

# Crude Oil Pollution in Soil: Causes, Effects and Remediation

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Crude oil is a naturally occurring, unrefined petroleum product composed of hydrocarbon deposits in natural underground pools or reservoirs and remains liquid at atmospheric pressure and temperature. Although it is often called "black gold," crude oil has a wide-ranging viscosity and can vary in color to various shades of black and yellow depending on its hydrocarbon composition. Crude oil can be refined to produce usable products such as gasoline, diesel and various forms of petrochemicals.

Even though most crude oil is produced by a relatively small number of companies, and often located in remote locations far from the point of consumption, trading in crude oil on a global basis has always been robust. Nearly 80% of international crude oil is transported through waterways in large tankers and most of the rest by inland pipelines

**Table 1: Composition of crude oil**

Element	Weight (%)	Hydrocarbons	Weight (%)
Carbon	83-87	Paraffin	30
Hydrogen	10-14	Naphthene	49
Nitrogen	0.1-2	Aromatics	15
Oxygen	0.1-1.5	Asphaltic	6
Sulfur	0.5-6		
Metals	<0.1		

Crude oil is composed of volatile liquid hydrocarbons with varying molecular weight and structure. It contains more than 17,000 hydrocarbons and its classification are based on the most prevalent compound present in it. The three main hydrocarbons components present in crude oil are compiled in Table 2.

## Transportation of crude oil

### 1) Pipeline transportation of crude oil

Crude oil pipelines are the most common, safest, and cheapest of all modes of crude oil and

refined product transport. With a high upfront investment cost their long-term payoff comes from decades of use

**Table 2: Three main hydrocarbons components present in crude oil.**

Paraffins	Methane
	Ethane
	Octane
Naphthenes	Benzene
	Toluene
	Xylene
PAH	Naphthalene
	Anthracene
	Benzopyrene

### 2) Crude oil transportation through barges

Marine transport, largely via barge or tanker, is the second cheapest mode of oil shipment. This is especially true for companies that export crude oil internationally.

### 3) Transporting crude oil through rail

Not all oil wells are accessible via pipeline, making rail the most financially feasible option for accessing land-locked oil wells that later feed the refining landscape.

### 4) Crude oil transportation through truck

Over-the-road transportation is the most expensive and inefficient means of crude oil transportation. The amount of crude oil an average truck can transport is only between 200-250 barrels of oil per movement. This makes it an expensive and inefficient option. This method is typically utilized only when wellhead locations are not accessible by pipeline or rail networks, or for short distances during final-mile segments of the movement.

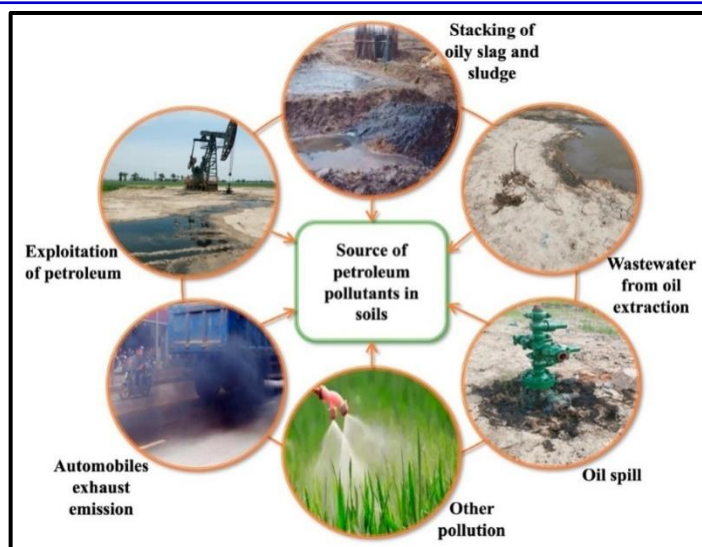


Fig. 1 Sources of petroleum pollutants in soil

### Environmental behavior of oil pollutants in soil

- Soil is an important part of human environment. It is a multi-medium complex system composed of solid-liquid-gas-biology.
- The environmental behaviors of oil in soil mainly include:
  - ✓ **Migration,**
  - ✓ **Adsorption**
  - ✓ **Degradation**
- The environmental behavior of petroleum in the soil and its harmful pollutants will infiltrate into the soil and remain in the soil. Because there are a large number of organic and inorganic colloids, soil plants, animals and microorganisms in the soil.
- The pollutants entering the soil are continuously adsorbed, decomposed, migrated and transformed through the physical, chemical and biological processes of the soil. Generally, the migration ability of oil in the soil is very weak, and it is mostly absorbed and concentrated in the surface soil.
- The oil on the soil surface can be self-purified by volatilization. When the pollution intensity is high and the content of small molecules of hydrocarbons is high, they can migrate into the groundwater aquifer.

### Remediation of oil polluted soils

#### Chemical methods

- ✓ Chemical oxidation is an efficient method to remove dangerous wastes from the soil at the oil spilled sites. The efficiency of this method strongly depends on the soil matrix.
- ✓ Fenton's reagent, a mixture of Hydrogen peroxide and Ferric ion, is used for chemical oxidation. Hydrogen peroxide is a strong oxidizing agent that generates hydroxyl ions during Fenton's reaction while ferric ion acts as catalyst. Hydroxyl ions are very powerful and effective agents that destroy the contaminants present in the soil.
- ✓ Removal of oil from sand at lower pH by using Fenton's reagent is much efficient than at natural pH or peat. Another efficient oxidant that is used for the removal of crude oil from soil is ozone.

#### Physical methods

- ✓ Excavation of crude oil contaminated soil is the quickest and safe way but not a sophisticated and cheap method. The contaminated soil is removed and transported to appropriate landfill for the disposal.
- ✓ The samples are collected from bottom and sidewalls of the excavated area to check if the site is clean or not. Another physical method is the washing of contaminated soil. Washing with organic solvents such as ethanol- water mixture and ethyl acetate-acetone-water mixture exhibited significant removal of hydrocarbons from the contaminated soil.
- ✓ Soil washing does not only treat the oil contaminated soil but also remove the heavy metals from the soil. The efficiency of washing can be enhanced by the addition of surfactants.

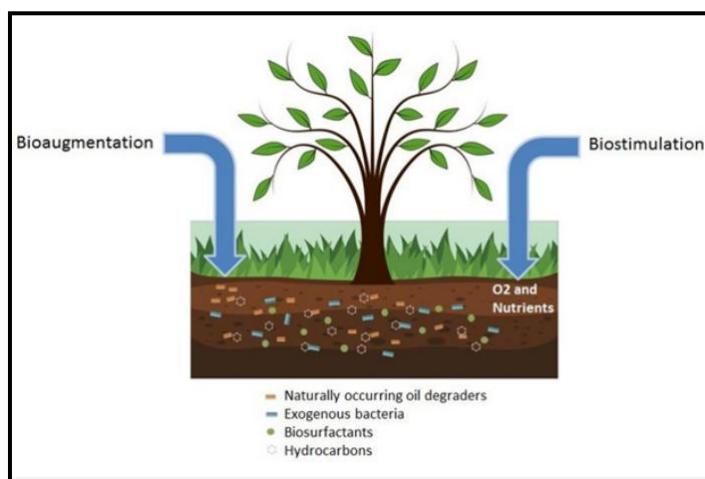
#### Thermal methods

- ✓ In Thermal stripping/low temperature thermal desorption/soil roasting contaminated soil is heated to very low temperature (200- 1000 °F) to increase the vaporization and separation of low boiling point contaminants from the soil.

- ✓ By this process organic contaminants can be completely or partially decomposed depending upon the thermal stripping temperature and organic compounds present in the soil.
- ✓ This method can remove approximately 90% of the contaminants but it is very costly and not eco-friendly. Another way to remove crude oil from the soil is incineration.

## Biological methods

- ✓ Bioremediation is a traditional method that involves the use of living organisms (bacteria, fungi and plants) to degrade harmful substances present in the environment.



**Fig. 2 Strategies to enhance microbial crude oil degradation in soil.**

- ✓ Bioremediation of crude oil from the soil is very efficient, cheap and environmentally friendly solution. The effectiveness of this method is depended on hydrocarbon

concentration, soil characteristics and composition of pollutants.

Microbial remediation of contaminated soil is affected by many factors such as water amount, temperature and pH of soil, concentration of oxygen, soil quality and amount of nutrients. Change in any of these factors can decrease the population of microbes and in turn decreases the bioremediation. Microbial activity can be accelerated by using bioaugmentation and biostimulation strategies.

In bioaugmentation exogenous oil degrading bacteria are supplemented to enhance soil microbiota while in biostimulation addition of nutrients, aeration and optimization of physical conditions like pH and temperature is performed. Research has shown that bioaugmentation and biostimulation when used together effectively remediate crude oil hydrocarbons polluted soil. It has been observed that the number of exogenous bacteria decreases after sometimes because of nutrient unavailability or other abiotic factors (pH, temperature or oxygen).

Therefore, bio stimulation incorporation with bioaugmentation provided effective results in the degradation of crude oil pollutants. Different types of surfactants produced by many microorganisms are called biosurfactants. These biosurfactants enhance the bioavailability of hydrocarbons to the microbes and in turn increases its degradation. Use of biosurfactants producing microbes is a good bioremediation choice as this process is cheap, nontoxic with efficient degradation rate.

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