brown soils of natural cenoses (Karadag massif)

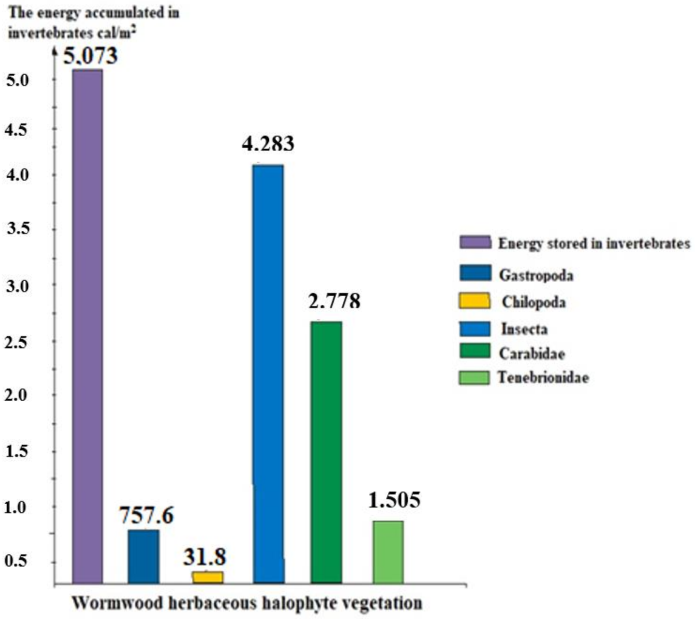

Figure 4. The energy accumulated in invertebrates of slightly oil-contaminated gray-brown soils of natural cenoses (Binagadi massif)

4. CONCLUSION

In uncontaminated gray-brown soil under grassy-grass vegetation (Binagadi), the bulk of the invertebrate complex is made up of mollusks (gastropoda). Among other groups of invertebrates, insects (ınsecta), ground beetles (carabidae), and dark beetles (tenebrionidae) have been noted. In lightly oiled soil under sagebrush-herbaceous-halophytic vegetation, insects (insecta) dominate; other groups include mollusks (gastropoda) and labial centipedes (lithobiidae). The dominant group in uncontaminated biotopes under herbaceous-cereal vegetation (Lokbatan) are insects (insecta) represented by darklings (tenebrionidae), beetles (carabidae), and gold beetles (buprestidae). Woodlice of the genus Hemilepistus are the main dominant group in slightly oil-contaminated soil under halophyte vegetation. The total abundance and biomass of invertebrates in the uncontaminated biotopes of the Binagadi massif average 19.2 ind/m^2 and 26 gr/m^2. In the soil slightly contaminated with oil, the number and biomass of invertebrates are 25.67 ind/m^2 and 3.5 gr/m^2, respectively. The total number and biomass of invertebrates in uncontaminated biotopes of the Karadag massif average 20 ind/m^2 and 3.64 gr/m^2. In slightly oil-contaminated biotopes, the total abundance and biomass are 12.8 ind/m^2 and 0.84 gr/m^2. In natural biotopes under halophyte vegetation of slightly oil-contaminated gray-brown soils of the Karadag massif, in the total mesofauna biomass of 0.3268 gr/m^2, the total accumulated energy is 1418.94 cal/m^2. In natural biotopes under sagebrush-halophytic vegetation on slightly oil-contaminated gray-brown soils of the Binagadi massif, in the total mesofauna biomass of 1.0468 gr/m^2, the total accumulated energy is 5072.20 cal/m^2.

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