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The Effect of Oil Field Waste on Soil Properties using Spatial Analysis

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ABSTRACT

Background: Oil field waste is among the leading causes of environmental contamination, adversely impacting soil quality and nearby ecosystems. In Baghdad, the Dora refinery is a central location for oil refining activities. However, the pollution generated by its operations, which includes heavy metals and hydrocarbons, threatens the health and fertility of the soil. Spatial analyses help in determining the distribution patterns of these pollutants and their effects on the environment. This study intends to investigate the effects of pollutants such as lead, cadmium and hydrocarbons on the soil around the Dora refinery in Baghdad. Besides, it aims to create a predictive model to assess hydrocarbon levels based on the concentrations of lead and cadmium using spatial analysis.

Methods: Soil samples were gathered from three zones with varying pollution levels (low, medium and high) and were examined using spectral analysis methods to identify lead and cadmium concentrations. Geographic Information Systems (GIS) were employed to analyze the spatial data and determine the distribution patterns of pollutants. A multiple regression model was also created to forecast hydrocarbon levels based on lead and cadmium concentrations.

Result: The findings indicated that lead, cadmium and hydrocarbon concentrations rose greatly as the distance to the Daura refinery decreased. A correlation was established between the levels of these pollutants, showing that hydrocarbons contribute to the movement of heavy metals within the soil. Using the regression model, the concentrations of hydrocarbons were predicted from lead and cadmium levels.

Key words: Oil pollution, Oilfield waste, Risk assessment, Soil properties, Spatial analysis.

INTRODUCTION

Oil field waste is a major contributor to environmental pollution, arising from the extraction, transportation and refining activities within oil refineries. This waste adversely affects soil quality and the surrounding ecosystem (Farooq *et al.,* 2022). In Baghdad, the Dora refinery is integral to oil refining, yet spills and industrial waste generated by its operations can lead to significant soil contamination. These contaminants, including hydrocarbons and heavy metal, pose risks to soil health and undermine its agricultural viability. Furthermore, the consequences of this waste extend beyond chemical alterations in the soil; they also encompass physical changes such as alterations in permeability, water retention capacity and overall fertility (Lee *et al.,* 2024). By employing spatial analysis, we can map the distribution of these pollutants within the soil, facilitating a deeper understanding of their impacts and enabling the implementation of effective remediation strategies. Prior studies into the effects of oil field waste on soil properties using spatial analysis concentrated on the consequences of oil pollution in southern Iraq. Researchers used geographic information systems (GIS) to assess the influence of oil contaminants on soil properties in the Basra region, using spatial analysis methods to identify pollution hotspots and map the distribution of hydrocarbons in the soil. The findings found significant changes in soil structure, decreased fertility and elevated amounts of heavy metal, including lead and cadmium (Fadhel *et al.,* 2019).

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The study used spectral analysis to assess soil contamination by petroleum hydrocarbons in the areas surrounding Nigerian oil fields, as well as spatial analytic tools to determine the extent of hydrocarbon pollution caused by oil spills. According to the findings, such oil pollution reduced organic matter in the soil while increasing toxic element levels, which had a negative influence on agriculture and biodiversity. This study used spatial analysis approaches to investigate the impact of oil

extraction-related contamination on Qatari soil. The findings found that oil-polluted soil had altered water retention capacity, increased acidity levels and higher heavy metal, concentrations (Zhou and Wang, 2022). Plant growth was noticeably reduced in contaminated locations, assessing the Environmental Impact of Oil Field Waste in Algeria Using Geographic Information Systems (Ajmi *et al.,* 2018). The purpose of this study was to use GIS methodologies to identify areas in Algeria that were affected by oil pollution. The data showed that oil contamination reduced plant diversity and degraded soil quality in these locations, as well as a considerable increase in hydrocarbon and other hazardous compounds (Bagdi *et al.,* 2023 and Ati *et al.,* 2024).

These studies are essential for understanding the effects of oil pollution on soil characteristics, as well as for using spatial analysis tools to identify damaged areas and design soil remediation plans also focuses on analyzing how the waste from the Baghdad Dora refinery affects soil parameters fellow:

1. Using spatial analysis to identify the spread of oil pollutants and heavy m*et al.,*s in soil near the Dora refinery.
2. Examining how oil waste affects soil chemical and physical properties such as organic content, acidity, permeability and water retention.
3. Assessing the impact of oil pollution on soil deterioration, agricultural productivity and fertility.
4. Propose environmental remediation solutions to improve soil quality and mitigate the negative consequences of oil pollution.

MATERIALS AND METHODS

Soil samples are collected at numerous areas the coordinates of the Dora area in Baghdad 33.2626°N, 44.3600°E, near the Dora refinery in Baghdad at varying depths (0-30 cm and 30-60 cm) using specialist sampling equipment according (Bhatti *et al.,* 2022).Hydrocarbon Analysis: Gas chromatography (GC) is used to determine the concentrations of petroleum hydrocarbons in soil samples. Additionally, Gas Chromatography-Mass Spectrometry (GC-MS) is used to identify and quantify specific hydrocarbon concentrations according (Ati *et al.,* 2022).

Heavy metal analysis

Soil samples are analyzed to determine the amounts of heavy metal, such as lead (Pb) and cadmium (Cd) using spectroscopic techniques such as atomic absorption spectroscopy (AAS) according (Osman *et al.,* 2024).

Sample drying

Place the samples in a well-ventilated place to remove moisture (Ajmi *et al.,* 2018 and Rama Lakshmi, 2016).

Sample crushing

Use a grinder to reduce the samples to a fine powder, maintaining even distribution (Bingari *et al.,* 2022).

Hydrocarbon analysis using Gas Chromatography (GC) involves extracting hydrocarbons from soil using ethanol as a solvent. The sample is subsequently pumped into the gas chromatography system *via* a hydrocarbon-specific column and distinct hydrocarbons are recognized using MS detection converters (Bodor *et al.,* 2022). The quantities of hydrocarbons in each sample are documented and compared to established environmental guidelines (Khosravi *et al.,* 2023).

Atomic absorption spectroscopy (AAS)

Begin by preparing the sample, which may include burning in a furnace to ease the examination of heavy components or the use of acidic solutions to break down the samples. The processed samples are then injected into the AAS equipment to determine the levels of lead and cadmium (Rahmatullah *et al.,* 2022).

Determination of limits

The results are compared to the permitted levels outlined in environmental regulations, including WHO standards (Bingari *et al.,* 2023). Using spatial analysis methods such as geographic information systems (GIS) to effectively depict and assess the spread of pollutants in soil, as well as developing a spatial database that includes the geographical locations of soil samples, hydrocarbon concentration levels and heavy metal (Rahman *et al.,* 2023 and Rajalakshimi *et al.*, 2025).

Spatial model analysis

Geostatistical analysis is used to analyze the level of pollution and connect it to geographical elements such as distance from the refinery, wind patterns and environmental variables based on the area's coordinates (Asem and Zeng 2023).

RESULTS AND DISCUSSION

Lead concentration

The low-pollution area (Area 1 Low) had a lead content of 5 mg/kg, deemed low in comparison to other locations. This suggests that human activities and pollution sources have had a limited impact in this area. The lead levels in the medium polluted area (Area 1 Medium) were 15 mg/kg. This suggests an increase in lead pollution levels, which could be attributed to increased industrial activity or oil field waste. The lead content in the high-pollution area (Area 1 High) was 30 mg/kg. This shows a high degree of lead pollution, which may harm soil quality and nearby ecosystems agree with Zeki *et al.* (2019).

Cadmium concentration

The low-pollution area had a cadmium content of 0.2 mg/kg, indicating very low levels. Cadmium is a hazardous heavy metal, yet its concentration does not constitute a substantial environmental threat. Cadmium concentrations increased to 1.0 mg/kg in areas with medium pollution. This suggests

an increase in pollution, possibly from industrial sources or oil field trash. Cadmium levels in the heavily polluted area reached 5.0 mg/kg. This poses a bigger environmental danger because cadmium may cause severe damage to soil and the agricultural environment, as well as health consequences for living things agree with Bao *et al.* (2022).

Hydrocarbon concentration

In the low-pollution area, the hydrocarbon concentration was 100 mg/kg. This level implies modest pollution, potentially the result of minor oil or petroleum spills.In the moderately polluted area, the hydrocarbon concentration exceeded 300 mg/kg, indicating a significant rise in soil pollution. This rise could be attributed to oil spills or industrial waste.The hydrocarbon concentration in the severely contaminated area was just 6 mg/kg, which is very low when compared to other places, his could indicate that the biodegradation or absorption of hydrocarbons in this area is more efficient agree with De Souza *et al.* (2020).

The relationship between pollutants (lead, cadmium and hydrocarbons) and the environment, as well as the impact of pollution on ecosystems and human health is due to a variety of factors, including chemical interactions, as hydrocarbons are considered a mode of transportation, particularly for heavy metal, such as lead and cadmium within the soil. When oil spills occur, they can combine with other particles, resulting in a higher concentration of heavy metal. The combined effects, such as the toxic interaction of metal, like lead and cadmium, are detrimental to living beings. Their existence in combination with hydrocarbons can increase their toxicity, resulting in more damaging effects on living beings and plants (Eissa *et al.,* 2022; Chaudhary and Mishra, 2019) by evaluating the data, relationships between the amounts of various contaminants can be discovered. For example, high quantities of hydrocarbons may be associated with high levels of lead and cadmium (Asem and Zeng, 2023).

The findings show that human activities, such as oil waste, have a direct impact on soil pollution levels. To reduce environmental pollution and protect ecosystems, it is critical to follow up on these findings and examine the elements that contribute to pollution, such as the influence of oil fields and factories according Table 1 connection between pollutants (lead, cadmium and hydrocarbons).

Spatial analysis model for pollution levels (Lead, Cadmium and Hydrocarbons)

This model seeks to examine the spatial distribution of lead, cadmium and hydrocarbon concentrations in various places surrounding the Dora refinery in order to identify patterns and trends in environmental data and compare the results to known pollution levels. It includes concentration readings of lead, cadmium and hydrocarbons from a variety of places, as well as sample coordinates, the average concentrations of heavy metals and hydrocarbons have been estimated for each location and descriptive analysis is used to discover underlying patterns indicated by standard deviation and range by Kriging algorithms agree with (Mokhtari *et al.,* 2022). The used to create comprehensive models of contaminants' geographical distribution. The multiple regression study to investigate the relationship between pollution levels (lead and cadmium) and hydrocarbon concentrations has been reported as follows:

Lead concentration is calculated as β0 + β1.....

(Rahman *et al.,* 2023).

Hydrocarbon concentration + β2

Cadmium concentration + 1……..(Rahman *et al.,* 2023).

Both quantitative and qualitative evaluations have been conducted to measure the impact of pollution sources on soil quality and symbols and colors have been used to

Table 1: The connection between pollutants (lead, cadmium and hydrocarbons).

Area	Lead conc. (mg/kg)	Cadmium conc. (mg/kg)	Hydrocarbon conc. (mg/kg)
Area 1 (low)	5	0.2	100
Area 1 (Medium)	15	1.0	300
Area 1 (High)	30	5.0	6

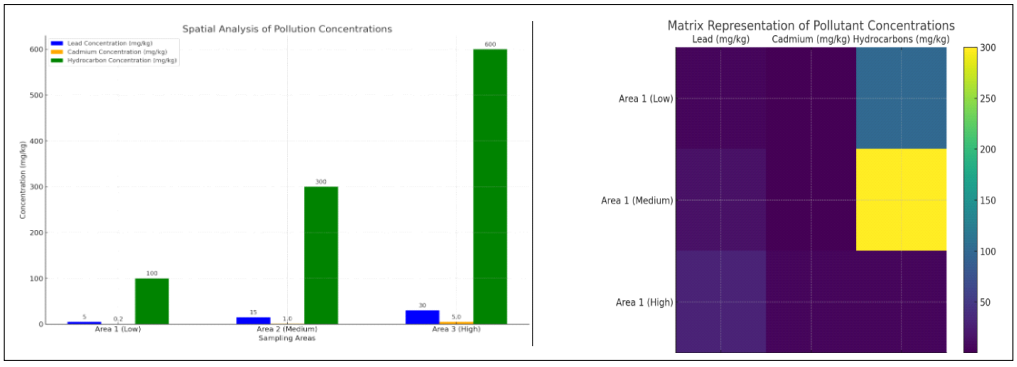


Fig 1: The quantitative and qualitative evaluations measure the impact of pollution sources on soil quality.

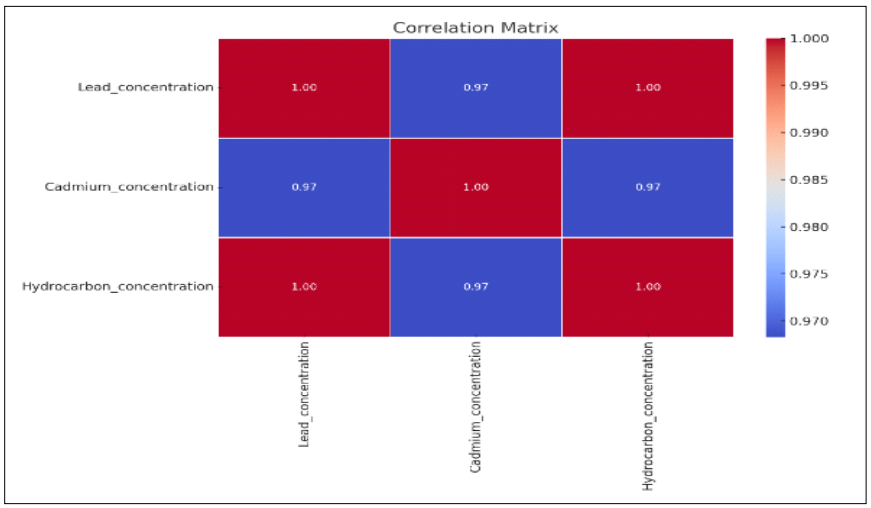


Fig 2: Spatial data analysis concerning pollutant concentrations across various regions.

improve comprehension of various pollution levels (Green denotes low levels, yellow represents medium levels and red indicates high levels) in Fig 1 show the quantitative and qualitative evaluations measure the impact of pollution sources on soil quality.

Individual concentration data for various types of pollutants (lead, cadmium and hydrocarbons) are displayed and spatial analysis tools assist in identifying the most polluted locations based on their closeness to pollution sources. This strategy aids in the prioritization of environmental monitoring and remediation efforts, promotes environmental management and safeguards public health (Bingari *et al.,* 2023).

Spatial data analysis concerning pollutant concentrations across various regions

The link between pollutants direct association between lead and cadmium pollution levels and hydrocarbon molecules, the spatial analysis of the data is dependent on the dispersion of contaminants. It is possible to investigate how lead, cadmium and hydrocarbon concentrations vary by geography. The data shows that in Fig 2.

1. Region 1 (Low) contains relatively low amounts of lead (5 mg/kg), cadmium (0.2 mg/kg) and hydrocarbons (100 mg/kg).
2. Region 1 (Medium): A noticeable increase in all contaminants, indicating environmental degradation.
3. Region 1 (High): Peak concentrations suggest serious environmental pollution. This is consistent with regional regional factors and pollution sources. Possible pollution sources in each location must be recognized, such as proximity to industrial, major highways, or densely populated cities. Higher pollutant concentrations in a certain region may be associated with human activities (such as industrial operations or farming) and proximity to the Dora refinery.

For the cumulative assessment, it is critical to consider how contaminants interact with one another. For example, the presence of lead and cadmium can harm soil microorganisms, preventing hydrocarbon decomposition. This could have implications for the local food chain and public health, areas with elevated lead and cadmium levels may offer concerns to people, such as heavy metal poisoning. Given the possible harmful influence on local species and biodiversity, research into the impacts of these contaminants on human health and the ecosystem agree with Bao *et al.* (2022); Mokhtari *et al.* (2022).

Determine the prediction according (Sahu *et al.,* 2024, Huang *et al.,* 2023)

After creating the spatial model for elements and regions, we applied the derived equation.

$$\text{Hydrocarbon}=50+5\times \text{Lead}+10\times\text{Cadmium}$$

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The hydrocarbon levels were determined when the lead concentration is 20 mg/kg and the cadmium concentration is 2.5 mg/kg, as follows:

$$\text{Predicted hydrocarbon} = 50+5\times20+10\times2.5$$

Possible consequences have been perform the prediction, we obtain a value for the hydrocarbon concentration. This helps to understand how pollution impacts the ecosystem because the estimated hydrocarbon content is 175 mg/kg. Regression models were used to create predictions based on input data. In this scenario, the hydrocarbon level is anticipated using the lead and cadmium concentrations. The predicted value (*e.g.,* 175 mg/kg for hydrocarbons, 20 mg/kg for lead and 2.5 mg/kg for cadmium) reflects the pollutants' influence on the environment (Zhao *et al.,* 2023).The association between them, as revealed by the discovery of patterns for spatial analysis, aids in finding trends that may influence the outcomes, as well as crucial variables applicable in prediction models, which add to environmental planning and effective interventions. The more precise and

comprehensive the spatial data, the more dependable and accurate the prediction models (Jones *et al.,* 2022; Ahmed *et al.,* 2022).

CONCLUSION

1- The study confirmed that the waste generated by the Dora refinery negatively affects the quality of the soil, as it contains high concentrations of lead, cadmium and hydrocarbons.
2- The study revealed that the level of pollution increases the closer we get to the refinery, indicating a clear link with the sources of pollution.
3- There is a link between the concentrations of lead, cadmium and hydrocarbons, which increases the toxicity of pollutants and poses health risks.
4- Creating a model to predict hydrocarbon concentrations based on lead and cadmium levels helps in analyzing environmental concerns as part of predictive modeling in a sustainable environmental plan.
5- It is recommended to focus on reducing pollution and implementing effective treatment solutions, with the need for continuous monitoring and future studies to analyze the effects of pollution on the environment and human health.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All procedures for experiments were approved by the Standardization and Quality Control Laboratories, Ministry of Higher Education and Scientific Research, Baghdad, Iraq.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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