HTTPS://DOI.ORG/ 10.5281/zenodo.23211934



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The risks of crude oil leakage into the soil, the consequences of petroleum hydrocarbon pollution, and ways to combat it safely

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ABSTRACT

The use of crude oil is a good way to provide a high standard of living and prosperity. However, it has become a disaster for the land and water environment and the atmosphere with its harmful effects, as it contains materials that are harmful to the environment and organisms such as polycyclic aromatic hydrocarbons (PAHs) which led to serious injuries such as mutations and cancer. Since crude oil leaks into the soil more, it causes great damage to the soil and this has become a concern for human health and other living organisms, including plants that are a food source for humans and animals. For this reason, multiple technologies have been invented to eliminate the damage caused by crude oil pollution, and research is still ongoing to reach solutions and treatments that are more beneficial and less costly. The most prominent of these methods is treatment using synergistic use between microorganisms and plants, noting that there are other methods of treatment such as physical, chemical and thermal, but they have many disadvantages, the most important of which is the high financial cost.

Keyword: aromatic hydrocarbons (PAHs), synergistic, Bioremediation

1- Introduction

One of the important topics that has become a source of concern for governments, environmental scientists, and societies is the issue of environmental pollution from oil leaks and the compounds contained in crude oil that harm the composition and texture of the soil and leave a negative impact on plants and living organisms that live in those soils contaminated with petroleum hydrocarbons [31].

Although crude oil is an important source of energy that many countries depend on and provides societies with energy and well-being for life, its arrival to soils and water bodies leads to problems with dire consequences. It is difficult to find professional and radical solutions to oil pollutants. If solutions are found, they are difficult to achieve or expensive. Even if they are solutions that use plants or microorganisms (Bioremediation Technologies), they ultimately lead to the production of unsafe plants in addition to the harm they cause to soil microbial communities. Detoxification of soils contaminated with petroleum hydrocarbons

has always been a global challenge due to the carcinogenic and mutagenic substances and complex aromatic compounds that these pollutants contain[33].

- **Crude Oil**

Crude oil is characterized by a complex composition of different compounds that may reach thousands of complexes that give it the characteristic of thick oil with an unpleasant odor and a distinctive black color, which is relied upon as a source of energy in various parts of the world and oil is used in many refining and petrochemical industries where oil is refined through many different technological processes in consumer industries such as gasoline and paraffin oils [40,21].

indicated that crude oil contains mainly different amounts of carbon, hydrogen, sulfur, nitrogen, oxygen and a variety of compounds containing minerals and is classified as light, medium or heavy oil based on the molecular, components and weight present in it. Its percentage may vary depending on the location, age, depth and on the basis of the composition of the oil well. Crude oil is characterized by four main sections of elements, which are as follows:

1- Classifying them according to their structure into alkanes with linear chains, alkenes with branched chains.

2- Aromatic compounds typically consist of heterogeneous saturated cyclic compounds because they find Nitrogen or sulfur oxygen atoms in their ring, aromatic hydrocarbons, most of these being found linked to each other and forming ring complexes, which are known alkyl groups.

3- Tar and asphalt, which are heavy unknown composition compounds that are solid and of a waxy nature hydrocarbon compound.

4- Non-hydrocarbon compounds include nitrogen, oxygen, sulfur, and some heavy metals [40]. As shown in (Fig.1), this is the composition of crude oil, indicated that crude oil varies in composition and quality from one region to another, from one country to another, and from one extraction field to another, and its color and viscosity range from light brown w region to another, from one country to another, and from one extraction field to another. Its color and low viscosity to dark black with high density. Through studies, microorganisms have been examined near oil fields, pipelines, and crude oil processing facilities for decades. [41]. Microbial degradation of crude oil, both aerobic and anaerobic conditions, has been known for millions of years [12]. Most reservoirs are anoxie to molecular oxygen in the injected water, the oil, and gas may be described as four groups based on solubility in organic solvents and water. According to the authors, these were: hydrocarbons saturated (alkanes, or aliphatic) all branched alkanes; aromatic hydrocarbons; polycyclic aromatic hydrocarbons; and major components of crude oil. Oils and oil derivatives are released to the environment through incomplete combustion or accidental spillage over the oil supply chain. Polycyclic aromatic hydrocarbons make up organic compounds fused benzene or aromatic rings linear, angular, or cluster arrangements diverse in structural configuration.

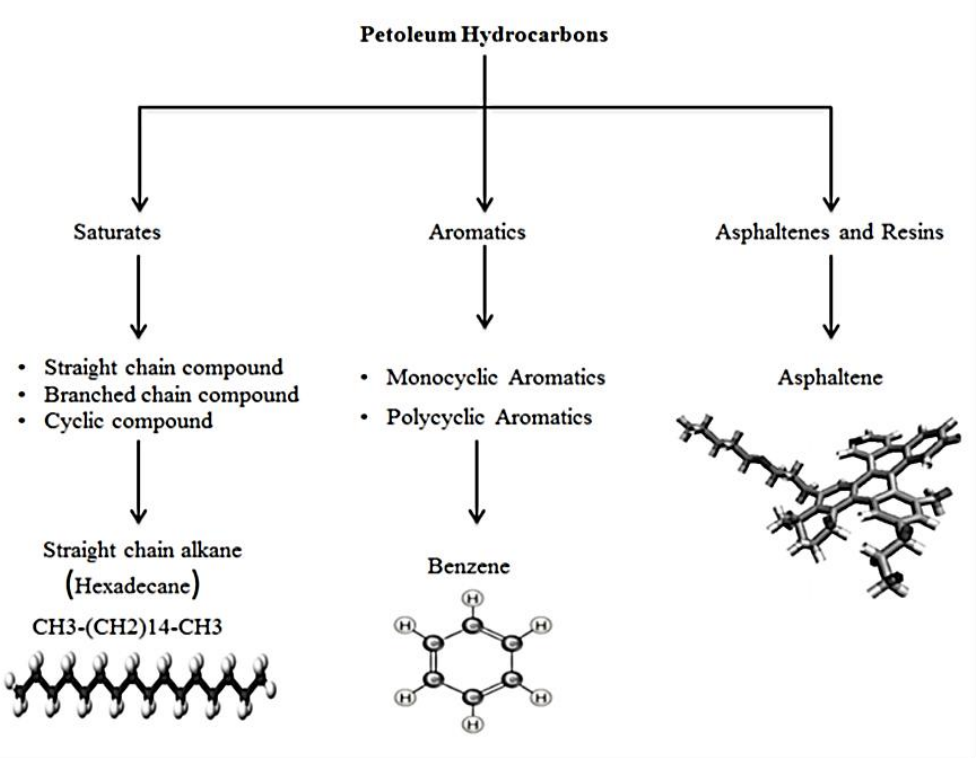


Fig.1 Aliphatic and aromatic compounds [20]

• Damage caused by crude oil to the soil

When surveying the research on the damage of soil contaminated with oil, the following aspects were mainly found:

1- One of the characteristics of oil is that it has a high viscosity coupled with a low density, which makes it easy to penetrate the soil, affecting the soil permeability and porosity of the soil [48] and [22]crude oil is also low in nitrogen compounds and high in carbon, which allows it to change the composition, structure and components of the soil. and organic matter and also affect C, N, P, salinity, pH, heavy metals and electrical conductivity of the soil Ec [11]

showed that nickel and vanadium are heavy metal elements found in oil mixtures and in high concentrations in the soil and that oil field production can harm environmental of the soil.

2- In the natural environment the microorganisms are very profuse in healthy and clean soil in the natural situation. This is consistent with what [6] stated, who also indicated that microorganisms it can be opposed by the severity of oil pollution., while in contaminated soil, have been developed in order to adapt to this type of environment, where a specific enzyme system can be produced and a gradually dominant population can be formed with a symbiotic or synergistic effect. A number of studies have proven, including what [50] did, where he indicated that the restoration of oil-contaminated soil is a complex project at present. Currently, treatment methods are used, mainly physical, chemical, thermal and chemical filtration methods, which can treat contaminated soil on a large scale and quickly, but they are expensive. While there is also a need for some other low-cost treatment techniques. Bioremediation technology has now achieved certain achievements through large numbers of researches, which is what came in the study [48], where the study confirmed that the original microorganisms can maintain high effectiveness and great decomposition efficiency, but very few in nature, and therefore how to separate, sift and cultivate on-site organisms makes them more efficient.

• Treatment methods for soil contaminated with crude oil

1. Chemical Method

Oxidation is a very effective chemical process that can be used to remove hazardous materials and waste from soils at the site of an oil spill. Basically, oxidation methods would be most efficient based on the nature of soils, as confirmed in the study by [8]. In addition, other researchers, Fenton reagent and ozone can be used to oxidize the different chemicals present in the soils [18]. Soil treatment is determined by its effectiveness in relation to soil quality, texture, and the extent and type of organic contamination. According to [47], chemical treatment of oil-contaminated soil involves filtration, oxidation, stabilization, and chemical precipitation. Treatment of soil by the method leads to the formation of harmful and toxic sediments into the environment. It is also not a method that can completely remove pollutants. The chemicals may provide a major threat to soil life and living organisms due to leaching or side reactions and high energy and high-cost involvement.

2. Physical Method

Physical treatments for crude oil-contaminated sites are mainly affected based on the nature of the site, be it soil or water since each is managed under its own special protocol, as indicated by the study by [43]and through the study by [4] drilling is the fastest and safest method of drilling the pollution source in the soil but is not an advanced and expensive way for pollution removal. The soil which is contaminated is excavated and then brought to a proper dumping site for pollution removal and then samples should be taken from the bottom and side walls of the dug area to check if it's clean or not.

3. Method of Thermal

The primary thermal technique, as discussed by [29], he reported that it occurs through the induced erosion by heat and low-temperature thermal desorption of soils contaminated to be desorption it is the percentage temperatures decomposition this was prove and can vary between (200 and 500°) Fahrenheit. Polluted to low values organic i.e, induced rising soils against high-temperature erosion over low can be organic pollutants low within the decomposability by be temperatures and nature achieved partially the some in influenced depending temperature Was Approximately be removed pollutants method this with indicates of the approximately 90% most that expensive not and be although very environmentally also is friendly however, very. And in comparison, to the washing method with organic solvents, as reported by a study by [9], for example, water-ethanol mixture or ethyl acetate-acetone-water mixture, it removes a large number of hydrocarbons from contaminated soil (since washing the soil does not only treat soil contaminated with oil, but also removes heavy metals from the soil. This method is undoubtedly effective, but it is an expensive, complex and often difficult to implement method, as indicated by the researchers [43].

4. Biological method

Bioremediation, according to [43], is an old approach that operates with the exploitation of living organism's bacteria, fungi, and plants. Biological treatment of crude oil in soils is highly effective, low cost, environmentally benign, and time-consuming. The process effectiveness depends on the carbon concentration that serves as an energy source for the living organisms and the soil properties, the composition of polycyclic aromatic hydrocarbons which are the main pollutant group present in crude oil and very resistant and toxic.

plays a major role in slowing down the treatment process. As for [34], they showed that polycyclic aromatic hydrocarbons are trapped in the pores of the soil and then enter the soil and are retained by the soil. Therefore, removing them from the soil is very difficult, and biological treatment is the most suitable because it is a method capable of removing polycyclic aromatic hydrocarbons from the soil through microorganisms and plants, as they can reach the roots quickly and these compounds can be analyzed.

5. Biotechnological role in treating pollution

Biotechnology can be used to assess the development of ecosystems as indicated by [39] who showed that it is possible to convert pollutants into less toxic substances, produce non-harmful biodegradable materials, and develop environmentally safe manufacturing and disposal. Genetic engineering is used to improve efficiency and cost by taking advantage of environmental biotechnology from a suitably mixed living environment between living organisms (plants and microorganisms). [32] This has shown that genetic engineering is going to be the prime driving force for the untapped future use of microorganisms in unburdening the environment from toxic wastes, in view of the pressing need for a viable environmental biotechnology process.

As pointed out by researchers, bioremediation is an emerging approach to rehabilitate polluted or otherwise damaged areas through poor ecosystem management.

6. Bioremediation

[10] defined bioremediation as the use of living organisms to remedy environmental issues, like soil or ground pollution. In this case, we will refer to bioremediation as bacteria removing a pollutant from the environment or preventing it from further polluting the environment. In other words, this is a technology to clean up a pollutant or pollutants from the environment and give back, as much as possible, the original natural environment, and prevent further pollution. When microorganisms, that is, bacteria, are used to remove pollution from a polluted environment, it is termed bioremediation. The environment could be terrestrial-only, aquatic-only, or both. But, defined him can be provided below: Bioremediation is the process of clearing polluted environments by exploiting the diverse metabolic potential of microorganisms to transform the pollutants into harmless end-products through mineralization, water generation, and carbon dioxide. The potential of studying biodegradation by microorganisms was recognized by [27]. They also indicated that even though microorganisms have been used in the processing and conversion of wastes for more than a century, this makes bioremediation somewhat not new thus heightened as environmentally harmless cleanup technology. it is further reported that waste and pollution can be permanently eliminated with additional other upper more costly treatments that are used to be ruled out when bioremediation falls as alternative. Bioremediation technologies can be organized as an integrated approach with the associated treatments; scholastically, because it is natural and, therefore, biological, and perceived as an appropriate method for waste treatment on contaminated soils. It is most treatment by degraders of pollutants, which are microorganisms.

• Types of Bioremediation Technologies

The practicability of bioremediation can be facilitated through different techniques such as bioremediation, bio intensification, bio cultivation, bioassay, biofilters, biostimulation, land cultivation and composting [44].

1. Bioventing

One of the in-situ bioremediation technologies that stimulate oxidation is bioventing. It enhances the inherent potential of indigenous microorganisms to biodegrade organic pollutants adsorbed on the soil by way of oxygenating the unsaturated zone. The induced air goes directly to the zone of contamination (both vertical and horizontal wells) to supply the volume of air necessary to support the decomposition process. An appropriate method of technology that supplies the required quantity of air essential for the oxidation process and minimizes volatilization of the pollutants into the environment is appropriate.

2. Bioaugmentation

Bioaugmentation as explained by [2]indicates that it is the process of introducing a specific mixture of natural or genetically modified microorganism strains that have enhanced capabilities in controlling inoculated sites to increase the natural decomposition process.

(Bioaugmentation is based on the knowledge of a certain number of factors on which much should depend, biotic and abiotic factors, as he discussed in this study, that everything should depend on. Bioaugmentation involves the selection of microbial strains, which possess the ability of pollutant degradation as well as outcompeting native microorganisms in the soil. Sometimes the microorganisms may be genetically engineered for this purpose; Factors include the physical and chemical properties of the soil (composition, types, and concentrations of the pollutants

3. Bio piling

The bioremediation technique as was applied by [49]— not until we had proof of its efficiency in cleaning the soil, yes, but not where soils are contaminated with different classes of hydrocarbons — is known as in situ bioremediation. Which [14] is simply a methodology that used to apply treatment in the place of pollution by presenting large masses of chemically contaminated soil for on-site bioremediation as a treatment exercise. Results of the process applied by [14] over the years in treating large masses of groups of petrochemical pollutants by piling up polluted soils on the surface proved in action. This is then followed by exciting microorganisms with ideal conditions for their growth concerning temperature, nutrients (nitrogen and phosphorus), humidity at optimum level, and control of pH so that growth could be enhanced since as mentioned earlier it was successful in leaching 75% of contamination by petroleum hydrocarbons from amended soil, and 38% of control soil at the end of the observation period. The study also proves the extent to which this technique can dilute pollutants from different types of soils; sandy, clayey, or mixed.

4. Composting

Composting is an advanced aerobic decomposition technology in which organic pollutants are transformed into a substance similar to humus at high temperatures under both aerobic and anaerobic conditions. The wasteland can be further fortified with non-hazardous organic waste like animal waste, agricultural residue, or manure to encourage microbial growth. There can be produced aerobic piles or static piles. Despite the toxic stress put by these substances and minerals found in nature on the microbial activity, microorganisms play a very essential role in a cycle for remediation. The most probable strains of microorganisms are those which have evolved specific chromosomally or extra chromosomally controlled (plasmid) metal detoxification mechanisms to nullify the adverse effect of toxic metal compounds. This was proved by the study of [30]. These mechanisms are ones which prevent the metal ions from entering into the cell or which efflux them out of the cell effectively by very highly specific systems resorted to the different resistance genes. This is also in agreement with the study by [17] They suggested that pathways include biosorption, intracellular uptake, fixation, extracellular take-up and deposition, intracellular uptake and deposition, aqueous sequestration, efflux, oxidation/reduction/demethylation, etc. reactions and volatilization detoxification from outside the cell. Bioremediation has been identified as a very attractive, sustainable, and novel technology based on the study by [38], who also indicated that it will be much more effective in clearing the hazardous pollutants present in the environment than using the typical processes; physical and chemical treatment methods which do not only take up large volumes of waste sludge but also have low detoxification efficiency. With biomass-based treatment processes, there is also a non-toxic material developed and recovered using adsorption technology to recover biomass and quantitative recovery of metals.

5. Phytoremediation

[7] revealed the alternative typical extractants of trace elements from the Plant roots or demonstrate the capability of plants to absorb

Ionic compounds present in the soil at very low concentrations through their roots owing to the structural development of their roots reaching the soil and the effective system in diluting heavy metal accumulation and modifying bioavailability, hence restoring soil health and fertility.

There are advantages of using phytoremediation as pointed out by [15] which include:

(1) Economic- phytoremediation would be considered a solar driven self-feeding process, very easy to handle resulting in low installation and maintenance cost.

(2) Environmentally friendly, it can lower the rate at which pollutants are exposed in the natural environment.

(3) Applicability- it can be pronounced over a large range of scales and has an easy, natural disposition.

(4) Use of plants as remediation. where organic pollutants (oil hydrocarbons) are decomposed through different processes such as root decomposition, plant decomposition.

Based on the findings of [26] plants of high adsorption capacity and high biomass can be suitable for phytoremediation. The tree species are growing in nature for this, that is, high biomass potential, a well-developed root system, and high transpiration; the latter being very effective in influencing the phytoremediation process.

As pointed out by [46], some plants can be used to immobilize, extract, decompose and/or accumulate toxic elements, especially heavy metals and organic pollutants. The use of such treatment in contaminated sites is not easy to implement due to site conditions or difficulty of access and the preference of traditional methods by practitioners. The aim of current research as stated in the studies of [28,1]) are to increase the efficiency of phytoremediation to remove heavy metals and other xenobiotics and includes genetic modification of some plants. Improving the accumulation of metals can lead to the promotion of plants - and the use of plants for metal mining. Although this environmentally friendly method of treating contaminated soil, sediment and water has not been widely marketed and used, it is expected to become more widely used in the future. The efficiency of phytoremediation increases the chances of removing excessive accumulation of heavy metals and petroleum hydrocarbons by plants, as indicated by [36].

• Phytoremediation Mechanics of

Phytoremediation uses (Fig.2) as a low-cost method for treating and cleaning contaminated sites while maintaining biological activity, physical composition and soil fertility. This is consistent with what was stated by [3] Because plants use solar energy to grow and cause the absorption and analysis of pollutants, they are more sustainable than other physical and chemical treatment methods, which are impractical and expensive. Phytoremediation mechanisms are also effective in surface and groundwater, according to a study by [35].

1. Phytoextraction

Phytoextraction was demonstrated by [19] involves the uptake of the metals from soil through plant roots, translocation of these metals to the aboveground plant parts, and subsequent storage within plant tissues in vacuoles, cell walls, cell membranes, and metabolically inactive compartments of plant tissues. The capability of the plant for hyperaccumulation is hence the capacity for an exclusive accumulation of high amounts of heavy metals within its roots and tissues; therefore, it is best to use plants as described in research [5]while a methodology to remove the contaminant from the roots of the plant to the producers is available (vegetative part of the plant above the soil), hence the plant biomass can be collected for proper disposal at the end of the treatment.

2. Plant stabilization / plant stimulation phytostabilization

Treatment can be achieved by blocking the toxic substance or pollutant mobility either in or through the root. Where activity occurs in the plant's root regions and when pollutants are mobile, bioavailability will lead to the reduction of toxic effects. For instance, Ryegrass takes in trifluralin herbicide and turns it into harmless bound residues as reported by [21]. Pollutants can be degraded in the rhizosphere through phytochemical

secretions or trapped at root surfaces by protein transport. Or sequestered inside the root cell vacuole during cellular processes as in the work by [42]. Some pollutants can be converted into non-toxic compounds in sugar derivatives, proteins, amino acids, and certain peptides when they conjugate and are complexed at the roots. An illustration of this is seen with the binding of arsenic at the root epidermis in a plant that takes it up. Binding it within the vacuoles with ferric sulfate to give a trivalent complex of As-tris-thiolate to be formed in the rhizosphere.

3. Rhizofiltration

According to [25], rhizofiltration removes toxic agents by the use of plant roots in treating pollutants (groundwater or Surface water) through absorption, concentration, and eventual deposition on roots or other submerged organs that tolerate heavy elements such as aquatic plants. In their work, [37]assert that plant roots can either absorb pollutants as well as decontaminating soils or cleaning water resources from pollutants. The study mentioned says it is good mainly for heavily polluted soils and waters.

4. Phytovolatilization

Phytovolatilization includes the absorption of organic matter in soil and groundwater by plants and emission through the stomata in plants in the form of gases, according to [23]. This technique works with volatile pollutants whose toxicity is not high once they are broken down in the soil and the atmosphere. Organic pollutants, in most cases, develop the volatilization method quite well.

Compounds may volatilize from the stem and leaves directly; the others volatilize, because the root is interacting with the soil.

Stomata and epidermis and suberin and other plant layers shall work as exit points of organic matter from stem and leaves of the plant. Compounds move up the plant system through respiration, and some come out of some openings to reach the atmosphere during transpiration.

5. Phytodegradation and Rhizodegradation

Alternatively, the roots of plants can metabolize and break down pollutants by what is termed phytodegradation of pollutants in the plant tissue. The possible way of processing organic the kind of herbicides and/or pesticides is degradation or transportation through the different parts of the plant. In phytodegradation, phytodegradation may be dependent on different plant parts, either directly or indirectly since the mechanism of the process is explained by [24].

The plant absorbs pollutants and metabolizes or decomposes them into small parts, becoming less toxic and less harmful compounds, and they are distributed within the plant tissues. This was confirmed by [13]in their study, indicating that there are no active transporters in plants since these organic pollutants absorb passively, i.e. they are freely transferred to the roots.

This process is called root decomposition, which is a biological analysis of organic pollutants by the roots, as it leads to the activation of microorganisms in the root zone, and thus these organisms help in the process of decomposing pollutants. This is also called biostimulation.

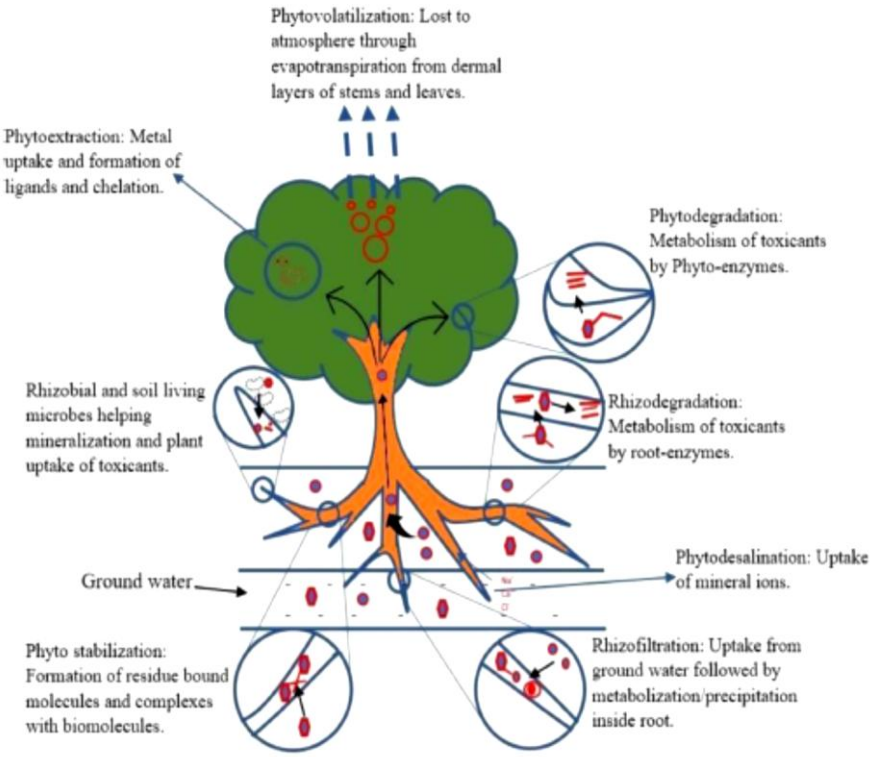


Fig. 2. Phytoremediation Mechanics [16]

3- Conclusion

No matter how important crude oil is, preserving the environment and living organisms is more important The chances of crude oil leaking into the soil may be low under the strict conditions and laws imposed by governments and institutions on oil extraction and refining companies, but even a small leakage requires those interested in the environmental field to quickly solve this problem. Attention to the vital aspect of methods for treating soils contaminated with crude oil.

Conflict of interests: The authors declared no conflicting interests.

4- Sources of funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

5- Author contribution: Authors contributed equally in the study.

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