

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 investigates the environmental impact of oil pollution in the vicinity of the Dora Refinery, with a particular focus on its effects on local flora. The research utilizes selected plant species such as *Salvia rosmarinus*, *Eucalyptus globulus*, *Ficus nitida*, *Conocarpus lancifolius*, *Nerium*, *Eucalyptus camaldulensis* and *Dodonaea viscosa* as biological indicators to assess the extent of contamination and the plants' adaptive responses to polluted conditions. Oil pollution is identified as a significant environmental issue in the Dora Refinery area, contributing to severe soil degradation and posing challenges to plant survival. The primary objective of this study is to evaluate the physiological and biochemical responses of these plant species to oil-contaminated soils, including growth performance, stress response mechanisms, and their potential role in environmental monitoring and land reclamation. The methodology involved selecting both polluted and non-polluted sites in proximity to the refinery. Soil samples were collected from these locations and used to cultivate the target plant species under controlled conditions. Growth rates were recorded, and several biomarkers associated with oil pollution exposure were analyzed. These included measurements of soil hydrocarbon content, chlorophyll concentration, antioxidant enzyme activities, and the accumulation of heavy metals and hydrocarbon pollutants in plant tissues. Results revealed that plants grown in polluted soils exhibited significantly reduced growth rates compared to those in uncontaminated environments. Notably, *Salvia rosmarinus* and *Dodonaea viscosa* demonstrated substantial accumulation of hydrocarbon pollutants, indicating their high sensitivity to contamination. In contrast, *Eucalyptus globulus* and *Conocarpus lancifolius* showed greater resilience, maintaining relatively stable growth and physiological parameters under stress. Polluted plants also exhibited clear signs of environmental stress, including decreased chlorophyll content and elevated antioxidant enzyme activity, reflecting their biochemical response to oxidative stress induced by pollutants. These findings suggest that the studied species vary in their tolerance to oil pollution, making them valuable bioindicators for environmental assessment. In conclusion, the physiological traits of these plant species significantly influence their susceptibility to oil pollutants. Their differential responses provide critical insights for environmental monitoring programs and offer promising avenues for the development of phytoremediation and land management strategies in oil-contaminated regions.

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, mainly the impact of these pollutants on their growth, as well as their susceptibility to environmental toxicity as well and stress caused by these pollutants. As mentioned by Zeki et al. (2019), previous studies have proved that an increased oil pollutant concentration significantly downgrades the plant growth process. A study conducted by Afolabi



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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 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, oil-polluted plants face severe environmental stressors as a result of the changes in the structure of the soil, such as pH and oxygen content. Studies by Khan et al. (2021) on the effects of environmental stress caused by oil pollution showed that plants demonstrate 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 that 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 Al-Ibady et al. (2025), the problem of oil pollution is one of the most important environmental hazards in Iraq, especially in 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 have considered the topic of interest and the environmental impact caused by the operation of the oil industry.

Assessment of the impact of oil pollution on soil and flora of the Dora area (Smith & 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 many other species. The Iraqi Ministry of Environment carried out research, "Compare research on oil refineries' effects on the environment in Baghdad's ecosystem (Ibrahim et al. 2025) to assess the impact of oil operations on the environment in Baghdad, including the 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 for the restoration and management of areas that have been affected by contamination.

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:

Selection of study sites: Contaminated sites near the Dora Refinery were selected as pilot sites, 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 were based primarily on the impact of oil pollution (Adeel et al. 2022).

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 & Hameed 2023).

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).

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, and include the following: *Salvia rosmarinus*, *Eucalyptus globules*, *Ficus nitida*, *Conocarpus lancifolius*, *Nerium*, *Eucalyptus camaldulensis*, and *Dodonaea viscosa*.

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. 2022).

Environmental stress and toxicity analysis: Environmental stress and toxicity were assessed by quantifying the activities of key antioxidant enzymes, namely catalase and superoxide dismutase, to determine the extent of oxidative damage potentially induced by oil pollution. Furthermore, inter-species comparisons were conducted to evaluate plant tolerance, using the studied species as a biological indicator for biodiversity shifts by observing differential resistance levels and growth patterns (Khishamuddin et al. 2022).

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 et al. (2023).

RESULTS

The mean TPH in the contaminated soil surrounding the Daura refinery was around 8000 mg.kg^{-1} , while the TPH concentration in the uncontaminated soil was about 50 mg.kg^{-1} , with fluctuation between samples, where the standard deviation was about 1200 mg.kg^{-1} , 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^{-1} and with about 50 mg.L^{-1} 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.100g^{-1} , and in the uncontaminated soil,

25 mEq.100g^{-1} , with a standard deviation of $1.8 \text{ mEq.100g}^{-1}$. The contents of toxic heavy metals in the contaminated soil were in high proportion, with the average lead Pb-250 mg.kg^{-1} , cadmium Cd-8 mg.kg^{-1} , and mercury Hg-1.5 mg.kg^{-1} , in comparison with the uncontaminated soil: Pb-15 mg.kg^{-1} , Cd-0.5 mg.kg^{-1} , Hg-0.1 mg.kg^{-1} , while standard deviation of the contaminated samples was about: Pb-20 mg.kg^{-1} , Cd-0.9 mg.kg^{-1} , Hg-0.2 mg.kg^{-1} . 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 shows the soil parameters in the Dora refinery area.

It is seen from the results in Table 2 that oil pollution 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 $30 \pm 2.5 \text{ cm}$ as compared to $55 \pm 3.5 \text{ cm}$ in uncontaminated soil. About *Eucalyptus globulus*, for example, it attained $32 \pm 3.0 \text{ cm}$ in the contaminated soil against $60 \pm 4.0 \text{ cm}$ in the uncontaminated soil. Also, the area of the leaf diminished since *Ficus nitida* reached $18 \pm 1.8 \text{ cm}^2$ in the contaminated soil as opposed to $30 \pm 2.0 \text{ cm}^2$ 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.

According to 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^{-1} grown on uncontaminated soil to 7.0 mg.g^{-1} on contaminated soil. Similarly, *Ficus nitida* recorded a reduction in ascorbic acid level from 11.0 mg.g^{-1} on uncontaminated soil to 5.8 mg.g^{-1} grown on contaminated soil.

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

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

Parameter	Average in Polluted Soil	Average in Unpolluted Soil	Standard Deviation
Total Petroleum Hydrocarbons (TPH)	8000 mg.kg ⁻¹	50 mg.kg ⁻¹	1200 mg.kg ⁻¹
Volatile Organic Compounds (BTEX)	300 mg.L ⁻¹	-	50 mg.L ⁻¹
pH Level	5.8-6.2	7.0-7.2	0.15
Cation Exchange Capacity (CEC)	15 meq.100g ⁻¹	25 meq.100g ⁻¹	1.8 meq.100g ⁻¹
Lead (Pb)	250 mg.kg ⁻¹	15 mg.kg ⁻¹	20 mg.kg ⁻¹
Cadmium (Cd)	8 mg.kg ⁻¹	0.5 mg.kg ⁻¹	0.9 mg.kg ⁻¹
Mercury (Hg)	1.5 mg.kg ⁻¹	0.1 mg.kg ⁻¹	0.2 mg.kg ⁻¹
Organic Matter Content	1.2%	2.5%	0.3%

Table 2: The analyzed parameters in all the plant species in the polluted and unpolluted soils.

Plants Species	Height [cm]	Leaf Area [cm ²]	Number of Branches
<i>Salvia rosmarinus</i>	30 ± 2.5 (Polluted)	20 ± 2.0 (Polluted)	6 ± 0.5 (Polluted)
	55 ± 3.5 (Unpolluted)	35 ± 2.5 (Unpolluted)	12 ± 0.8 (Unpolluted)
<i>Eucalyptus globulus</i>	32 ± 3.0 (Polluted)	22 ± 2.3 (Polluted)	7 ± 0.6 (Polluted)
	60 ± 4.0 (Unpolluted)	40 ± 3.0 (Unpolluted)	15 ± 1.0 (Unpolluted)
<i>Ficus nitida</i>	28 ± 2.8 (Polluted)	18 ± 1.8 (Polluted)	5 ± 0.7 (Polluted)
	52 ± 3.2 (Unpolluted)	30 ± 2.0 (Unpolluted)	10 ± 0.9 (Unpolluted)
<i>Conocarpus lancifolius</i>	29 ± 3.1 (Polluted)	19 ± 2.1 (Polluted)	6 ± 0.5 (Polluted)
	58 ± 3.8 (Unpolluted)	34 ± 2.7 (Unpolluted)	11 ± 0.8 (Unpolluted)
<i>Nerium oleander</i>	27 ± 2.4 (Polluted)	16 ± 1.9 (Polluted)	4 ± 0.4 (Polluted)
	50 ± 3.0 (Unpolluted)	29 ± 2.4 (Unpolluted)	9 ± 0.7 (Unpolluted)
<i>Eucalyptus camaldulensis camaldulensis</i>	31 ± 2.7 (Polluted)	21 ± 2.2 (Polluted)	7 ± 0.6 (Polluted)
	54 ± 3.6 (Unpolluted)	36 ± 2.8 (Unpolluted)	13 ± 0.9 (Unpolluted)
<i>Dodonaea viscosa</i>	26 ± 2.0 (Polluted)	15 ± 1.5 (Polluted)	5 ± 0.5 (Polluted)
	48 ± 3.2 (Unpolluted)	28 ± 2.3 (Unpolluted)	8 ± 0.6 (Unpolluted)

Table 3: Chlorophyll and ascorbic acid content measurement results.

Plant Species	Chlorophyll Content (SPAD Units)	Ascorbic Acid Content [mg.g ⁻¹]
<i>Salvia Rosmarinus</i>	21 ± 1.5 (Polluted)	6.5 ± 0.5 (Polluted)
	36 ± 2.0 (Unpolluted)	12.5 ± 0.7 (Unpolluted)
<i>Eucalyptus globulus</i>	23 ± 2.0 (Polluted)	7.0 ± 0.4 (Polluted)
	42 ± 1.8 (Unpolluted)	13.0 ± 0.6 (Unpolluted)
<i>Ficus nitida</i>	19 ± 1.2 (Polluted)	5.8 ± 0.3 (Polluted)
	31 ± 1.5 (Unpolluted)	11.0 ± 0.5 (Unpolluted)
<i>Conocarpus lancifolius</i>	20 ± 1.8 (Polluted)	6.0 ± 0.5 (Polluted)
	38 ± 2.1 (Unpolluted)	11.5 ± 0.4 (Unpolluted)
<i>Nerium oleander</i>	18 ± 1.4 (Polluted)	5.5 ± 0.2 (Polluted)
	32 ± 1.9 (Unpolluted)	10.0 ± 0.3 (Unpolluted)
<i>Eucalyptus camaldulensis</i>	22 ± 1.7 (Polluted)	6.8 ± 0.5 (Polluted)
	40 ± 2.0 (Unpolluted)	12.0 ± 0.6 (Unpolluted)
<i>Dodonaea viscosa</i>	20 ± 1.5 (Polluted)	6.2 ± 0.4 (Polluted)
	34 ± 2.3 (Unpolluted)	11.0 ± 0.5 (Unpolluted)

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. A similar depressive effect is reported by other species, such as *Nerium* and *Dodonaea viscosa*, indicating that contaminated soil harms 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* were recorded from 21 g in uncontaminated soil to 10 g in contaminated soil.

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⁻¹ dry weight in the polluted plants. This increase in catalase activity is used as an indication of the plant's 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⁻¹ 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 hydrocarbon accumulation reached 500 to 1500 mg.kg⁻¹ dry weight in contaminated plants, reflecting the intensity of the pollution effect.

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⁻¹), which means both species contain high chlorophyll content, indicating good photosynthetic activity and their ability to tolerate higher levels of pollution. On the other hand, *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 a medium range, reflecting variable pollution effects. Catalase enzyme activities (U.g⁻¹ dry weight) in *Salvia rosmarinus* and *Nerium* also presented high activities, proving their response to pollution-

Table 4: Dry and fresh weight measurement results in all plant species.

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

Table 5: The environmental stress and toxicity analysis.

Item	Value	Interpretation
Catalase Activity [U.g ⁻¹ dry weight]	5.0 - 10.0 (in contaminated plants)	Increased activity due to oxidative stress
Superoxide Dismutase Activity [U.g ⁻¹ dry weight]	3.0 - 8.0 (in contaminated plants)	Another response to oxidative stress
Total Petroleum Hydrocarbons Accumulation [mg.kg ⁻¹ dry weight]	500 - 1500 (in contaminated plants)	High accumulation indicates the effect of pollution on plants
Statistical Analysis (p-value)	Less than 0.05	Statistical significance of differences between groups

induced effective stress levels. The high activities in *Salvia rosmarinus* and *Nerium* showed a 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^{-1} , 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, and these species could act as efficient bioindicators in the monitoring of pollution due to their capacity for supporting the 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 the appropriate selection of plant species for pollution monitoring and environmental impact studies.

DISCUSSION

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 accumulation of toxic organic compounds in the soil. It agreed with a study result by Ajmi et al. (2018) that the accumulation of heavy organic compounds 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 those 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 & Umer (2022), such changes in soil can lead to physiological disorders that 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's 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 to Saeed et al. (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

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

Bioindicator	<i>Salvia rosmarinus</i>	<i>Eucalyptus globulus</i>	<i>Ficus nitida</i>	<i>Conocarpus lancifolius</i>	<i>Nerium</i>	<i>Eucalyptus camaldulensis</i>	<i>Dodonaea viscosa</i>
Chlorophyll Content [mg.g^{-1}]	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)	Moderate (2.5-3.5)
Catalase Activity [U.g^{-1} 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^{-1} 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^{-1}]	Low (200-500)	Moderate (300-700)	High (800-1200)	Moderate (400-600)	Low (250-500)	Moderate (350-650)	Moderate (400-700)
Growth Rate [% change]	+20%	+10%	- 50%	+5%	+15%	+10%	+5%

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 affect plants, increasing soil toxicity and impairing their ability to retain nutrients. This effect is 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, which is important for health. Ascorbic acid is an important antioxidant that plays a major role in protecting 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 et al. (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 the 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 findings of Aswad et al. (2025) and Resmi et al. (2023), who made an inference on the negative effect of oil pollution on soil and plants' structural properties and hindering 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. In comparison with those grown in the polluted one, a 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. (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 the 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 the mitigation of 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 their 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 shows that oil pollution results in the accumulation of hydrocarbons in the soil in a similar manner to Arora et al. (2022). This study reported high TPH concentrations in polluted areas around fuel stations and refineries and their adverse effects on plant growth.

Volatile Organic Compounds (VOC) and BTEX: Some studies have 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 has been linked to a decrease in soil pH, as previously observed in studies where contaminated soils exhibited lower pH levels compared to adjacent, unpolluted areas (Cai et al., 2020). The present findings support this, highlighting that the reduced pH results from the slow decomposition of hydrocarbons and a decline in the soil's cation exchange capacity (CEC). This reduction in CEC impairs the soil's ability to retain and absorb essential nutrients. Supporting this, Zhang et al. (2023) reported that oil pollution significantly diminishes the soil's ion absorption capability.

Multiple studies have confirmed that oil pollution leads to the buildup of heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg) in the soil. For example, Liu et al. (2022) found a significant increase in the concentration of these metals in oil-contaminated soils. This contamination also affects plant health. Pundir et al. (2020) reported reduced plant growth and visible deterioration in leaf quality due to oil pollution. Similarly, Sharma et al. (2021) observed a decline in chlorophyll content and a rise in antioxidant activity in plants exposed to polluted soil. These findings collectively suggest that oil pollution negatively impacts both soil quality and plant physiological responses.

The effect of oil pollution on fresh and dry weight is similar to what was mentioned in the study by 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) 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 in studies on the effect of oil pollution on photosynthesis and growth in plants. In addition, Dias & Taveres (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 the 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.

CONCLUSIONS

1. TPH concentration in the contaminated soil of the Daura refinery was relatively high, about 8000 mg.kg⁻¹, showing high oil contamination.
2. While the uncontaminated soil showed relatively low levels of contamination at about 50 mg.kg⁻¹, 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 to 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, which show very dangerous levels in polluted soil against plant health and the surrounding environment. The organic matter content of the contaminated soil decreased, indicating a decline in biological activity and soil fertility.
5. Oil pollution resulted in a reduction in plant height, leaf area, and the number of branches. This means that pollution reduces both the growth and development of the plants. In the plants that 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 processes to resist the 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.

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