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General characterıstıcs of oil-contaminated soils of the Absheron Peninsula and the impact of pollution on biota

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The Republic of Azerbaijan has substantial oil and gas reserves and, as the world's first land-based oil extraction area, has historically faced issues with oil pollution, which has been a pressing concern in the republic. It is clear that the toxic effects of oil, the changes caused by pollution in the structure and physical and chemical properties of the soil, and its impact on the biota in the soil, plants, animals and people living in the vicinity of these areas, as well as the risks they pose, are serious research topics. Additionally, the serious consequences of oil and oil products on human health, combined with the negative impact they have on the ecosystem, make it impossible to restore the ecosystem in the long term. Undoubtedly, the most serious negative impact of oil is considered to be on the water and soil ecosystem, which remains relevant in the direction of remediation of oil-contaminated soils and cleaning of contaminated soils, especially bioremediation. This review article is devoted to the general characteristics of oil-contaminated soils of the Absheron Peninsula and aims to investigate the impact of oil pollution on biota.

Keywords: *Absheron Peninsula, fungi, bioremediation, oil-contaminated soils, phytotoxic activity*

INTRODUCTION

Relevance of the research: The problem of oil pollution of soils, one of the environmental problems caused by the oil industry, which dates to the mid-19th century, remains one of the main and urgent problems of modern Azerbaijan. The increase in demand for oil during the Soviet Empire led to major environmental problems both on land and in the Caspian Sea, which deepened during that period and took its modern form in the present period, causing the total area of oil-polluted soils in Baku and the Absheron Peninsula alone to exceed thousands of hectares (Abdullayeva & Sultanova, 2021).

Already in 1980, the Absheron Peninsula was in third place in the USSR in terms of the amount of technogenic impact of oil products. At that time, the amount of oil per 1 km² of area was more than one hundred tons. This led to the loss of biological indicators of the soil in subsequent periods and the further deterioration of the biota there (Babaev et al., 2020).

In general, the characteristics of oil-contaminated soils refer to the physical, chemical, and biological properties of these areas, including soil pH, porosity, odour, species diversity of the biota present there, biomass, etc. (Devatha et al., 2019; Elsaigh & Oluremi, 2022).

The Absheron Peninsula, located in the east of the republic and on the western coast of the Caspian Sea, where 80% of the country's oil and gas reserves are concentrated, has 10 thousand hectares of oil-contaminated land (Hashimov & Zawadzki, 2022). The total area of the peninsula is 2274 km². The lands of the peninsula are divided into several categories according to their purpose: agriculture, construction, specially

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protected areas, industry, transport and communication, defense facilities, and lands belonging to the reserve fund. The reserve land fund of the peninsula is 43.1% (227,406 ha), of which 98,012 ha are industrial lands. Over the past 30-40 years, there have been serious changes in the lands in the listed categories. Thus, most lands have been exposed to technogenic impact, and the natural land cover has changed (Hajiyeva and Ibrahimova, 2024).

The depth of oil pollution in the peninsula varies between 2-2.5 m depending on the area. Moreover, oil pollution is not the only reason for the erosion of the soil cover of the area. Thus, soils are also subject to serious erosion due to socio-economic reasons. Oil-contaminated soils are classically divided into three types based on the level of contamination: weak (below 5%), medium (5-7%) and high (above 7%). However, in the research conducted by Khuduzade and Gasimova, this division was slightly modified and given as follows (Khuduzade & Gasimova, 2019).

1. Relatively clean lands - areas where natural ecological conditions are not disturbed, including Khirdalan, Guzdek, Fatmayi, Yeni Yashma, Shikhlar, etc.
2. Lands with relatively degraded natural and ecological conditions, including areas such as Gobustan, Dubendi, and Zira.
3. Areas such as Sabunchu, Balakhani, Ramana, Zabrat, Lokbatan, Garadagh and Sangachal, whose natural and ecological conditions have been seriously disrupted.
4. Areas such as Binagadi, Pirshaghi, Garaheybat, Masazir, etc., whose natural ecological state has reached a crisis level and has been subjected to catastrophic changes

As you know, soil pollution with oil and oil products is usually an irreversible process, and sometimes requires high capital investment for restoration, as during pollution, its physicochemical, morphological, biological properties and productivity decrease, and the structure of the soil changes. Direct observation of pollution in the AR is possible in the morphology of the genetic layers of the oil-contaminated soils of Balakhani. In the studies conducted by Guliyev and others in 2023, soil samples were taken from various areas of the Absheron Peninsula (Guliyev et al., 2023).

1. Oil-contaminated grayish-brown soils of south-facing slopes within oil fields. Vegetation ephemeral, camel thorn grass, wormwood, clover formations.
2. On the right of the Binagadi-Balakany highway, intersection with land plot No. 1, located 100 m southwest. The microrelief is smooth, sloping to the south, the soil is gray-brown, the granulometric composition is clay, rich in soil-forming rocks, small stones, sand, various marine sediments, ephemeral plants, grasses, meadows, clover, wormwood. There is no groundwater, swamp, or erosion.
3. In the territory of oil field No. 2, 300 m southeast of section No. 1, on the Binagadi-Balakany road, on a smooth micro-sediment, between oil wells, a large oil-contaminated hardened area. The relief is bare; there were oil wells that were then removed, there are concrete foundations, herbaceous plants are ephemeral, wormwood, grass, etc.
4. An oil well is located 80-100 m east of the highway in the territory of Binagadi oil and gas field No. 2, on the right side, near a smooth micro-slope with an underground water channel flowing towards Lake Boyukshor. Clayey, sandy, oil-contaminated, relatively hardened surface.

As a result of research conducted on oil-contaminated soils of the Absheron Peninsula, it was proven that while part of the light fractions of oil evaporate on the peninsula, the remaining part is absorbed into the soil. In the case of heavy fractions, on the contrary, they settle on the surface of the soil, disrupting aeration there, destroying living organisms, especially fungi, which are oxyphilic organisms. This pollution diffuses to a depth of 2 m, and the heavy fraction of oil prevails in the 0-16 cm section. During the spectral analysis of the light and heavy fractions, it was determined that both toxic and non-toxic micro and macro elements in the composition of Absheron oil are above the permissible limit (Babayeva, 2008).

Soils are contaminated with oil and oil products from several sources (during oil spills, during oil extraction and processing, from oil wells, pipelines, accidents on railways and automobiles). This increases the ecological threat

in the area for many years, causing serious damage to the air, water, soil ecosystem and its biota. There are up to 7,000 oil wells on the Absheron Peninsula. Up to 5,000 of them are actively operating, and the main source of oil pollution on the peninsula is oil and well water discharged from these wells (Babayeva, 2008).

Recently, the number of oil-contaminated land plots in Azerbaijan has been steadily increasing as a result of unauthorized interventions in oil wells for theft. At the same time, not only do such plots increase several times, but the amount of oil in these plots rises to 100-400 g/kg. Moreover, this is not the only problem in Azerbaijan in this area, as spills in oil wells, the use of old equipment, and accidents during oil transportation also lead to a further deterioration of the ecological situation. Another problem occurs during the construction of oil wells, when a large amount of drilling cuttings is discharged, which has a serious negative impact on the environment (this amount is 6000-8000 m^3 when drilling a 4500-5000 m well). The technology used in this process, the water system, and the discharged water are also among the main factors affecting the state of the environment (Ismayilov, 2007).

Absheron oil has a number of unique properties. Thus, Baku oil is characterized by the predominance of naphthenes in the composition of tricyclic-saturated hydrocarbons in a specific homologous sequence of n-alkylcyclopentane and n-alkylcyclohexane. The soil, due to its characteristics, texture, pH, water capacity, porosity, oxygen regime, and the complexity of climatic conditions, reacts in a unique way to the biodegradation and decomposition of oil. The main factor directly affecting the decomposition ability of petroleum hydrocarbons is the molecular weight of hydrocarbons. In addition, the high density of Absheron oil (0.917-0.925 g/cm^3), acidity of 2.88-3.75 KOH g, boiling point +238–248 ^{0} C and freezing point -7–10 °C also affect its decomposition. In addition, considering the lack of low molecular weight n-alkanes, the high abundance of saturated polycyclic alkanes in our oil-contaminated soils, and the influence of local ecological conditions, this process is quite weak even a hundred years after the contamination, making the use of appropriate technologies necessary (Wei et al., 2021).

In other studies conducted on oil-contaminated soils of the Absheron Peninsula, the gray-brown soils of Binagadi, Sabunchu, Surakhani and Koroglu (Azizbeyov) districts of the peninsula were studied, and the mechanical, physicochemical properties, morphological and genetic characteristics and agrochemical composition of these soils were studied comparatively. Then, the radioactive background of oil-contaminated soils and relatively clean soils was evaluated and compared. The amount of humus in Binagadi district was studied, and it was determined as a result of the studies that the amount of humus in the soil varies from 0.64% to 1.44% depending on the degree of oil contamination of the soil and that there is a negative correlation between oil contamination and the amount of humus. Finally, the incidence of various diseases (infections, respiratory, cardiovascular, and digestive system diseases) in people living near relatively clean and NDT areas was studied, and it was concluded that people living near NDT are more exposed to such diseases (Hekimova, 2005).

Impact of oil pollution on biota:

Oil pollution causes negative changes in the biocenoses of the soil ecosystem. This effect is first manifested in the soil fauna. Thus, higher animals have several types of relationship with the soil, some of which use the soil as a habitat and spend their entire lives in the soil (naked blind mice, moles), while a group of animals uses the soil only for nesting and reproduction (Arabian hares, island rabbits and most rodents). The groups in question belong to the megafauna of the soil, and they are the first victims of the toxic effects of oil. The next victims are representatives of the macro and mesofauna that have settled in the soil. They die both from the toxic effects of oil and from a lack of oxygen as a result of impaired aeration (Barron et al., 2020; Li et al., 2020; Tukenova et al., 2020; Zheng et al., 2022).

Plants, in turn, suffer greatly from the effects of oil. Some plants are sensitive to the effects of oil and quickly die. However, some plants can live in oil-contaminated soils and can be used in their cleaning. During the study of the phytotoxic

effect of gray-brown soils of Absheron contaminated with oil and oil products, it was found that the said pollution reduces the germination percentage of plant seeds, weakens the growth of roots and the ability of plants to sprout, and causes a decrease in the total biomass of plants. It was determined that in oil-contaminated soils, depending on the concentration of oil, there is a 60-82% decrease in the germination of plant seeds, and the length of the roots decreases by 4.5 times (Aliyeva, 2024).

Of course, when talking about the soil ecosystem, microorganisms distributed in the soil should not be overlooked as the widest range of species diversity in this ecosystem. The biomass and species diversity formed by microorganisms in the soil are incomparably greater than other groups. These organisms both live and reproduce in oil-contaminated soils and carry out oil biodegradation by feeding on oil hydrocarbons, which is why these properties are widely used in the bioremediation of oil-contaminated soils (Cabral et al., 2022; Sui et al., 2021).

Based on the results of studies conducted in our republic, we can say that oil pollution significantly reduces the number and species composition of both bacteria and fungi, causes changes in the composition of dominant species, and increases the number of species such as *Proteobacteria*, *Pseudomonas*, *Pseudoxantho-monas*, and *Pseudoallescheria.* On the other hand, the high content of carbon and Cu in oil-contaminated soils and the low content of nitrogen and potassium in oil-contaminated soils compared to clean soils are the main factors that cause the reshaping of the microbiota there and the change in dominant species (Li et al., 2022).

In another study conducted in the Republic of Azerbaijan to investigate the effect of the chemical composition of oil on microbiota, samples were taken from Kursangi and as a result of the analysis of the salt content, it was determined that chloride and sodium ions predominate in the produced water. The amount of Na^+ and Cl^- ions in produced water is an indicator for the ecosystem, which in turn causes salinization of the soil, leading to the death and erosion of plants there. In water, it is characterized by the deterioration of the living conditions of hydrobionts, a decrease in their number and species composition. As a result of the studies, it was determined that 1 ml of produced water taken from the Kursangi oil field contains 170 mg/l H_2S (which is also a result of the activity of bacteria in the produced waters). The corrosion aggressiveness of produced waters was studied at 50°C for 5 hours, and the corrosion rate was determined to be ρ=0.77 mm/year, which is further enhanced by the recently widely used sulfurous oil refining. Therefore, in-depth investigation of the corrosion process and finding solutions remains a pressing issue today, considering that the damage caused by corrosion is estimated at millions of manats per year (Aliyeva et al., 2023).

During the studies conducted to study the mycobiota of oil-polluted soils in Azerbaijan, it was determined that while the number and species composition of microbiota in contaminated soils were the same as in clean soils in the first stage (1868), the composition of microbiota in soils around the wells that were completed in 2003 was extremely poor, and in wells that are still in operation, the species and number composition were still normal. In the first case, the satisfactory state of the microbiota is explained by the self-repair of those soils, in the second case, the deficiency in the microbiota is explained by the destruction of biota by the toxic effect of oil, and in the third case, the satisfactory growth is explained by the use of oil as food by microorganisms (Babayeva, 2008).

In order to study the mycobiota of oil-contaminated soils of the Sabunchu, Balakhani, and Garadagh regions of the Absheron Peninsula, soil samples were taken in 2002-2006, and the fungi isolated from them were identified. At that time, it was determined that up to 45 species belonging to 3 divisions and 19 genera belonging to true fungi (Mycota or Fungi) were distributed in the area. 31 species were included in the Deuteromycota division, which is the richest division in terms of species diversity, constituting 65.0% of the total mycobiota. Then, 9 species were attributed to the Zygomycota division and 5 species to the Ascomycota division. The enzymatic and phytotoxic activity of the identified fungi was studied (Aliyeva, 2007).

During the study of fungi biodiversity of soils exposed to technogenic impact, samples

were taken from the soils contaminated with oil and oil products, contaminated with industrial waste and exposed to technogenic impact, selected as the research area and fungal species were identified. At this time, it was determined that *Aspergillus nidulans, A.solani, A.ustus, Candida alpicans, C.lipolytica are widespread in the oil-polluted soils of Azerbaijan, Aspergillus ruber, Penicillium granulatum, Trichoderma viride* are widespread in the soils contaminated with industrial waste, and *Aspergillus versicolor, Fusarium oxysporium, F.semitechtum, F.sporotrichiella* and *P.variabile* are widespread in the soils exposed to technogenic impact. In the current research work, the toxic activities of these species were further studied (Alkishiyeva, 2016).

In the conducted studies, it was determined that almost all of the identified species belong to mesophiles in terms of temperature, and a very small number (*A.niger, Ch.cellulolitucum* and *Ch.globossum*) belong to thermotolerant species. The researcher concluded that it is incorrect to take the ratio of polyphenol oxidase and peroxidase activities as humification activity. Thus, the researcher determined that there is no correlation between the ratio of the activities of the aforementioned enzymes and the degree of oil pollution and structural changes occurring in mycobiota (Aliyeva, 2007).

In 2006, more than 100 soil samples were taken from the Garadagh region of Absheron, fungi were cultured, and during identification, it was determined that the strains belonged to 45 species. These mainly belonged to the three departments Zygomycota, Ascomycota and Deuteromycota, with the most widespread genera at the genus level being *Mycor* and *Chaetomium*. Among the species, information was provided about *Absidia ramosa, Mucor circinelloides, M. racemosus, Rhizopus oryzae, Mortierella alpina, Yarrowia lipolytica, Pichia minuta, Chaetomium celluloliticum, and Chaetomium globosum* (Ibrahimov and Aliyeva, 2009). Extensive and comprehensive studies in recent years have been conducted directly by us.

Aim of the study: The aim of the study is to clarify the impact of oil on microorganisms and other living groups distributed in oil-contaminated soils of Azerbaijan and to emphasize the importance of considering the toxic effects of soil during bioremediation.

RESULTS AND DISCUSSION

It is possible to observe that there is not enough oil-contaminated land on the Absheron Peninsula, and also, taking into account the physical-geographical and ecological factors of the peninsula, there are a number of difficulties in cleaning the land. In particular, the toxic effect of oil on animals and most higher plants, as well as the changes caused by oil in the structure of the soil, leads to the destruction of oxyphilic microorganisms there.

Considering the topic from the historical aspect of the oil industry, the region, as the area where the first oil was extracted on land, has faced this problem for many years. Also, when the republic was part of the USSR, there was continuous exploitation of oil wells, which reached its peak during World War II. Of course, against the background of such a high oil demand, the exploitation of wells in turn led to the further depletion of oil-contaminated land areas and the deepening of pollution.

In modern times, many processes contribute to the problem of oil pollution. Referring to the literature, we can say that the source of the problem of oil pollution of soils is the operation of oil wells (old equipment, oil leakage during operation, discharge of oil cuttings into the environment during well drilling and the water used at this time); illegal interference with oil wells; accidents during oil transportation and accidents of cars and freight trains, oil spills into the environment and oil spills, etc.

Regarding the impact of oil on biota, most higher plants and animals cannot withstand even low concentrations of oil. However, some plants, thanks to their phytoremediation properties, can survive in oil-contaminated soils and be used in their cleaning. Microorganisms, on the other hand, are more tolerant to the effects of oil and, in comparison with other groups, spread more widely in those areas and carry out oil biodegradation.

In conclusion, to summarise all that has been said, there are more than ten thousand hectares of oil-contaminated land in Baku and the Absheron

Peninsula of the Republic of Azerbaijan, and the remediation of these areas is a rather urgent issue. The toxic effect of oil and the changes it causes in the structure of the soil endanger the biodiversity of biota and complicate remediation work. However, since microorganisms are more widespread in contaminated soils than plants and animals, their use, especially fungi, in bioremediation is more appropriate.

At the same time, the toxic effect of oil manifests itself in different forms in the life of organisms belonging to different groups, creating negative changes. Although the basis of toxicity in the soil is created by oil products, sometimes the microbiota there can also cause toxicity. The toxic background of the soil is also of particular importance for bioremediation, as this background tells us when to move plants to the area.

REFERENCES

Abdullayeva M.Y., Sultanova G.D. (2021) Cleaning of oil-contaminated lands in the climatic conditions of Azerbaijan. In: *Experimental and teoritical reseraches in modern science, p. 45* **(in Russian)**

Aliyeva I.B. (2024) Assessment of the impact of oil and oil products on the environment and living organısms. *Adv. in Biol. & Earth Sci.*, ***9*(1):** 161-167; doi: 10.62476/abes9161.

Aliyeva I.B. (2007) Mycobiota of oil-polluted soils of Absheron. *Dissertation submitted for the degree of Candidate of Biological Sciences*. 154 p.

Aliyeva N., Aghamaliyeva D., Huseynova J., Mammadov E., Hamzayeva G. (2023) Study of the chemical salt composition of the formation water from Kursangi oil field of the Republic of Azerbaijan. *Processes of Petrochemistry and Oil Refining*, **24(4):** 770-777; doi: 10.36719/1726-4685/96/770-777

Alkishiyeva K.S. (2016) Species composition and ecology of toxigenic fungi (on the example of Baku city). *Abstract of the dissertation submitted for the degree of Doctor of Philosophy in Biology*, 23 p.

Babaev M.P., Ismailov N.M., Nadzhafova S.I., Keiserukhskaya F.S., Orudzheva N.I. (2020) Approaches to determining maximum permissible concentrations of oil and oil products for different soil types on the basis of the assimilation potential (by the example of Azerbaijan soils). *Eurasian Soil Science*, **53:** 1629-1634; doi: 10.1134/S1064229320110046.

Babayeva I.T. (2008) Distribution of mycobacteria in oil-polluted soils of Absheron. *Dissertation submitted for the degree of Candidate of Biological Sciences*, 152 p.

Barron M.G., Vivian D.N., Heintz R.A., Yim U.H. (2020) Long-term ecological impacts from oil spills: comparison of Exxon Valdez, Hebei Spirit, and Deepwater Horizon. *Environmental Science & Technology*, **54(11):** 6456-6467; doi: 10.1021/acs.est.9b05020

Cabral L., Giovanella P., Pellizzer E. P., Teramoto E.H., Kiang C.H., Sette L.D. (2022) Microbial communities in petroleum-contaminated sites: structure and metabolisms. *Chemosphere*, **286:** 131752; doi: 10.1016/j.chemosphere.2021.131752

Devatha C.P., Vishnu Vishal A., Purna Chandra Rao J. (2019) Investigation of physical and chemical characteristics on soil due to crude oil contamination and its remediation. *Applied Water Science*, **9:** 1-10; doi.: 10.1007/s13201-019-0970-4

Elsaigh W.A.H. Oluremi J.R. (2022) Assessment of Geotechnical Properties of Oil Contaminated Subgrade Soil. *Soil and Sediment Contamination: An International Journal*, **31(5):** 586-610; doi: 10.1080/15320383.2021.1985079

Guliyev A., Babayeva T., Abdullayeva M. (2023) Characteristics of oil-contaminated gray-brown soils of the Absheron Peninsula. In *E3S Web of Conferences*, **419:** 03003. EDP Sciences; doi: 10.1051/e3sconf/202341903003

Hajiyeva G.N., Ibrahimova L.P. (2024) Ecological problems of technogenically disturbed lands on the Absheron Peninsula. *Journal of Geology, Geography and Geoecology*, **33(1):** 70-76; doi: 10.15421/112408

Hashimov S., Zawadzki J. (2022) Observations of the oil-polluted soil of Absheron Peninsula using Landsat 8 OLI and Sentinel 2A imagery. *Acta Montanistica Slovaca*, **27(3):** 607-619; doi: 10.46544/ams.v27i3.04.

Hekimova N.F. (2005) Ecological fertility model of oil-bearing soils of the Absheron Peninsula.

Dissertation submitted for the degree of Candidate of Biological Sciences, 148p.

Ibrahimov A.Sh., Aliyeva I.B (2009) Mycobiota of oil-polluted soils of Absheron. *Baku University News,* **1:** 36-39.

Ismayilov N.M. (2007) Cleaning of oil-contaminated soils and drilling cuttings. Baku: "Tehsil" NPM: 168 p.

Khuduzade A.I., Gasimova E.E. (2019) Ecological condition of the areas contaminated with oil and oil products on the Absheron Peninsula. *European Journal of Natural History*, **2:** 12-16.

Li Y., Li C., Xin Y., Huang T., Liu J. (2022) Petroleum pollution affects soil chemistry and reshapes the diversity and networks of microbial communities. *Ecotoxicol. and Env. Safety*, **246:** 114129; doi: 10.1016/j.ecoenv.2022.114129

Li Y., Wang X., Sun Z. (2020) Ecotoxicological effects of petroleum-contaminated soil on the earthworm Eisenia fetida. *Journal of hazardous materials*, **393:** 122384; doi: 10.1016/j.jhazmat.2020.122384

Sui X., Wang X., Li Y., Ji H. (2021) Remediation of petroleum-contaminated soils with microbial and microbial combined methods: Advances, mechanisms, and challenges. *Sustainability*, **13(16):** 9267; doi: 10.3390/su13169267

Tukenova Z., Akylbekova T., Alimzhanova M., Ashimuly K., Saparov A. (2020) Environmental assessment of the impact of technogenic factors on the soil mesofauna of the South-East of Kazakhstan and development bioindicative and indicative factors. *ARPN Journal of Engineering and Applied Sciences*, **15(22):** 2706-2712.

Wei X., Bocharnikova E.A., Matichenkov V.V., Demin D.V. (2021) Age-old transformation of oil hydrocarbons in polluted grey-brown soil in the Absheron Peninsula. In: *IOP Conference Series: Earth and Environmental Science*, **931(1):** 012006; doi: 10.1088/1755-1315/931/1/012006

Zheng X., Wang H., Tao Y., Kou X., He C., Wang Z. (2022) Community diversity of soil meso-fauna indicates the impacts of oil exploitation on wetlands. *Ecol. Indicators*, **144:** 109451; doi: 10.1016/j.ecolind.2022.109451.

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