

The Impact of Oil Industrial Operations on the Contamination of Soil Ecosystem by Harmful Chemicals

Hadiya Khalilova¹, Vagif Mammadov²

¹Institute of Physics of ANAS, AZ1143, Baku, Azerbaijan

²Institute of Geology and Geophysics of ANAS, AZ1143, Baku, Azerbaijan

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ABSTRACT

Harmful chemical contaminants are defined as containing compounds causing potential risk to both human health and the environment. Problems of chemical contamination of the environment concern all the industrially developed regions worldwide.

The chemical contaminants can be divided into the following groups:

- oil and oil products;
- heavy metals and biologically non-degradable synthetic organic compounds;
- biologically degradable organic compounds;
- low toxic inorganic compounds (they basically include inorganic salts).

Oil and oil products are considered as most priority contaminants due to their toxicity, migration and accumulation ability. It is well known that hydrocarbon resources development, transportation and use are followed by the release of a huge amount of hazardous chemicals into the environment. Being interacted with other components of ecosystem, soil becomes the main source of most toxic compounds. The results of the studies carried out in this area have shown that the development of hydrocarbon resources significantly increases the levels of chemical contamination in soil ecosystem. Both natural and man-caused processes are responsible for soil pollution during oil and gas operations. Crude oil, natural gas, produced water and rocks are the natural sources of contaminants. Crude oil constitute a great number of chemical compounds such as hydrocarbons and various heterocyclic substances, which include little amounts of nitrogen, oxygen, sulphur, metals and natural radionuclides. The hydrocarbon composition of oil contains alkanes, cycloalkanes, hundreds of unsaturated aliphatic and aromatic hydrocarbons. The major part of crude oil includes:

- Alkanes (paraffins) in the form of gas, liquid and solids. In comparison with the majority of hydrocarbons, alkanes are easily biodegradable and less harmful to the ecosystem.
- Cycloalkanes (naphthenes). These compounds include 5-6 carbon atoms rings. They are stable and degrade difficultly. Crude oil may contain up to 30-60% naphthenic compounds.
- Aromatic hydrocarbons make up 20-40% of oil. These include volatile (benzene, toluene, xylene), bicyclic (naphthalene), tricyclic (anthracene, phenanthrene) and polycyclic compounds.

Getting in soil, oil hydrocarbons are subjected to various changes depending on the conditions. Microbial degradation of hydrocarbons occur under microbes influence. The studies indicate that microorganisms activity is very low in the oil contaminated soils. The microbial degradation of such light fractions of oil as n-paraffins, phenols and thiols, etc. proceed slowly. The asphaltene-tar fraction of oil is more environmentally dangerous, because of their non-biodegradability.

Among other oil hydrocarbons, polynuclear aromatic hydrocarbons (PAHs) are especially dangerous for ecosystem. PAHs are also obtained during the use of hydrocarbons and other carbon containing fuels. PAHs



released into atmosphere as a result of fossil fuel burning spread to wide distances. The most dangerous for human health PAHs – benzo(a) pyrene is mainly found in exhaust gases. In atmosphere, PAHs form suspended particles that can spread to large territories and transform to other pollutants through photochemical reactions. Further, these pollutants return to the earth surface and accumulate in soils and bottom sediments of surface waters.

As it was mentioned above, crude oil has certain amount of trace elements. From the ecological viewpoint, they are divided into two groups: toxic and non-toxic. Among them Si, Fe, Al, Mn, Ca, Mg and P are low toxic microelements. V, Ni, Co, Pb, Cu, As, Hg and Zn have negative impact on biocenosis at high concentrations. About 10⁻³ % toxic metals and halogens are found in the asphaltene-tar fraction of oils. Some of metals are in the form of salts of organic acids, and others in the form of chelate complexes.

Produced water is most hazardous natural pollutant of the environment. They contain various ions, oil and dissolved gases, such as CO₂ and H₂S. Both the oil polluted rocks and produced water cause pollution of the ecosystem components, first of all soil cover. The rocks obtained from oil extraction may constitute of 1-5% even 10% hydrocarbons. Depending on the pollution level, they can form complex substances with Fe and Al ions and various soluble complexes thus leading to the depletion of important minerals in soil.

Drilling solutions and drill cuttings are by volume the largest anthropogenic waste formed when exploring and development of oil fields. These discharges include water-oil emulsions, corrosion inhibitors, surface active agents, Ca (NO₃)₂, Mg (NO₃)₂, HCl, KCl, NaOH, NH₄OH, various polymers and mechanical mixtures, etc.

Light fractions of hydrocarbons easily migrate to deeper sections of soil, and therefore, increased content of heavy asphaltene-tar fraction accumulate in the upper layers. The asphaltene-tar fraction of oil is toxic and difficult degradable. This fraction contains the most toxic environmental pollutants – heavy metals. Potential threat of heavy metals to ecosystem components, especially to human health, is associated with two factors: high toxic impact at low concentrations and bioaccumulation abilities. Many of them like Hg, Pb, Cd, Cr, Zn and Cu can be very toxic to the ecosystem. Heavy metals are mainly gathered in soils and bottom sediments. Concentrated in soils heavy metals can be adsorbed and accumulated in different parts of plants through root system. One of the major global problems of the present days – acid rains can wash heavy metals from soil rocks into lakes, rivers and bays. Most of heavy metals disrupt enzyme function forming bonds with sulfur groups in enzyme and may eventually kill living organisms. Due to their migration and accumulation in the environment, most heavy metals can easily enter the food chain and create serious threats to human health. The negative effects of heavy metal contamination are viewed as global concern.

The results of researches devoted to the impact of oil contamination on the soil microbiological peculiarities and plants quality have shown that the cereals cultivated in these soils contain increased quantities of Pb, Cd, Fe, Ni, Zn and Cu. High concentrations of heavy metals in soil can damage fertility and productivity of the farmlands. It was revealed that high concentration of heavy metals in the oil polluted soils not only affects the plant quality, and also reduces the number and activity of microbes. The results confirmed that the number of heterotrophic bacteria was 89% lower in oil polluted soils compared to unpolluted soils.

Taking into consideration all the above stated, it can be concluded that the activities associated with the development of hydrocarbon fields lead to the release of large amount of chemicals to ecosystem causing serious problems including contamination and degradation of soil resources.

Therefore, it is necessary to treat the waste formed during oil-gas operations properly prior to their discharge into the environment. The great attention should be paid to the development of contaminants minimization and pollution preventing measures to ensure ecological safety throughout the industrial territories.