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The impact of oil and gas production and industry of qayyarah oilfield on soil and groundwater quality

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Abstract

The process of producing oil after exploration depends on extracting the components of petroleum from petroleum reservoirs and converting them into refinery products that can be used. As for the refining process, it depends on breaking down crude oil into its various components, which are selectively reformed into new products. Oil production and refining are activities that cause negative impacts on the environment, including soil and groundwater. This is evident in the current study of the research area through conducting analysis of samples of soil and groundwater around and inside Qayyarah oilfield and refinery. Soil and water samples obtained from eight sites; around and inside of Qayyarah refinery area plus two surface water samples of Tigris River from above and down Qayyarah oil field and refinery. These samples were analyzed for their heavy metals content such as lead (Pb), copper (Cu), Nickel (Ni), cadmium (Cd), iron (Fe), zinc (Zn), and chromium (Cr). The results showed that the amount of lead present in the soil ranges from (13.40 – 99,40) mg/kg, copper values were in the range of (5.10- 36.70)mg/kg, Nickel concentration vary from (0.64 – 13.80) mg/kg, values for cadmium, iron, zinc, and chromium were (0.12 – 0.82) mg/kg, (221.0 –739.0) mg/kg, (11.1-98.0)mg/kg and (8.5-73.0) mg/kg respectively. Apart from zinc and nickel, all other heavy metals were higher than the toxicity limits for heavy metals in naturals oil; this implies pollution of the soil by heavy metals. Also, the groundwaters were found to be polluted by lead, the pH of the water samples was found to deviate significantly from DPR limits and WHO standard for potable water. This also implies pollution. Such contamination for both soil and groundwater grows and becomes bigger in the future, which could adversely affect human health and the region's ecosystems.

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Materials and methods:

1-Location of the study area

The Qayyarah sub district is part of Mosul District in southern Nineveh Governorate on the west bank of Tigris River in Iraq. Qayyarah is rich with natural resources, including oil and sulfur. The extracted oil is very heavy sour crude (American Petroleum Institute API gravity 15°) therefore the production was in small quantities.[1] The name of the sub district derives from the Arabic word for tar. The Qayyarah oilfield is situated on the west bank of the Tigris River in Iraq, in Qayyarah sub district, southern Nineveh (50-60) km south of Mosul. According to Iraq's tectonic model, the research area is located within the low-folded zone (Sadeq and Yosiff, 2015) (Fig. 1). It is one of the most significant fields in Nineveh's southern region. The asymmetrical anticline extending southeastern and in the west is the main structure of the Qayyarah oil field with flank dips of about 3 to 6 degrees. The field's length and width are approximately 16 and 4-5 kilometers, respectively.

2-Regional and Local Geology:

Stratigraphically, the Euphrates Formation, according to Jassim and Goff (2006), is heterogeneous; the formation consists primarily of limestone with textures ranging from oolitic to chalky limestone, which contains corals and coquina shell; mostly recrystallized and siliceous, green marl beds, argillaceous limestone, brecciated conglomerate, and conglomeratic limestone also present. The Euphrates Formation was divided into two units (Berbakhesh, 1990): the lower unit, which is influenced by dolomitization and recrystallization, and the upper unit, which is not affected by diagenetic processes.

The study area lies within the low folded zone (Fig.2). The region is delineated low structures with NW-SE direction, such as the folds of Najmah, Jawan, and Qaiyarah. These structures are accompanied by low synclines, which characterized by multiple sinkholes of varying widths. (Fig. 2). Stratigraphically, the lower Miocene Euphrates, and Middle Miocene Jeribe formations are regarded as the primary targets of the Tertiary petroleum system in the western section of the Zagros Basin. The formations are the important oil reservoirs in the Qayyarah field, which is characterized by their good permeability and porosity (Al-Majid, A. M. H., 2021). Below is a brief description of each of the two formations, based on National Oil Company (NOC) reports. The Jeribe Formation consists mainly of grey limestone with thin overlaps of chalky limestone. The thickness of formation is about 45 m. The Euphrates Formation is mostly made of limestone and dolomite, with anhydrite nodules. Because the Dhiban Formation is primarily formed of anhydrite, it is considered the cap rocks for the Euphrates reservoir. Its thickness in the studied well is about 62 m, while its cap rock (Dhiban Formation) is about 22 m.

3-Soil studies:

Soil samples were taken at four points of interest. Thus; (a) Around oil well heads soil sample one (SS1). (b) Flare sites soil sample two (SS2).

(c) Waste pit soil sample three (SS3). (d) Effluent discharge point soil sample four (SS4). The soil samples were taken at 0 – 15 cm for top soil, 15 – 30 cm for middle soil and 30 – 60 cm for bottom soil for heavy metals analysis. 4-Heavy metals analysis methods for soil and groundwater samples:

4-Heavy metals in oil

Soil samples were air dried and sieved through a 2 mm sieve. The fine earth was then used for the analysis. Particles larger than 2 mm mesh size were discarded. The heavy metal contents of soil determined using the atomic absorption spectrophotometric method as described in standard methods (APHA,1995; Ademoroti, 1996b). The heavy metal content of soil was determined after dry ashing the soils and extracting with dilute nitric acids. An aliquot of the filtrate of the samples was taken (about 3-5 ml). Iron, zinc, copper, chromium. cadmium, nickel and lead were determined by atomic absorption spectrophotometer (AAS) using air acetylene flame. The concentrations of the metals of interest are determined and presented in table 1.

5-Hydrogeology Setting:

The hydrogeology of the study area is interpreted on the basis of the available documentary evidence and records such as bore hole lithology and geology.

1-Unconfined aquifer, mainly in the Quaternary sediments which has wide geographical distribution and of thickness ranges from 3 to 6 m . This aquifer is underlined by the Pliocene clay which act as a confining bed. The main source of recharge to this aquifer takes place from direct rainfall and wadis runoff.

2- Al-Fatha formation is considered to be a semiconfined aquifer. This formation is separated from Quaternary sediments by an aquiclude of clay sediments in some places, and are hydraulically connected with Quaternary sediments in others. This aquifer consists mainly of variable lithological units of permeable and impermeable beds and receives its water mainly by underflow and leakage from upper regional aquifer. This aquifer is well jointed and fissured in local scale exhibits solution channels. Rainfall is the main source of aquifer recharge. It occurs along Quaternary sediments. In addition, infiltration from intermittent tributaries that drain water during period of heavy precipitation.

6-Heavy metals in groundwater:

Groundwater samples have been collected from four wells distributed in the study area represented by the Qayyarah refinery area, namely W1, W2, W3 and W4, and two surface water samples from upward and downward Tigris River reach that facing Qayyarah oilfield. The heavy metal contents of groundwater and surface water were determined using the atomic absorption spectrometric method as determine in table 2 described in standard methods (APHA, 1995; Ademoroti, 1996b). The concentrations of the metals of interest are sites (SS2), Waste pit (SS3), and Effluent discharge point (SS4).

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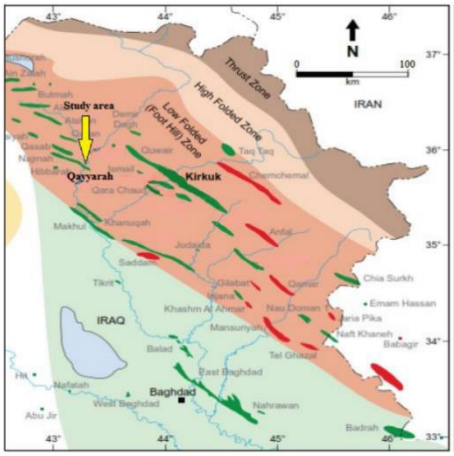

Fig.1.Qayyarah oil field location (Sadeq and Yosiff, 2015).

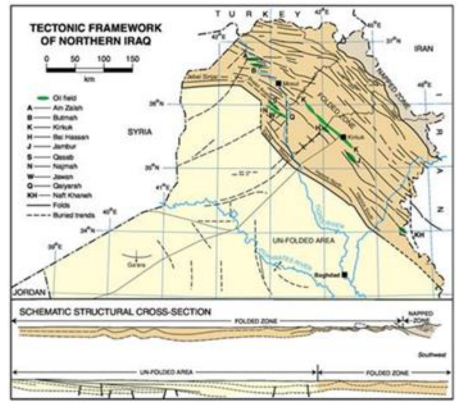

Fig.2 Tectonic framework of Northern Iraq (Dunnington, 2005).

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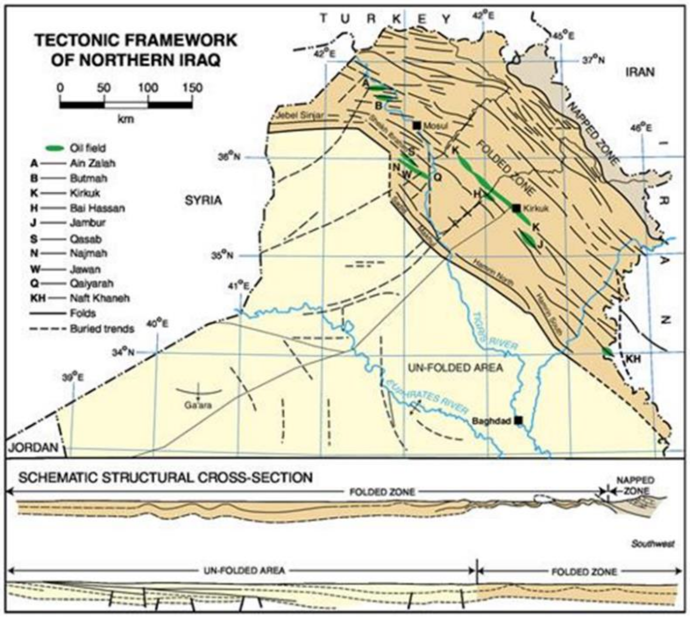

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Table 1. Results of heavy metals content of soil in four sampling points viz; around oil well heads (SS1), Flare sites (SS2), Waste pit (SS3), and Effluent discharge point (SS4).

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Sampling Points	Depth (cm)	Pb mg/kg	Cu mg/kg	Ni Mg/kg	Cd Mg/kg	Fe Mg/kg	Zn Mg/kg	Cr Mg/kg
	0-15	24.0	49.8	4.8	0.95	221.0	11.1	8.5
SS1	15-30	22.0	5.1	2.9	0.05	631.0	78.0	14.8
	30-60	30.0	5.3	1.6	0.13	485.0	16.2	25.5
	0-15	99.4	16.7	6.7	0.15	782.0	52.7	45.0
SS2	15-30	13.6	11.2	3.5	0.23	533.0	21.2	13.4
	30-60	18.8	14.3	3.5	0.23	500.0	28.3	9.8
	0-15	12.4	33.6	3.5	0.12	670.0	58.8	10.5
SS3	15-30	27.8	31.7	5.4	0.43	490.0	94.0	8.9
	30-60	17.2	30.6	4.1	0.33	937.0	18.0	12.5
	0-15	52.9	32.1	7.40	0.33	850.0	82.1	56.0
SS4	15-30	61.9	12.5	0.64	0.82	867.0	98.0	73.0
	30-60	38.3	36.7	13.8	0.74	890.0	87.0	62.8

All values are mean values of triplicate determinations

Table 2. Results of heavy metals content of groundwater in four sampling points.

Well No.	Lead Pb^2 (mg/l)	Copper Cu^2 (mg/l)	Nickel Ni^2 (mg/l)	Cadmium Cd^2 (mg/l)	Total Iron Fe^2, Fe^3 (mg/l)	Zinc Zn^2 (mg/l)	Chromium Cr6+ (mg/l)	pH
W1	0.25	0.005	<0.05	<0.005	1.4	<0.01	0.005	6.80
W2	0.30	0.005	<0.05	<0.005	1.3	<0.01	0.005	6.50
W3	0.32	0.005	<0.05	<0.005	1.3	<0.01	0.005	6.30
W4	0.31	0.005	<0.05	<0.005	2.5	<0.01	0.005	5.70
SW1	0.002	<.0.005	<0.01	<0.01	0.1	<0.005	0.005	7.4
SW2	0.007	<0.005	<0.01	<0.01	0.15	<0.005	0.005	7.6

All values are mean values of triplicate determinations. W1, W 2, W 3, and W 4 means groundwater well 1, 2, 3 and 4 respectively, and surface water SW1, surface water SW2.

Table3. DPR (1991), WHO (1971) and FEPA (1991) limits standard for Potable and Domestic water for some parameters.

Parameters	DPR limits	WHO Standard	FEPA limits
Lead (Pb^2)	0.05mg/l	0.01-0.05mg/l	0.05mg/l
Copper (Cu^2)	1.00mg/l	1.00 – 1.5mg/l	1.00mg/l
Nickel (Ni^2)	-	-	0.01mg/l
Cadmium (Cd^2)	-	0.01mg/l	0.01mg/l
Total Iron ($Fe^2$and Fe^3)	1.00mg/l	0.3mg/l	0.3mg/l
Zinc (Zn^2)	1.50mg/l	5.0 - 15mg/l	5.0mg/l
Chromium (Cr6+)	0.03mg/l	0.05mg/l	0.05mg/l

Discussion

The results obtained in this study are presented in considerable amount as shown in table (1) which indicates that some heavy metals occurred above the natural occurring values, their occurrence at such levels indicates pollution of the sampling points in the studied area. This is so because of the wide use of chemicals containing heavy metals being discharged into the environment as a result of petroleum exploration and production activities. The amount of lead (Pb^2) in soil of the sampled areas varies from 3.40 - 99.40 mg/kg. These values are higher than toxicity characteristic leachate limits (TCL) of 5.00 mg/kg for lead (Bowen, 1979). Lead is toxic to many plants species, although a few are relatively tolerant. When ingested, lead can cause a disease called plumbism; lead also is known to damage the brain, the central nervous system, kidney, liver and the reproductive system (Ademoroti, 1996a). Natural occurring concentration by lead in soil ranges from 2.0 - 20.00 mg/kg (Bowen, 1979). The concentration level of copper ranges from 5.1 – 49.8 mg/kg, these values are relatively higher compared to the normal range of 5.0–20.0 mg/kg required by plants in natural soil concentration (Bowen, 1979). Copper in excess amount can be harmful and pollution occurs in areas where copper are found and worked. Nickel concentration level vary from 1.60-13.80 mg/kg, it falls within the normal range of 2.0- 750.0 mg/kg in natural soil concentration (Bowen, 1979). The concentration of cadmium in soils of the study area ranges from 0.04 – 0.95 mg/kg. Naturally occurring cadmium concentration ranges from 0.03 to 0.30 mg/kg. Therefore cadmium concentration in the soil analysed is far above the naturally occurring range. Cadmium is known to cause itai-itai disease; (Jun, 1969; Jun 1974; Gustav, 1974; Ademoroti, 1988). The results of soil samples analysis for iron calls for concern because of the relatively high values, it ranges from 221.0 - 937.0 mg/kg. Iron toxicity rarely creates problems in the field. Although groundwater table in the area is shallow and the iron could find its way to the groundwater thereby polluting it. Iron was found to have infiltrated greatly up to 60 cm depth in the soil horizons. The amount of zinc in the sampled soil vary 11.1- 98.0 mg/kg, these levels are within the natural range of 1.0 – 900 mg/kg in soil (Bowen, 1979). Zinc is an essential lement in our diet. Too little zinc can cause problems, but too much zinc is also harmful. Large doses taken by mouth even for a short time can cause stomach cramps, nausea, and vomiting. Taken longer, it can cause anemia and decrease the levels of your good cholesterol. Zinc can be a pollutant, because zinc is directly added to the drilling fluids as zinc carbonate and act as corrosion inhibitor for mud formations and part of the zinc can be trapped by the soil layer (Katherine, 1985).

The chromium values range from 1.3 – 165.0 mg/kg in excess of the toxicity characteristics leachate procedure limits of 5.00 mg/kg. Ingesting very large amounts of chromium can cause stomach upsets and ulcers, convulsions, kidney and liver damage, and even death. It is not known if chromium harms humans but mice that ingested large amounts of chromium had reproductive problems and offspring with birth defects. Results in Table 2 show that the pH of the water samples from the four well sampled (W1, W2, W3 and W4) and surface water samples SW1 and SW2 were 6.80, 6.50, 6.30 and 5.80, and for surface water samples were 7.4 and 7.6 respectively. These values of ground water are acidic and surface water are alkalin which is approximately very near to the standard of 6.5 -8.5 recommended by WHO and Department of Petroleum Resources for potable water (WHO, 1971; DPR, 1991). Table 2 also shows the level of heavy metals present in the ground water in the exploration site. From the result, it is observed that only lead was found to be above WHO and DPR standards shown in table 3 while iron is found under the permissible level. The lead contamination of virtually all the boreholes could be as a result of mud type used for drilling the wells. This could be dangerous for the users of such water. Lead is known to cause plumbism, and damages to the brain, the central nervous system, kidney, liver and the reproductive system (Ademoroti, 1996a). Moreover, hydrocarbon exploration and extraction has been identified as a relevant threat to groundwater systems (Jia et al., 2019), and contamination of the shallow aquifer system in the study areas by unconventional oil and gas (UOG) extraction would likely disrupt and considerably impact the lives of communities in the region.

Conclusion

From the results of this study, it is evident that exploration and production activities introduced lots of heavy metals into the soil and groundwater where such activities are carried out. This has been traced to the many chemicals used for these activities which leads to contamination for both soil and groundwater and may be grows and becomes bigger in the future, which could adversely affect human health and the region's ecosystems. It is therefore suggested that remediation process be carried out so as to render the polluted soil and groundwater fit for use especially for agricultural and domestic purposes.

Within Qayyara oilfield areas, both conventional and unconventional oil and gas could be extracted in the target oil and gas areas if proven to be economically viable. Groundwater contamination is the most common environmental threat from conventional and unconventional gas extraction in this region. The water tables of the shallow aquifers in the target oil and gas areas in Qayyara oilfield and adjacent area are in some areas as little as 5 m deep. These shallow water tables can exacerbate localized groundwater pollution in these areas. Groundwater is often the sole water source and is critical to the health and livelihoods of the communities in these regions. Hydrocarbon exploration and extraction has been identified as a relevant threat to groundwater systems and contamination of the shallow aquifer system in the study areas by unconventional oil and gas (UOG) extraction would likely disrupt and considerably impact the lives of communities in the region.

Acknowledgment

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الخلاصة

تعتمد عملية إنتاج النفط بعد الاستكشاف على استخراج مكونات البترول من مكامن البترول وتحويلها إلى منتجات تكرير يمكن استخدامها. أما عملية التكرير فتعتمد على تفكيك النفط الخام إلى مكوناته المختلفة، والتي يتم إصلاحها بشكل انتقائي إلى منتجات جديدة. إن إنتاج النفط وتكريره من الأنشطة التي تسبب آثارًا سلبية على البيئة، بما في ذلك التربة والمياه الجوفية. ويتضح ذلك في الدراسة الحالية لمنطقة البحث من خلال إجراء تحليل لعينات من التربة والمياه الجوفية حول وداخل حقل نفط ومصفاة القيارة. تم الحصول على عينات من التربة والمياه من ثمانية مواقع؛ حول وداخل منطقة مصفاة القيارة بالإضافة إلى عينتين من المياه السطحية لنهر دجلة من أعلى وأسفل حقل نفط ومصفاة القيارة. تم تحليل هذه العينات لمحتواها من المعادن الثقيلة مثل الرصاص (Pb) والنحاس (Cu) والنيكل (Ni) والكادميوم (Cd) والحديد (Fe)والزنك (Zn) والكروم (Cr). أظهرت النتائج أن كمية الرصاص الموجودة في التربة تتراوح من (13.40 - 99.40) ملجم/كجم، وكانت قيم النحاس في نطاق (5.10 - 36.70) ملجم/كجم، وتركيز النيكل يختلف من (0.64 - 13.80) ملجم/كجم، وكانت قيم الكادميوم والحديد والزنك والكروم (0.12 - 0.82) ملجم/كجم، (221.0 - 739.0) ملجم/كجم، (11.1 - 98.0) ملجم/كجم و(8.5 - 73.0) ملجم/كجم على التوالي. وبصرف النظر عن الزنك والنيكل، كانت جميع المعادن الثقيلة الأخرى أعلى من حدود السمية للمعادن الثقيلة في الزيوت الطبيعية؛ وهذا يعني تلوث التربة بالمعادن الثقيلة. كما وجد أن المياه الجوفية ملوثة بالرصاص، ووجد أن الرقم الهيدروجيني لعينات المياه ينحرف بشكل كبير عن حدود DPR ومعيار منظمة الصحة العالمية لمياه الشرب. وهذا يعني أيضًا التلوث. ويتزايد هذا التلوث للتربة والمياه الجوفية ويصبح أكبر في المستقبل، مما قد يؤثر سلباً على صحة الإنسان والنظم البيئية في المنطقة.