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The Large-Scale Exploration and Production of Oil in Kurdistan, Iraq and its Associated Impacts on the Environment

Bachelor Thesis

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Abstract

The objective of this study is to extrapolate the reality of the oil industry in the Iraqi Kurdistan region of Iraq and the assessment of environmental pollution caused by the oil industry in the physicochemical properties of soil and water near the oil field in Zakho district**.** 16 different samples of water and soil were taken from the surrounding environment near these oil fields to assess their impact on soil and water physiochemical properties in 3 different sites close to the oil field in Zakho province and a fourth location far from the oil fields the highway between Duhok city and Zakho city as control. The Republic of Iraq, including the Kurdistan Region of Iraq (KRI), is endowed with a range of easily exploitable oilfields. It has recently emerged as one of the most active inland oil and gas exploration places. Despite these advantages, the exploration and production operations can have a considerable environmental effect. The problems posed by the oil and gas industries have infiltrated economic, political, social, legal, and environmental concerns in Iraq's Kurdistan region. This research examines large-scale oil and gas exploration and production in KRI to find related environmental consequences. The findings show that Kurdistan's oil and gas operations significantly influence the atmosphere, aquatic, terrestrial, and biosphere. Results revealed that the pH values of studied locations namely Tawke, Pishabire, Qadya are slightly alkaline, and different values of EC indicate that the location was affected variably with oil effluents discharged to the surrounding environment. Available nitrogen in all locations is around 75 mg/kg and in sufficient amounts which indicates that the soil is positively affected by industrial effluents**.** Available K, Ca, Mg, Na, OM, micronutrients, base saturation, and $CaCO_3$ and not affected by petroleum hydrocarbon released to this environment. CEC of the soil varies between 9- 22 $Cmol^-/Kg$ which reflects the probability of being affected by oil hydrocarbons released into the soil. The pH of water is affected by petroleum hydrocarbon discharged into the and makes it slightly alkaline close to 8. The EC of water samples are highly affected by hydrocarbon discharges to water resources, the water also is influenced by oil hydrocarbons making it slightly turbid from turbidity ranges between 92 to 100 NTU. The first sample in Tawke and the first sample of Qadya were significantly affected by pollution recording 40 and 50 ppm nitrate, which makes them unsafety even to livestock. In conclusion, soil and water quality were adversely affected by the discharge of petroleum in the environment.

Keywords: Kurdistan Region of Iraq, oil, exploration, production, environment, ecosystem.

Abstract Czech language

Cílem této studie je extrapolovat realitu ropného průmyslu v iráckém Kurdistánu v Iráku a hodnocení znečištění životního prostředí způsobeného ropným průmyslem ve fyzikálně chemických vlastnostech půdy a vody v blízkosti ropného pole v okrese Zakho. Z okolního prostředí poblíž těchto ropných polí bylo odebráno 16 různých vzorků vody a půdy, aby se posoudil jejich vliv na fyzikálně-chemické vlastnosti půdy a vody na 3 různých místech v blízkosti ropného pole v provincii Zakho a na čtvrtém místě daleko od ropných polí dálnice mezi Město Duhok a město Zakho jako kontrola. Irácká republika, včetně Kurdistánského regionu Iráku (KRI), je vybavena řadou snadno využitelných ropných polí. Zásoby KRI se odhadují na 45 miliard barelů ropy, 200 bilionů kubických stop (tcf) prokázaných zásob plynu a až 198 bilionů kubických stop (tcf) primárně nevyzkoušeného plynu. Nedávno se ukázalo jako jedno z nejaktivnějších vnitrozemských míst těžby ropy a zemního plynu. Navzdory těmto výhodám mohou mít průzkumné a výrobní operace značný vliv na životní prostředí. Problémy způsobené ropným a plynárenským průmyslem pronikly do ekonomických, politických, sociálních, právních a ekologických zájmů v iráckém Kurdistánu. Tento výzkum zkoumá rozsáhlý průzkum a těžbu ropy a zemního plynu v KRI s cílem nalézt související důsledky pro životní prostředí. Zjištění ukazují, že ropné a plynové operace Kurdistánu významně ovlivňují atmosféru, vodní, suchozemskou a biosféru. Výsledek ukázal, že hodnoty pH pro tři studované lokality, jmenovitě Tawke, Pishabire, Qadya, jsou mírně alkalické a různé hodnoty EC naznačují, že lokalita byla různě ovlivněna ropnými odpady vypouštěnými do okolního prostředí. dostupný dusík ve všech lokalitách je kolem 75 mg/kg a v dostatečném množství, což naznačuje, že půda je pozitivně ovlivněna průmyslovými odpadními vodami. Dostupné K, Ca, Mg, Na, OM, mikroživiny, nasycení zásadami a CaCO3 a nejsou ovlivněny ropnými uhlovodíky uvolňovanými do tohoto prostředí. CEC půdy se pohybuje mezi 9-22 Cmol-/kg, což odráží pravděpodobnost ovlivnění ropnými uhlovodíky uvolňovanými do půdy. pH vody je ovlivněno ropným uhlovodíkem vypouštěným do vody a činí ji mírně alkalickou blízkou 8. EC vzorků vody jsou vysoce ovlivněny vypouštěním uhlovodíků do vodních zdrojů, voda je také ovlivněna ropnými uhlovodíky a díky zákalu je mírně zakalená se pohybuje mezi 92 až 100 NTU. První vzorek v Tawke a první vzorek Qadya byly významně ovlivněny znečištěním zaznamenávajícím 40 a 50 ppm dusičnanů, což je činí nebezpečnými i pro nápoje pro hospodářská zvířata. Závěrem lze říci, že kvalita půdy i vody byla nepříznivě ovlivněna vypouštěním ropy do životního prostředí.

I declare that I have prepared the bachelor's thesis myself and that I have stated all the used information resources in the thesis.

Olomouc, 27th May 2024 ……………… …JFB………………………

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List of Abbreviations

KRI: Kurdistan Region of Iraq

MNR-KRG: Kurdistan Region Ministry of Natural Resources

KRG: Kurdistan Regional Government

USAID: United States Agency for International Development

PAHs: Polycyclic Aromatic Hydrocarbons

UNEP: United Nations Environment Program

ESA: Ecosystem Service Approach

1 Introduction

Rapid industrialization and globalizations are a major contributor to environmental damage and pollution of varying degrees. All forms of effluents and most byproducts from any type of industry contaminate water bodies and soil to dangerous levels. Therefore, industrial operations frequently lead to soil contamination, either directly or indirectly. Study reported that contaminated water used for irrigation has an impact on the agricultural system such as soil quality and crop health. Over the last few years, heavy metals are one of the most significant pollutants in the environment because of their toxicity, persistence and bio-accumulation issues. Heavy metals in industrial effluent are one of the most dangerous environmental contaminants; toxic metals such as Cr, Cu, Zn, Pb, and Cd are accumulated in different parts of plant which negatively affect growth and metabolism of plant.The heavy metals have been variously classified; one classification considers those elements that have atomic weights greater than 55 heavy metals. Under this classification, the micronutrients Cu (atomic weight 63.54), Fe (atomic weight 55.85), Mn (atomic weight 54.993), Mo (atomic weight 95.95), and Zn (atomic weight 65.38) would be identified as heavy metals. Elements that are considered toxic to plants and animals: the elements Cd, Cr, Hg, Ni, and Pb. Due to their toxicity, persistence, and bioaccumulation issues, heavy metals have recently become one of the more harmful contaminants in our environment. The majority of heavy metals can be hazardous to all life forms, including bacteria, humans, and animals, at large quantities, despite the fact that some of them are necessary trace elements. Moreover, untreated oil effluent cause several problem to soil quality as the rise of soil pH, disturb the texture and color of soil, impact the balance of macro and micro nutrient in soil, also negatively impact of microbial activates in soil and change natural cycle, decrease oxygen supply in soil and ultimately decline the percentage of germination. In addition, the dissolved oxygen in soil is reduced due to the high concentration of biological and biochemical oxygen demand in these oil effluents which negatively impact on the soil microorganism. Sodium, magnesium, Sulphur and chloride rise the salinity of soil, deteriorate soil structure. A high salt and surfactant concentration cause destruction of soil structure and also harmful impacts on plant health and reduced natural water quality, changes water and soil pH, eutrophication, reduced light transmission, and increased salt in water, due to their low biodegradability and toxicity of oil.

1.1 Background

The Republic of Iraq, including the Kurdistan Region of Iraq (KRI), is endowed with several oilfields that are easy to exploit. Iraq began exploring oil in the 1920s and producing it in the 1930s. In 1975, the central Iraqi government fully nationalized the country's oil sector (Amereller & Amereller, 2021). The KRI's reserves are estimated to be 45 billion barrels of oil, 200 trillion cubic feet (tcf) of proved gas reserves, and up to 198 tcf of mostly untested gas, according to the Kurdistan Region Ministry of Natural Resources (MNR). The KRI's reserves of gas and oil would position it as one of the top ten oil-rich nations on earth if it were an independent entity. Even though it has semi-autonomy, the area remains a vital component of the Republic of Iraq. The KRI's total exported and consumed oil for 2020 was 165,942,861 barrels, according to the MNR data (Amereller & Amereller, 2021).

Following the approval of the Iraqi constitution and the issuance of the oil and gas law by the Kurdistan Parliament in 2003 (Amin, 2017), the Kurdistan regional government (KRG) granted the territory of the intellectual property rights to extract oil for several global firms. A portion of these companies began to produce oil, such as DNO and GENEL, which began producing oil from the Tawke field, Genel Energy, and Addax from the Taq Taq field, Gulf Keystone Shaikan, and KAR Oil & Gas from the Khurmala field.

Oil and natural gas exploration and production can cause significant harm to the environment. The challenges generated by the oil and gas sectors have permeated economic, political, social, legal, and environmental issues in emerging countries, including the Kurdistan region of Iraq. Environmental legislation is sometimes ineffectual and inadequate (Koshesh & Jafari, 2019).

Industry in the region, and the oil industry, in particular, are activities that have a detrimental impact on the environment and produce a variety of environmental issues. The oil contains at least (300) distinct compounds, most of which are harmful to human health or living creatures (Amin, 2017). Direct consequences of oil industry operations such as exploration, oil extraction, oil transportation, and oil refining may be summed as pollution of Kurdistan's environment, unfavorable change in the natural landscape, and exhaustion of Kurdistan's natural resources.

The oil industry's activities pollute Kurdistan's environment as a result of chemicals used in oil extraction, oil spilled on land, crude oil combustion, which results in the emissions of many extremely poisonous gases and the discharge of some toxic metallic elements, and pollution from crude oil transport accidents by pipelines and oil tankers (Amin, 2017).

1.2 Problem Statement

The Kurdistan region of Iraq is associated with large-scale petroleum extraction. It has become one of the most active sites for inland oil and gas exploration in recent years. These exploration and production have become a significant and contested subject since 2005. The Kurdistan region's economy is nearly wholly built on its vast oil and gas reserves. Kurdish autonomy has confirmed oil deposits of 45 billion barrels, which are roughly comparable to Libya's reserves (47 billion barrels), and makeup approximately one-third of Iraq's overall oil deposits (Amereller & Amereller, 2021). While the Kurdistan administration has reaped enormous benefits from oil production, the region's ongoing oil operations have created a huge environmental concern.

Iraq, and notably the KRI, is confronted with major environmental issues ranging from soil salinity, poor water quality, and carbon emission to the destruction of vital ecosystems, the effects of climate change, and the prospect of water scarcity. Its environment has been subjected to various converging stresses caused by population increase, climate change, inadequate spatial planning, and the incursion of vulnerable habitats.

Oil fires have been known to emit toxic compounds into the atmosphere, including nitrogen dioxide, sulfur dioxide, polycyclic aromatic hydrocarbons (PAHs), carbon monoxide, particulate matter, and metals such as lead, vanadium, and nickel (Kamal, 2016). Acid rain is related to nitrogen and sulfur molecules and can have a deleterious influence on flora and contribute to soil degradation. Moreover, these chemicals can have short-term severe health consequences, particularly for persons who already have respiratory issues. The large-scale discharge of PAHs has the capacity to cause protracted ecological repercussions. PAHs are long-lasting chemical molecules, and some of these are cancerous and can exacerbate respiratory issues (Kamal, 2016). They can be carried across a considerable region before depositing in soils when released by fires. This, in turn, impacts the health of citizens living in affected localities. Metals emitted by combustion are also ecologically resilient, and overexposure can have a variety of health consequences.

According to the World Bank (2017), the yearly mean temperature in Iraq has risen by 12 degrees Celsius. Iraq has little rainfall, and the bulk of the nation is arid and semi-arid. Annual precipitation fluctuated between 1951 and 2000, with both rises (northeast Iraq) and declines (southeast and west Iraq). In the future, Iraq is expected to have greater heat waves, higher temperatures, a drop in mean annual rainfall but an increase in intensity, sea-level rise in the Gulf, and a decrease in the runoff. These potential possibilities are inextricably linked to the consequences of oil exploration and production. The changes are projected to negatively impact Iraq's agriculture, water quality, people's health, infrastructures, and energy industry (USAID, 2017).

While the demand for water is growing dramatically due to rising population, economic progress, and environmental concerns (Danboos et al., 2017), most Kurdish people rely on surface and groundwater. Despite this, the Kurds confront a severe danger of water scarcity as a result of internal and external difficulties such as climate change, inadequate water resource management, a lack of local legislation, and global development rules. The amount and quality of water have changed as a result of the extent of contamination produced by oil exploration and production. Similarly, there have been reports of increasing salt levels (Abdullah et al., 2016). Groundwater is becoming more important as a strategic water supply as a result of climate unpredictability and ongoing surface water scarcity.

The loss of biodiversity in Iraq's numerous areas, especially the KRI, is alarming. Iraq's biodiversity has been severely degraded as a result of unrestrained hunting and harvesting of vulnerable species, excessive salinity and ecosystem pollution, uncontrolled development, and a lack of care in many of the country's most significant biodiverse locations. Despite not being in the KRI, the Mesopotamian Marshes have been extensively impacted by oil prospecting and water drainage. Despite global attempts to reestablish the habitats, regeneration has been patchy owing to excessive soil and water salinities. The marshes have grown fragmented, threatening the survival of numerous species and the sustainability of the wetlands (Fawzi and Mahdi, 2014).

While none of these circumstances can be directly linked to oil and gas exploration in Iraq, particularly in the KRI, there is a high probability that they are related to oil production. Examining the environmental implications of large-scale oil extraction at the KRI aims to prove or disprove the source of the region's existing state.

1.3 Research Objective

This study aims to examine the potential environmental impacts of large-scale exploration and production of oil and gas in the Kurdistan Region of Iraq (KRI) to make the necessary recommendations for confronting the situation, and preventing future adverse consequences.

Objective: To examine the potential environmental impacts of large-scale exploration and production of oil and gas on the Kurdistan Region of Iraq (KRI) environment.

1.4 Research Question

The achievement of the objective mentioned above shall depend on the research question. The question helps in research planning and facilitates the achievement of a research solution.

Research Question: What are the potential environmental impacts of large-scale exploration and production of oil and gas on the Kurdistan Region of Iraq (KRI) environment?

1.5 Significance of the Research

Studying the potential environmental impacts of oil and gas exploration and their largescale production is significant and helps realize the extent of challenges posed to the environment. It further leads to developing necessary intervention measures to prevent further damage to the environment. Policymakers are able to adapt the necessary measures, including proposals for regulations that protect and ensure environmental sustainability. Common diseases associated with air, water, and land pollution because of oil and gas pollution will be greatly reduced, leading to a healthy population.

2 Literature Review

2.1 Oil Industry Operation

2.1.1 Exploration

Driven by political challenges, there were no oil drilling efforts in this Kurdistan area of Iraq before 1991. (Global, 2015). In 2004, world oil corporations started researching the area for oil and natural gas, and the Kurdistan region has witnessed notable developments. Over 200 oil wells were drilled by 2018, with an overall oil output capacity of 450000 bpd. Over 15 billion barrels of oil were projected to be recoverable in this region (Mackertich & Samarrai, 2015). MNR divided the Kurdistan region into more than 50 oil blocks, which were eventually granted to multinational oil firms for investment under Product sharing contracts. Five major oil reserves within Kurdistan Region are able for significant production. They include; Taq Taq (managed by TTOPCO), Khurmala, Bai Hassan, Avana (controlled by the Kar Group), and Tawke (controlled by DNO). The current average oil production capability of areas operational in KRG territory was over 500,000 barrels each day in 2015. However, the Kurdistan region's oil production was halved in 2017 when the Iraqi force seized Kirkuk's oil fields, which had been under the KRG's authority since 2014 (Heshmati and Auzer, 2018).

Since the first exploration well in nearly two decades was spudded, the Kurdistan Region of Iraq has seen unprecedented levels of exploration activity. While the location is adjacent to several of Iran's and Iraq's vast and supermassive sites, the reservoirs where deposits have been discovered are entirely different (Salih & Yamulki, 2020). In Iraq, Cenozoic and Cretaceous rocks topped by Cenozoic evaporite sequences account for a high proportion of identified deposits. Cenozoic strata are missing from much of Kurdistan, especially in the north and northeastern regions of the country.

Many people doubted that considerable amounts of fuels could be locked in without the sequence of Cenozoic evaporite a decade ago. Reservoirs in Kardestan are Taq Taq, Khurmala, and Tawke. The additional reserves within the Tawke field have been crucial due to enhanced performance in production facilitated by better reservoir properties, good communication, better pressure and additional reserves found in older reservoirs (Mackertich & Samarrai, 2015). Similar trends are likely to emerge in other domains and discoveries. Barriers still exist in a complex structure and previously weakened province (MathPro, 2011). There is still a lot of discovery and evaluation going on, and new transmission facilities are being built. The Kurdistan Region of Iraq is anticipated to grow into a significant contributor to global oil and gas output.

2.1.2 Oil extraction

The initial step in oil extraction is to drill a large hole in the earth. A casing using a steel tube is inserted into the drilled hole to ensure the construction's overall stability and enhanced strength. More holes are drilled later to enable a greater outflow of the produced oil (Thomas, 2015). Hydrochloric acid (HCL) is frequently used to dissolve contaminants in drilled wells because it efficiently acidifies carbonate and aids in lime formations, and dissolves scale, carbonite, and rust, deposits (Thomas, 2015). Hydrochloric acid is also used to dissolve any leftover cement left over from the drilling procedure.

In the following step, a unique setup, frequently referred to as a "Christmas tree," is installed just at the top of the well. It is a collection of linked pipes, valves, and fittings used to control fluid pressure such as gas and oil (MathPro, 2011). The major recovering stage begins when the complete equipment is connected. Many natural processes, such as gravity drainage, are exploited to extract oil in this procedure. In the first stage, the recovery rate is frequently less than 15%. As more oil is removed, the subterranean pressure decreases, thus becoming inadequate to keep displacing oil to the top of the surface (MathPro, 2011; Lyadov & Petrukhina, 2018). The secondary recovery stage begins at this moment. There are several strategies for secondary or subsequent petroleum recovery. They often entail injecting fluids like water or gases, for instance, carbon dioxide and air, into the deposit to boost the pressure beneath (Lyadov & Petrukhina, 2018).

The typical recovery rate during primary and secondary oil recovery procedures is usually less than 45 percent. The last extraction process is defined as third-order recovery, and it may be produced utilizing a variety of ways. The first decreases the fluid and oil viscosity via heat treatments. The second introduces gas, namely carbon dioxide, into the oil deposit. The last approach is known as chemical floods. They involve dissolving thick, insoluble polymers inside water and infusing them beneath. Tertiary recovery provides for an extra 15 percent of the deposit's oil output (Wu, 2020).

Because the supplies of onshore oil deposits are depleting, the quest for oil reserves beneath the seafloor has commenced. Exploration platforms are being erected for this reason, which is a difficult, time-consuming procedure as building the mining platform typically takes two years and is also very costly (Pang et al., 2015). They can be permanently attached to the bottom of depths up to 90 m) or floating on special floats that are secured with an anchoring system. Offshore oil platforms are often linked to a network of dozens or hundreds of wells that collect oil from permeable rocks.

Oil can be extracted from gas as well. The resulting raw material is routed through a pipe network to refineries or a mine and transshipping vessel. The oil and gas are then transferred to a tanker, which carries them onshore. The volume of oil retrieved is not only determined by the drill strategies utilized. The essential elements in this scenario are geological parameters like rock porosity, the intensity of geological forces, mineral permeability, and oil viscosity (Pang et al., 2015).

Figure 3.The Oil Exploration and Extraction in Tawke Iraqi Kurdistan Region.

2.1.3 Refining Process

Each refinery is explicitly built to transform certain crude oils into specified products. The KAR Group runs the Kalak Refinery and is located in Erbil's governorate. The refinery has a 100,000 bpd capacity. However, the corporation intends to increase its capacity or volume to 200,000 bpd in the future with the support of American engineering firm Ventech (MathPro, 2011).

Conversely, the Bazian refinery is located in the Slemani governorate and has been operated by the Qaiwan since 2009 (Demirbas & Bamufleh, 2017). The Bazian refinery now produces kerosene and diesel and will soon begin manufacturing local gasoline. However, after the underway expansion program with the help of Ventech, the plant shall soon have a refining capacity of 34,000 bpd (MathPro, 2011).

The process designer chooses from a variety of basic processing units in order to suit the refinery's business objectives. These units generally separate the various types of hydrocarbons found within the crude oils into portions with almost similar properties, chemically convert the isolated hydrocarbons to become more preferable reaction products, and purify the final product (Babalola & Susu, 2019).

Figure 4: Oil refinery in Iraqi Kurdistan Region.

2.1.4 Separation

Advanced separation includes passing crude oil via heated furnaces. The resultant fluids are fed into distilling units. All refineries contain air separation units, while more complicated distilleries may consist of vacuum distillation units (MathPro, 2011). The liquids and vapors in the distillation units split into hydrocarbon components referred to as fractions depending on their boiling points. Heavily loaded fractions are beneath, while lighter fractions are at the pinnacle (Ramkumar, 2020). The lightweight fractions, which include liquefied refinery gases and gasoline, evaporate and climb up the fractionator, condensing back into liquids. Moderate liquids, such as paraffin and refined products, remain in the distillery tower's center. Bulkier fluids, known as gas oils, segregate lower in the distillate, while the heaviest fractions with the greatest boiling points settle at the top (MathPro, 2011).

2.1.4 Conversion

Following distillation, heavier and lower distilling fractions can be converted into a lightweight, relatively high-value products like gasoline. This process through which distilling unit fractions are transformed into flows of transitional ingredients eventually becomes essential final products (Ramkumar, 2020). Cracking is the most prevalent method of converting, and it uses heat, pressure, catalysts, and occasionally hydrogen to break down heavy hydrocarbon molecules into lighter ones. A cracking unit consists of one or more tall, robust exterior, rocket-like reactors, as well as a heat transmission, furnace network, and other vessels (MathPro, 2011). Any form of cracker, such as fluid catalytic cracking units and hydrocracking/hydrocracker units, may be present in complex refineries.

Cracking is not the only way to transform crude oil. Rather than breaking molecules, other refining techniques rearrange them to add value. Alkylation, for example, produces gasoline components by combining some of the gaseous byproducts of cracking. The process, which is practically reverse cracking, takes place in a series of large, horizontal containers and tall, narrow towers (Ramkumar, 2020). In the reforming process, heat, moderate pressure, and catalysts are utilized to turn naphtha, a light, often low-value fraction, into high-octane gasoline components.

2.1.5 Purification

Certain contaminants must be eliminated or rendered less objectionable before petroleum products may be commercialized. The most prevalent contaminants are sulfur complexes such as sulfur dioxide (H2S) or mercaptans ("R" SH)—the latter being a class of complex compounds containing up to six carbonyl groups in the hydrocarbon radical ("R"). Aside from their unpleasant odor, sulfur compounds are technically unfavorable. They decrease the efficiency of antiknock additives in motor and aviation gasoline and interfere with the functioning of exhausts. They generate motor rusting and hamper exhausts in diesel fuel. Furthermore, many significant residual and industry fuel users are located in developed regions and are susceptible to Sulphur dioxide emission limitations (Saleema et al., 2020).

Most crude oils include trace quantities of hydrogen sulfide, although these levels can be enhanced during refinery processing by breaking down heavier sulfur compounds like mercaptans. The majority of the hydrogen sulfide is found in gases in the process-unit overhead, eventually utilized in the refining fuel system (MathPro, 2011). Most refining fuel fumes are desulfurized to reduce harmful emissions. Flavoring, extraction of mecarptan, treatment of clay, treatment of hydrogen, and molecular sieves are all part of the treatment procedure.

2.1.6 Storage

Both incoming crude oil and the outgoing final products are stored temporarily in large tanks on a tank farm near the refinery. Pipelines, trains, and trucks carry the final products from the storage tanks to other locations across the country.

2.1.7 Transport

Pipelines are vital infrastructure for oil and natural gas transmission, linking drilling wells to refineries, chemical plants, residential users, and commercial demands (Chen et al., 2021).

Natural gas and crude move through pipelines for at least part of the route from processing to distribution. Pipelines transmit crude oil to some other carrier or straight to a refinery once isolated from natural gas. The refinery's products are then transported to market via tanker, truck, train tank car, or pipeline. The number of injection wells and hydrocarbon compression plants along the line and terminal warehouses must all be analyzed in order for oil from nearly any field to be delivered to any processing facility on demand. Offshore networks are more vulnerable to spills and environmental destruction than onshore pipelines; however, advances in pipeline construction and tracking systems have increased pipeline effectiveness and security. The Kurdistan Oil Pipeline is an operational oil pipeline that runs from the Taq Taq oilfield in Iraq's Kurdistan Region through Khurmala, southwest of Erbil, to Fishkhabur on the Turkish border.

Presently two main export-oriented pipelines in northern Iraq are fully operational. They include Kurdistan's major pipeline and the DNO/Tawke pipeline, all constructed by the Kurdistan regional government and its partner nations. Both connect the Turkey pipeline to the Ceyhan port. Other minor channels connect KRG's main pipeline with crude oil from different fields.

2.1.9 Other Methods

The conflict between the ethnic Kurdish-run northern and Arab-led Iraqi central government is centered on oil. This statement affects the transportation methods as the crude earnings, control of oilfields, and land have to be divided between the two governments. Although the pipeline is the most used method in Iraq's Kurdish region, other methods are discussed below.

2.2 Potential Environmental Impacts

Oil and gas exploration and extraction processes have the potential to have a wide range of environmental effects (Cordes et al., 2016). The step of production, the size and complexity project, the type and susceptibility of the immediate environment, and the success of preparation, environmental protection, abatement, and control approaches (UNEP, 2020) determine these effects. The possible effects include those on the atmosphere, the oceans, the land, and the biosphere. The map below shows the climate zone in Iraq, including the KRI, to help comprehend oil and gas exploration and production in the environment.

Figure 3: Climate Zones in Iraq (USAID, 2017).

2.2.1 Atmospheric Impacts.

The problems posed by oil and gas exploration and production have heightened interest in atmospheric-related concerns, garnering increased attention from both business and government agencies throughout the globe (UNEP, 2020). As a result, the oil and gas exploration and production business has shifted its attention to techniques and technology that reduce emissions. According to the articles by the United Nations Environment Programme (UNEP), it is necessary first to determine the origins and type of the pollution, as well as their relative contribution to local and global atmospheric impacts such as stratospheric ozone depletion and climate change to facilitate the analysis of possible implications of exploration and production activities,

Flaring, venting, and purging of gases; combustion processes such as diesel engines and gas turbines, fugitive gases from loading operations and tankage and losses from process equipment and airborne particulates from soil disturbance during construction and vehicle traffic are the main sources of atmospheric emissions. Other source in this category include particulates from other burning sources, such as well testing (Cordes et al., 2016). Carbon monoxide, carbon dioxide, volatile organic carbons, methane, and nitrogen oxides are the leading exhaust gases. Also, Cordes and colleagues noted that sulfur dioxide and hydrogen sulfide emissions can occur and are influenced by the sulfur content of the hydrocarbon and diesel fuel, especially when employed as a power source. Sulfur concentration might cause odors around the facility in specific situations.

Figure 4: Impacts of oil exploration on air pollution.

The amount of emissions released into the atmosphere and their potential impact are determined by the process in question. Emissions from exploratory operations are typically thought to have a minimal potential for causing atmospheric consequences (UNEP, 2020). During production, however, when there is more vigorous operation, there are higher levels of emissions in the immediate area of the activities (USAID, 2017). Therefore, the USAID suggested that production-related emissions should be seen from the perspective of overall emissions from all sources, which are typically less than 1% of regional and global levels.

The principal sources of carbon dioxide emissions from manufacturing processes are flares, venting, and burning (UNEP, 2020). Process vents, for example, are the primary source of methane emissions, with leaks, flaring, and combustion contributing to a lesser level. While much effort is required to address the primary sources of carbon dioxide emissions, UNEP calls for interventions that target these sources as well as minor sources to achieve significant outcomes.

2.2.2 Aquatic Impact

The aquatic impacts of oils and gas exploration activities comprise those operations that contribute to the pollution of water, causing significant danger to lives in water (Soares et al., 2021). Produced water, sanitary, sewerage, and household wastes, drilling fluids, cuttings, and well treatment chemicals; leaks and spills, cooling water; process, wash, and drainage water are the primary aqueous waste streams generated by exploration and production activities. According to the studies by Soares et al. (2021), oil spillage into water bodies is associated with the deposition of heavy metals such as mercury (Hg), cadmium (Cd), Pb, and copper (Cu). These metals are contained within the oil and oil processes.

Again, the amount of trash generated is determined by the phase of the exploration and production operation. Pollution amounts are modest throughout seismic activities and are mostly related to camp or vessel activities (UNEP, 2020). The principal aqueous effluents in exploratory drilling are cuttings and drilling fluids, but in the production process, once development wells are finished, the primary effluent is generated water.

Because of their toxicity and redox potential, oil-based drilling fluids and oily cuttings have a more significant impact. Ocean discharges of water-based mud and cuttings have been demonstrated to suffocate benthic creatures up to 25 meters away from the discharge and reduce species diversity up to 100 meters away (Soares et al., 2021). Benthic organisms are impacted by oil-based muds and cuttings due to higher hydrocarbon levels up to 800 meters from the discharge (UNEP, 2020). Certain drilling fluids and cuttings have a high pH and salt content, which may influence freshwater sources.

Other liquid waste sources, such as leaks and water runoff, may pollute underground and surface waterways. Impacts may occur, especially when ground and surface waters are used for domestic purposes or if fisheries or ecologically important regions are impacted (Alanbari et al., 2016). Poor building practices in the development of roads, drilling, and process sites may also have indirect or secondary consequences on local drainage patterns and surface hydrology.

2.2.3 Terrestrial Impacts

According to Cordes et al. (2016), the terrestrial environmental consequences of oil and gas activities frequently target species, assemblages, and populations by altering a number of ecosystem characteristics such as biodiversity, productivity, and biomass. The origins of these impacts include physical disruption caused by construction, pollution caused by oil leaks and spills or solid waste disposal, and detrimental influence caused by extending accessibility and societal change (UNEP, 2017).

Soil erosion caused by poor soil form, slope, or rainfall is one of the potential consequences of bad design and construction. Soils will retain their integrity if left undisturbed and vegetated; however, soil erosion may occur if trees are removed and topsoil is uncovered (UNEP, 2017). Changes in soil conditions can have far-reaching downstream effects, such as changes in surface hydrology and channel morphology, heightened silting, and habitat degradation, diminishing the ecosystem's capability to accommodate and support plants and wildlife. According to Chowdhury et al. (2021), the land disturbance related to energy footprints is crucial. It contributes largely to a shift in environmental pathways, such as changing a forested area into an oil exploration and production site resulting in disruption of surface soil and erosions.

In addition to the consequences of soil erosion and changed hydrology, the land clearing may cause secondary ecological difficulties, particularly in cases where much of the nutrients in a region are stored in vegetation such as tropical rainforests; or when the few trees present are crucial for animal browsing activities such as in the savannah; or locations with a prolonged natural recovery such as the Arctic and desert ecosystems (Chowdhury et al., 2021; UNEP, 2017). Clearance by contractors may encourage more vegetation removal by the local populace near the oil and gas explorations zones. Instances of burial of solid wastes, especially in drilling and production zones, have also contributed to the pollution of the terrestrial environment (Cordes et al., 2016). Pits have historically been utilized for the burying of inert, non-recyclable substances and trenching solids; the vaporization and preservation of fracking wastewater and workover/completion fluids; emergency containment of generated fluids; and the disposal of stabilized wastes (UNEP, 2017). However, if leakage and flushing are not controlled, the dangers associated with pollution migration paths can harm soils and useful surface and groundwater water supplies.

During the drilling of a standard 3000m deep well, 300–650 tons of sludge may be utilized, with 1000–1500 tons of cuttings generated (UNEP, 2017). An essential factor in the case of muds and cuttings is the possibility of the waste having a high salt content. Arid locations, such as the KRI, are more vulnerable to adverse impacts than wetter climates. Alkali soils or soils with a high clay content when contrasted to acidic, heavily fertile/organic, or sandy soils (UNEP, 2017). Contamination of soil can occur as a result of chemical and oil spills and leaks, posing a threat to both plants and animals.

2.2.4 Ecosystem Impacts

Changes in the ecological conditions due to oil exploration activities can also impact plant and animal populations by interfering with the quality of air, sediments, and interruption from noise, external light, and alterations in natural vegetation (Harfoot et al., 2018). The United Nations Environment Programme (UNEP, 2017) described such adjustments as having the potential to contribute to a profound influence on the ecosystem, such as loss of habitat, inadequate nutrient, and food supplies, disruptions of breeding areas, migratory patterns, exposure to predators, or shifts in herbivores feeding habits, leading to a secondary impact on predators. The disruption of soil and loss of vegetation and secondary consequences such as siltation and runoff can have an influence on ecosystem functions and have a downstream impact by disrupting nutrient ratios and microbial biomass in the soil. According to (UNEP, 2017), habitat loss affects both plants and animals. It may induce alterations in species diversity and major production processes, a possible long-term consequence if not effectively regulated.

The potential environmental repercussions of oil and gas exploration and production are extensive, according to (UNEP, 2017), and must be regulated. These implications are caused mainly by the oil process, which includes exploration, production, and transportation. The table below summarizes the many possible implications of oil and gas explorations based on the various phases or activities.

2.2.5 Oil and Gas Exploration and Production

The exploration and production of oil and gas in the Kurdistan area have substantial environmental consequences, which are exacerbated by the release of pollutants and discharges from such activities. When they accumulate over time, these effects give birth to the 2nd and 3rd orders of impact. The table below depicts the stages of processing, the pollutants connected with them, and the environmental implications. In the column of "Affected Components," H=Humans; At=Atmospheric; B=Biosphere; Aq=Aquatic and T=Terrestrial

Table 1, *Mariano, J., & La Rovere, E. (2017).* Environmental impacts of the oil industry. *Sunnyvale, CA, USA: LAP Lambert Academic Publishing.*

Stage	Effect	Subcategory
Exploration	Deforestation and disturbance of aquatic ecosystems	Infectious diseases
Drilling and extraction	Chronic environmental degradation	• Discharges of hydrocarbons, water and mud • Increased concentrations of naturally occurring radioactive materials increasing the chances of occurrence of cancer

	Physical Fouling	• Reduction of fisheries • Reduced air quality resulting from flaring and evaporation • Soils contamination • Morbidity and mortality of seabirds, marine mammals and sea turtles
	Habitat Disruption	• Noise effects on animals • Pipeline channeling through estuaries • Artificial islands
	Livestock Destruction	
Transport	Oil spills	• Destruction of farmland, terrestrial and coastal marine communities • Contamination of groundwater • Death of vegetation • Disruption of food chain
Combustion	Air pollution	• Particulates • Ground level ozone
	Acid rain	• NOx, SOx • Acidification of soil • Eutrophication; aquatic and coastal marine
	Climate change	• Global warming and extreme weather events, with associated impacts on agriculture, infrastructure, and human health

The observed damage to petroleum refining, pipes, drilling rigs, and other oil resources has resulted in localized pollution hotspots. The nearby community is at risk of chronic and acute exposures to a variety of particulate matter, heavy metals, and toxic chemicals, which might have major health consequences. Petroleum products from soot and oil spills have polluted underground and surface waterways, threatening the provision of drinkable and irrigation water. Arable and pastureland fields have also been poisoned, threatening agriculture and livelihoods. The assessment, remediation, and monitoring of the health, environmental, and economic repercussions of these assaults will impose a significant technical and financial burden on the Iraqi government.

3. Methodology

3.1 Research Approach

The Ecosystem Services Approach (ESA) is being used in this study to assess the consequences of oil and gas exploration and production operations in the KRI. The benefits that individuals obtain from the ecosystem are referred to as ecosystem services. The method operates as a mirror, allowing researchers and individuals to perceive natural systems in a fresh light. They typically see the environment as a source of people's services and products. This perspective on the environment deconstructs each natural system into a succession of ecosystem services and products, revealing its value (ESA). The advantages of the ecosystem contribute to the preservation of life on Earth by providing services such as food and water, flood and disease preventive regulation, cultural services such as spiritual and cultural benefits, and support services.

The ecosystem approach also serves as a method for the integrative management and conservation of land, water, and living resources, promoting fair protection and long-term usage. In this approach, humans and their cultural variations are recognized as important components of the environment. In this work, I evaluated the many advantages derived from the environment. I then used the idea of ecosystem services to precisely assess society's dependency and the implications of changes in these ecosystems.

The ideas of sustainability and conservation are central to the ecosystem services approach. These themes address the ecological and social difficulties that the oil and gas exploration and production sectors face on a local and worldwide scale. These issues are air pollution, biodiversity and habitat conservation, oil spillage, marine and freshwater discharges, land, and underground water contamination, and socioeconomic and cultural consequences. As a result, the ecosystem services method is significant in providing a beneficial framework for assessing and acting on the links underlying people and the environment.

The current study regards biodiversity as an essential component of the ecosystem. According to Harfoot et al. (2018), biodiversity is the inherent variation among living species from all sources around the globe. They encompass all organisms living on land, water, and other complex ecological systems. This phrase may alternatively be described as a dynamic complex of animal, plant, and microbe populations functioning as a functional unit with their nonliving surroundings.

3.2 Study Area

The focus area of study is the Kurdistan Region of Iraq (KRI). The region is regarded as an autonomous entity in Iraq consisting of the four Kurdish-majority governorates of Erbil, Duhok, Sulaymaniyah, and Halabja and borders Iran, Syria, and Turkey. And especially I bring my samples from the Zakho from three different oil field (Tawki,Qadia,Peshkhbor) The Kurdistan Regional Government (KRI) governs the majority of Iraqi Kurdistan but excludes the disputed regions of Northern Iraq, which the federal Iraqi government claims in Baghdad and the Kurdistan Regional Government (Issazadeh et al 2018).

The KRI's reserves are estimated to be 45 billion barrels of oil, 200 trillion cubic feet (tcf) of proved gas reserves, and up to 198 tcf of mostly untested gas, according to the Kurdistan Region Ministry of Natural Resources (MNR) (Amereller & Amereller, 2021). The KRI's reserves of gas and oil would position it as one of the top ten oil-rich nations on Earth if it were an independent entity. The KRI's total exported and consumed oil for 2020 was 165,942,861 barrels, according to the MNR data (Amereller & Amereller, 2021). Given the region's current large-scale oil and gas production and ongoing exploration activities, I considered it relevant to assess the environmental repercussions of oil and gas exploration and production operations.

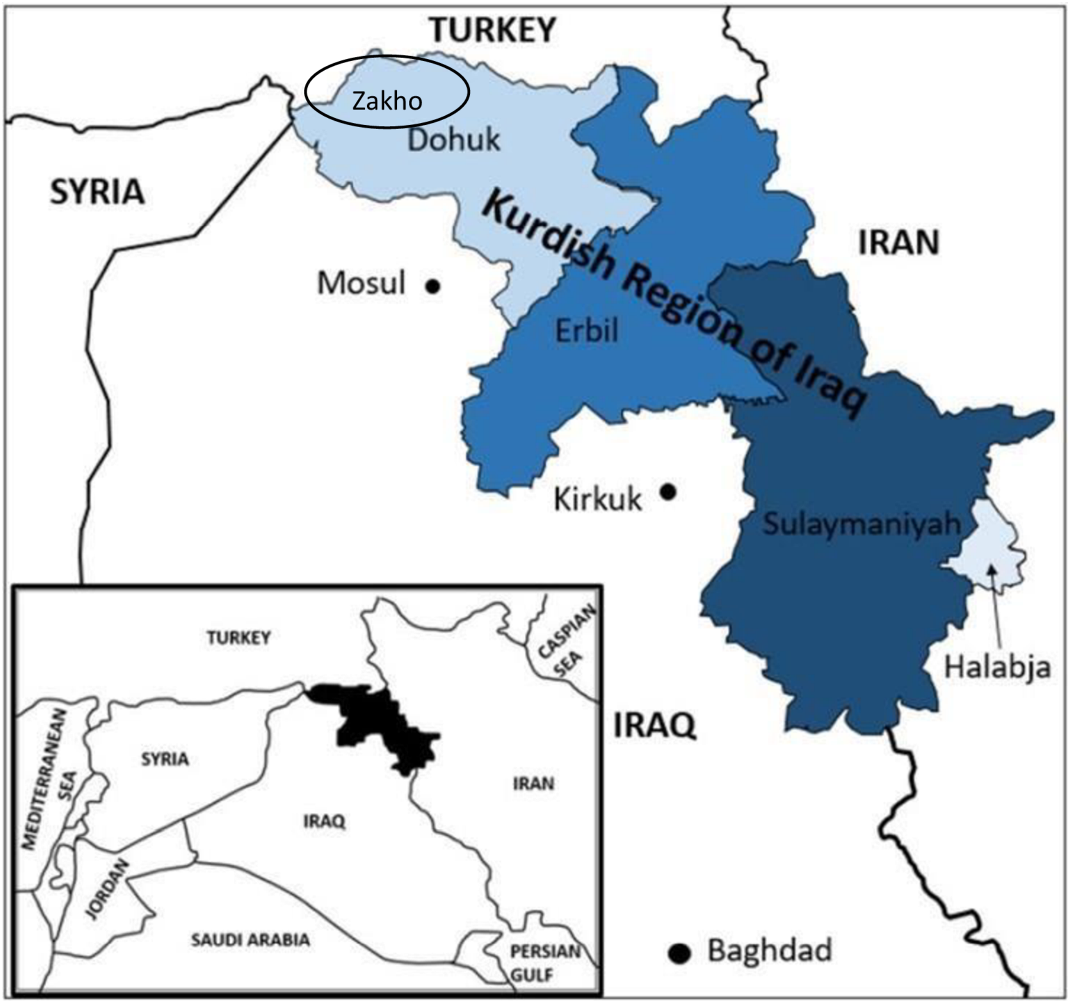

Figure 5: The Kurdistan Region of Iraq (KRI) map, the research study area. (Mohammed & Schrock 2019).

3.3 Study Area and Sample Location

Zaxo is a city in the Kurdistan Region of Iraq.District of the Dohuk Governorate, located a few kilometers from Iraq–Turkey border. Zakho population in 2023 is estimated to be 595,000. As shown in figure 5, it has three different oil fields namely Tawke, Peshkhabor, and Qadya and forth location far from oil fields in the high way between Duhok city and Zakho city as control was taken as control. These fields contribute to large extend in soil and water pollution. So, 16 different samples of water and soils were taken from surrounding environment nearby these oil fields to assess their impact in soil and water physiochemical properties. The first one from the north of the city (Peshabir oil field), the second one from the west of the city (Tawke oil field),and the third one from the south of the city (Qadya oil field)

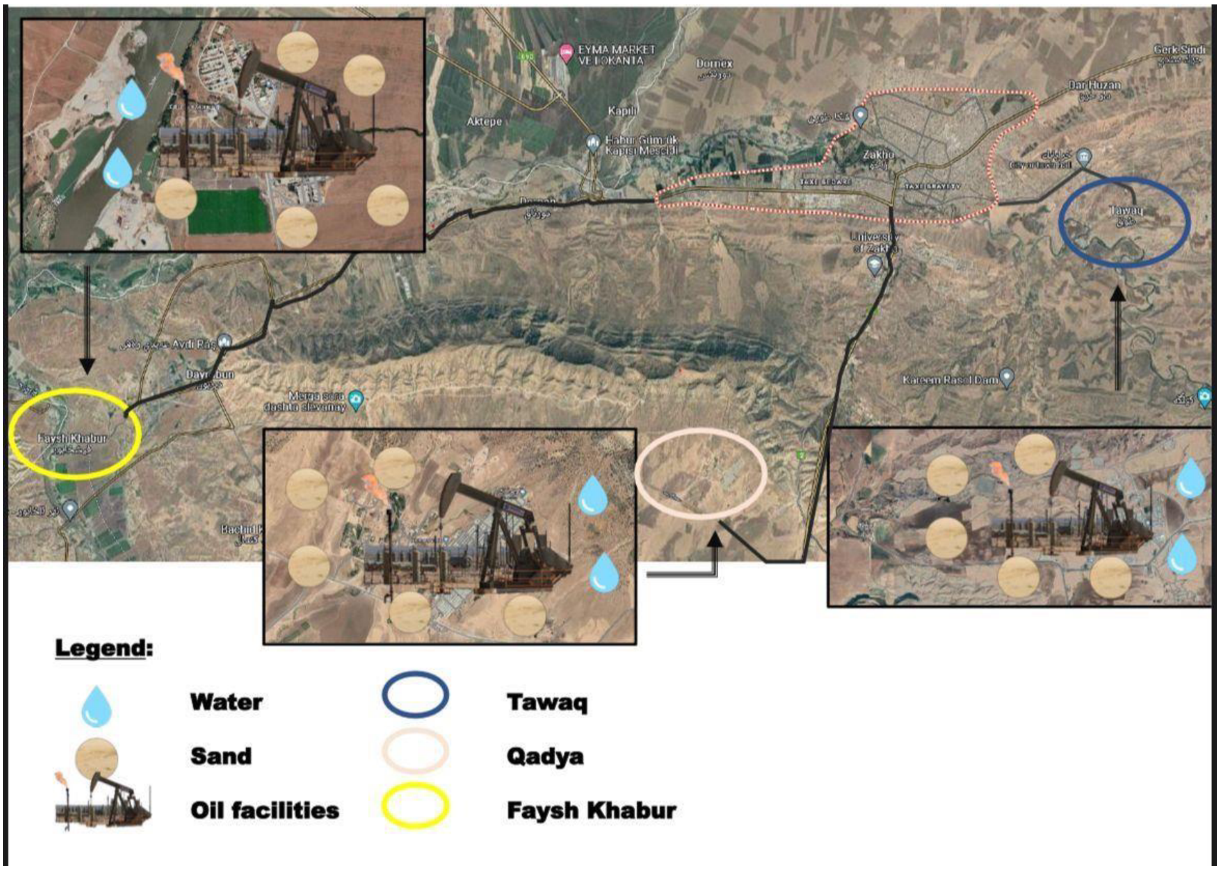

Figure 6. The location of study area showing the location of three oil fields around Zakho city.

Zakho City

Zakho, also spelled Zaxo is a city in the Kurdistan Region of Iraq, at the center of the eponymous Zakho District of the Dohuk Governorate, located a few kilometers from the Iraq–Turkey border. The population of the town Zakho population in 2023 is estimated to be 595,000. It has three different oil field, The first one from north of city (peshkhbor field) production 20,000 bpd and the second one from west of city (tawki field) protection is 33,000 bpd and the third one from south of city (Qatdia field) protectionists is 13,000 bpd And I bring samples (Air ,soil, water)from Village close to those field.




Figure 7. Study area and sampling of soil samples polluted by crude oil.

3.4 General Description of the study research methods.

A review of the literature was conducted in various databases, including PubMed, Scopus, and Google Scholar, for works published between 2010 and 2022. Given the current study, the selected papers were examined based on their titles and abstracts. The selected references for the papers were examined to ensure that no similar articles were overlooked during the first search. Similar and cross-referenced works were eliminated, files were filtered based on inclusion and exclusion criteria, full-text articles were evaluated for eligibility, and a qualitative synthesis was performed.

Search terms for related publications included "environmental impacts," "oil production in Kurdistan," and "gas production in Kurdistan." Following the discovery of relevant papers, a critical evaluation was carried out in order to choose the appropriate articles for the systematic qualitative review. The study's inclusion criteria were surveyed, qualitative and quantitative research, no sample size constraints, and only publications written in English. The current study did not include any conference abstracts, case reports, or unpublished data.

3.5 Sampling and chemical analysis

Composite soil samples (600 g) composed of 6 separate subsamples were taken from the plowing layer (0–30 cm) in 3 different sites close to the oil field in Zakho province and forth location far from oil fields but near the transportation of crude oil in the high way between Duhok city and Zakho city was taken as control, Kurdistan Region, Iraq. Samples were dried in an oven at 75 °C for 72 h. 0.5 gram of each soil samples were digested in the presence of aqua regia (mixture of nitric acid HNO_3 + $HClO_4$ in the ratio 3:1). The Soil samples for heavy metals determination were analyzed according. The particle size distribution analysis was performed by sieving and pipette method and bulk density was determined by clod method. Determination of the heavy metals in the filtrate of samples was carried out by using atomic absorption spectrophotometer (AA-7000) graphite furnace atomizer (GFA-7000) Shimadzu.

The soil pH was estimate in 2: 1 water soil ratio and determined by using pH meter, conductivity was measured using conductivity meter. Available phosphorous was determined by Olsen's method, Soil Organic matter was determined using Walkley-Black method, Sodium and potassium were determined by using flame photometer as described. Total nitrogen was estimate by (Kjeldahl method), sulfur, calcium and magnesium were determined using standard methods.

The water quality parameters were analyzed using standard analytical methods, The parameters analyzed in this assessment include temperature, water temperature was measured directly using a graduated thermometer (0° 100°) in situ., turbidity, electrical conductivity (EC), EC measured by pH-meter Toledo. Total dissolved solids (TDS), pH, Hydrogen ion concentration was measured in the laboratory by pH-meter toledo (FE20 Five Easy). Biochemical oxygen demand (BOD) was measured based on oxygen consumed in the 5-day test period (BOD_5), Chemical oxygen demand (COD) was measured by the reflex condenser titrimetric method, dissolved oxygen (DO) determination by the Winkler method., alkalinity was determined using the titration method, ethylene diamine tetraacetic acid (EDTA) titrimetric method was used for the determination of total hardness, calcium hardness (Ca^{2+}) by EDTA titrimetric method, Magnesium hardness (Mg^{2+}) by subtracting calcium hardness from total hardness, chloride(Cl^-) determined by titration method with silver nitrate, Nitrate (NO_3^-) ,ammonium (NH_4) and sulfate (SO_4) were determined by a photometer system. Phosphate (PO_4) determined by vanadomolybdo phosphoric acid (colorimetric method). Heavy metals such as were measured by atomic absorption spectrometry.

4. Results

4.1.1 Assessment of Soil and Water Pollution Around Oil Fields in Zakho District, Kurdistan Region, Iraq

Soil analysis is so crucial to assess the degree to which extend the soil is affected and polluted by direct oil effluents and from the deposition of volatile organic compounds from atmospheric deposition. The recent scientific work will give insights into the soil fertility status of three different locations close to the oil fields in Zakho province within the Iraqi Kurdistan region. Soil is the system which supplies plants with available nutrients through the root. Physical and Chemical analyses of the soil are carried out to indicate the efficiency of soil for supplying plants with nutrients in available forms as well as identification of the factors affecting this efficiency in the soil. Therefore, besides perfect sampling in the field, soil samples must be properly prepared and analysed in order to reach the correct evaluation of the soil nutritional status.

4.1.2 Soil pH

The measure of acidity or alkalinity of soil on a scale of 0 to 14, with 7.0 soil pH being neutral. Soils with a pH below 7.0 are acidic, while soils with a pH above 7.0 are alkaline. The pH is important because it governs the nutrient availability in soil, the acidic condition increases the solubility of cationic nutrients as iron, copper, manganese, and many others while the alkaline pH values increase the solubility of anionic nutrients like boron, selenium, and molybdenum, so these nutrients can be affected when pH is too high or low. The pH values for the three studied locations namely Tawke, Pishabiry, Qadiya are slightly alkaline as indicated from table2,3, and 3 and range between 7.4 to 7.9 compared to the fourth far location in the highway between Duhok and Zakho. This slight alkalinity may attribute to the effects of the alkaline nature of petroleum hydrocarbons reaches the soil with rainfall or it may be due to the limestone parent material of the region.
Row crops are typically most efficient with pH between 6.2 and 7.2. Outside of these pH parameters, certain crops can have a difficult time absorbing essential nutrients. With a low pH (less than 6.0), it may be necessary to apply calcium to adjust and elevate pH upward. Lowering the soil pH is a more difficult and expensive task — sometimes, an application of elemental sulphur can be used to lower soil pH. when a soil's pH is below 5.8, this characteristic is used to estimate the lime (Ca) required to correct the soil pH to around 7.0. That is the only reason it is reported on your soil test analysis, and only on soils with a pH below 5.8.

4.1.3 Electrical Conductivity EC

Soil electrical conductivity (EC) measures the ability of soil water to carry electrical current. Electrical conductivity is an electrolytic process that takes place principally through water-filled pores. Cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, and NH_4^{+}) and anions (SO_4^{2-}, Cl^{-}, NO_3^{-}, and HCO_3^{-}) from salts dissolved in soil water carry electrical charges and conduct the electrical current. Consequently, the concentration of ions determines the EC of soils. Soil EC directly affect plant growth, it plays a vital role in plant health as it indirectly indicates nutrient availability as pH and salinity levels. Too low or too high EC values can both have detrimental effects on plants growth.

Salts can accumulate due to excessive fertilizer applications, poor quality irrigation water or limited rainfall, and from pollution by certain industrial effluents. With proper soil drainage accompanied by rainfall or irrigation, the salt can sometimes be flushed out of the root zone to correct the problem.

Table 2. The characteristics of soil surrounding Tawke oil field.

No.	Parameters	Tawke Samples					units	Acceptable Limits
		1	2	3	4	5		
1	**pH**	7.68	7.49	7.54	7.66	7.62	--------	5.5-10
2	**EC,**	0.23	0.22	0.49	0.24	0.48	$dS.m^{-1}$	0.25-1
3	**Available Potassium**	17.7	18.01	19.04	17.98	18.11	mg/Kg	0- 150
4	**Avail. Phosphorous**	5.62	5.89	5.56	5.11	5.23	mg/Kg	25 to 50
5	**Avail. Nitrogen**	77.43	80.08	78.43	76.59	77.32	mg/Kg	25-40
6	**Total Magnesium**	1352	1376	1778	1397	2352	mg/Kg	500-5000
7	**Avail. Calcium**	2130	2132	2830	2090	3045	mg/Kg	2000-3000
8	**Organic Matter**	0.9	1	1	1.1	1.1	%	0.5-2
9	**CEC**	18.26	22.87	10.538	10.53	9.937	$Cmol^{-}/Kg$	10-20
10	**Fe**	12.4	10.34	11.09	10.29	10.67	mg/Kg	100-150
11	**Zn**	13.54	13.67	14.11	15.12	14.78	mg/Kg	2-25
12	**Mn**	2.1	2.43	2.97	3.3	3.51	mg/Kg	40-60
13	**Cu**	2.11	2.2	2.12	2.2	2.2	mg/Kg	1-250
14	**Cd**	0.21	0.16	0.25	0.21	0.23	mg/Kg	<0.35
15	**Saturation %**	66.64	65	64.23	65.12	64.34	%	50-70
16	**Field capacity**	34.18	33.56	31.98	34.07	32.18	%	25-35
17	**$CaCO_3$**	15.1	15.3	16.7	18.3	19.5	%	3-25
18	**Clay**	41.28	16.28	16.28	16.28	11.28	%	-
19	**Silt**	18.50	31.00	31.00	37.50	25.00	%	-
20	**Sand**	40.23	52.73	52.73	46.23	63.73	%	-
21	**Soil Texture**	Clay	Loam	Loam	Loam	Sandy Loam	------	-
22	**Bulk density**	1.15	1.2	1.05	1.05	1.17	$g.cm^{-3}$	0.3-1.5

As shown in tables 2,3, and 4 EC value for the 1st, 2nd, and 3rd locations fluctuate within the same location between 0.20 to 0.48 soil was 0.23 $dS.m^{-1}$, these different values of EC indicates that the location were affected variably with oil effluents discharged to the surrounding environment. The electrical conductivity of the soil solution determines the risk of salt injury to plants. Soluble salts are largely affected by environmental conditions — soils that contain high salt content are called saline soils (NaCl). Soils high in sodium (Na) are referred to as sodic soils. The EC concerned values that need correcting soluble salts is over 0.75 mS/cm (millimhos per centimetre, which is the basic unit of measure of electrical conductivity in soil).

Table 3. The characteristics of soil surrounding Pishabire oil field.

No.	Parameters	Pishabire Samples					units	Acceptable Limits
		6	7	8	9	10		
1	**pH**	7.73	7.64	7.59	7.91	7.83	--------	5.5-10
2	**EC,**	0.384	0.236	0.418	0.379	0.221	$dS.m^{-1}$	0.25-1
3	**Available Potassium**	18.57	17.09	18.76	19.68	17.81	mg/Kg	0- 150
4	**Avail. Phosphorous**	5.42	5.59	5.51	5.31	5.53	mg/Kg	25 to 50
5	**Avail. Nitrogen**	79.49	80.01	78.13	79.58	77.82	mg/Kg	75-100
6	**Avail. Mg**	1242	1256	1282	1291	1242	mg/Kg	500-5000
7	**Avail. Ca**	2123	2137	3136	2087	2034	mg/Kg	2000-3000
8	**Organic Matter**	1.0	1.2	1.3	1	1	%	0.5-2
9	**CEC**	22.87	10.538	10.538	9.9375	7.4375	$Cmol^{-}/Kg$	10-20
10	**Fe**	10.79	11.78	11.43	10.53	10.75	mg/Kg	100-150
11	**Zn**	13.65	14.05	15.08	14.29	15.21	mg/Kg	2-25
12	**Mn**	2.97	3.25	3.56	3.52	4.01	mg/Kg	40-60
13	**Cu**	2.13	2.19	2.22	2.21	2.22	mg/Kg	1-250
14	**Cd**	0.26	0.19	0.23	0.20	0.21	mg/Kg	<0.35
15	**Saturation %**	66.24	66	64.12	65.54	64.56	%	50-70
16	**Field capacity**	34.08	33.56	32.78	33.56	32.44	%	25-35
17	**$CaCO_3$**	21	23	24	27	28	%	3-25
18	**Clay**	41.28	16.28	16.28	16.28	11.28	%	-
19	**Silt**	16.00	43.50	43.50	40.00	47.50	%	-
20	**Sand**	42.73	40.23	40.23	43.73	41.23	%	-
21	**Soil Texture**	Clay	Loam	Loam	Loam	Loam	----	-
22	**Bulk density**	1.11	1.03	1.07	1.12	1.3	$g.cm^{-3}$	0.3-1.5

4.1.4 Nitrogen

Nitrogen (N) is an essential nutrient for both animals and plants. Soils can naturally supply N to the plants but in most cases, this is not enough to ensure the development of a healthy crop. Table Nitrogen (N) is an essential nutrient for both animals and plants. Soils can naturally supply N to the plants but in most cases, this is not enough to ensure the development of a healthy crop. Available nitrogen comprises from nitrate and ammonium ions available in soil solution. The normal range of available nitrogen in soil is between 75-100 mg/kg soil. As indicated from tables 2,3, and 4 the available nitrogen in all locations is around 75 mg/kg and in sufficient amounts which indicate that the soil positively affected by industrial effluents in elevating the levels of available N in the soil, or it may return to chemical fertilization of the soil.

Nitrogen pollution is caused when some nitrogen compounds – like ammonia and nitrous oxide – become too abundant. Nitrogen pollution causes nitrogen-tolerant species to thrive and outcompete more sensitive wild plants and fungi. This reduces wildlife diversity and damages plant health. Excessive application of synthetic fertilisers has been shown to acidify soils too, damaging soil health and reducing the productivity of soils.

4.1.5 Phosphorus (P)

Phosphorus is one of the major plant nutrients in the soil. It is a constituent of plant cells, essential for cell division and development of the growing tip of the plant. For this reason, it is vital for seedlings and young plants. Soils with 25 to 35 ppm P is typically adequate on most soils. It was apparent from tables 2,3, and 4 that the available phosphorous in the soil is low and in all locations is around 5 mg/kg and not affected by industrial effluents as the nature of the soil is calcareous and precipitate the available forms of P.

Table 4. The characteristics of soil surrounding Qadya oil field

No.	**Parameters**	**Qadya Samples**					**units**	**Acceptable limits**
		11	**12**	**13**	**14**	**15**		
1	**pH**	7.47	7.43	7.28	7.43	7.92	--------	5.5-10

2	**EC,**	0.482	0.510	0.550	0.388	0.328	$dS.m^{-1}$	0.25-1
3	**Available Potassium**	19.67	18.12	18.77	19.87	17.69	mg/Kg	0- 150
4	**Avail. Phosphorous**	5.65	5.42	5.23	5.89	5.66	mg/Kg	25 to 50
5	**Avail. Nitrogen**	80.01	80.12	79.13	80.28	78.76	mg/Kg	75-100
6	**Avail. Magnesium**	1221	1266	1257	1297	1252	mg/Kg	500-5000
7	**Avail. Calcium**	3128	3139	3146	2507	2114	mg/Kg	2000-3000
8	**Organic Matter**	1.11	1.21	1.38	1.3	0.9	%	0.5-2
9	**CEC**	21.738	9.4375	10.498	10.238	7.5775	$Cmol^{-}/Kg$	10-20
10	**Fe**	11.49	10.89	11.45	12.29	11.76	mg/Kg	100-150
11	**Zn**	9.85	9.01	11.01	10.54	10.61	mg/Kg	2-25
12	**Mn**	2.94	3.45	3.86	4.12	4.42	mg/Kg	40-60
13	**Cu**	2.13	2.19	2.22	2.21	2.22	mg/Kg	1-250
14	**Cd**	0.18	0.19	0.20	0.23	0.22	mg/Kg	<0.35
15	**Saturation %**	65.26	66.43	66.52	65.84	64.98	%	50-70
16	**Field capacity**	33.18	32.93	33.75	33.76	32.84	%	25-35
17	**$CaCO_3$**	28	27	25	26	25	%	3-25
18	Clay	40.28	15.28	16.28	15.28	10.28	%	-
19	Silt	14.50	39.50	23.50	26.00	11.00	%	-
20	Sand	45.23	45.23	60.23	58.73	78.73	%	-
21	Soil Texture	Clay Loam	Loam	Sandy Loam	Sandy Loam	Loamy Sand	-----------	-
22	Bulk density	1.2	1.1	1.2	1.31	1.33	$g.cm^{-3}$	0.3-1.5

Table 5. The characteristics of soil surrounding the high way between Zakho to Sumail district.

No.	Parameters	Control samples			units	Acceptable Limits
		16	17	18		
1	pH	7.02	7.43	7.23	--------	5.5-10
2	EC,	0.360	0.376	0.370	$dS.m^{-1}$	0.25-1
3	Available Potassium	15.72	16.07	16.59	mg/Kg	0- 150
4	Avail.Phosphorous	4.43	4.37	4.26	mg/Kg	25 to 50
5	Available Nitrogen	80.42	81.55	79.42	mg/Kg	75-100
6	Avail. Magnesium	1402	1418	1438	mg/Kg	500-5000
7	Available Calcium,	2489	2430	3390	mg/Kg	2000-3000
8	Organic Matter	1.32	1.3	1.27	%	0.5-2
9	CEC	18.28	19.32	18.09	$Cmol^{-}/Kg$	10-20
10	Fe	7.18	8.41	8.43	mg/Kg	100-150
11	Zn	10.03	10.43	11.33	mg/Kg	2-25
12	Mn	0.19	0.13	0.18	mg/Kg	40-60
13	Cu	1.03	1.06	1.13	mg/Kg	1-250
14	Cd	0.0018	0.0019	0.0015	mg/Kg	<0.35
15	Saturation %	68.54	66.76	65.23	%	50-70
16	Field capacity	34.12	34.65	32.39	%	25-35
17	$CaCO_3$	12.87	12.87	12.873	%	3-25
18	Clay	36.52	15.28	15.28	%	-
19	Silt	55.95	39.50	26.00	%	-
20	Sand	7.525	45.23	58.73	%	-
21	Soil Texture	Silty clay loam	Loam	Sandy Loam	-------	-
22	Bulk density	1.12	1.3	1.23	$g.cm^{-3}$	0.3-1.5

4.1.6 Potassium (K)

If K is deficient or not supplied in adequate amounts to the soil, it stunts plant growth and reduces yield. For perennial crops such as alfalfa, potassium plays a role in stand persistence through the winter. Other roles of K include: Increases root growth and improves drought resistance. Ranges of available K are between 165-220 gm/kg to supply the needed amounts of potassium to maximize production. As shown from table the available K form is very low and less than 20 mg/kg in the studied soil showing that are not affected by the petroleum industries as this effluent contains negligible amounts of K.

4.1.7 Calcium (Ca)

Calcium (Ca) is an essential plant nutrient required by animals and plants in relatively large amounts for healthy growth. In addition to its role as one of the macronutrients in plant nutrition, sufficient Ca has a role in maintaining soil physical properties, and in reclaiming sodic soils. Calcium is typically plentiful in soils with pH of 6.0 and higher; however, calcium can be applied as gypsum and not affect soil pH. Calcium ppm of 1400 or higher is generally right for most crops. As indicated from tables 2,3, and 4, the studied are contain high amounts of available Ca and about 2000mg/kg as mean as the parent material of these soils is $CaCO_3$ and not affected by petroleum hydrocarbon released to this environment.

4.1.8 Magnesium (Mg)

Magnesium is the central core of the chlorophyll molecule in plant tissue. Thus, if Mg is deficient, the shortage of chlorophyll results in poor and stunted plant growth. Magnesium also helps to activate specific enzyme systems. Magnesium is often adequate in soils with a pH 6.5 and higher, though magnesium at 100 mg/kg or more is acceptable. Mg in studied soil is high as shown in tables 2,3, and 4 , ranging from1200 to 1400 mg/kg as parent material of soil contain also gypsum rock beside limestone. The Mg content of soil not affected by the release of petroleum hydrocarbon to this environment.

4.1.9 Sodium (Na)

Na considered essential plant nutrients for some plants; however, Na is playing an important role in soil physical properties. Soil Na level is needed for calculations of cation exchange capacity (CEC) and exchangeable sodium percentage (ESP). This Na analysis is primarily for use in repairing saline or alkali soils. Sodium is not a soil nutrient — adding other elements, such as gypsum or elemental sulphur, will help with water infiltration to flush away the sodium have present. The range for sodium in most common soil types is typically 80-120 ppm.

4.1.10 Calcium Carbonate

Calcium carbonate plays an important role as a cementing agent of soils. alcium carbonate bonds to clay and/or silt particles, which affects particle-size analysis (PSA). Highly aggregated, stable clay soils may behave like coarse sands in terms of water infiltration; hence, they may be mistakenly identified in the field as sands or coarse loams. As well has a negative effects of P availability in calcareous soils. This a measurement of the amount of free lime in the soil. The $CaCO_3$ can be important in herbicide selection and fertilizer applications, so that you can avoid product tie-ups with the calcium present — which would render it ineffective and unavailable to your plants. The $CaCO_3$ is an inherited soil property in study area and not affected by crude oil releases and as shows from tables 2,3, and 4 the amounts of $CaCO_3$ is significant and vary within location ranging between 12 to 28%.

4.1.11 Organic Matter (OM)

The higher the organic matter in the soil, the healthier the soil. It measures the ability of the soil to supply nutrients, water and other physical wellbeing to growing plants. Organic matter accumulation occurs in a slow process called humification. Reduced tillage has been shown to have a positive impact on organic matter and soil tilth. Row crops should be at around 2.5% OM or higher. But in study area the ranges of organic matter in the soil is very low between 0.5- 1% as indicates from tables 2,3, and 4 and not affected positively or negatively by releasing oil to the surrounding environment.

4.1.12Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants. This measures the ability of the soil to store and release nutrients. This number also helps to define the soil’s texture and composition. Sandy soil to loam soil CEC will vary from 1 to 40, but the most common range is from 13-25

CEC. As indicates from listed tables, the CEC of the soil in various location are not stable within the same location and vary between 9- 22 $Cmol^{-}/Kg$ that reflect the probability of being affected by oil hydrocarbons released to the soil.

4.1.13 Percent Base Saturation

Soils with high percent base saturation have a higher pH; therefore, they are more buffered against acid cations from plant roots and soil processes that acidify the soil (nitrification, acid rain, etc.). They contain greater amounts of the essential plant nutrient cations K^{+}, Ca^{2+} and Mg^{2+} for use by plants. Percent base saturation is closely related to CEC and pH. This measurement indicates the nutrient supply and balance of cations for K, Mg, Ca, H, and Na. Soils with a high percent base saturation can be more fertile because they often have a higher pH and can contain greater amounts of these nutrients for use by plants. Base saturation is study is an inherited soil property as it contains high alkaline earth metal like Ca and Mg. As shows in tables 2,3, and 4, the contents of Base saturation n almost location is about 65% that indicate, it not affected by oil release.

4.1.14 Iron (Fe)

Iron (Fe) minerals play an important role in stabilizing soil organic carbon (SOC). Fe-mediated SOC protection is mainly achieved through adsorption, co-precipitation, or aggregation. The typical iron concentrations in soils range from 0.2% to 55% (20,000 to 550,000 mg/kg), and concentrations can vary significantly, even within localized areas, due to soil types and the presence of other sources. As result shows in tables 2,3, and 4, the contents of Fe in soil of Duhok governorate is quite low, however the Iron ppm of 10-20 is typically common on most soils. The high pH of soil in Kurdistan region render cationic micronutrients like Fe,Mn, Cu,and Zn . So, the Iron chlorosis in plants like grapes is a common problem in this area that cause with iron shortage and high pH issues, so applying additional iron could potentially help to alleviate any iron chlorosis problems you might see.

4.1.15 Zinc (Zn)

Zinc deficiency significantly affects the root system including root development and therefore the absorption of water and plant available nutrients from soil. In agricultural soils Zn is bound to the soil complex (clay, organic material, etc.) The zinc (Zn) content of soils, according to rather extensive surveys, is generally in the range of 10-300 ppm. Certainly Zn, because of its concentration, can be considered as a trace element in soil. It occurs most frequently in the lithosphere as the mineral ZnS (sphalerite). Soil tests can also predict if adding zinc will affect your plant health and crop yields. The desired ppm for zinc ranges from 1.0 to 3.0. The result in tables 2,3, and 4, shows that the Zn content in soils is low and suffer from precipitation like Fe and the this results are with harmonize with those achieved by (Umer et al 2020).

4.1.16 Manganese (Mn)

Mn toxicity is a world-wide problem in areas with acid soils. This toxicity alters physiological, biochemical and molecular processes at the cell level. Total Mn in soils generally ranges from about 20 to 3,000 ppm (0.002 to 0.30 percent), but only a fraction of this total is plant available. The most common form of Mn in soil solution is Mn2+, which is often complexed by organic compounds. Manganese (Mn) is an important micronutrient for plant growth and development and sustains metabolic roles within different plant cell compartments. Manganese at 8-11 ppm is typically sufficient. Mn availability is influenced by soil pH, and low pH can increase Mn availability, while high pH can lessen it. Tables 2,3, and 4 shows that the contents of available Mn are very low and the soil need to be fertilized with this essential micronutrient.

4.1.17 Copper (Cu)

Copper is highly toxic to microorganisms if present in excess concentration which consequently cause change in soil biological equilibrium with adverse effect on both soil fertility, plant development and yield. Copper exists in soils as Cu^{2+} and most of the copper is absorbed by the plant as Cu^{2+}. Once absorbed, it accumulates mainly in the roots. Its concentration in plant tissue ranges from 5 to 20 ppm and in soil from 2 to 100 ppm (mg kg^{-}). However, most of the copper in the soil is not available for plants. Plants only need a small amount of copper. Copper at 0.8-1.0 is adequate for most crops. As indicated from table 2,.3, and 4, the Cu content is sufficient in the soils of Duhok city, The majority of the copper deficiencies occur in highly acidic soils as its solubility increased and easily leached from soil body.

4.1.18 Cadmium Cd

Cd stress influences plant growth and its grain accumulation poses health risks. Immobilization, adsorption and precipitation of Cd can reduce its bioavailability. Use of amendments may can immobilize Cd in soil without affecting plant health. Among the heavy metals, Cd is the most abundant in soil, and readily taken up toxic heavy metal by the crop plants; that do not have any beneficial physiological functions, therefore, of great concern. Its normal concentration in soil ranges from 0–1 mg/kg, while 1–3 mg/kg indicates slight contamination. The result of recent investigation indicates that the soil is not contaminated with this toxic non-essential heavy metal and these findings agree with those reported by (Umer et al 2018).

4.1.19 Particle Size Distribution and Particle Density

Individual soil particles vary widely in any soil type. Similarly, as these particles are cemented together, a variety of aggregate shapes and sizes occur. For standard particle size measurement, the soil fraction that passes a 2-mm sieve is considered. Laboratory procedures normally estimate percentage of sand (0.05 - 2.0 mm), silt (0.002 - 0.05 mm), and clay.

Soil Texture Once the percentage of sand, silt, and clay is measured, the soil may be assigned a textural class using the USDA textural triangle (Fig.9). Within the textural triangle are various soil textures which depend on the relative proportions of the soil fractions. The variation of texture among the sites is mainly due to the nature of parent material that soil raised from and not affected by oil spills.

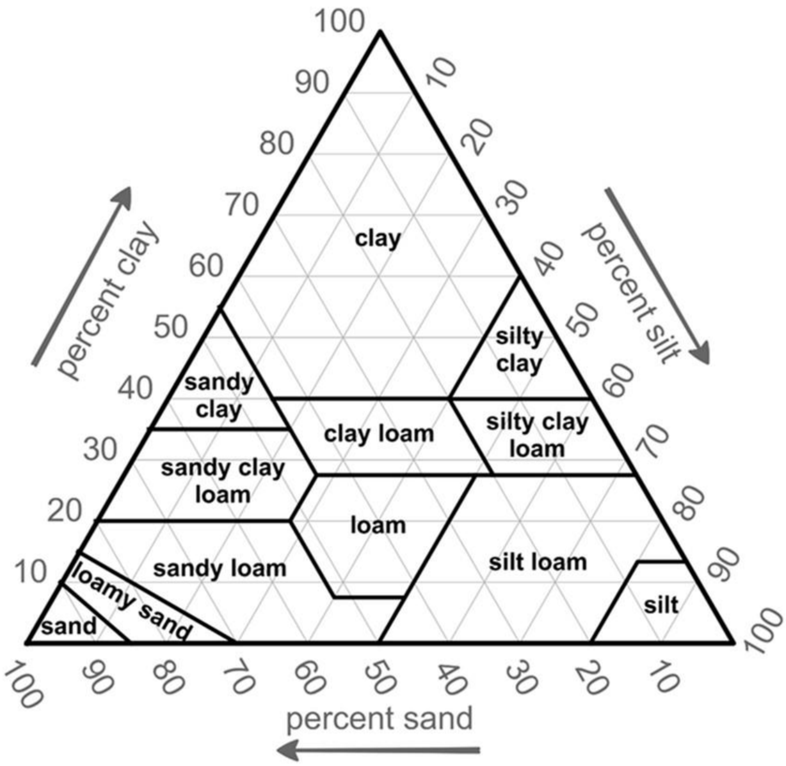

Fig.9.Soil texture triangle (Groenendyk et al. 2015).

Bulk density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles. Bulk density is typically expressed in g/cm3.As revealed from tables 2,3, and 4 the particle of the soil bulk density of the pishabire location is lighter than the rest of location as it close to the Khabur river banks that make soil lighter as it bring course fraction of sand ad continuously deposited in the banks.

4.2 Water Analysis results

Table 6. Some water quality parameters affected by oil petroleum hydrocarbons in study area.

Parameters	Tawke Oil Field			Pishabire Oil Field			Qadya Oil Field		Tab water As control	Standard Range (WHO)
pH	8.1	8.2	8.0	7.9	8.0	8.3	7.8	8.4	8.01	6.5-8.5
Conductivity µS/cm	813	530	989	930	1081	454	783	821	365	850 µS/cm
Turbidity NTU	92.2	95.8	99.3	100	97.4	98.9	99.5	92.2	0.23	Max. 5 NTU
Sulphate mg/l	20.4	16.7	32.2	29.0	23.6	6.3	15.8	25.2	13.95	200
Nitrate mg/l	51.5	3.6	1.3	1.6	3.5	2.6	41.4	1.8	18.8	45

4.2.1 pH of water samples

Low-pH water will corrode or dissolve metals and other substances. Pollution can change a water's pH, which in turn can harm animals and plants living in the water. The pH scale ranges from 0 to 14. In general, water with a pH < 7 is considered acidic and with a pH > 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5 and for groundwater systems 6 to 8.5. as indicted from table 6, the water pH is affected by petroleum hydrocarbon discharged to the and makes it slight alkaline over pH 8 compared to tap water as Just 1 litre of oil can contaminate 1 million liters of water. Oil pollution can have a devastating effect on the water environment, it spreads over the surface in a thin layer that stops oxygen getting to the plants and animals that live in the water.

4.2.3 Electrical Conductivity of water samples

Significantly elevated electrical conductivity can indicate that pollution has entered the river. A measure of electrical conductivity cannot exactly predict what the pollutant is, but it can help identify that there is a problem that may harm invertebrates or fish. Electrical conductivity is measured in micro siemens per centimeter (uS/cm). Freshwater is usually between 0 and 1,500 µS/cm. The electrical conductivity in this study increased with an increasing oil content in water.

The EC of water samples are highly affected by hydrocarbon discharges to water resources and obvious in table 6 that within the same site and between sites ranging between 530 to 1080 uS/cm, comparing with 365 µS/cm of tap water as control. This indicate the conductivity of water is highly affected by oil spill.

4.2.4 Water Turbidity

The suspended solids contributing to turbidity can affect water chemistry and microbiology. The particles can adsorb (take up on their surfaces) pollutants, including nutrients, metals, and organic compounds like oils. If the particles settle on the bottom of the waterbody, then the pollutants settle with them. the WHO (World Health Organization), establishes that the turbidity of drinking water shouldn't be more than 5 NTU, and should ideally be below 1 NTU, common method for converting %T to NTU is to use the following formula: NTU = 120 / %T. Turbidity is a measure of the clarity of water, and oil in water causes the water to appear cloudy. By measuring the turbidity of the water, it's possible to determine the concentration of oil in the water. From table 6 it indicate that the water also is influenced by oil hydrocarbons and make it slight cloudy from turbidity ranges between 92 to 100 %TU compared with non-turbid tap water .

4.2.5 Water Sulfate

Sulfate levels above 250 mg/L may make the water taste bitter or like medicine. High sulfate levels may also corrode plumbing, particularly copper piping. In areas with high sulfate levels, plumbing materials more resistant to corrosion, such as plastic pipe, are commonly used. The concentration of sulfates in water may not exceed 250 milligrams per liter (mg/L). As shown in table 6, the water sulfate levels are very low and within the permissible level stated by WHO ranging between 6-32 mg/L, however, the soils close to oil field recorded higher than those of tap water indicating that was slightly affected by oil discharge.

4.2.6 Water Nitrate

Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. The U.S. Environmental Protection Agency (EPA) standard for nitrate in drinking water is 10 milligrams of nitrate (measured as nitrogen) per liter of drinking water (mg/L). Drinking water with levels of nitrate at or below 10 mg/L is considered safe for everyone.

Consuming too much nitrate can affect how blood carries oxygen and can cause methemoglobinemia (also known as blue baby syndrome). the highest risk of getting methemoglobinemia can cause the skin to turn a bluish color and can result in serious illness or death. Other symptoms connected to methemoglobinemia include decreased blood pressure, increased heart rate, headaches, stomach cramps, and vomiting. The table 6 shows that the first sample in Tawke and first sample of Qadya were significantly affected by pollution recording 40 and 50 ppm nitrate, that makes them unsafety even to livestock drinks. This pollution comes either from oil spill or may be due to other organic pollutants as sheep manures.

4.3.1 Increase in Artisanal Oil Refining

Several studies have found an upsurge in artisan oil refining operations in the Kurdistan area. The majority of people in this field lack basic and essential skills and access to professional oil infrastructure. Similarly, a spike in backyard refining in northern Iraq has stemmed from increased demand for oil products in disputed regions. Weir (2017) discovered 20 clusters comprising approximately 1,600 artisanal oil refineries, predominantly in the governorates of Ninewa and Kirkuk. According to the data, citizens who have worked or have worked in these locations in the previous two years have been exposed to harmful substances leading to acute and chronic respiratory infections. Furthermore, the sites have contaminated the environment with harmful waste products produced by the combustion of petroleum products.

4.3.2 Widespread Damage to Urban and Agricultural Areas

The KRI's large-scale oil output has exacerbated the internal conflict. These clashes have destabilized the ecosystems and pose a significant threat to residential and industrial regions. Cities such as Mosul saw severe levels of damage, responsible for millions of tons of debris and rubble, which was frequently mixed with domestic, medical, or industrial waste. All of this devastation has one result: poisoning of the ecosystem. Thousands of people have been murdered, and many more have been injured since the armed war in northern Iraq began. Vast numbers of people have been displaced across the region, and rebuilding the devastated areas would take years. Along with the humanitarian disaster, the continued war is leaving a massive environmental imprint in its wake, which will impede rehabilitation efforts and have protracted economic and health ramifications for populations.

According to satellite data and field reporting, the trend of pre-conflict environmental deterioration of agricultural fields, driven in part by oil and gas exploration operations, and inadequate management of water and climate emergencies, has intensified the conflict over oil within the KRI. Agriculture output was low in areas where conflict occurred, with lands polluted, turned inaccessible by the war, or deserted as farm owners fled.

4.3.3 Community Concerns

The voices of communities afflicted by toxic war relics and ongoing contamination from oil and gas exploration and production are presently being heard. The conclusion emphasized the substantial health risks that residents had as a result of being exposed to poisonous gases from burning oil wells for months. Studies have emphasized the significance of medical care and health monitoring for individuals living in these locations, as well as the need for rapid evaluation and cleanup of contaminated sites.

4.4.1 Social Aspects and Interview with Inhabitant in Polluted Area

Several direct interviews were done with people lives near these overmentioned oil fields to know the direct effect of oil industry on the inhabitant's health in these areas. A young of 16 years old in Gerik Hasan village nearby Tawke oil field claim that they frequently suffer different respiratory disease as the throat sort, nasal congestion, burning eyes, addition to continuous air pollution that negatively affects cardiovascular system. Another married 34 years old man in Mamizina village claims of the burden of pollution, and is often forced to leave the village because of the bad and pungent smells that comes from these fields, further he said that impact of pollution is more obvious in children health. Another tanker truck driver of 25 years old claim from the toxic material in crude oil and their pungent smell during driving, he even said that one of his driver friend faints while driving the truck due to the severity of these substances in the crude oil.

Figure 10: Interviews with inhabitants around polluted area.

5. Discussion

The findings of present study show that the soils of this region are slight alkaline due to the effects of alkaline nature of petroleum hydrocarbons reaches the soil with rainfall or it may be due to the limestone parent material of the region. Same result about soil pH were reported by (Meshabaz & Umer 2022). EC values of present study indicates that the location was affected variably with oil effluents discharged to the surrounding environment. The result also indicate that the soil positively affected by industrial effluents in elevating the levels of N in the soil, or it may return to chemical fertilization of the soil. While, the phosphorous, potassium, calcium, magnesium, and sodium were not affected by the discharge of oil effluents to the surrounding environment due to negligible content of these elements in crude oil.

The $CaCO_3$ is an inherited soil property in study area and not affected by crude oil releases. Regarding the other important soil chemical proprieties like cation exchange capacity CEC, they're is a slight evidence that the oil release interfered to this vital soil property. Organic matter and dase saturation of soil were not affected by oil spill, these finding were I align with reported by (Meshabaz & Umer 2022).

Heavy metal content in the investigated soil were in low concentration are there is no evidence of being polluted by oil discharge in this are due to the calcareous alkaline nature of this soil that precipitate heavy metal and minimize their risks. Regarding water quality parameter like turbidity, the result indicate that the water also is influenced by oil hydrocarbons and make it slight cloudy, the sulfate contents in the water close to oil field recorded higher than those of tap water indicating that was slightly affected by oil discharge. Nitrate in water is highly affected especially in Tawke and first sample of Qadya were significantly affected by pollution recording 40 and 50 ppm nitrate, that makes them unsafety even to livestock drinks.

According to evidence from several studies and the ecosystem service concept, oil and gas exploration and extraction activities contribute to a wide range of environmental repercussions (Cordes et al., 2016). The production processes, including the phase of production, the size and complexity of the project, the kind and sensitivity of the nearby environment, and the efficacy of preparation, environmental protection, abatement, and control measures (UNEP, 2020), determine these impacts. The significant implications presented by large-scale oil and gas exploration and production at the KRI are expressed in the atmospheric, aquatic, terrestrial, and biosphere impacts.

According to the United Nations Environment Programme (UNEP, 2020), oil and gas exploration and production operations at the KRI have raised worries about the environment, garnering policymakers' attention. The majority of the publications evaluated show that the KRI's oil activities have significantly contributed to climate change, as seen by the alteration of precipitation patterns. Cordes et al. (2016) discovered the emission of hazardous gases such as nitrogen dioxide, sulfur dioxide, polycyclic aromatic hydrocarbons (PAHs), carbon monoxide, particulate matter, and metals such as lead, vanadium, and nickel. Kamal has also reported similar results (2016).

Soares et al. have previously reported on the aquatic repercussions of oil and gas exploration operations comparable to those investigated in this study (2021). Heavy metal depositions such as mercury (Hg), cadmium (Cd), lead (Pb), and copper (Cu) include sewage and household wastes, drilling fluids, cuttings, well treatment chemicals, leaks, and spills, and cooling water are the main concerns within the KRI. The majority of these pollutants have high toxicity and redox potential, resulting in a higher impact. According to Soares et al. (2021), these pollutants can choke benthic life up to 25 meters distant from the source of release. They jeopardize species diversity in an area of 100 meters square. Similar findings have been reported by Alanbari et al. (2016).

The terrestrial implications are also intertwined with all aspects of oil and gas exploration and production. These impacts target species, assemblages, and populations by affecting ecosystem attributes such as biodiversity, productivity, and biomass. The main component resulting from this impact is the physical disturbances created by buildings, as well as pollution caused by oil leaks and spills or solid waste disposal. Cordes et al. (2016) and UNEP (2017) also reported these alterations.

Soil erosion caused by poor soil form, slope, or rainfall is one of the potential consequences of bad design and construction. Soils will retain their integrity if left undisturbed and vegetated; however, soil erosion may occur if trees are removed and topsoil is uncovered (UNEP, 2017). Changes in soil conditions can have far-reaching downstream effects, such as changes in surface hydrology and channel morphology, heightened silting, and habitat degradation, diminishing the ecosystem's capability to accommodate and support plants and wildlife. Chowdhury et al. (2021) reported that the land disturbance related to energy footprints is crucial and contributes largely to a shift in environmental pathways such as a change of a forested area into an oil exploration and production site resulting in disruption of surface soil surface and erosions.

Also, changes in ecological circumstances caused by oil exploration activities also influence plant and animal populations by interfering with the quality of air, sediments, and interruption from noise, external light, and changes in natural vegetation. Such changes significantly impact ecosystems, causing habitat loss, insufficient nutrition, food supplies, disruptions of breeding regions, migratory patterns, predator exposure, or modifications in herbivore eating habits, which have a secondary impact on predators. Soil disturbance and vegetation loss, as well as secondary repercussions such as siltation and runoff, impact ecosystem functioning by changing nutrient ratios and microbial biomass in the soil. Loss of habitat affects both plants and animals, causing changes in species diversity and important production processes.

functioning by changing nutrient ratios and microbial biomass in the soil. Loss of habitat affects both plants and animals, causing changes in species diversity and important production processes.

6. Conclusions and Recommendations

1- The findings show that the oil industry is affected by a variety of parameters, including the stage of operations, the scale and scope of the project, and the susceptibility of the external environment.

2- Oil and gas exploration and production operation in the KRI is hugely associated with the atmospheric, aquatic, terrestrial, and biosphere impacts. These consequences pose a great danger to humans and animals, and plants. The noise, emissions, discharges, and physical destruction brought about by oil and gas exploration and production have negative impacts on KRI ecosystem services and biodiversity.

3- Based on the findings of this study, there is an urgent need for researchers to perform extensive research on a similar topic within the KRI.

4-The review of the literature reveals that very few studies have investigated the environmental impacts of oils and gas exploration within the Kurdistan region. Also, future studies and policymakers should focus on the management of the environmental impacts posed by operations relating to oil and gas exploration. This action will protect biodiversity by preventing unnecessary pollutants that substantially influence life on Earth.

5- It concluded that some soil properties near oil fields were negatively affected by the various gaseous and liquid emissions from these oil fields. So, it recommends to monitor these soils periodically to assess the progress of pollution status.

6-The water bodies surrounding these fields has been deteriorated in quality parameters especially in their content of hazardous nitrate ions. So, it is recommended to treat this water before being used for human consumption or livestock drinking.

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