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NORM in Markazia Degasing Station within North Rumaila Oilfield-Southern Iraq

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Abstract

Concentration of natural occurring radioactive material (NORM) in Markazia Degasing Station in North Rumaila oilfield (NDS) was measured in this study. Then, radiological assessment due to existing of NORM in different samples including soil, sludge, scale, oil, and water collected from different stages of oil and gas production NDS was done. Radioactivity concentration of Ra-226, Th-232 and K-40 were measured using gamma spectrometry system based on HPGe detector with efficiency of 30%. The results show that some locations within NDS are contaminated with NORM. The activity in Bq/kg of Ra-226, Th-232 and K-40 range between 15.19 in oil to 68.73 in sludge, 8.5 in oil to 23.45 in sludge and 80.23 in oil to 319.73 in saline water samples respectively. The places to be more contaminated among the other places within the processing stages of oil and gas production within NDS are dehydrator and desaltor stages. These locations have to be monitored and remediated periodically.

Keywords: NORM, Radiological, Oil and Gas, Rumaila, Radioactivity, Radiation.

المواد المشعة المتواجدة طبيعيا في المحطة المركزية لانتاج النفط والغاز في حقل نفط الرميلة الشمالي، جنوبي العراق

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الخلاصة

تم قياس تراكيز المواد المشعة المتواجدة طبيعيا في المحطة المركزية لانتاج النفط والغاز في حقل نفط الرميلة الشمالي. ثم اجري تقييم اشعاعي لمنطقة الدراسة المتسبب عن وجود تلك المواد المشعة في نماذج مختلفة من التربة والمخلفات والقشرة والنفط والمياه المصاحبة خلال مراحل انتاج النفط والغاز المختلفة في المحطة المركزية. تم قياس تركيز النشاط الاشعاعي للراديوم-226، الثوريوم-232 والبوتاسيوم-40 بواسطة منظومة تحليل اطياف كاما المستندة الى عداد الجرمانيوم عالي النقاوة ذي الكفاءة 30%. بينت النتائج تلوث بعض الاماكن بالمواد المشعة الطبيعية اعلاه. كانت مستويات النشاط الاشعاعي بوحدات بكريل/كغم للراديوم-226 والثوريوم-232 والبوتاسيوم-40 قد تراوحت بين 15.19 في النفط الى 68.73 في المخلفات، 8.5 في النفط

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الى 23.45 في المخلفات و 80.23 في النفط الى 319.73 في المياه المالحه المصاحبة ، على التوالي. وتبين ان المواقع التي تبدو اكثر تلوثا من غيرها ضمن مراحل عمليات الانتاج للنفط والغاز ضمن منطقة الدراسة هما موقعي الانتاج الرطب وعزل الاملاح والتي يجب ان تراقب وتعالج بصورة دورية.

Introduction

Natural occurring radioactive material (NORM), representing by ^{238}U and ^{232}Th series and ^{40}K, can be found in different amount in the rock formation within the reservoir depending on the type of rock. NORM could be transfer to the surface during the production of oil and gas. Radioactive decay of ^{238}U and ^{232}Th produces several series of daughter radioisotopes of different elements and of different physical characteristics with respect to their half-lives, modes of decay, and types and energies of emitted radiation [1, 2]. These NORMs may be accumulated as brine, sludge and scale due to the change of physical and chemical condition of oil and water formation at the surface. Most of NORM deposits as sludge and scale in equipment and pipes or as sediments in in brine water tanks and polls. Processing of oil and gas production increase the accumulation of NORM within the stages of production. This accumulation may cause an additional radiological risk to the workers in the oilfield. A common understanding of the radiation hazards and protection principles within the petroleum industry would lead to efficient and increasingly safer operations. Rumaila Oil and Gas Industries, within Rumaila Oil Field, southern Iraq, is one of the biggest industries which produce oil and gas in Iraq. One of these industries is named North Rumaila Markazia Degasing Station (NDS).To determine whether or not NDS facilities have NORM contamination, NORM survey, sampling and analysis need to be conducted. This is the objective of current study.

Location and Geology

Rumaila Oil Field extends over a large area within Basrah Governorate, southern Iraq Figure- 1. It seems difficult to cover the entire field in the current study. So one site for oil and gas production was investigated in this study which was North Rumaila Markezia Degasing Station (NDS) Figure- 1.

The oil is produced from sedimentary rocks belong to the Zubair and the Mishrif Formations. Zubair Formation is the most prolific reservoir in the southern Iraq [3]. The formation, which comprises 380-400m of alternating shale, siltstone and sandstone, extends from central of Iraq southward to the Iraqi-Kuwaiti borders. The proportion of the shale decreases to the SW. The carbonate comprise about of 15% of the formation southern Iraq. The thickness of the sandstone increases towards the south and west to reach about 200m near Al-Zubair city. The Mishrif Formation in its type area is composed of grey-white dense algal limestone including gastropods and shell fragments, very shelly and foraminiferal limestone with limestone, with rudist debris below. Its thickness in Rumaila oil field is about 270m. The underlying unit is usually Rumaila Formation in southern Iraq.

The industry of NDS includes 8 trains (lines of production), given names Train-A to Train-I Figure-1. Each begins with wells inlets complex which receives the crude oil from many oil wells drilled within the Zubair and the Mishrif Formations. The crude oil then goes within many chemical and physical operation stages. First, crude oil subjected to different conditions of heat and pressure through many separation stages (3-4 separators) to separate oil and gas from formation water. Then, oil subjected to dehydrated desalters. One important line is the gas production line. In this stage, again, oil goes under low and high pressure to separate gas from oil before it goes to dehydrated desalters stage. Finally, the separated oil and gas are collected in storage tanks in order to be transferred it to the export tanks using export pumps. These operations lead t sludge deposition and scaling in the collecting tanks, pipes and valves in addition to contaminate the soil surface within the industry. The final products are oil, gas and produced water. Produced water then is transferred to injection wells.

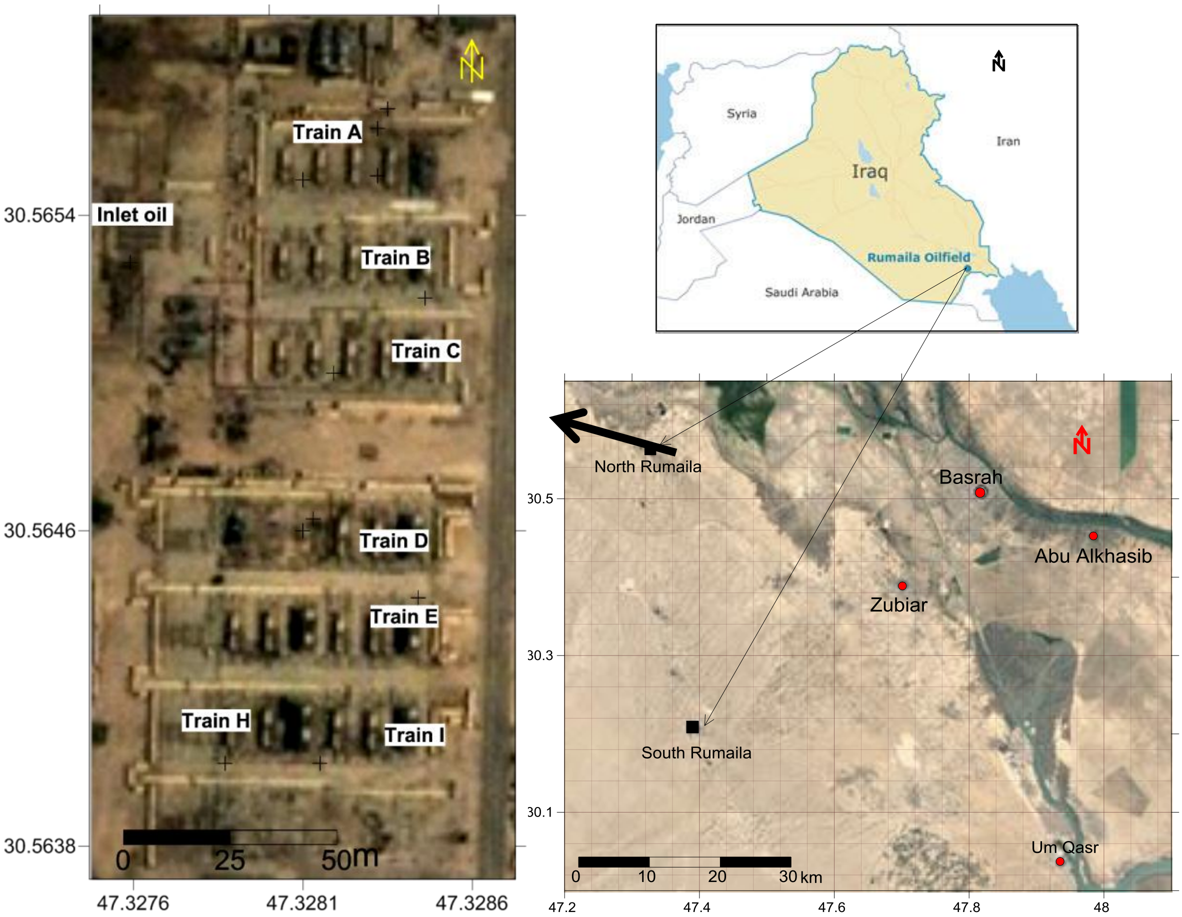

Figure 1- Google Earth location map of Rumaila Oilfield and base map of NDS

Materials and methods

The field work includes collecting of fourteen samples of surface soil, sludge, scale, oil and water, were collected from the different operation stages within the trains of oil and gas production. At least one kilogram for each sample in were put in polyethylene bag, sealed tightly labeled with ID, date, location, material type. Soil, sludge and scale samples were dried for a sufficient period of time at a fixed temperature (at 105ºC) to acquire a constant dry weight using electric oven. Large gravels, sand and plants were removed if any while water and oil sample used as it is. All samples are then thoroughly homogenized, then (0.5-1) kg of each sample (0.5-1L of water and oil) was taken and storaged for 25 days in completely sealed Marinilli beaker to achieve equilibrium between radon and its daughters [4].

Gamma spectrometry system based on HPGe with efficiency 30% was used for analysis of NORM in the samples. Concentration in Bq/kg of Radium-226, Th-232, and K-40 were measured in all samples. The specific activities were averaged from gamma-ray photo peaks at several energies. The gamma-ray lines at 180.5 of Ra-226 and/ or at 295.2 keV and 351.9 keV from ^{214}Pb and at 609.3 keV and 1764.5 keV from ^{214}Bi were used to determine the specific activity of ^{226}Ra. The gamma-ray lines of 338.4 keV, and 911.2 keV from ^{228}Ac, the 727.3 keV from ^{212}Bi, and 583.2 keV and 2614.5 keV from ^{208}Tl were used to determine the specific activity of ^{232}Th. The specific activity of ^{40}K was measured directly by its own gamma-ray line at 1460.8 keV. The energy calibration and efficiency was calibrated using a standard source of a multi energy made by the American Canberra Company. The Marinilli geometrical shape was used to measure the radioactivity of the samples and in the source of calibration.

Measuring of Exposure dose and estimation of hazard indices

Exposure dose rate in micro-Sievert per hour (μSv/h) at sampling locations were recorded by using portable dosimeter, Geiger Muller Counter type GMC-3000. It measures ambient doses between 0.01-1000μSV/h.

The external terrestrial gamma radiation absorbed dose rate D ($nGyh^{-1}$) in air at a height of 1 m above the ground were calculated according to the suggestions of UNSCEAR [5] as in the following equation

$D = 0.43A_{\mathrm{Ra}} + 0.662A_{Th} + 0.0424A_{\mathrm{K}}$ ………………………………………………………………… (1)

Where D is exposure dose rate in nanogray ($1x10^{-9}$ gray) per hour and A_{Ra}, A_{Th} and A_{K} are the activity concentrations ($Bq\ kg^{-1}$) of radium, thorium and potassium in the samples.

The annual average effective dose equivalent received by a member is calculated as follows [6]:

Outdoor ($nSvy^{-1}$) = Absorbed dose ($nGrayy^{-1}$) * 2503h * $0.7SvGy^{-1}$ ………………………..… (2)

In current study, maximum of 8 hours/day for 6 days per a week (2503h per year) are assumed as working time for workers inside the oil and gas production plant.

The radium equivalent activity (Ra_{eq}) is used to assess the hazards associated with materials that contain ^{226}Ra,^{232}Th and ^{40}K in $Bq\ kg^{-1}$ [7] because their distribution in raw materials is not uniform [8]. The radium equivalent activity is a weighted sum of activities of the ^{226}Ra, ^{232}Th and ^{40}K radionuclides based on the assumption that 370 $Bqkg^{-1}$ of ^{226}Ra, 259 $Bq\ kg^{-1}$ of ^{232}Th and 4810 $Bq\ kg^{-1}$ of ^{40}K produce the same gamma ray dose rate [9]. Radium equivalent activity can be calculated from the following formula suggested by Beretka and Mathew [10]. The published maximal admissible Ra_{eq} is 370 $Bq\ kg^{-1}$ [7].

$\mathrm{Ra_{eq}} = A_{\mathrm{Ra}} + 1.43A_{Th} + 0.077A_{\mathrm{k}}$ …………………………………………………....……….(3)

Where: A_{Th}, A_{Ra} and A_{K} are the activity concentration of ^{232}Th, ^{226}Ra and ^{40}K in $Bqkg^{-1}$ respectively.

The external hazard index (Hex) is defined as follows [11]:

$H_{ex} = A_{\mathrm{Ra}}/370 + A_{\mathrm{Th}}/259 + A_{\mathrm{K}}/4810$ ……………………………………………………………..…(4)

Where: A_{Ra}, A_{Th}, A_{K} are the radioactivity concentration in Bq/Kg of ^{226}Ra, ^{232}Th, and ^{40}K respectively. The value of this index must be less than unity for the radiation hazard to be negligible [11]. Hex equal to unity corresponds to the upper limit of Ra_{eq} 370 Bq/Kg [10].

Results and discussion

Distribution of NORM in NDS samples

The activity concentration of NORM in Bq/kg in all samples and the exposure dose rate in (µSv/h) in NDS were presented in Table -1

Table 1- Activity of Ra-226, Th-232 and K-40 in samples selected from different stages in NDS in addition to total exposure dose rates.

ID	Location	Material	Ra-226 Bq/kg	Th-232 Bq/kg	K-40 Bq/kg	Exposure dose µSv/h
NDS1	Inlet Train-A	Crude oil	18.56	9.85	98.63	0.05
NDS2	Train-A	Soil	49.78	18.49	169.86	0.05
NDS3	Well inlet complex	Soil	38.50	17.38	202.33	0.03
NDS4	Train-B	Soil	40.50	18.37	204.12	0.07
NDS5	Train-C	Sludge	51.56	17.18	231.07	0.10
NDS6	Train-E	Sludge	46.91	15.63	187.64	0.05
NDS7	Abandoned pipe	Scale	42.77	15.48	171.09	0.03
NDS8	Abandoned pipe	Scale	44.17	16.35	167.85	0.03
NDS9	Train-F	Sludge	60.10	15.60	178.50	0.07
NDS10	Train-G	Sludge	52.30	17.20	167.50	0.08
NDS11	Train-I	Sludge	68.73	23.45	309.31	0.10
NDS12	Train-H	Sludge	63.47	21.50	296.27	0.07
NDS13	Outlet	Crude oil	15.19	8.15	80.23	0.06
NDS14	Dehydrated oil	Saline water (produced)	67.33	22.44	319.73	0.08

Distribution of Ra-226, Th-232, K-40 concentrations (Bq/kg) and exposure dose rates (µSv/h) in NDS were represented in colored classed position maps as shown in Figures- (2, 3).
The radium activity ranges from (15.19 – 68.73) Bq/kg. The maximum value of radium is (68.73) Bq/kg in sludge sample in train-I while the minimum value is (18.56) Bq/kg in crude oil (post-treatment) in outlet train –A. The Thorium activity ranges from (8.15-23.45) Bq/kg, maximum value was measured in sludge sample in Train-I while the minimum value was measured in crude oil in outlet Train –A. The range of activity K-40 is between 80.23 Bq/kg in crude oil in outlet stage to 319.73 Bq/kg in saline water (wet oil stage). The maximum values of Th-232 and K-40 are below the worldwide average value documented in earth crust (45, 412) Bq/kg for Th, and K-40 respectively [12, 13] while the maximum value of Ra-226 is above the world average value (32) Bq/kg [12].

The total exposure dose rates in the NDS area were recorded to be between (0.03-0.1) µSv/h corresponding to (43-143) nGy/h with average value of (89±34) nGy/h. This value is above the worldwide average outdoor dose rate of 58 nGy/h recorded by UNSCEAR [7].

Figure (2) shows that more than 85% of the sampling locations have Ra-226 concentration higher than the worldwide average (32 Bq/kg) of Ra-226 in soil which may indicate the dispersion of radium resulting from oil and gas production processes over most area of NDS. The highest concentrations of Ra-226 were found in sludge samples with average of 57.2 Bq/kg while its average concentration is 44.8 Bq/kg in scale samples and 42.9 Bq/kg in ambient soil samples Figure- 4. Th-232 concentrations are mostly with approximate values in all samples as appear in Figure-5. It's concentrations in all samples are below the worldwide average. The concentration of K-40 is found to be higher in sludge while, approximate values are found in scale and soil as shown in Figure-6. The difference in the distribution of radium, thorium and potassium in the samples attribute to the differences in their geochemistry and mobility under different conditions.

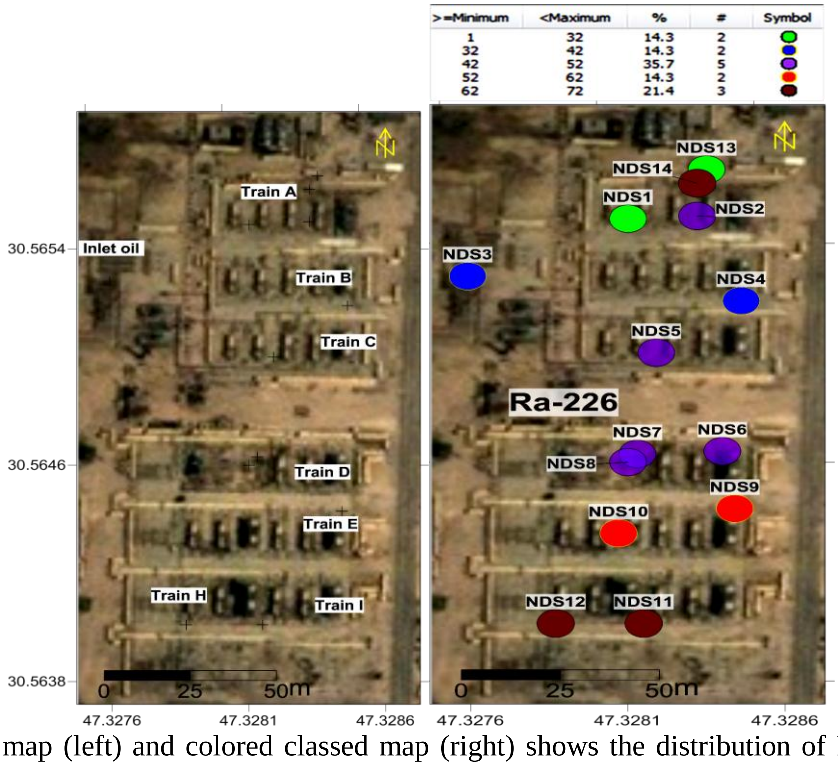

Figure 2-Base map (left) and colored classed map (right) shows the distribution of Ra-226 in NDS area.

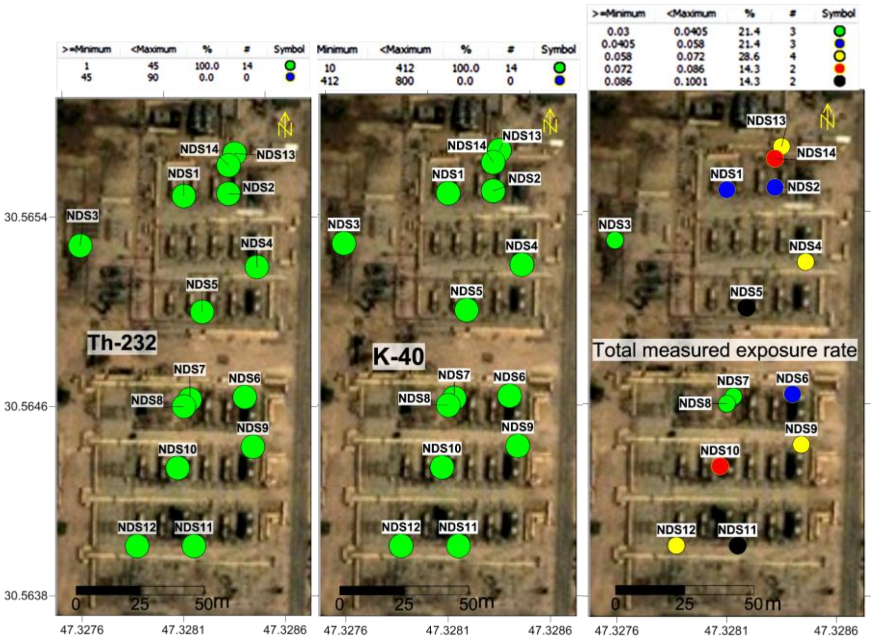

Figure 3- colored classed maps show the distribution of Th-226 (Bq/kg) (left) and distribution of K-40 (Bq/kg) (middle) and total measured exposure rate (μSv/h) (right) in NDS area.

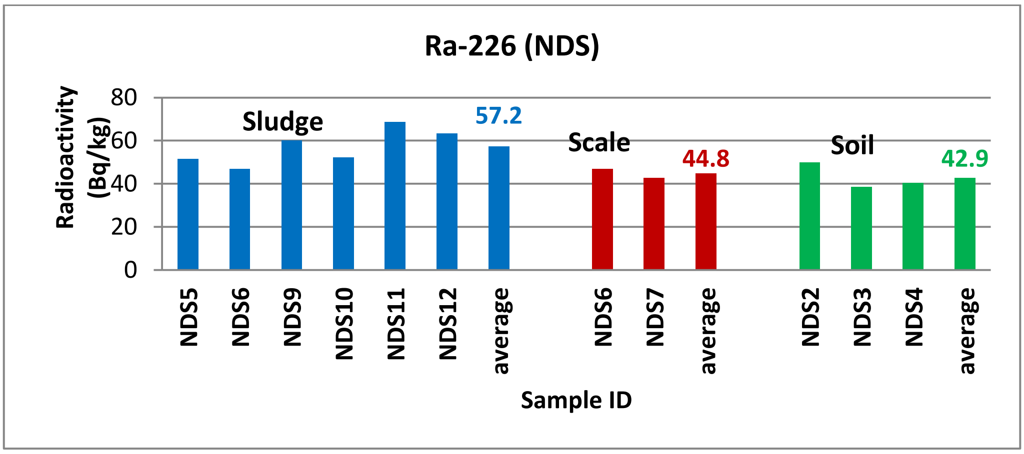

Figure 4- Ra-226 concentration in sludge, scale and soil in NDS.

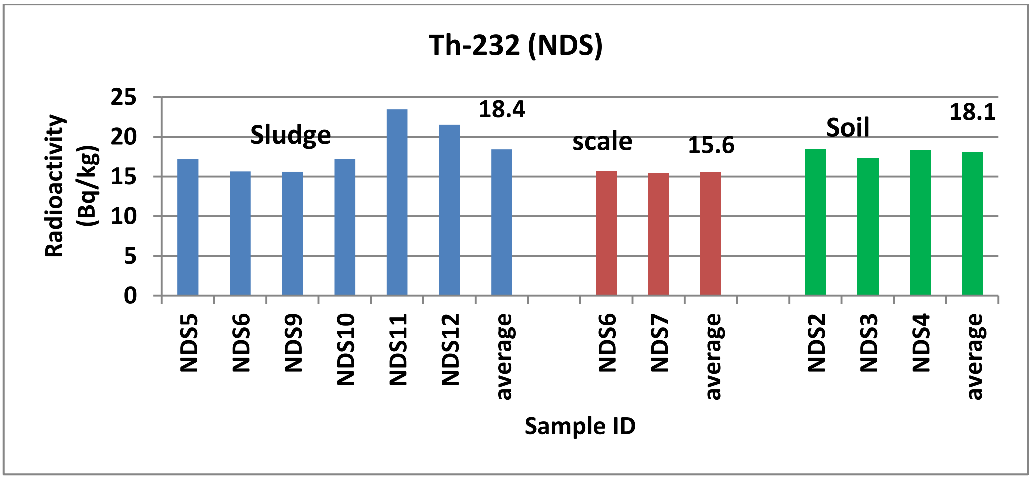

Figure 5- Th-232 concentration in sludge, scale and soil in NDS.

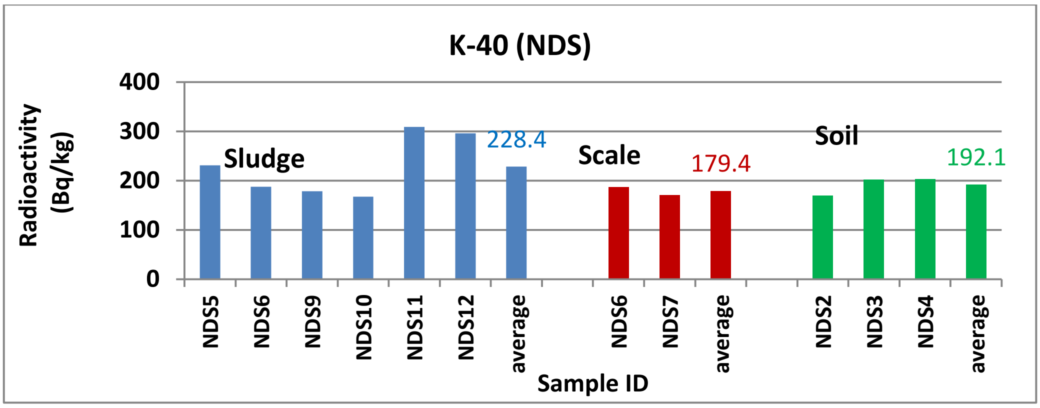

Figure 6- K-40 concentration in sludge, scale and soil in NDS.

These radionuclides are controlled by the processing of oil production. In order to pumping the oil towards the surface it is need to increase the pressure inside the oil- bearing formation, so water is injected inside the reservoir through water injection. When the pressure and temperature of oil is reduced at the surface, radium is co-precipitated with barium as Ba/RaSO4 in sludge and scale [14]. This interprets why most radium concentrates in sludge, scale and produced water. Most NORM deposits in produced water, sludge and scale, so very little remain in the oil [15].

Although 85% of the sampling locations (Figure-2) have Ra-226 exceeds the worldwide average, no one of these locations has Th-232 and K-40 higher than the worldwide average in soil. Consequently, most locations (78.6%) exhibits total exposure rate (Fig.3 right) exceeds the worldwide average (0.0406 µSv/h) corresponding to 58 (nGy/h) [7]. This indicates that most of the exposure rates are caused by radium among others NORMs.

Hazard indices

The results of estimating these indices are shown in Table-2.

Estimated Absorbed Dose Rates

Absorbed dose rates (nGy/h) caused by exposure to NORM (Ra-226, Th-232 and K-40) in the ambient soil and other materials in sampling locations are estimated by using equation (3-2). The values of the estimated absorbed dose in NDS range between (15.3) nGy/h in crude oil sample in outlet to (58.2) nGy/h in sludge sample in Train-I. These values represent 18%-86% of the total measured doses in the same locations which range between (43-143) nGy/h.

The Highest absorbed dose caused by sludge comes from the contribution of Ra-226 (56%) while Th-232 and K-40 caused (24%) and (20%) respectively (Figure- 7a). Ra-226, also, has the highest contribution in absorbed dose caused by scale and soil among others NORMs Figures- (7b, 7c). Moreover, Ra-226 gives the higher value of contribution in absorbed dose caused by the exposure to all types of samples together Figure-7d and Figure-8. This is due to that the activity of radium in sludge, scale and other samples is higher than the activity of other NORMs.

Table 2- Hazard indices due to existing of NORM in samples selected from study area (NDS) in addition to the measured total exposure dose rates.

ID	Total Dose mSv/y (measured)	Gamma Absorbed Dose (calculated) (nGray/h)	AEDE (mSv/y)	Ra-eq (Bq/Kg)	External Hazard Hex	Internal Hazard Hin
NDS1	0.13	18.7	0.033	40.2	0.11	0.16
NDS2	0.13	40.8	0.072	89.3	0.24	0.38
NDS3	0.08	36.6	0.064	78.9	0.21	0.32
NDS4	0.18	38.2	0.067	82.5	0.22	0.33
NDS5	0.25	43.3	0.076	93.9	0.25	0.39
NDS6	0.13	38.5	0.067	83.7	0.23	0.35
NDS7	0.08	35.9	0.063	78.1	0.21	0.33
NDS8	0.08	36.9	0.065	80.5	0.22	0.34
NDS9	0.18	43.7	0.077	96.2	0.26	0.42
NDS10	0.20	41.0	0.072	89.8	0.24	0.38
NDS11	0.25	58.2	0.102	126.1	0.34	0.53
NDS12	0.18	54.1	0.095	117.0	0.32	0.49
NDS13	0.15	15.3	0.027	32.9	0.09	0.13
NDS14	0.20	57.4	0.101	124.0	0.34	0.52

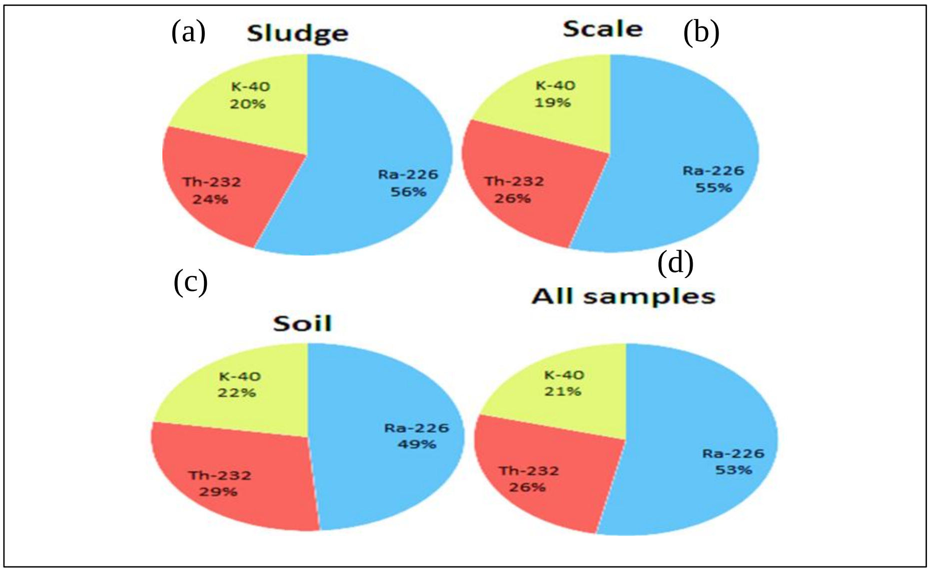

Figure 7- Contribution of average activity of Ra-226, Th-232 and K-40 in the estimated absorbed dose due to NORM in (a) sludge, (b) scale, (c) soil and (d) all samples collected from NDS.

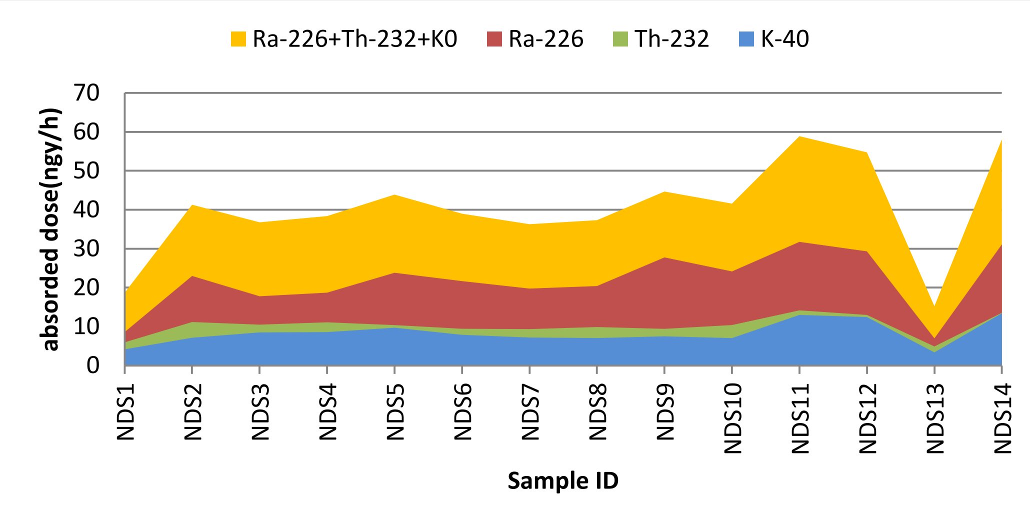

Figure 8- adsorbed dose caused by NORM in the samples selected from NDS .

Annual Effective Dose Equivalent (AEDE)

Annual effective dose equivalent (mSv/y) caused by NORM (Ra-226, Th-232 and K-40) in the ambient soil and other materials collected from NDS are estimated by using equation (2). The values AEDE in NDS range between (0.027) mSv/h in crude oil sample in outlet to (0.102) mSv/h in sludge sample in Train-I. All values (Figure-9) have AEDE below the worldwide average value (0.45) mSv/y [7] and subsequently, they are below the value (1) mSv/y recommended by ICRP [16] the individual effective dose limits for the public in normal situations. For comparison, the western part of Iraq has values range (0.03-1.84) mSv/y [17, 18] while northern region oilfield in Iraq about 0.04-0.536 mSv/y [19].

Although all values of AEDE below the world wide average value, monitoring the sites periodically is required to ensure that there is no increasing of doses for the workers according to principle of ALARA (As Low As Reasonably Achievable) recommended by UNSCEAR [6].

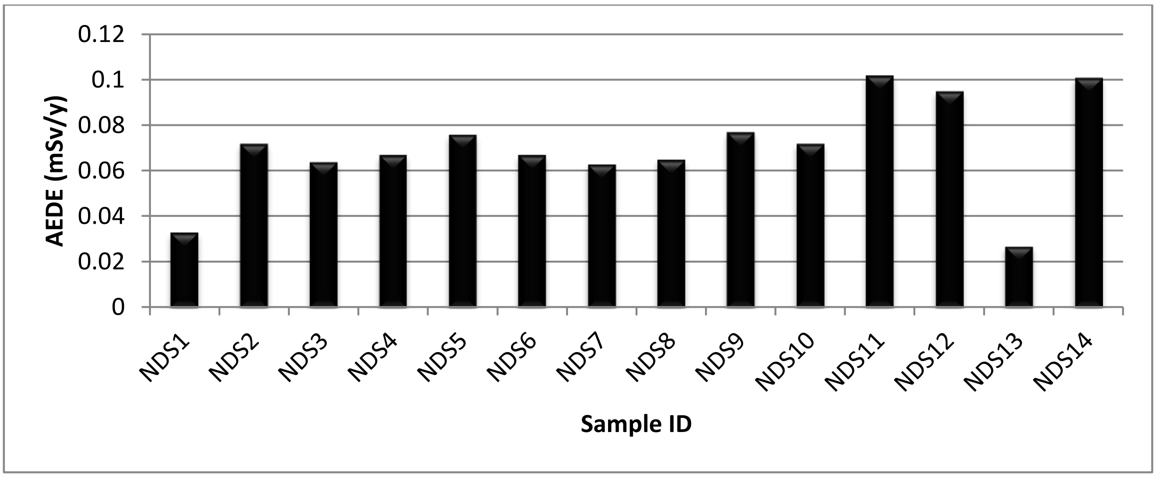

Figure 9- The annual effective dose equivalent caused by NORM in samples selected from NDS.

Radium equivalent (Ra_{eq})

The estimated values Ra_{eq} for all samples in NDS range between (32.9-126.1) Bq kg^{-1} as shown in Figure- 10. The figure shows all values are below the maximum admissible Ra_{eq} of 370 Bq kg^{-1} [7].

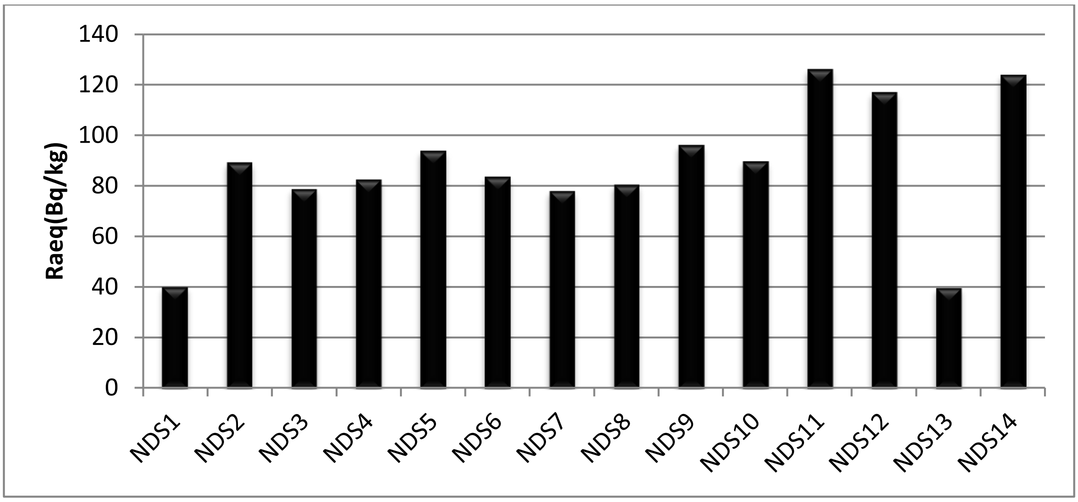

Figure 10- The Ra_{eq} for samples selected from NDS.

External hazard (H_{ex}) and internal hazard (H_{in})

The external and internal hazards caused by existing of NORM in NDS for workers is estimated in the different stages of oil and gas production according to equations (3) and (4) and the results, as shown in Figure-11.All values H_{ex} and H_{in} values less than the permissible value of unity for radiological safety.

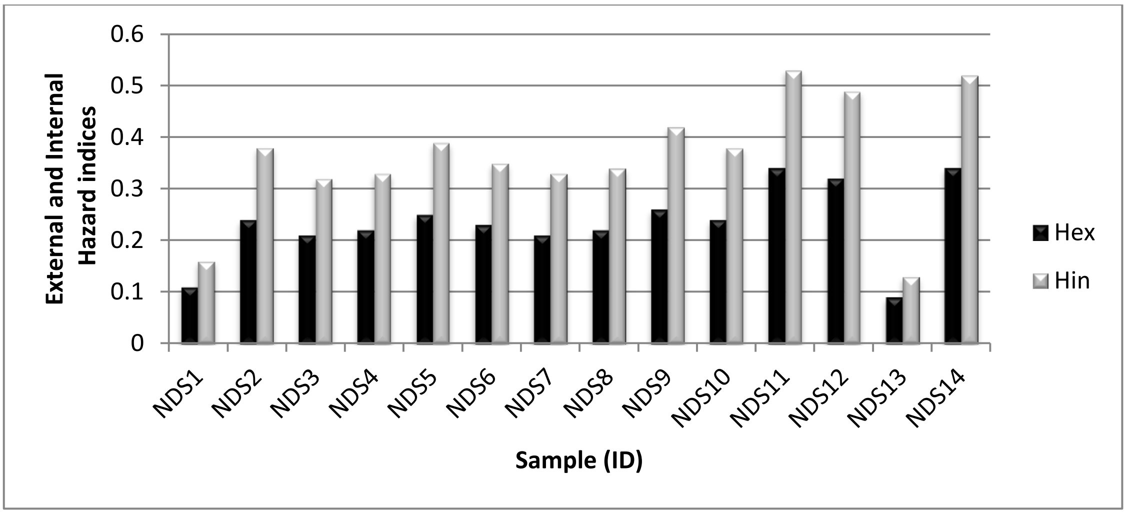

Figure 11- The external and internal hazards caused by existing of NORM in samples selected from the different stages in NDS.

Comparison current results with other studies

There are no regulations discuss the limits of NORM in oilfield neither in Iraq nor in other countries, So concentrations of NORM would be compared with the worldwide average of Ra-226, Th-232 and K-40 concentration in soil. The worldwide average of Ra-226, Th-232 and K-40 in soil are (32, 45, 412) Bq/kg, respectively. The maximum values of Th-232 and K-40 are below the world average value documented in earth crust (45, 412) Bq/kg for Th, and K-40 respectively [12, 13] while the maximum value of Ra-226 is above the world average value (32) Bq/kg [12].

The concentration values of NORM in all types of materials in NDS are less than those in South Rumaila Degasing station (SDS) [20] except in produce water. Consequently, AEDE values in NDS are less than those in SDS. This is may be because of the continuous trailing of cleaning and remediation of the area in NDS more than in SDS with little leakage of the oil and waste from the pipes and tanks.

Nafae [21] among the others found high concentrations of NORMs (Ra-226: 6474 Bq/kg, Th-232: 774 Bq/kg, K-40: 156 Bq/kg) in ambient contaminated soil in very restricted area in Markezia Degassing Station within South Rumaila Oilfield.

The average values in current study are very lower than those values obtained by Nafae [21] while Ra-226 concentration in current study above values obtained in study achieved by Al-Talib [19] in sludge of oilfield in northern region of Iraq. Ali and Ibraheem [22] mentioned that low concentration of Ra-226 and Th232 (38.1 14.4 Bq/kg respectively) in sludge while higher concentration of these NORMs (252.4, 79.4 Bq/kg of Ra-226 and Th-232 respectively) were found in oily sediment in the final stage of separation of water from oil within the processing stage of oil and gas production in East Baghdad oilfield. the values in current study are considered very low comparing with result published by IAEA [23]. IAEA refers to values such as $8x10^5$ Bq/kg of Ra-226 in sludge. Other values such as 150-1000 (Bq/kg) and (100-600) Bq/kg for Ra-226 and Th-232 respectively, in some Omani oilfield [24] and (588) Bq/kg of Ra-226 and (246) Bq/kg in others Omani oilfield [25]. OGP [26] refers to (50-800, 000) Bq/kg and (2-100) Bq/kg of Ra-226 and Th-232 were found in sludge of oil production in European countries [27]. Other values for comparison are listed in Table-3.

Table 3- NORM concentration (Bq/kg) in NDS in current study with other results in other studies.

NO	Sample	Ra-226	Th-232	K-40	Reference
1-	Worldwide average(soil)	32	45	412	[12]
2	Oman NORM(Sludge)	547	271	118	[22]
3	China (Surface soil)	12.6±4	15.9±5	746.8±38	[28]
4	OGP (Crude oil)	$800\text{-}4\times10^5$	1-70	__	[23]
5	IAEA (Sludge)	$5\text{-}8\times10^5$	2-10	__	[20]
6	Iraq NORM(Sludge)	74.7	376.6	103.8	[19]
8	Iraq NORM (Sludge)	1.8-252	6.8-79.4	12.1-529	[29]
9	Iraq NORM (Crude Oil)	2.3-5.8	2.9-5.5	2.8-36.0	
10	Iraq (Surface soil)	3.7-43.3	6.7-23.1	216-595	
11	Iraq (sludge)	6.8-14.4	1.8-38.1		
12	Iraq (scale)	12.8-26.8	61.8-128.4		
13	Iraq (oily sediment)	79.4	252.4		
14	Iraq (Formation water)	8.8	1.2		
15	Iraq (sludge)	49.91-68.73	15.60-23.45	167.5-309.31	Current study
16	Iraq (Soil)	38.5-49.78	17.38-18.49	169.86-204.12	
17	Iraq (Scale)	42.77-44.17	15.48-16.35	167.85-171.09	
18	Iraq (Produced water)	67.33	22.44	319.73	
19	Oil (Iraq)	15.19-18.56	8.5-9.85	80.23-98.63	

Conclusion

Radiological measurement and assessment of NORM in oilfield is one of the most important points because of Oil and gas production is one of the main sources of NORM contamination. IAEA states that survey should be achieved more frequently especially after e.g. changes in the salinity of the produced water (IAEA, 2010). The radiological survey and the assessment of NDS in Rumaila Oilfield southern Iraq in current study conclude the following:

1. The studied locations in NDS are relatively not highly contaminated with NORM, if they compared with other oilfield in worldwide. Moreover, even when the study area is compared with the nearest oilfield in the region (south Rumaila oilfield).
2. The potential places to be more contaminated among the other places within the processing stages of oil and gas production within NDS are dehydrator and desaltor stages and saline water containers
3. The places, within the study area, which have relatively elevated NORM concentration, should be monitored more frequently to ensure that no more radiation doses are present due to exposure to these materials. For radiation protection these locations should be periodically monitored and the basic control procedures should be taken in consideration by workers when dealing with NORM.
4. Although the study area has values of NORM within or less than the worldwide average, nevertheless, as long as the values of the radiation doses still within these ranges, there is no significant hazard due to external radiation exposure provided that workers should use of correct personal protective equipment and minimize the exposure time to reduce the values of doses as low as possible according to ALARA principles.
5. Radiologically assessment of other places in Rumaila oilfield and others oilfields in Iraq is of highly recommended to ensure no more radiation hazard is exist in those places.

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