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Original Research

The Impact of Oil Pollution on the Growth of Local Plants as Bioindicators for Assessing Environmental Pollution Effects

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Abstract: The study explains oil pollution in Dora Refinery and its impact on the proliferation of flora around the refinery, using them as a biomarker in the study of pollution effects. Such studied plants are *Salvia rosmarinus, Eucalyptus globulus, Ficus nitida, Conocarpus lancifolius, Nerium, Eucalyptus camaldulensis, and Dodonaea viscosa.* It is expected that oil pollution is one of the major environmental problems in the Dora Refinery area, seriously polluting the soil and undermining plant survival in the area. This study tries to find out the response of such plants to the oil pollution: growth, reactions to the stress-toxicity mechanism, and assess its representative role in quantification of the impact of pollution on the environment, and adaptability of this species to adverse conditions, which could help in land reclamation and management. The methodology was followed: polluted and non-polluted sites were selected, which were close to the Dora Refinery, collection of soil samples for the cultivation of selected plants was done. The growth rates were measured; further biomarkers pertinent to oil pollutant exposure were monitored. In fact, the methodologies included assessment of oil pollutant levels in the soil, plant stress markers such as chlorophyll levels, antioxidant enzyme activities, and toxicity assessment as reflected by the accumulation of heavy metals and hydrocarbon pollutants. The results indicated that the growth rate of plants grown on polluted soil was much slower than that in a cleaner environment. It was indicated that *Salvia rosmarinus and Dodonaea viscosa* showed marked accumulation of hydrocarbon pollutants, while *Eucalyptus globulus* and *Conocarpus lancifolius* were more resistant to contamination. Besides, it demonstrated distinct features of environmental stress-an obvious decrease in chlorophyll content and an increase in the activity of antioxidant enzymes in polluted plants. These plant species may be good biological indicators in determining oil pollution effects, since their levels of tolerance

varied among species. In fact, physiological characteristics of each plant kind might have a greater impact on the susceptibility to oil pollutants and thus provide useful insights in environmental monitoring programs and management strategies in contaminated areas.

Key Words	Pollution, toxicity, environmental stress , bioindicators, native plants
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1. INTRODUCTION

Oil pollution is among the most dangerous contaminants found in industrial areas, such as those where refineries, like the Dora refinery area in Baghdad, are located. Oil spills and waste resulting from accidents in oil-related processes lead to the contamination of soil with harmful substances, resulting in a wide-scale negative effect on the local flora and disturbing the ecological balance. Plants that are present in the polluted soil face multiple issues, majorly the impact of these pollutants on their growth as well as their susceptibility to environmental toxicity as well as stress caused by these pollutants. As mentioned by Zeki *et al.* 2019, previous studies have proved that an increased oil pollutants' concentration significantly m downgrades the plant growth process. A study conducted by (Afolabi, *et al.* 2022) reported that plants grown in oil-polluted soil usually experience stunted growth due to the fact that the amassed chemicals reduce the ability of the roots to absorb vital elements required for plant growth. Another study by (Alkindi, *et al.* 2023) has also pointed out that oil pollution causes physiological changes in plants by affecting main processes such as photosynthesis and cellular respiration, which will lead to a decrease in growth and adaptation to their surrounding area.

Plants succeeding in oil-polluted conditions are exposed to toxic agents at higher levels, including the polycyclic aromatic hydrocarbons and heavy metals. The latter exerts toxic effects on the plant cells by way of interference with important cellular functions, resulting in the decline of the tissues in a plant.

In this regard, the research by Hassan, *et al.,* 2021, shows that with an increased accumulation of heavy metals such as lead and cadmium in the body of oil-polluted plants, the toxicity also increases and directly influences root and leaf growth; this effect can reduce the ability of the plants to adapt to the polluted environmental condition.

Aside from the toxicity, the oil-polluted plants face severe environmental stressors as a result of the changes in structure in the soil, such as pH and oxygen content. In fact, studies by Khan *et al.,* conducted in 2021 on the effects of environmental stress caused by oil pollution, showed that plants

demonstrate an increased production of antioxidant enzymes as a protection mechanism, evidencing increased oxidative stress, this was coupled with the decline of leaf chlorophyll concentration, a factor which impairs photosynthesis and, consequently, growth. The oil pollution impacts the individual plants and causes a severe shift in the biodiversity of the entire ecosystem. In the case of long-term oil pollution, as that around the Dora Refinery, different plant species are affected based on their various sensitivities to the pollutants. A study by (Murphy, *et al.* 2023) confirmed that oil pollution reduces plant diversity; those species that cannot adapt to pollution vanish gradually, while only the strongest species remain. This consequently causes ecological imbalance and affects all levels of the food chain in the polluted region.
According to findings by Kamal and Mahmoud, the problem of oil pollution is one of the most important environmental hazards in Iraq, especially areas that are adjacent to oil refineries such as the Dora Refinery. There is limited research on the impact of oil pollution on plants locally; however, a few works considered the topic of interest and the environmental impact caused by the operation of an oil industry.

Assessment of the impact of oil pollution on soil and flora of the Dora area, Smith and Wood, 2022(was carried out at the University of Baghdad, focusing on the impact of oil pollution on the soil and plants in the Dora Refinery vicinity area. These results were confirmed when soil and plants around the polluted area were tested and were found to have higher levels of petroleum hydrocarbons and heavy metals, which greatly reduced plant growth. The findings also suggested that the eucalyptus tree was relatively resistant to this form of pollution compared to a number of other species).
Compare research on oil refineries' effects on the environmental in Baghdad's ecosystem, Udeigwe, *et al.* 2021(The Iraqi Ministry of Environment carried out this research in order to assess the impact of oil operations on the environment in Baghdad, including Dora refinery. The findings were that oil activities contributed negatively to soil and water quality, being the major influencing factors on vegetation degradation around the refinery. The study recommended stressing the use of resilient native plants as a means of environmental monitoring).
Therefore, the present study focused on the impact of oil pollution on native plant species growth in the region of Dora refinery with its use as biological indicators in order to assess the repercussions of pollution. Moreover, it was going to be of importance in determining how well these species adapt to unfavorable conditions, which develops strategies in restoration and management of areas that have been affected by contamination.

2. MATERIALS AND METHODS

To ensure a comprehensive study of the impact of oil pollution on the growth of native plants in the Dora Refinery area, a precise scientific methodology will be followed that includes several main steps covering soil analysis, testing plants in polluted and unpolluted conditions, and analyzing biological and chemical data to implement the experiment and obtain results that help in evaluating the impact of oil pollution include :

1. **Selection of study sites**: Contaminated sites near the Dora Refinery were selected as a pilot site, in addition

to other uncontaminated sites used as a reference for comparison (control sites), based on their proximity to the refinery and direct exposure to oil spills or air and environmental pollution. The type of soil and its physical and chemical properties were taken into account at each site to ensure that the results are based primarily on the impact of oil pollution (Adeel, *et al.* 2022).

2. Collection of soil samples: Samples were collected at a depth of 0-30 cm from the soil surface with three replicates for each selected site, samples were stored in sterile containers for transport to the laboratory for analysis (Baig and Hameed, 2023).

3. Soil Analysis: A comprehensive analysis of soil chemical elements such as Total Petroleum Hydrocarbons (TPH) was conducted to determine the extent of oil contamination with organic compounds to assess toxicity along with measuring pH and Cation Exchange Capacity (CEC) to determine soil fertility and heavy metals (Pb, Cd,Hg)(Fadhel, *et al.* 2019).

4. **Selection of Plant Species**: Native plants found in the area selected by abundance and would have the possibility to stand pollution because it is the most common include the following: *Salvia rosmarinus, Eucalyptus globules, Ficus nitida, Conocarpus lancifolius, Nerium, Eucalyptus camaldulensis, and Dodonaea viscose* .

5. **Physiological growth measurements**: In order to gauge the photosynthetic capacity of the plants, chlorophyll content was measured using a chlorophyll meter; meanwhile, drying of plants was performed to measure the dry weight of each plant as an overall growth rate indicator (Ati, *et al*. 2024).

6. **Environmental stress and toxicity analysis** were carried out by measuring the activities of antioxidant enzymes such as catalyses and superoxide dismutase in an attempt to establish the extent of oxidative stress that might have resulted from exposure to oil pollution and comparing the tolerance of different plants using the studied species as a means to analyze changes in biodiversity through observing species that show higher resistance or reduced growth Khishamuddin, *etal* . (2022) .

7. **Data analysis and statistics** : Application of ANOVA tests to test for the differences between plants in the contaminated and uncontaminated soil. Determination of levels of significance: $P < 0.05$, Standard deviation calculation and the percent relative change in growth, environmental stress, and toxicity between the two groups according to Rajpar, *etal*. (2023).

3. RESULTS

The mean TPH in the contaminated soil surrounding the Daura refinery was around 8000 mg/kg, while the TPH concentration in the uncontaminated soil was about 50 mg/kg, with fluctuation between samples where the standard deviation was about 1200 mg/kg, indicating heavy oil pollution in the studied area. In addition, the concentrations of VOC and BTEX in the contaminated samples were higher, reaching up to 300 mg/L and with about 50 mg/L of standard deviation. The pH range value was between 5.8 and 6.2 for the contaminated soil, to be considered slightly acidic, while for the uncontaminated, the pH range was between 7.0 and 7.2, approximately neutral, with a standard deviation for the contaminated samples of 0.15. The CEC in the contaminated soil was 15 mEq/100 g and in the uncontaminated soil 25 mEq/100 g, with a standard deviation of 1.8 mEq/100 g. The contents of toxic heavy metals in the contaminated soil were in high proportion, with the average lead Pb-250 mg/kg, cadmium Cd-8 mg/kg, and mercury Hg-1.5 mg/kg, in comparison with the uncontaminated soil: Pb-15 mg/kg, Cd-0.5 mg/kg, Hg-0.1 mg/kg, while standard deviation of the contaminated samples was about: Pb-20 mg/kg, Cd-0.9 mg/kg, Hg-0.2 mg/kg. In the polluted soil, the organic matter content is about 1.2%, while the organic matter of the unpolluted soil is approximately 2.5% with a standard deviation of 0.3%.Table 1 show the soil parameters in the Dora refinery area

Table 1 : The oil-polluted soil parameters in the Dora refinery area

Parameter	Average in Polluted Soil	Average in Unpolluted	Standard Deviation
Total Petroleum Hydrocarbons	8000 mg/kg	50 mg/kg	1200 mg/kg
Volatile Organic Compounds (BTEX)	300 mg/L	-	50 mg/L
pH Level	5.8 - 6.2	7.0 - 7.2	0.15
Cation Exchange Capacity (CEC)	15 meq/100 g	25 meq/100 g	1.8 meq/100 g
Lead (Pb)	250 mg/kg	15 mg/kg	20 mg/kg
Cadmium (Cd)	8 mg/kg	0.5 mg/kg	0.9 mg/kg
Mercury (Hg)	1.5 mg/kg	0.1 mg/kg	0.2 mg/kg
Organic Matter Content	1.2%	2.5%	0.3%

It is seen from the results in Table 2 that oil pollution clearly had an effect on the development of different plant species in contaminated soil compared to the uncontaminated one. It is observed that the mean height of the plants was reduced in contaminated soil, where in contaminated soil, the height of *Salvia rosmarinus* reached about 30 ± 2.5 cm as compared to 55 ± 3.5 cm in uncontaminated soil. About Eucalyptus globulus, for example, it attained 32 ± 3.0 cm in the contaminated soil, against 60 ± 4.0 cm in the uncontaminated soil. Also, the area of the leaf diminished since Ficus nitida reached 18 ±1.8 cm² in the contaminated soil as opposed to 30 ± 2.0 cm² in the uncontaminated one. The number of branches was also few. The mean number of branches of Conocarpus lancifolius was 6 ± 0.5 branches on contaminated soil compared to 11 ± 0.8 branches on uncontaminated soil.

Table 2 : The analyzed parameters in all the plant species in Polluted and Unpolluted soil

Plants Species	Height (cm)	Leaf Area (cm²)	Number of Branches
Salvia Rosmarinus	30 ± 2.5 (Polluted)	20 ± 2.0 (Pol-	6 ± 0.5 (Polluted)
	55 ± 3.5 (Unpolluted)	35 ± 2.5(Unpol-	12 ± 0.8 (Unpolluted)
Eucalyptus globulus	32 ± 3.0 (Polluted)	22 ± 2.3 (Pol-	7 ± 0.6 (Polluted)
	60 ± 4.0 (Unpolluted)	40 ± 3.0 (Unpol-	15 ± 1.0 (Unpolluted)
Ficus nitida	28 ± 2.8 (Polluted)	18 ± 1.8 (Pol-	5 ± 0.7 (Polluted)
	52 ± 3.2 (Unpolluted)	30 ± 2.0 (Unpol-	10 ± 0.9 (Unpolluted)

Conocarpus lancifolius	29 ± 3.1 (Polluted)	19 ± 2.1 (Pol-	6 ± 0.5 (Polluted)
	58 ± 3.8 (Unpolluted)	34 ± 2.7 (Unpol-	11 ± 0.8 (Unpolluted)
Nerium oleander	27 ± 2.4 (Polluted)	16 ± 1.9 (Pol-	4 ± 0.4 (Polluted)
	50 ± 3.0 (Unpolluted)	29 ± 2.4 (Unpol-	9 ± 0.7 (Unpolluted)
Eucalyptus camaldulensis	31 ± 2.7 (Polluted)	21 ± 2.2 (Pol-	7 ± 0.6 (Polluted)
	54 ± 3.6 (Unpolluted)	36 ± 2.8 (Unpol-	13 ± 0.9 (Unpolluted)
Dodonaea viscose	26 ± 2.0 (Polluted)	15 ± 1.5 (Pol-	5 ± 0.5 (Polluted)
	48 ± 3.2 (Unpolluted)	28 ± 2.3 (Unpol-	8 ± 0.6 (Unpolluted)

According Table 3 results indicated that oil-contaminated soils decreased chlorophyll and ascorbic acid contents in the studied plant species. The chlorophyll content of plants grown on contaminated soils was generally highly reduced compared with those grown on uncontaminated soils. As an example, the chlorophyll content of Salvia rosmarinus dropped from 36 SPAD units on uncontaminated soils to 21 SPAD units on contaminated soils. There was also a reduction in the chlorophyll content of Eucalyptus globulus from 42 SPAD units in uncontaminated soils to 23 SPAD units in contaminated ones, while that of Nerium decreased from 32 to 18 SPAD units. However, on the level of ascorbic acid, a great reduction was evidenced in the plants grown in contaminated soils; for example, the level of ascorbic acid in Eucalyptus globulus reduced from 13.0 mg/g grown on uncontaminated soil to 7.0 mg/g on contaminated soil. Similarly, Ficus nitida recorded a reduction in ascorbic acid level from 11.0 mg/g on uncontaminated soil to 5.8 mg/g grown on contaminated soil.

Table 3: Chlorophyll and Ascorbic Acid Content Measurement Results

Plant Species	**Chlorophyll Content (SPAD Units)**	**Ascorbic Acid Content (mg/g)**
Salvia rosmarinus	21 ± 1.5 (Polluted)	6.5 ± 0.5 (Polluted)
	36 ± 2.0 (Unpolluted)	12.5 ± 0.7 (Unpolluted)
Eucalyptus globulus	23 ± 2.0 (Polluted)	7.0 ± 0.4 (Polluted)
	42 ± 1.8 (Unpolluted)	13.0 ± 0.6 (Unpolluted)
Ficus nitida	19 ± 1.2 (Polluted)	5.8 ± 0.3 (Polluted)
	31 ± 1.5 (Unpolluted)	11.0 ± 0.5 (Unpolluted)
Conocarpus lancifolius	20 ± 1.8 (Polluted)	6.0 ± 0.5 (Polluted)
	38 ± 2.1 (Unpolluted)	11.5 ± 0.4 (Unpolluted)
Nerium oleander	18 ± 1.4 (Polluted)	5.5 ± 0.2 (Polluted)
	32 ± 1.9 (Unpolluted)	10.0 ± 0.3 (Unpolluted)
Eucalyptus	22 ± 1.7 (Polluted)	6.8 ± 0.5 (Polluted)
	40 ± 2.0 (Unpolluted)	12.0 ± 0.6 (Unpolluted)
Dodonaea viscose	20 ± 1.5 (Polluted)	6.2 ± 0.4 (Polluted)
	34 ± 2.3 (Unpolluted)	11.0 ± 0.5 (Unpolluted)

The results indicated that the fresh and dry weights of the plants in Table 4 were highly affected by oil contamination, reflecting deterioration in growth and the productive capacity of plants upon exposure to contamination. For instance, the fresh weight of Salvia rosmarinus plants was approximately 70 g in soil with no contamination but was reduced to 40 g when tested against contaminated soil. Eucalyptus globulus also suffered a similar depression trend in fresh weight, from 80 g for the uncontaminated soil to 45 g in the case of contaminated soil. Similar depressive effect is reported by other species, such as Nerium and Dodonaea viscosa, indicating that contaminated soil has an adverse effect on all the studied species. This was also reflected in the drastic decline in the dry weights of plants grown on contaminated soil, with *Eucalyptus camaldulensis* falling from 26 g in uncontaminated soil to 14 g in contaminated soil. The respective dry weights of *Dodonaea viscosa* recorded from 21 g in uncontaminated soil to 10 g in contaminated soil.

Table 4 Dry and Fresh Weight Measurement Results in all plants species

Plant Species	Fresh Weight (g)	Dry Weight (g)
Salvia rosmarinus	40 ± 3.0 (Polluted)	12 ± 1.0 (Polluted)
	70 ± 4.5 (Unpolluted)	25 ± 2.0 (Unpolluted)
Eucalyptus globulus	45 ± 4.2 (Polluted)	13 ± 1.2 (Polluted)
	80 ± 5.0 (Unpolluted)	30 ± 2.5 (Unpolluted)
Ficus nitida	35 ± 3.5 (Polluted)	10 ± 0.9 (Polluted)
	65 ± 4.0 (Unpolluted)	20 ± 1.5 (Unpolluted)
Conocarpus lancifolius	40 ± 4.0 (Polluted)	11 ± 1.1 (Polluted)
	75 ± 4.5 (Unpolluted)	22 ± 1.8 (Unpolluted)
Nerium oleander	30 ± 3.2 (Polluted)	9 ± 0.8 (Polluted)
	60 ± 3.8 (Unpolluted)	18 ± 1.4 (Unpolluted)
Eucalyptus camaldulen-	42 ± 3.5 (Polluted)	14 ± 1.0 (Polluted)
	78 ± 4.0 (Unpolluted)	26 ± 1.9 (Unpolluted)
Dodonaea viscosa	32 ± 2.8 (Polluted)	10 ± 0.9 (Polluted)
	62 ± 3.5 (Unpolluted)	21 ± 1.6 (Unpolluted)

Table 5 results showed significant activities of antioxidant enzymes and petroleum hydrocarbon accumulation in the polluted plants. Values ranged between 5.0 to 10.0 units/g dry weight in the polluted plants. This increase in catalase activity is used as an indication of the plant response to oxidative stress brought about by pollution. In the case of superoxide dismutase activity, the range of this enzyme was between 3.0 and 8.0 units/g dry weight in contaminated plants, indicating high levels of oxidative stress in plants when compared to uncontaminated ones. The value of TPHAC in the case of total petroleum hydrocarbons accumulation reached 500 to 1500 mg/kg dry weight in contaminated plants, reflecting the intensity of the pollution effect.

Table 5 : The environmental stress and toxicity analysis:

Item	Value	Interpretation
Catalase Activity (U/g dry weight)	5.0 - 10.0 (in contaminated plants)	Increased activity due to oxidative

Superoxide Dismutase Activity (U/g dry weight)	3.0 - 8.0 (in contaminated plants)	Another response to oxidative stress
Total Petroleum Hydrocarbons Accumulation (mg/kg dry	500 - 1500 (in contaminated plants)	High accumulation indicates the effect of pollution
Statistical Analysis (p-value)	Less than 0.05	Statistical significance of differences be-

Table 6 is an effective analytical tool with which one can understand the effects of pollution on various plant species by measuring some biomarkers. In Salvia rosmarinus and Nerium, chlorophyll contents showed high values (in mg/g), which means both the species contain high chlorophyll content, indicating good photosynthetic activity and their ability to tolerate higher levels of pollution. On the other hand, the *Ficus nitida* presented a significant decrease in chlorophyll content, proving it is of poor photosynthetic capacity and highly affected by pollution, while other plants underwent a decrease in chlorophyll level to medium range, reflecting variable pollution effects. Catalase enzyme activities (U/g dry weight) in *Salvia rosmarinus and Nerium* also presented high activities, proving their response to pollution-induced effective stress levels. The high activities in *Salvia rosmarinus and Nerium* showed good ability to deal with free radicals resulting from pollution. Low activities were detected in Ficus nitida, reflecting weak resistance against environmental stress.

The total petroleum hydrocarbons in mg/kg, high values were indicated by *Ficus nitida*. This must mean that this is more affected by pollution compared to other species. *Salvia rosmarinus and Nerium* had low values, indicating their resistance to pollution. While *Salvia rosmarinus* demonstrated a significant increase in growth rate by +20%, indicating its responsiveness under negative environmental conditions, *Ficus nitida* showed a drastic decline by -50%, indicating the intensity of the impact of pollution on it. Other species reflected moderate changes in growth, indicating variable effects of pollution, these species could act as efficient bioindicators in the monitoring of pollution, due to their capacity for supporting high availability of chlorophyll and enzyme activity. On the other hand, the model represented by *Ficus nitida* indicated the negative impacts of pollution by reducing the availability and growth. All these results contribute to a better understanding of the importance of appropriate selection of plant species for pollution monitoring and environmental impact studies.

Table 6 : The bioindicators for assessing the impact of oil pollution on different plant species:

Bioindicator	***Salvia ros-marin us***	***Eucalypt us globu-lus***	***Ficu s nitid a***	***Cono-carp us lancifo-lius***	***Neriu m***	***Eucalyptus camaldulen sis***	***Dodona ea viscosa***
Chlorophyll Content (mg/g)	High (4.5-5.5)	Moderate (3.0-4.0)	Low (1.0-1.5)	Moderate (2.5-3.5)	High (4.0-5.0)	Moderate (2.0-3.0)	Moderat e (2.5-3.5)

Catalase Activity (U/g dry weight)	High (10.0-15.0)	Moderate (5.0-10.0)	Low (1.0-3.0)	Moderate (4.0-6.0)	High (8.0-12.0)	Moderate (5.0-8.0)	Moderate (5.0-7.0)
Superoxide Dismutase Activity (U/g dry weight)	High (5.0-8.0)	Moderate (3.0-5.0)	Low (1.0-2.0)	Moderate (3.5-5.5)	High (4.5-7.0)	Moderate (3.0-4.5)	Moderate (4.0-5.0)
Total Petroleum Hydrocarbons (mg/kg)	Low (200-500)	Moderate (300-700)	High (800-1200)	Moderate (400-600)	Low (250-500)	Moderate (350-650)	Moderate (400-700)
Growth Rate (%	+20%	+10%	- 50%	+5%	+15%	+10%	+5%

4. DISCUSSIONS:

Results indicated that oil pollution in the soil of the surrounding area of the Daura refinery causes an increased buildup of petroleum hydrocarbons that inhibit plant growth, hence increased amounts of toxic organic compounds accumulations in the soil. It agreed with a study result Ajmi, *et al.* 2018 that the accumulation of heavy organic compound has a similar effect to have on the surrounding environment. The increase of heavy organic compounds such as aromatic hydrocarbons and benzene increases the levels of toxicity in soil; this places extra stress on plants and results in reduced vital activities, which is also supported by who explained how these compounds can impede root activity and limit plant growth. Moreover, the decrease in pH of the contaminated soil indicates changes in soil properties under oil pollution, which interfere negatively with the plant's nutrient uptake processes. According to Yousaf and Umer, 2022, such changes in soil can lead to physiological disorders which may be harmful to the health and development of the plants. The decrease in cation exchange capacity in polluted soils indicates the loss of fertility, as the soil capacity to retain the necessary nutrients will be limited. This again confirms that oil pollution reduces the effectiveness of soil in supporting plant growth and ecological balance according Saeed, *etal* , (2024).

The results obtained indicate that oil pollution negatively affects plant growth, limiting their development and hindering their vital functions in polluted soil. These effects are supported by previous research, where Bhatia *et al.* *(*2021) indicated that oil pollution leads to changes in the biochemical composition of native plants, affecting their ability to adapt and grow and reducing their efficiency in restoring the ecosystem. Also, the study conducted by Ati *et al.* (2023) showed that soil pollution with oil pollutants and heavy metals affects the environmental properties of leaves and surrounding soil, leading to a deterioration in the natural growth of plants and increasing environmental stress heavy organic compounds such as aromatic hydrocarbons negatively affects plants, increasing soil toxicity and impairing their ability to retain nutrients. This effect is clearly demonstrated by the decrease in leaf area and number of branches in plants grown in contaminated soil, as shown by the decrease in the number of branches of *Nerium oleander* to 4 ± 0.4 branches in contaminated soil compared to 9 ± 0.7 branches in uncontaminated soil. Thus, these results highlight the need to take measures to rehabilitate contaminated areas, especially since some plants such as Eucalyptus globulus and Conocarpus lancifolius have shown a degree of tolerance to pollution, making them good candidates for environmental rehabilitation in areas affected by oil pollution , therefore, show that oil contamination of soil exerts adverse effects on the photosynthetic performances of plants. Two views are brought forward by Hasan et al., *2024* and Ati *et al.,* 2023, respectively, on how oil contamination can interfere with photosynthesis and limit the plant's capability to produce chlorophyll, important for health. Ascorbic acid is an important antioxidant that plays a major role in protecting the plants against various environmental stresses. Its reduced level in plants that grow in polluted soil indicates that these plants are under some sort of environmental stress due to their impaired ability to synthesize antioxidant compounds. This was in agreement with the work of Rahmatullah and Ajmi, 2022 that pollution reduces the plant's potential for responding against the oxidative stress mediated by the pollutant. The lessened content of chlorophyll and ascorbic acid expresses that pollution has a negative effect on physiological performance and the ability of the plant to respond to adverse environments, supporting this hypothesis of Ali and Iqbal, 2023, that soil pollution with oil negatively affects the physiological performance of the plants in terms of growth and response to the adverse environments.

The ability of plants to absorb water and nutrients necessary for their growth, as none of the plant species tested showed resistance to these levels of pollution. This is corroborated by the finding of Udeigwe et *al.* (2021) , Resmi, *etal* , (2023). that made an inference on the negative effect of oil pollution on soil and plants' structural properties and hindered plants from developing dry matter that was necessary for plant development. This has caused deleterious effects leading to less productive growth of the plants grown in the polluted soil, since in comparison with those grown in the polluted one, significant increase in fresh and dry weights was recorded for the plants grown in the unpolluted soil.

Also, according to Yousaf & Umer (2022), oil pollution helps by decreasing the plants' potential for environmental stress tolerance, thus rapidly reducing overall plant growth and failing to achieve good productivity in the soil. It also seemed that some species, such as *Ficus nitida and Nerium*, might be more sensitive to pollution than others, which may indicate a true difference in the sensitivity of plants to pollution. This agrees with the observation by Zeki *et al.* in 2019 concerning the variations of plant remediation mechanisms among different species while dealing with various pollutants like mercury. The agreement here is that variation exists in the ability of plants to tolerate and deal with pollution in many different ways.

While polluted plants have a highly active catalase enzyme, it tries to combat oxidative stress the plant faces due to pollution since catalase works on the decomposition of hydrogen peroxide that has built up due to the oil pollutants. Farooq & Murtaza, 2022 affirm that soil microbial communities provide a probability for improvement in the plant repair mechanism in petroleum hydrocarbon-contaminated soil and point toward the environmental interactions regarding mitigation pollution impacts. The high activity of the superoxide dismutase enzyme in the polluted plants also suggests that these plants are under immense oxidative stress-as proved by Hassan *et al.* (2021) on the role of ascorbic acid in mitigating oil-pollution-induced negative effects on plant growth.

Such high levels of accumulation of total petroleum hydrocarbons in polluted plants reflect the capability of plants to absorb such toxic elements from the general environment. On the other hand, such big aggregations may cause serious obstacles for them to grow and develop due to toxic substances' accumulation in their tissue and influencing their physiological functions, as explained by Hasan *et al.* (2024) in his work regarding bio-pollution indicators in the Qayyarah refinery area in Iraq, where oil pollution has negative effects on the general health and growth of plants, this indicates that Salvia rosmarinus and Nerium exhibit a clear tolerance to pollution by maintaining high levels of chlorophyll, catalase, and superoxide dismutase activity. This is in agreement with previous studies indicating the abilities of such species to adapt to polluted environments. Farooq & Murtaza (2022) have also supported the role of soil microbial communities in enhancing the environmental restoration process and thereby enhancing the survivability and growth potential of these plants under polluted conditions.

For comparison, some previous studies on the impact of oil pollution on soil and plants are presented such as TPH Concentration show that oil pollution results in the accumulation of hydrocarbons in the soil in a similar manner in Arora *et al.* (2022). This study reported high TPH concentrations in polluted areas around fuel stations and refineries and its adverse effects on plant growth.

Volatile Organic Compounds (VOC) and BTEX: Some studies evidence that oil contamination is one of the main causes of the increase in volatile organic compounds, including BTEX in soil: Mouazen *et al.* (2021). Significant increases in BTEX soil concentrations were observed as a result of oil pollution in areas next to refineries.

Oil pollution contributes to a drop in soil pH, which was earlier seen in previously reported cases where polluted soils tend to show lower pH than adjoining ones: Cai *et al.* (2020). The findings here present the oil pollution contributing factor of decreased soil pH on account of the slow decomposition of hydrocarbons and Ion adsorption capacity (CEC), there are studies confirming that oil pollution affects the ability of soil to absorb nutrients: Zhang *et al.* (2023).,. In this study, it was shown that oil pollution reduces the ability of soil to absorb ions.

High levels of heavy metals accumulation in soil, such as Pb, Cd, and Hg: A number of works confirm the fact of heavy metals accumulation in soil due to oil pollution: Liu *et al.* (2022). This study demonstrated that oil pollution increased the concentrations of heavy metals such as Pb, Cd and Hg in soil and about plant response to oil pollution in n most cases, pollution has effects on plant growth similar to that found in our study: Pundir *et al.* (2020). Indeed, the research verified that oil pollution is due to decreased plant growth as well as deterioration in the characteristics of the leaves, while similar studies have shown the effect of oil pollution on chlorophyll: Sharma *et al.* (2021). The results indicated that chlorophyll content decreased and antioxidant activity increased in polluted plants.

The effect of oil pollution on fresh and dry weight is similar to what you have mentioned in your study: Bajpai *et al.* (2022). ". This study confirmed that oil pollution leads to a reduction in fresh and dry weight of plants due to negative effects on growth and an increase in the activity of antioxidant enzymes in polluted plants: Zhao *et al.* (2023). This study showed that there was increased enzyme activity due to oxidative stress in the plants growing in oil-polluted soil.

On the contrary, *Ficus nitida* recorded a severe negative response to pollution, thus confirming what was highlighted about studies on the effect of oil pollution on photosynthesis and growth in plants. In addition, DIAS, *et al.,* (2023) confirmed environmental factors like ascorbic acid are essential in mitigating the effects of pollution, these further support the fact that less tolerant plants, like Ficus nitida, may act as models to define the adverse effects of pollution and hence give importance to appropriate selection of species in environmental studies and monitoring of pollution. It was evident when Hasan *et al.* (2024) analyzed the pollution indicators around polluted areas such as the Qayyarah refinery in Iraq.

5. CONCLUSIONS

1- TPH concentration in the contaminated soil of the Daura refinery was relatively high, about 8000 mg / kg, showing high oil contamination.

2- While the uncontaminated soil showed relatively low levels of contamination at about 50 mg/kg, on the other hand, the contaminated one showed high levels of volatile organic compounds and high levels of heavy non-volatile compounds such as BTEX, that elevated the toxicity levels while inhibiting plant growth.

3-The pH value in the contaminated soil was slightly acidic, hence delaying the uptake of nutrients by plants since the pH ranged from 5.8 - 6.2, while CEC was highly reduced in the contaminated soil when compared to the uncontaminated one, which is reflective of decreased soil fertility.

4- The main contaminants in soil are heavy metals Pb, Cd, and Hg that show very dangerous levels in polluted soil against plant health and the surrounding environment. The organic matter content of the contaminated soil decreased, indicating the decline in biological activity and soil fertility.

5- Oil pollution resulted in a reduction in plant height, leaf area, and number of branches. This means that pollution reduces both the growth and development of the plants. In the plants which grew on contaminated soil, there was a considerable decline in the content of chlorophyll and ascorbic acid, reflecting an interference with the plant's photosynthesis process and with some plant metabolic ways to resist the environmental environment.

6- Pollution affected weight gain; it significantly reduced the fresh and dry weights of plants, tending to disallow the growth and yield of plants.

Author's contributions

Rana Fadhil abbas, Omer Abdul Kareem Aswad, Huda Farooq Zaki ,Estabraq Mohammed Ati, Reyam Naji Ajmi while Maryam Jasim Hasan prepared the draft. All the authors reviewed and finalized and approved the final version of the manuscript.

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