Ali et al. Iraqi Journal of Science, 2017, Vol. 58, No.2C, pp: 1037-1050
DOI: 10.24996/ijs.2017.58.2C.8

ISSN: 0067-2904

Radiological Assessment of NORM Resulting From Oil and Gas Production Processing in South Rumaila Oil Field, Southern Iraq

Kamal K. Ali*[1], Shafik Sh. Shafik[2], Husain A. Husain[3]

[1&3] Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq.

[2] Department of physics, College of Science, University of Baghdad, Baghdad, Iraq.

Abstract

Radiological assessment due to existing of natural occurring radioactive materials (NORM) in South Rumaila oil field was achieved in this study. Different samples including soil, sludge, scale, oil, and water were collected from different stages of oil and gas production in Markazia Degassing Station (SDS) in South Rumaila oil field. Radioactivity 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 SDS are contaminated with NORM. The activity of Ra-226, Th-232 and K-40 range between 18.4 to 312.8, 9.4 to 140.8 and 66.4 to 800.8 (Bq/kg) respectively. The places to be more contaminated among the other places within the processing stages of oil and gas production within SDS are dehydrator and desaltor stages.

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

تقييم المواد المشعة المتواجدة طبيعيا الناتجة من عمليات انتاج النفط والغاز في حقل نفط الرميلة الجنوبي، جنوب العراق

كمال كريم علي*[1] ، شفيق شاكر شفيق[2]، حسين علي حسين[3]

[3&1] قسم علم الارض، كلية العلوم، جامعة بغداد، بغداد، العراق.

[2] قسم الفيزياء، كلية العلوم، جامعة بغداد، بغداد، العراق.

الخلاصة

أُجرِي التقييم الاشعاعي المتسبب عن وجود المواد المشعة المتواجده طبيعيا في حقل نفط الرميلة الجنوبي. جمعت نماذج مختلفة من التربة، والمخلفات والقشرة والنفط والمياه المصاحبة من مراحل انتاج النفط والغاز المختلفة في المحطة المركزية ضمن حقل نفط الرميلة الجنوبي. تم قياس 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 للراديوم–226 والثوريوم–232 والبوتاسيوم–40 قد تراوحت بين 18.4 الى 312.8، 9.4 الى 140.8 و 66.4 الى 800.8 بكريل/كغم، على التوالي. وتبين ان الاماكن التي تبدو اكثر تلوثا من غيرها ضمن مراحل عمليات الانتاج للنفط والغاز ضمن منطقة الدراسة هما مرحلة الانتاج الرطب ومرحلة عزل الاملاح

*Email: kamalali@scbaghdad.edu.iq

Introduction

Globally, many books, reports, documents and researches have been published regarding NORMs. The International Atomic Energy Agency (IAEA) has published many safety report series and technical documents cover NORMs in oil and gas industries [1-5]. These references describe the technologies that involve the use of radioactive materials and radiation generators and situations where NORM is encountered within the various oil and gas industry sectors. They provide specific guidance on ensuring the radiological health, safety and welfare of workers, the public and the environment, the safe management of radioactive waste and training in radiation safety. NORMs in many countries have been investigated, for instance, Othman and Masri [6], discussed the characterization of NORM contaminated sites at the Syrian oilfield. The obtained data was used to carry out quantified risk assessment study and to approach the option for final disposal of contaminated soil. Elegba and Funtua [7] studied the naturally occurring radioactive material (NORM) assessment of oil and gas production installations in Nigeria presented in the NORM IV Conference which hold in May 2004, Szczyrk, Poland. However, the proceedings of this conference were published by IAEA including 74 participants from 25 countries [3].

The International Association of Oil & Gas Producers (OGP) published guidelines for the management of NORMs in the oil & gas industry [8]. Al-Farsi [9] achieved PhD. thesis, discussed the NORMs in petroleum exploration and production in the Sultanate of Oman, which concluded that all activity concentrations of natural radionuclides were higher than the ambient soil level and varied over several orders of magnitude. Clerckx, etal., [10] carried out a study discussing NORM in oil and gas in Baliguim. Garcia [11] in his study aimed to find potential improvements for the operational processes of the NORM waste management in Norwegian oil and gas industries. Also, Norwegian University for Science and Technology published a report titled occupational protection against exposure to radioactive sources and electromagnetic fields in the offshore petroleum industry talking about NORM in Norway [12].

Attallah et al. [13], wrote a chapter discussed the environmental radioactivity of TE-NORM waste produced from petroleum industry in Egypt, where they concluded that the waste generated in oil and gas equipment is due to the precipitation of alkaline earth metals as sulfate, carbonates and/or silicates and that sludge and scale wastes represent one of the major sources of ^{226}Ra in the environment. Since the concentration of ^{226}Ra found in both of the waste exceeds that permitted by the international regulations, it was found necessary to reduce the risks due to indoor radon and direct gamma radiation in each wastes to be used in different life aspects. Benedict [14] accomplished a study on radiation from oil fields using high-resolution gamma-ray spectrometry, to evaluate the NORMs in soil samples which were collected from areas of elevated natural radioactivity around oil field in the state of Qatar. He concluded that the average value of annual effective dose lies in the global range of outdoor radiation exposure given in UNSCEAR [15]. His results showes that soil samples collected from the state of Qatar can be regarded as having normal levels of natural background radiation. Environmental Protection Department, Saudi Aramco, in Saudi Arabia has developed NORM management guidelines and is implementing a comprehensive strategy to address all aspects of NORM management [16]. In UK a strategy for management of NORM is achieved and published in a report [17].

Review of NORM in Iraq

In Iraq, few researches have been published regarding NORM. Al-Talib [18] achieved a study of (NORM) and technologically enhanced NORM (TENORM) measurements on oil field in north region of Iraq.

Nafa [19] also studied radiological assessment and chemical treatment of contaminated soil with NORM by leaching with different solvents and their reuse. Ali and Ibraheem [20] have studied the radiological hazard due to NORM in oil and gas industry in East Baghdad Oilfield. They concluded that, radiologically most of the locations, in time of achievement of their research, consider as clean location except some locations which need to be managed of their waste periodically. These locations are water treatment, well disposal and burning bit.

Rumaila Oil and Gas Industries, within Rumaila Oil Field, southern Iraq, is one of the biggest industries which produce oil and gas in Iraq. During the production process, NORM flows with the oil, gas and water mixture and accumulates in scale, sludge and scrapings. It can also form a thin film on the interior surfaces of gas processing equipment and vessels. The level of NORM accumulation can vary substantially from one facility to another depending on geological formation, operational and other factors. To determine whether or not South Rumaila facilities have NORM contamination, NORM survey, sampling and analysis needs to be conducted, then assessment of NORM radiological effect in study area. This is the objective of current study.

Study area:

South Rumaila Oil Field extends over a large area within Basrah Governorate, southern Iraq (Figure- 1). It seems difficult to cover all the field in current study so; one sites for oil and gas production would be investigated in current study named; South Rumaila Markezia Degasing Station (SDS).

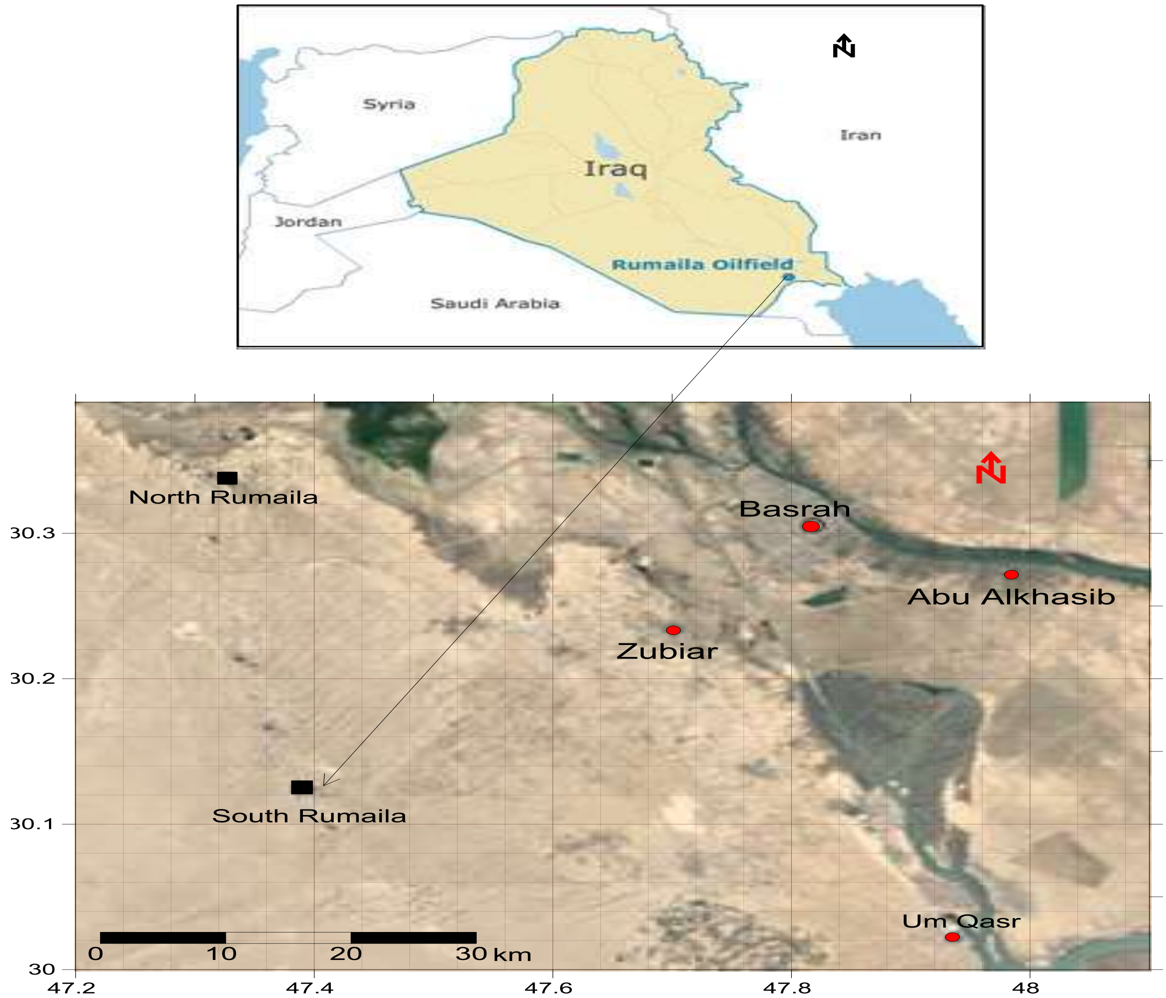

Figure 1- Geographic location of study area.

SDS of Oil and Gas production is the site to be investigated. The site consists of many facilities that include five trains (lines) given letters from A to E.

The processes begin with wells inlets complex which receive the crude oil from many oil wells drilled within the Zubair and the Mishrif Formation. Zubair Formation is the most prolific reservoir in the southern Iraq, especially in the Zubair and Rumaila oil fields [21]. The formation extends from central of Iraq southward to Iraqi-Kuwaiti border. The formation comprises 380-400m of alternating shale, siltstone and sandstone. While, 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 containing rudist debris below. Its thickness in Rumaila oil field is about 270m. The underlying unit is usually Rumaila Formation in southern Iraq [21].

The crude oil then goes within many chemical and physical operation stages. First, crude oil is 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 to product gas. 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 is collected in storage tanks in order to transfer it to the export tanks by using export pumps. Figure -2 represents base maps of this site. These operations lead to deposit sludge and scales in tanks, pipes and valves in addition to contaminate the soil surface within the industries. The final products are oil, gas and produced water. The produced water is transferred to injection wells.

Figure 2- Base map of SDS in South Rumaila oil field.

Materials and Methods

The field work includes determination of sampling locations within SDS in Rumaila Oil Field Figure- 2. Sampling locations were determined by aiding portable dosimeter which gives primarily indication about locations with relatively high radioactivity. Exposure dose rate in micro-Sievert per hour (µSv/h) at sampling locations were recorded by using portable dosimeter. Fourteen samples including, 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 of soil, sludge and scale were collected and put in nylon bag. One liter of each of oil and water was kept in polyethylene container. The samples were sealed tightly labeled with ID, date, location, material type to be sent to the laboratory for preparing and measurements.

Samples Preparing

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 samples 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) is taken and storage for 25 days in completely sealed Marinilli beaker to achieve equilibrium between radon and its daughters [22].

Radioactivity Measurement

Gamma spectrometry system based on HPGe was used for the 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 were calibrated by 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. All measurements were achieved by laboratories at Radiation Protection Center (RPC)/ Ministry of Health and Environment/Iraq.

The concentration of the radionuclides at specific energy was calculated using the following equation:

Activity (Bq) = $\frac{\text{cps}}{\text{BI}\times\text{eff}} \pm \frac{\text{cps(error)}}{\text{BI}\times\text{eff}}$ …………………………………………………….…………..(1)

Where, cps = Net count rate per second

B.I. = Branching Intensity for specific gamma energy and

eff = Efficiency of the detector at specific gamma energy.

Results and Discussion

The activity concentration of NORM in Bq/kg in all samples selected from SDS and the total measured exposure dose rates in (µSv/h) were presented in Table -1.

The activity of Ra-226, Th-232 and K-40 range between 18.4 to 312.8, 9.4 to 140.8 and 66.4 to 800.8 (Bq/kg) respectively. The max activity value of Ra-226 was found in sludge (SDS6) selected from dehydrators & desalters of Train-A, while the min activity value was in ambient soil near 4th stage of Train-A. The max activity of Th-232 was recorded in sludge sample (SDS10) selected from dehydrators & desalters of Train-B while, the min value was in produced water sample. K-40 has its max value in dehydrators & desalters of Train-B and the min value was found to be in produced water. The max activity values of the three radionuclides (Ra-226, Th-232 and K-40) in study area are above the worldwide average values recorded in soil (32, 45 and 412 Bq/kg) respectively, [23].

Table 1- Activity of Ra-226, Th-232 and K-40 (Bq/kg) in samples selected from different locations in SDS in addition to total measured exposure dose rates in (µSv/h).

ID	Location	Material	Ra-226	Th-232	K-40	Exposure rates
SDS1	Wells inlet	Soil	85.7	31.9	429.8	0.13
SDS2	Wells inlet	Mix crude oil	33.6	13.0	197.0	0.09
SDS3	Train-A 1st stage	Soil	45.7	27.9	357.1	0.1
SDS4	Train-A 2nd+3rd stages	Soil	97.6	42.7	485.6	2.6
SDS5	Train-A 4th stage	Soil	18.4	11.5	176.9	0.57
SDS6	Train-A Dehydrator& desaltors	Sludge	312.8	48.9	502.7	11.2
SDS7	Train-A Final stage	Produced Water	20.3	9.4	66.4	0.1
SDS8	Train-A Dehydrator& desalters	Scale	137.6	34.4	462.0	1.1
SDS9	Train-B Dehydrator& desaltors	Scale	152.4	38.1	539.7	1.4
SDS10	Train-B Dehydrator& desaltors	Sludge	297.6	140.8	800.8	4.85
SDS11	Train-C Abandoned pipe	Scale	148.9	49.4	750.3	1.6
SDS12	Train-D&E Dehydrator & desalters	Sludge	235.4	69.4	796.4	2.6
SDS13	Final stage-export pumps	Oil	31.6	14.4	387.6	0.08
SDS14	Burning stage	Soil	29.4	15.7	278.2	0.08

The total exposure dose rate readings in the SDS area ranged between (0.08-11.2) µSv/h corresponding to (114-16000) nGy/h. These values are many folds of value of the worldwide average outdoor exposure dose rate of 58 nGy/h [15]. This gives evidence that the SDS area is contaminated with NORM result from the oil and gas production processes.

The radioactivity distribution of Ra-226, Th-232, K-40 and total measured exposure dose rates were represented in colored classed position maps as shown in Figures-(3, 4, 5and 6).

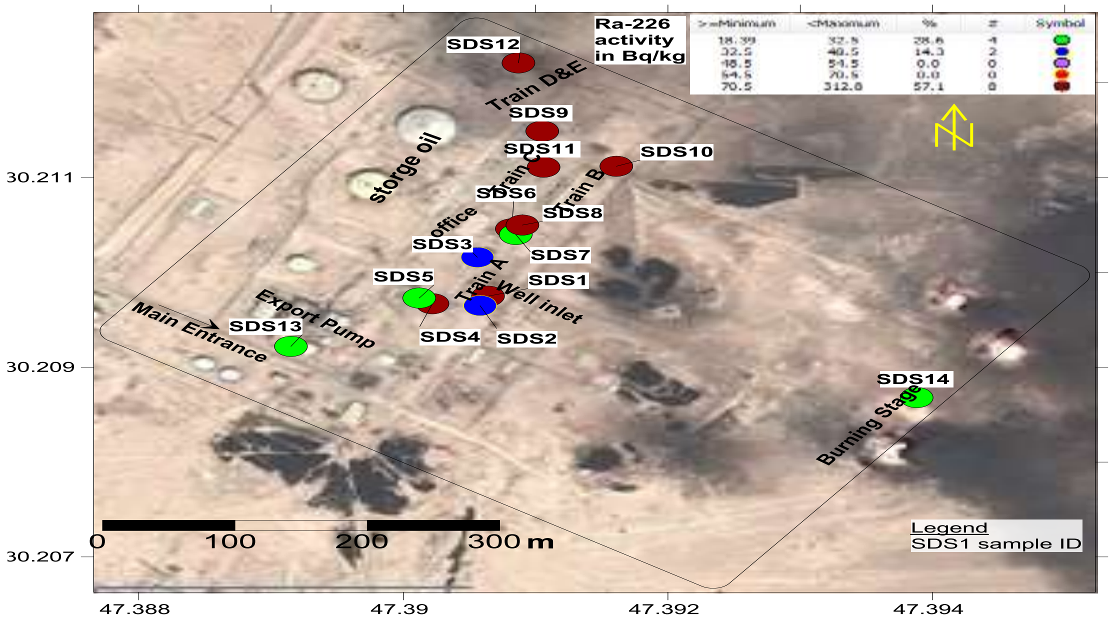

Figure 3- Distribution of Ra-226 in selected samples from different locations in SDS.

Figure-3 shows that more than 71% of sampling locations have Ra-226 more than 32 Bq/kg (the worldwide average) and more than 57% of the locations have Ra-226 concentration between 70 and 312 (Bq/kg). These values indicate that contamination has occurred in the SDS location due to spreading of NORM resulting from the production of oil and gas. The highest concentrations were noted near the Dehydrator & desalters stages in most of trains of production of oil and gas in SDS. The highest one recorded in sludge sample collected from Dehydrator & Desalters of Train-A. Here, it is important to explain that; in dehydration stage, oil is separated from water to be reduced to 0.2% water content while desalting stage is used to separate salts from the mixed oil and produced water. Salt should be reduced to less than 5-15 kg per 1000 barrels by using fresh dilution water. These processes causes to concentrate radium with other salt such as barium as Ra/ $BaSO_4$ in sludge while other fraction of salts dissolved in the produced water [23]. Therefore most of the radioactivity of NORM is found in these stages. The low activity of Ra-226 and other radionuclides of NORM measured in produced water sample in SDS may be due to separation of salts as deposits settle down in the container. The activity of NORM mostly concentrated in scale, sludge and produced water [8, 23].

Figure- 4. shows that Th-232 concentration is below the worldwide average in more than 71% of the locations. One location (Dehydrator & desalters) (SDS10) in Train B has Th-232 concentration about three times the worldwide average. While fig.5 revels that about 57% of the sampling locations have K-40 concentration above the worldwide average for K-40 in soil. The measured values of total exposure rates in all locations in SDS were higher than the value of 0.0604 (μSv/h) (corresponding to 58 nGy/h) of the worldwide average (Figure-6)

These concentrations of NORM and the total exposure rates in SDS location indicate that NORM contamination occurred in most of the SDS area with different levels. The dehydration, desalting and formation water collecting stages have the highest contamination among the others.

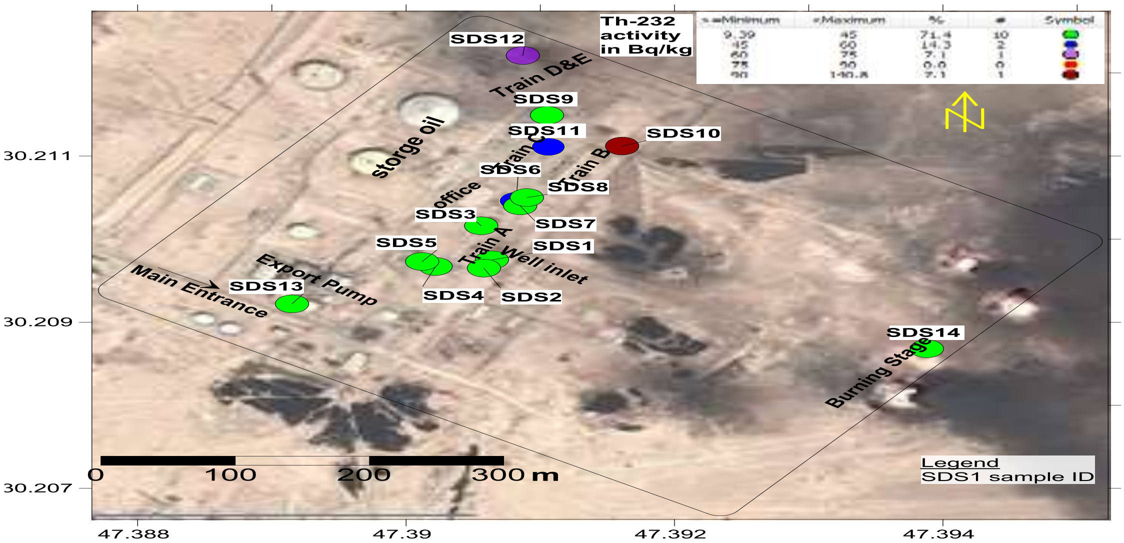

Figure 4- Distribution of Th-232 in selected samples from different locations in SDS.

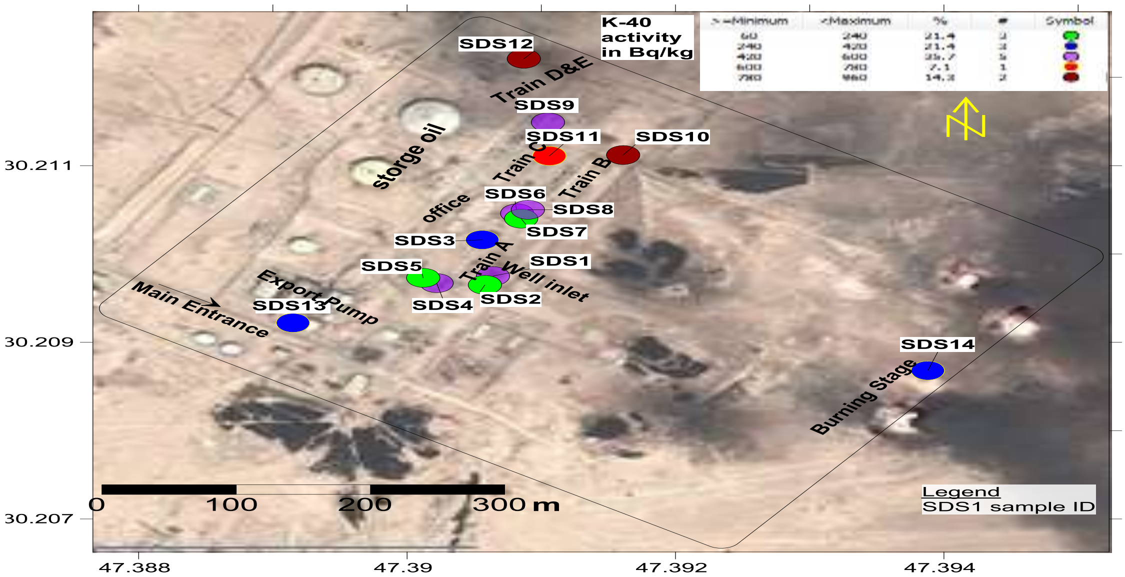

Figure 5- Distribution of K-40 in selected samples from different locations in SDS

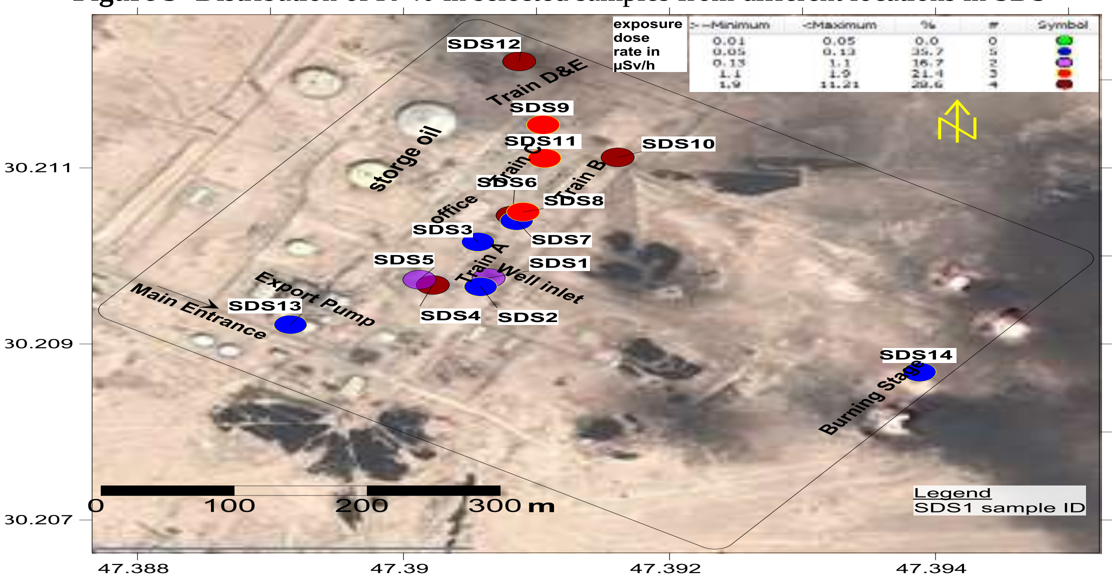

Figure 6- Distribution of total exposure dose rate in different locations in SDS

The highest concentrations of Ra-226 were measured in sludge (Figure- 7) with average value of (281.9± 41) Bq/kg while its average concentration in scale is (145±8) Bq/kg and in soil is (61.9±35) Bq/kg. The concentration of Th-232 is in the order of sludge > scale > soil with average values of (86.4±48), (36.3±8) and (28.5±13) Bq/kg, respectively (Figure-8). While the average value of K-40 was found to be higher in sludge (699.6±170) Bq/kg and (501±149) Bq/kg in scale and with lower value in ambient soil (362.4±122) Bq/kg (Figure- 9).

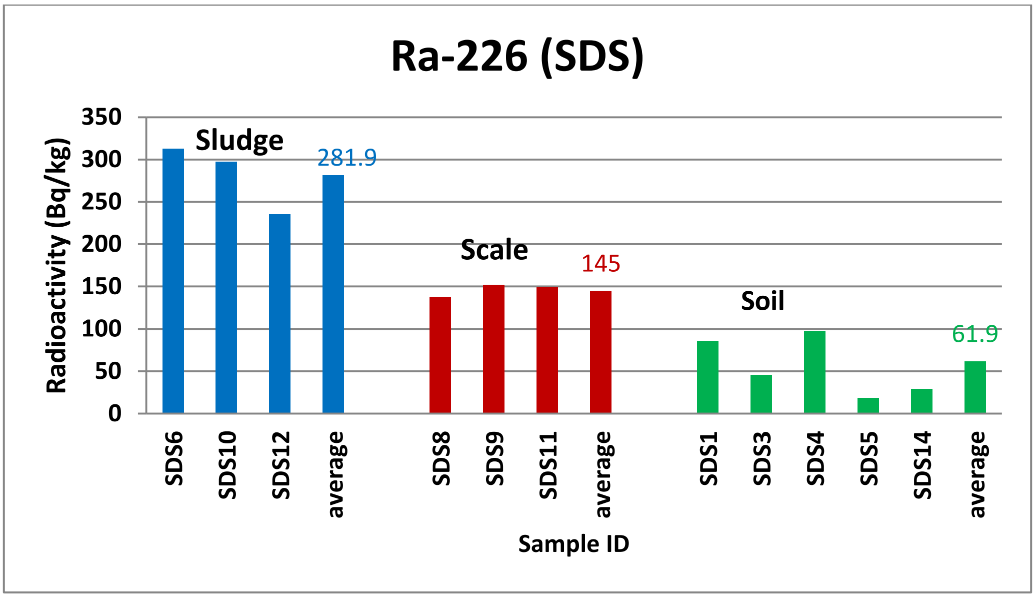

Figure 7- Ra-226 concentration in sludge, scale and soil in NDS.

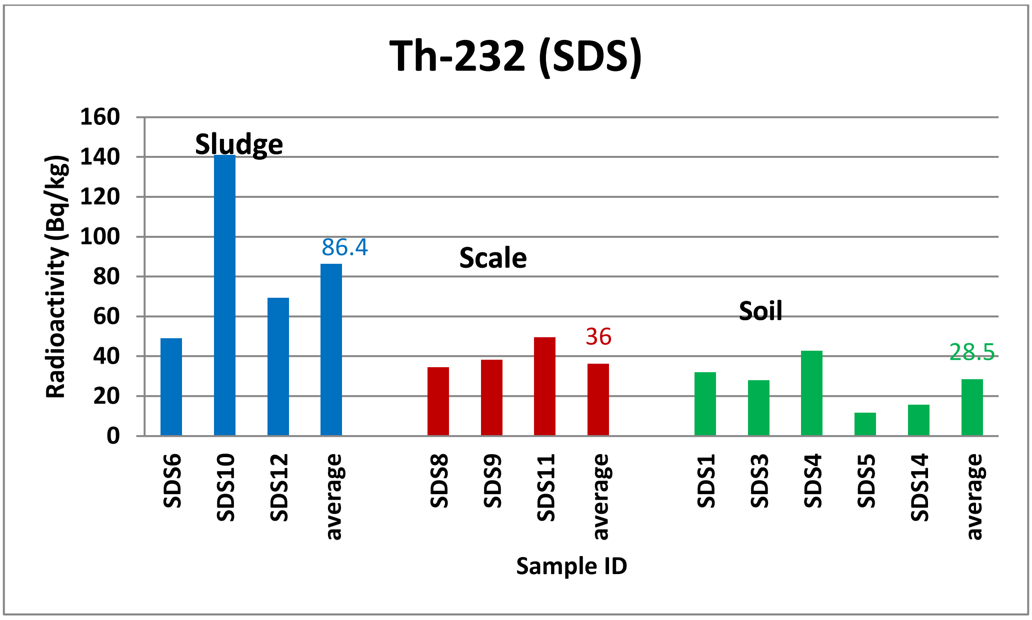

Figure 8- Th-232 concentration in sludge, scale and soil in SDS.

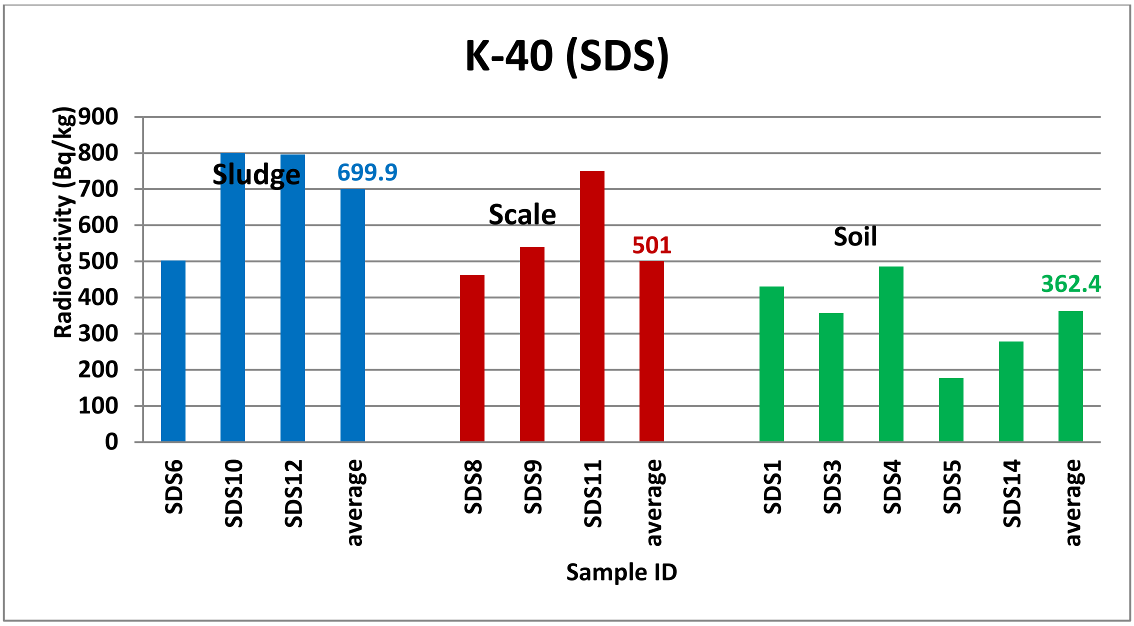

Figure 9- K-40 concentration in sludge, scale and soil in SDS.

Estimation of 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 the following equation [24].

$$D = 0.43A_{Ra} + 0.662A_{Th} + 0.0424A_{K} \quad (2)$$

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 respectively, in the samples.

The dose rate in SDS ranges between (17.8) nGy/h for produced water and (255.1) nGy/h for sludge and scale samples near dehydrate and desalter stages within Train-A.

The highest absorbed dose caused by sludge comes from the contribution of Ra-226 (63%), while Th-232 and K-40 caused (22%) and (15%) respectively (Figure- 10). Ra-226, also, has the highest contribution in absorbed dose caused by scale and soil among others NORMs (Figs. 10b, 10c). Moreover, Ra-226 gives the higher value of contribution in absorbed dose caused by the exposure to all types of samples (Figure- 10 (d) and Figure-11). This is due to that the activity of radium in sludge, scale and other samples is higher than the activity of other NORMs.

Some locations which have higher activity of NORM such as SDS6 and SDS10 expose total ambient absorbed doses much higher than the absorbed doses caused by exposure to NORM (Ra-226, Th-232 and K-40 only) in these locations (Figure- 12). This may be due to the doses caused by other radionuclides, especially radon in the ambient air.

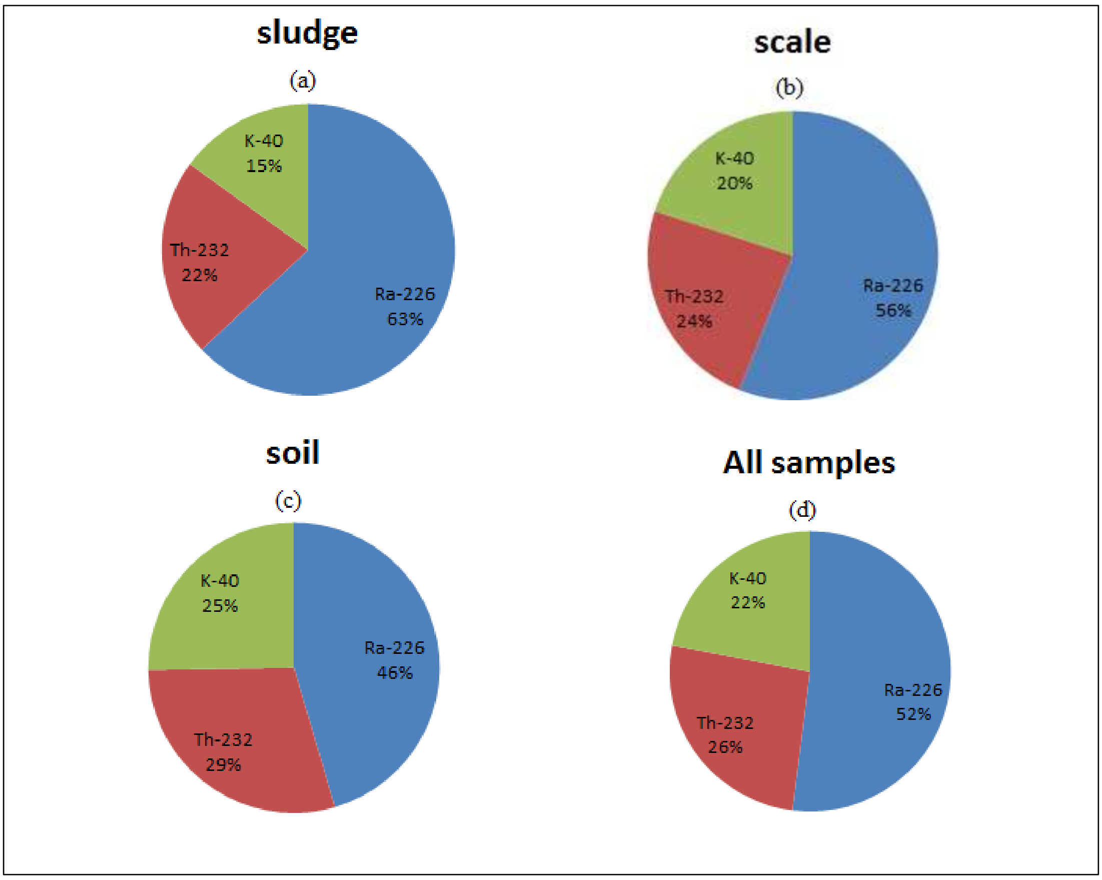

Figure 10- Contribution of average activity of Ra-226, Th-232 and K-40 in the estimated absorbed dose due to NORM in (a) sludge, (b) scale, (c) soil and (d) all samples collected from SDS.

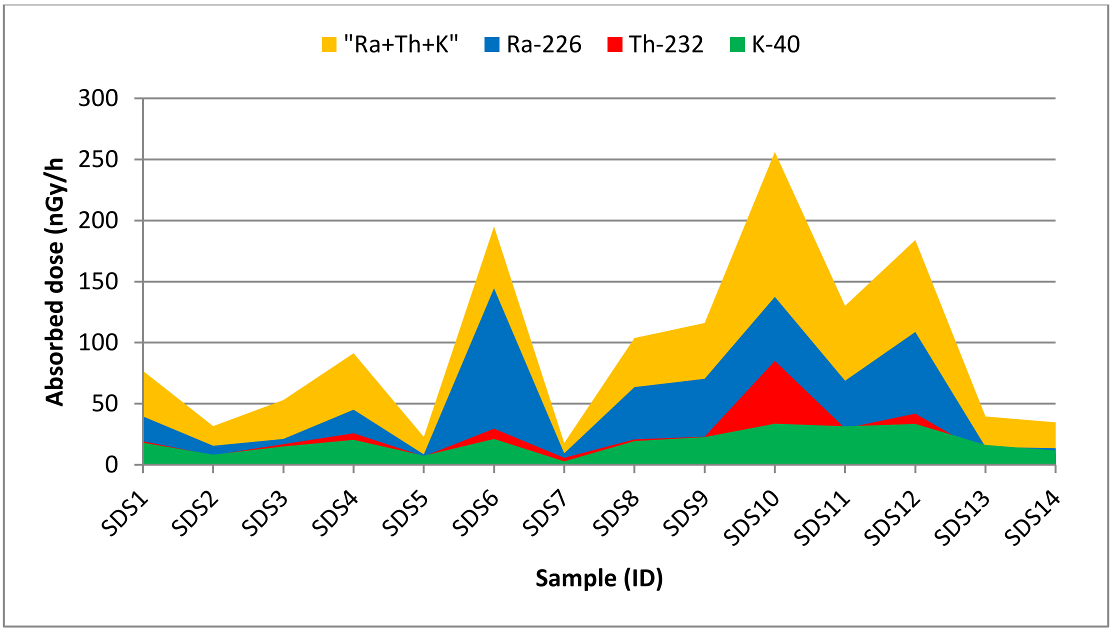

Figure 11- Adsorbed dose caused by NORM in the samples selected from SDS.

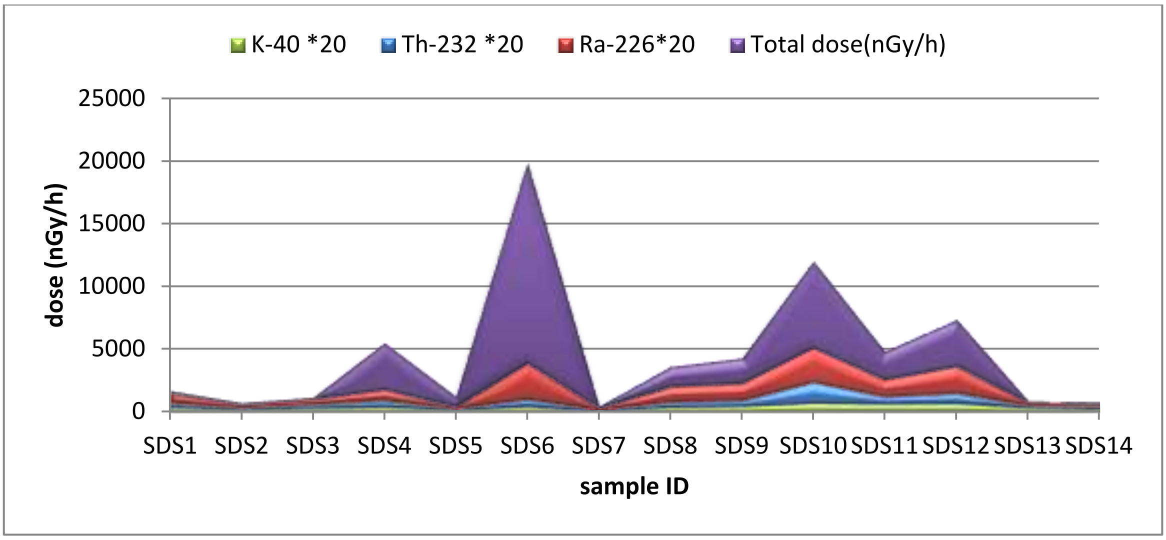

Figure 12- Total ambient absorbed dose and estimated absorbed doses caused due to exposure to NORM in the sampling locations in SDS.

Annual Effective Dose Equivalent (AEDE)

To estimate annual effective doses, account must be taken of (a) the conversion coefficient from absorbed dose in air to effective dose and (b) the outdoor occupancy factor. 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. Estimated annual average effective dose equivalent received by a member is calculated using a conversion factor of 0.7 $SvGy^{-1}$, which is used to convert the absorbed rate to human effective dose equivalent [25]. The annual effective dose equivalent is determined as follows:

Outdoor ($nSvy^{-1}$) = Absorbed dose ($nGrayy^{-1}$) * 2503h * 0.7$SvGy^{-1}$. ……………………..…..(3)

The AEDE values caused by NORM in samples of SDS range between (0.031) mSv in produced water to (0.447) mSv in sludge collected from dehydrator and desalter in Train-B. All values (Fig. 13) of AEDE below the worldwide average value (0.45) mSv/y [15] and subsequently, they are below the value (1) mSv/y recommended by ICRP [26] 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 [27, 28] while northern region oilfield in Iraq about 0.04-0.536 mSv/y [18]. 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 [24].

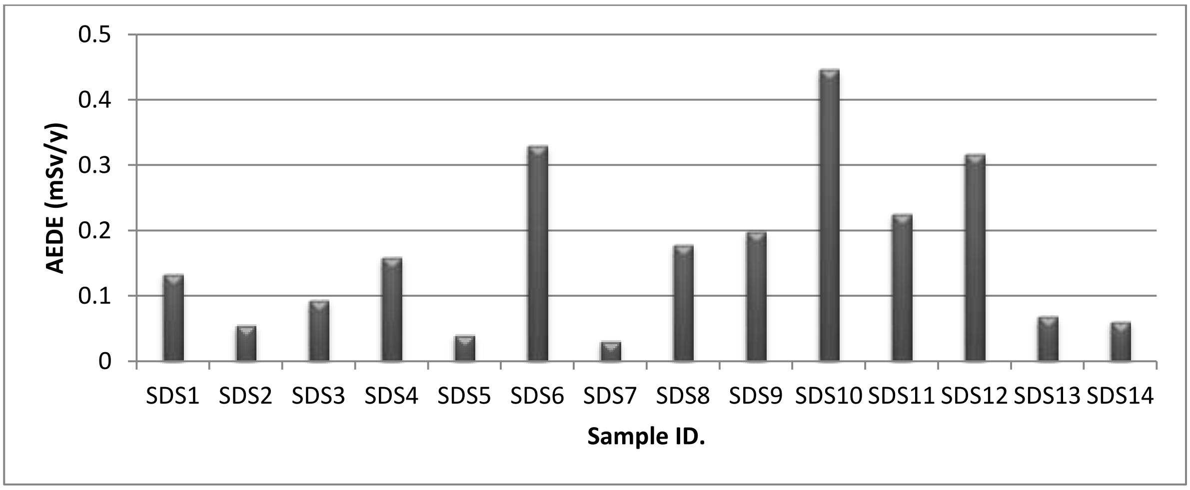

Figure 13-The annual effective dose equivalent caused by NORM in samples selected from SDS.

To investigate whether the NORM concentrations and their radiological effect in current study within the normal values or not, they should be compared with other studies in Iraq or other countries. The comparison will be between values of the average and max values of the NORM concentration in current study and some examples of the available published values in other studies. The concentrations of NORM compared with the worldwide average of Ra-226, Th-232 and K-40 concentration in soil because there are no regulations discuss the limits of NORM in oilfield neither in Iraq nor in other countries. So NORMs are considered as natural pollutants to the soil, although they are enhanced technologically.

The maximum concentration of NORMs in current study was found in sludge. The max values 312.8 Bq/kg of Ra-226 and 140.8 Bq/kg of Th-232 and 800.8 Bq/kg of K-40 were measured in SDS location with average values of (281.9, 86.4 and 699.9) Bq/kg for Ra-226 , Th-232 and K-40 respectively. These values are above the worldwide average value in soil (32, 45, 412) Bq/kg for Ra-226 , Th-232 and K-40 respectively [23].

Few studies are achieved in Iraq concerning the NORM in oilfield. Nafae [19] 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 SDS within South Rumaila Oilfield. Although this area is part of the area of current study but there is no concentration close to these values. Remediation may be done to these highly contaminated areas by the oil company. The average values in current study are very lower than those values obtained by [19] while Ra-226 concentration in current study above values obtained in study achieved by [18] in sludge of oilfield in northern region of Iraq. For comparison, [20] 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. Other results are shown in Table-2.

Table 2- NORM concentration (Bq/kg) in (SDS and 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**	**[23]**
2	**Oman NORM(Sludge)**	**547**	**271**	**118**	**[9]**
3	**China (Surface soil)**	**12.6±4**	**15.9±5**	**746.8±38**	**[29]**
4	**OGP (Crude oil)**	**$800\text{-}4\times10^{5}$**	**1-70**	**__**	**[8]**
5	**IAEA (Sludge)**	**$5\text{-}8\times10^{5}$**	**2-10**	**__**	**[1]**
6	**Iraq NORM(Sludge)**	**74.7**	**376.6**	**103.8**	**[18]**
8	**Iraq NORM (Sludge)**	**1.8-252**	**6.8-79.4**	**12.1-529**	**[30]**
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)**	**68.7-312.8**	**23.5-140.8**	**309.3-800.8**	**Current study**
16	**Iraq (Soil)**	**49.8-97.6**	**18.5-42.7**	**204.1485.6**	
17	**Iraq (Scale)**	**44.8-152.4**	**16.4-49.4**	**171.1-750.3**	
18	**Iraq (Produced water)**	**20.3-67.3**	**9.4-22.4**	**66.4-319.7**	
19	**Oil (Iraq)**	**18.6-33.6**	**9.9-14.4**	**98.6-278.2**	

Conclusions

Oil and gas production is one of the main sources of NORM contamination. Survey and monitoring for the oilfield area should be performed in order to assess whether NORM is present at low or high level. The radiological survey and the assessment of NORM in SDS in Rumaila Oilfield southern Iraq in current study conclude the following:

1. The studied locations are relatively not highly contaminated with NORM, if they compared with other oilfield in worldwide. Even if, some places within SDS have relatively high NORM concentration (above the worldwide average in soil).
2. The potential places to be more contaminated among the other places within the processing stages of oil and gas production within SDS are dehydrator and desaltor stages.
3. The places, within the study area, having relatively highly contaminated with NORM should be monitored more frequently to ensure that no more radiation doses are present due to exposure to these materials.
4. The result of assessment of SDS in current study does not mean that these location are radiologically safe forever, notify, 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.
5. Radiation dose values in some places in study area exceed the values that recommended by ICRP, UNSCEAR and IAEA for public but within the values recommended for workers. So 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 correct personal protective equipment and minimize the exposure time to reduce the values of doses as low as possible according to ALARA principles.
6. Sludge, scale and oily sediments are the main sources of NORM accumulation in study areas. The stabilizer and salters stages are the higher places where NORMs accumulate. The main causes of this accumulation are leakages from pipes and valves as sludge or salts (scale).

References

1. IAEA. **2003**. *Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry*. IAEA Technical Report Series No.34, Vienna.

2. IAEA. **2004**. *Soil Sampling For Environment Contaminants*. IAEA-TECDOC-1415.Vienna: IAEA.

3. IAEA. **2005**. Naturally Occurring Radioactive Materials (IV)), Proceedings of an international conference held in Szcyrk, Poland, 17–21 May 2004. IAEA- TECDOC-1472.

4. IAEA. **2008**. Naturally Occurring Radioactive Material (Norm V). Proceedings Of The Fifth International Symposium On Naturally Occurring Radioactive Material Organized By The University Of Seville In Cooperation With The International Atomic Energy Agency, The Spanish Nuclear Safety Council And The University Of Huelva And Held In Seville, 19–22 March 2007

5. IAEA. **2010.** Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry. Training Course Series No. 40. Vienna.

6. Othman, I. and Al-Masri, M. S. **2002.** Characterization of NORM contaminated sites at the Syrian Oilfield: sampling, analysis and data management. WM'02 Conference, February 24-28, 2002, Tucson, AZ.

7. Elegba, S.B. and Funtua, I.I. **2004**. Naturally occurring radioactive material (NORM) assessment of oil and gas production installations in Nigeria. Proceedings of an international conference held in Szczyrk, Poland, 17–21 May 2004. IAEA-TECDOC-1472, Vienna, (2005).

8. OGP. **2008**. Guidelines for the management of Naturally Occuring Radioactive Material (NORM) in the oil and gas industry. International Association of Oil & Gas Producers,Report No.412.

9. Al- Farsi A. N. **2008**. Radiological Aspects of Petroleum Exploration and Production in the Sultanate of Oman., Ph.D. Thesis, Queensland University of Technology School of Physical and Chemical Science Oman.

10. Clerckx T., Pellens V., Hulshagen, L., Chris, Schroeyers W., and Schreurs S. **2010**. Determination and quantification of NORM radionuclides. IRPA proceeding, Session6: NORM-Normally Occurring Radioactive Materials. P1043-1052.

11. Garcia, M.S. **2011**. Management of low radioactive waste – comparative analysis from the Norwegian oil and gas industry. MSc., Thesis, Modle University College, Norway, 95p.
12. Mogos, F.M. **2011**. *Occupational Protection against Exposure to Radioactive Sources and Electromagnetic Fields in the Offshore Petroleum Industry*. Norwegian University of Science and Technology.97p.
13. Attallah, M.F. Awad and N. S., Aly, H. F. **2012.** *Environmental Radioactivity of TE NORM Waste Produced from Petroleum Industry in Egypt: Review on Characterization and Treatment*. Atomic Energy Authority, Cairo, Egypt. http://dx.doi.org/10.5772/CHAPTERDOI.
14. Benedict, E. N. **2012**. Radiation from Oil Fields Using High-Resolution Gamma-Ray Spectrometry. MSc. Dissertation, University of Surrey, Guildford, Surrey Gu2 7XH UK. 65p.
15. UNSCEAR, **2000**. Sources and Effects of Ionizing Radiation Report to the General Assembly, Scientific Committee on the on the Effects of Atomic Radiation UN, New York, p 34-52.
16. Cowie, M., Mously, K., Fageeha, O., and Nassar, R., **2012**. NORM Management in the oil and gas industry, *Annals of the ICRP*, **41**(3–4): 318–331, Proceedings of the First ICRP Symposium on the International System of Radiological Protection.
17. UK NORM Waste Strategy. **2014**. *Strategy for the management of Naturally Occurring Radioactive Material (NORM) waste in the United Kingdom*. Available in https://www.gov.uk/government/consultations/strategy-for-the-management-of-naturally-occurring-radioactive-material.
18. Al-Talib., B. Kh. R. **2015**. Natural Occuring Radioactive Materails and Technologically Enhanced NORM Measurement on Oil Field in North Region of Iraq, PhD thesis, University of Baghdad, College of Science, Department of Geology, Iraq.
19. Nafae, T. M. **2015**. Radiological Assessment and Chemical Treatment Of Contaminated Soil With Naturally Occurring Radioactive Materials "Norm" By Leaching With Different Solvents And Their Reuse. PhD. Thesis, College Of Engineering, University Of Baghdad.
20. Ali, K.K., and Ibraheem, D.B. **2017**. Radiological assessment due to natural occurring radioactive materials (NORM) in oil and gas production industry-East Baghdad Oil field. *Iraqi Journal of Science*, **58**, 1A.
21. Jassim, S. Z. and Goff, J.C. **2006**. *Geology of Iraq*. Dolin , Prague and Moravian Museum ,Czech Republish.
22. IAEA, **1989**. *Measurement of radionuclides in food and environment.* Techical Report Series, No. 295, IAEA, Vienna.
23. UNSCEAR, **2008**. Health effects due to radiation from the Chernobyl accidentDraft report A/AC.82/R.673, 1–220.220United Nations Scientific Committee on the Effects of Atomic Radiation.
24. UNSCEAR, **1998**. Report of United Nations Scientific Committee on the Effects of Atomic Radiation. Exposures from man-made radiation; pp. 1–130.
25. UNSCEAR, **1993.** *Exposure from Natural Sources of Radiation*. United Nations Scientific Committee on the Effect of Atomic Radiation, United Nations, New York.
26. ICRP, **1991**. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Ann. ICRP 21 (1-3).
27. Ali, K. K., **2004.** Radiogeological study of Western Desert-iraq with special emphasis on radioecology. Ph.D. Thesis, Univ. of Baghdad, Baghdad, Iraq.
28. Ali K.K., Marouf B.A., and Al-Shaikh Z.D., **2011.** Exposure Rates And Radiation Doses Due To Ambient Gamma Rays/Anbar Governorate. *J. Of University Of Anbar For Pure Science:* **3**(3): 87-96.
29. Haribala, Hu B**.**, Wang C**.**, Gerilemandahu, Xu X**.**, Zhang S**.**, Bao S**.**, and Li Y. **2016**. Assessment of radioactive materials and heavy metals in the surface soil around uranium mining area of Tongliao, China. *Ecotoxicology and Environmental Safety*, **130:** 185–192.
30. Ibraheem, D.B., **2016**. Radiological Impact of NORMs in Petroleum Production Site in East Baghdad Oilfield. MSc. Thesis. College of Science, University of Baghdad.