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Radioactive Pollution Resulting from Crude Oil Ponds and its Dangerous to AL-Wahat Region, Libya

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ABSTRACT

Natural Radioactivity levels in soil and sediment remain of interest to many researchers because of the radiation-induced public health hazards. A large part of the Jalu city population were surrounded by many open ponds produced by oil companies. Therefore twenty eight sites of soil and sediment were collected from different locations around the Jalu area. Concentrations of radionuclides in soil and sediment were determined by gamma-ray spectrometer using (HPGe) detector. Average activity level of natural radionuclides ^{238}U, ^{232}Th, and ^{40}K were found to be (511.99 $BqKg^{-1}$, 225.49 $BqKg^{-1}$, and 311.18 $BqKg^{-1}$) respectively from the soil and sediment. Also, radium equivalent activity, dose rates, and other radiological hazard indicators soil, and sediment has been calculated. The results obtained in this study were all higher than their worldwide mean values and with the Comparison countries. The highest values were found in Nafoora field (ponds A, B), Jalu field (ponds A, B), Nafoora field Base, and Auglia city respectively. This study shows the seriousness of these radiations from the refining and production of oil companies to neighboring cities and could serve as important radiometric baseline data upon which future epidemiological studies and environmental monitoring initiatives could be based.

التلوث الاشعاعي الناتج عن برك النفط الخام وخطورته على منطقة الواحات

محفوظ زايد أغنيه أحمد مرسي عطية إبراهيم هنداوي صالح

تظل مستويات النشاط الإشعاعي الطبيعي في التربة والرواسب محل اهتمام العديد من الباحثين بسبب مخاطر الصحة العامة التي يسببها الإشعاع. جزء كبير من سكان مدينة جالو محاطًا بالعديد من البرك المفتوحة التي تنتجها شركات النفط. لذلك تم جمع ثمانية وعشرون عينة للتربة والرواسب من مواقع مختلفة حول منطقة جالو. تم تحديد تراكيز النويدات المشعة في التربة والرواسب بواسطة مطياف أشعة جاما باستخدام كاشف (HPGe). وجد أن متوسط مستوى نشاط النويدات المشعة الطبيعية ^{238}U ، ^{232}Th ، و ^{40}Kهو (511.99 $BqKg^{-1}$، 225.49 $BqKg^{-1}$، و 311.18 $BqKg^{-1}$) على التوالي من التربة والرواسب. كما تم حساب النشاط المكافئ للراديوم ، ومعدلات الجرعة ، ومؤشرات الأخطار الإشعاعية الأخرى في التربة والرواسب. حيث كانت النتائج التي تم الحصول عليها في هذه الدراسة أعلى من القيمة المسموح بها في جميع أنحاء العالم ومع دول المقارنة. تم العثور على قيم عالية في حقل النافورة (البرك أ ، ب) وحقل جالو (البرك أ ، ب) والموقع الرئيسي لحقل النافورة ومدينة أوجلة على التوالي. وتوضح هذه الدراسة خطورة هذه الإشعاعات الناتجة من التكرير وإنتاج شركات النفط بالمدن المجاورة ويمكن أن تكون هذه الدراسة بمثابة بيانات أساسية إشعاعية مهمة يمكن أن تستند إليها الدراسات الوبائية المستقبلية ومبادرات الرصد البيئي.

INTRODUCTION:

Radioactivity is a phenomenon associated with unstable atomic nuclei with an excess of energy and /or mass, which decays spontaneously in the form of electromagnetic waves (gamma rays) or currents of subatomic particles (alpha, beta, or neutron) **(UNSCER, 2010)**.

Humans are exposed to natural radiation from external sources, including terrestrial radionuclides and cosmic radiation, and internal radiation from radionuclides embedded in the body. The main methods of taking radionuclides are with food, water, and inhalation. A specific class of internal radiation exposure, in which the bronchial epithelium is irradiated by alpha particles from short-lived radon atoms, constitutes a large portion of the exposure from natural sources **(**EPA, 1999).

The generation of natural radionuclides in the soil is an important component of background radiation exposure of the population. The component of natural radionuclides is based on the composition of the soil and rocks present in the natural radionuclides. Both natural and synthetic radionuclides preserve many environmental materials, including soil. The level of absorption depends on the physical and chemical properties of the radionuclides as well as on the environmental matrix of interest (Miah, F.K. *et. al*., 1998).

These radionuclides are contained in variable concentrations in the range of oxide minerals, silicates, arsenates, vanadate's, and phosphates.
One of the main sources of radiation risks of Technologically Enhanced Naturally Occurring Radioactive Material (TE-NORM) results from mining operations where materials with relatively high radioactive content are extracted from their natural sites (which may be deep in the ground) and can be concentrated and redistributed throughout the environment. The presence of radium or thorium in these materials may increase the concentration of radon, oxides and blocks at the general site of the mining or milling process (Katherine, 1984).

Oil and natural production entail a unique environmental issue, and this includes the need to treat waste and polluted water from the drilling process, tailings from oil tanks, farms, chemical waste, naturally occurring radioactive materials, oil pits and spills. Libya is slowly realizing the need to address the environmental impact of oil and gas production. Environmental issues are becoming more and more important to Libya's oil and gas industry, especially with the influx of foreign companies. Pollution is the entry of pollutants into the environment or ecosystem that causes negative changes. Severe cases of radioactive contamination lead to changes in the DNA that lead to a genetic mutation, as happened in Hiroshima and Nagasaki in Japan and Chernobyl. The radioactive contamination that occurred in Iraq in the recent wars (1991-2015) due to uranium munitions. It leads to serious environmental and health disasters such as cancer, leukemia, and birth defects (Menkhi *et. al*., (2017).

The aim of this study is to measure the concentration of radionuclide activity ^{226}R, ^{232}Th, and ^{40}K in soil and sediment samples collected from eight sites (twenty eight) Samples in the Jalu region - Libya to assess the radiation risks of Technologically Enhanced Naturally Occurring Radioactive Material (TE-NORM) residues from the oil and gas industry, and to estimate all indicators of Radiation risk, radium parabolic activity, absorbed dose, annual effective dose, annual gonadal overdose and cancer risk.

MATERIALS AND METHODS:

Study Area Jalu area

The city of Jalu, located at length 21° 53' and latitude 29° 02' South East of the city of Benghazi with a distance of 400 km and a population of about 32 thousand people, where is famous for the cultivation of palm and various agricultural crops due to its desert nature. It is a strategic and vital center for its natural resources represented by non-renewable natural resources (oil and gas), which represents the nerve and backbone of the Libyan economy, accounting for 65% of the production of this wealth, according to sources from the National Oil Corporation.

The locations include Jalu city, Nafoora field, Auglia city, Ajkira city, Nafoora Field- (ponds A and B) and Jalu Field- (ponds A and B). **(Figure 1)** illustrate the Location map of the study area.

. *Sample Preparation And Measurements*

Twenty eight Samples were collected from eight locations as follows Six Samples from each pond were four from border and other two from the center of the pond as seen in the **Figures (2 – 6).** Twenty four Samples were collected from four ponds and The other four Samples collected from Jalu, Ajkira, Auglia cities and center of Nafoora base .

The Samples were collected by small brush made of soft plastic from twenty eight flat undistributed ground sites to avoid any parts of the original components of ground soil. The samples were collected from all sites during the period from 1st of September 2017 to 30th September 2017. The collected samples were packed in PVC bags then transferred to the radiation laboratory of institute of Graduate Studies and research, Alexandria University, each sample was dried in an oven at 105-110 ^{o}C for approximately twenty four hours and sieved through a 2-mm mesh-sized sieve to remove any macro-impurities. The**y** measured by high resolution gamma rays spectrometry system equipped with hyper pure germanium detector. Collection Samples were mapped using a handheld global positioning system (GPS) device.

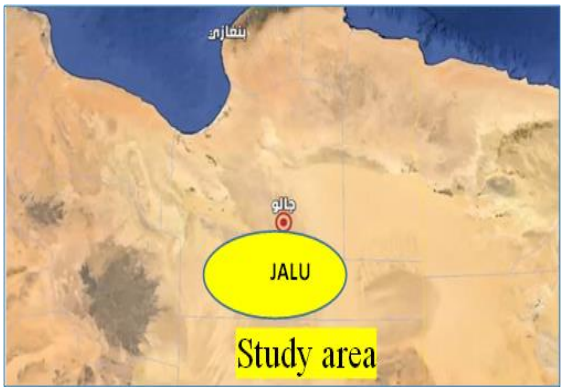

Fig. 1. Location map of the study area

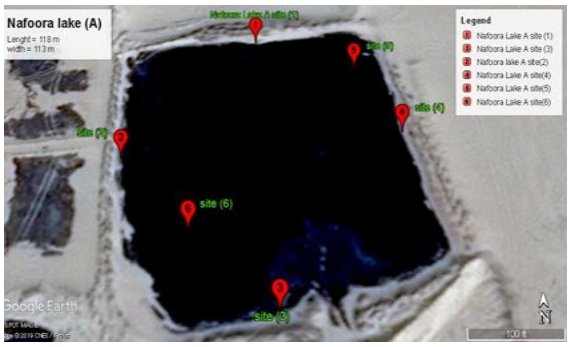

Fig. 2. Location of samples collected from pond (A) Nafoora oil Field.

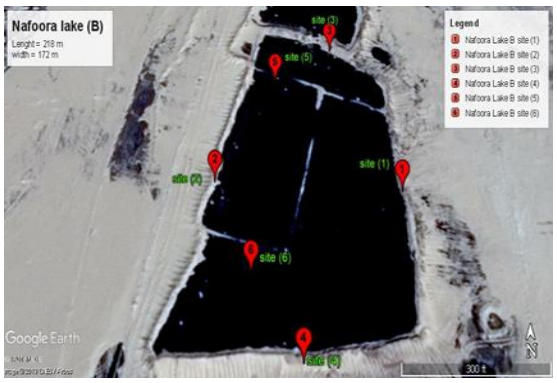

Fig. 3. Location of samples collected from pond (B) Nafoora oil Field.

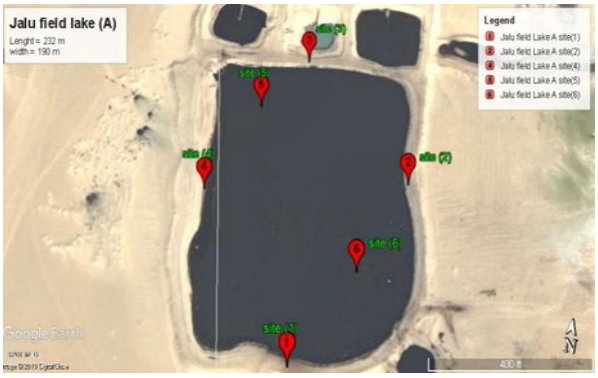

Fig. 4. Location of samples collected from pond (A) Jalu oil Field.

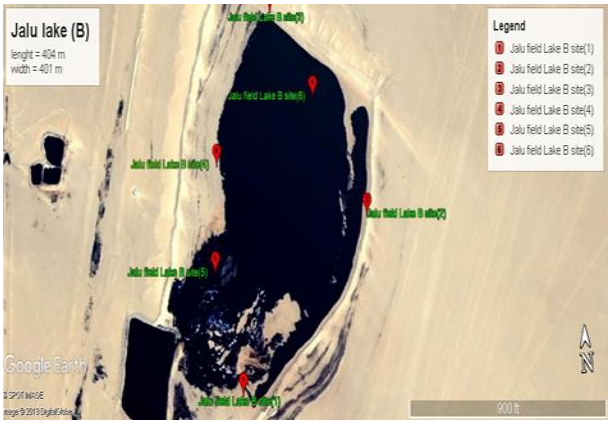

Fig. 5. Location of samples collected from pond (B) Jalu oil Field.

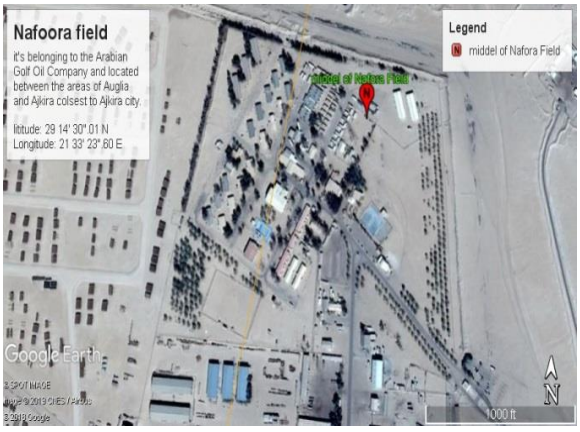

Fig. 6. Location of samples collected from Nafoora oil Field Base.

Gamma-Ray Spectra Measurements

A high purity vertical HPGe detector (p-type with a relative efficiency of 25% and peak to Compton ratio of 54:1) was used for measuring the g-ray spectra of the

samples. The energy resolution (FWHM) of the detector was 1.9 keV at the 1332 keV g-ray line of ^{60}Co source. The detector was coupled to a Canberra data acquisition system applying a Genie-2000.Analysis software, version 3.0, with many functions including peak area determination, background subtraction together with both g-ray energy and radionuclide identification. The HPGe detector was shielded with a lead cylinder of 10 cm thickness internally lined with 2 mm thick copper cylinder to absorb lead X-rays. The Sample containers were placed one at a time on the top of the detector (under the shield) for counting during an accumulation time of 80,000s.

*Calibration***.**

The energy and efficiency calibrations of the detection system were performed using a set of high quality certified reference sources (IAEA, RG-set) with density similar to the densities of the measured samples. In the present work energy calibrations were performed using standard sources, ^{57}Co,^{60}Co, ^{137}Cs and Americium (^{241}Am) of known energy lines. The radionuclides concentration of ^{238}U series radionuclides were determined from the photo peaks of ^{214}Pb (295 KeV) line, ^{214}Bi (609 KeV) and (185.6 KeV) of ^{226}R. the radionuclides concentration of the ^{232}Th series were determined from the photo peaks of ^{212}Pb (238 KeV) line, ^{208}TI (583 KeV) line, ^{228}Ac (911 KeV) line of ^{232}Th, while the Radionuclide concentration of ^{40}K is determined directly by measuring the gamma-ray transitions at 1460.8 KeV line, ^{137}Cs radioactivity's were determined using (661.8 KeV) line and ^{7}B determined using (477.6KeV) line**.** These peaks have been chosen to include whole spectrum for the radiation of the error ratio, and for appropriate statistical data using different energies.

RESULT AND DISCUSSION:

Activity Concentration

The activity concentration of, ^{238}U, ^{232}Th and ^{40}K in the study area varies from minimum values of (18.99 Bq Kg^{-1} and 14.32 Bq Kg^{-1}) for ^{238}U, ^{232}Th in Ajkira city respectively and (153.595 Bq Kg^{-1}) for ^{40}K in Nafoora pond (B), to maximum values (2936 Bq Kg^{-1}, 1512.64 Bq Kg^{-1}) for ^{238}U, ^{232}Th in Nafoora pond (A), and (492.06 Bq Kg^{-1}) for ^{40}K in Galu City as shown in **(Table 1)** and **(Figure 7).** The mean activity concentration of **^{238}U** is above the global permissible limit of (35 Bq Kg^{-1}) in Nafoora (ponds A and B), Jalu (ponds A and B), Auglia and Nafoora field, were lower than the global average in Jalu and Ajkira cities . ^{232}Th is above the world average of (30Bq-kg^{-1}) in Nafoora (ponds A and B), and lower than in the others. ^{40}K above global average, (400 Bq Kg^{-1}) in Nafoora Field and Galu City and below global average value for other locations [(UNSCEAR, 2000).

Radium Equivalent Activity (Ra_{eq})

According to (UNSCEAR, 2000), Radium Equivalent Activity in (Bq/Kg) is estimated using the equation (1.0) as given below, (Orosun *et. al.*, 2016; Abdullahi Ismail *et. al.*, 2019):

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad 1.0$$

Where, Ra_{eq} is a single parameter used to represent the radionuclide concentrations of ^{226}Ra, ^{232}Th and ^{40}K taking into account their respective radiation hazards.
The average value of the Ra_{eq} ranges from the minimum value (64.307 Bq Kg^{-1}) in Ajkira city to maximum value (5123.08 Bq Kg^{-1}) in Nafoora ponds (A). **(Table 2)** illustrates the calculated values of $Ra_{eq.}$ The result of average values is higher than the upper limit of (370 Bq Kg $^{-1}$) in the Nafoora ponds (A) and (B) but lower than the dose limit in the other locations as shown in the (Figure 8).

Annual Gonadal Equivalent Dose (AGED)

The gonads, the bone marrow and the bone surface cells are considered as organs of interest by **(UNSCEAR, 1988)**, because they are the most sensitive parts of human body to radiation. An increase in AGED has been known to affect the bone marrow and destroys the red blood cells which are then replaced by white blood cells. This situation results in a blood cancer (leukemia). AGED is calculated with given concentration of ^{226}Ra, ^{232}Th and ^{40}K (in Bq/Kg) using the relation no (2.0), (Mamont-Ciesla *et. al*., 1982; Sivakumar *et. al.*, 2018; Avwiri *et. al.*, 2014; Darwish *et. al.*, 2015).

$$AGED = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \quad 2.0$$

Where, C_{Ra}, C_{Th}, and C_K are the radioactivity concentration of ^{226}Ra, ^{232}Th and ^{40}K (in Bq/Kg) in soil samples respectively.
The mean values of AGED are varies between (219.83 mSv/yr) in the location of Ajkira city to (15492.38 mSv/yr) in the Nafoora pond (A) as shown in **(Table 2)**, the result of values are higher than the world average value of (300 mSv/yr) and lower values in the Jalu and Ajkira cities. The **(Figure 9)** represents the AGED level along

Gamma Index (I_γ)

Another radiation hazard index called the representative level index, used to estimate the level of gamma radiation associated with different concentrations of some specific radionuclides, can be defined by equation (3.0), (Sheela,M.U.R., & Shanthi, G., 2016; Abdullahi Ismail *et. al.*, 2018; NEA –OECD, 1979).

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \quad 3.0$$

where C_{Ra} ,C_{Th} ,C_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq·Kg^{-1} were calculated for the samples under investigation to indicate different levels of external

gamma-radiation due to different combination of specific natural activities in other materials. This index can be used to estimate the level of gamma-radiation hazard associated with the natural radionuclide in the materials. The average value activity concentration index determined were (34.90) as maximum in Nafoora pond (A) to (0.49) as minimum in Ajkira city as shown in (**Table 2)** and **(Figure10).** The result of activity concentration mean value was found excessed unity limit of 1 in Nafoora (ponds A and B), Jalu (pond A) and Nafoora Field, but not excess unity in Jalu (pond B), Auglia, Jalu and Ajkira cities. An increase in the representative gamma index greater than the universal standard of unity may results in radiation risk leading to the deformation of human cells thereby causing cancer (Avwiri *et. al*., 2014).

Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent received outdoor by a person is calculated from the absorbed dose rate by applying dose conversion factor of 0.7 Sv/Gy. Taking into consideration that people on average, spent 20% of their time outdoors, occupancy factor for outdoor and indoor is 0.2 (5/24) and 0.8 (19/24) respectively **(UNSCEAR 2000 ; Veiga *et. al.*, 2006).** AEDE is determined by the equations(4.0,5.0,6.0) **(A**dagunodo *et. al.,* 2018; Avwiri *et. al.,* 2014).

$$D_{Outdoor} = [D_r \times 8760 \times 0.2 \times 0.7] \times 10^{-3} \quad 4.0$$

$$D_{Indoor} = [D_r \times 8760 \times 0.8 \times 0.7] \times 10^{-3} \quad 5.0$$

The absorbed dose rate D (nGh/h) calculated by the following equation (Nguelem *et. al.,* 2016; Caridi *et. al.,* 2019).

$$D(nGy/h) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K \quad 6.0$$

Where D is the dose rate at 1 m above the ground, and A_{Ra}, A_{Th}, and A_K are the activity concentrations (Bq kg^{-1}) of ^{238}U, ^{232}Th, and ^{40}K, respectively, in the soil sample (Saito and Jacob, 1995). The average annual outdoor effective dose (Table 2) column 6 ranged from (2799.97µSv/y) in the Nafoora pond (A) to (37.98µSv/y) in the Ajkira city. However, the mean annual effective dose calculated in this study was higher than the world average value of (70 µSv/y) except Ajkira, Jalu pond (B) and Jalu city are lower than the acceptable value(UNSCEAR, 2000). As shown in the (Figure 11). The values of the annual effective dose equivalent of the indoor are ranged from (11199 µSv/y) in the Nafoora pond (A) to (151.93µSv/y) in the Ajkira city as illustrate in (Table 2) and (Figure 12) the mean value of Nafoora ponds (A and B) and Jalu pond (A) are excessed the upper limit of AEDE is value (450µSv/y).while the other locations are below the upper limit of AEDE. These indices measure the risk of stochastic and deterministic effects in the irradiated individual (Alias *et. al*., 2008).

External Life Cancer Risk (ELCR)

An increase in the ELCR causes a proportionate increase in the rate at which an individual can get cancer of the breast, prostate or even blood.
Excess lifetime cancer risk (ELCR) is given according to the equation (7.0), (Ekong *et. al.,* 2019;Abdullahi Ismail *et. al.,* 2019; Joel *et. al.,* 2018; Taskin *et. al*., 2009), as

$$ELCR = AEDE \times DL \times RF \quad 7.0$$

The values of the external life cancer risk is ranges from 48.99 in the Nafoora pond (A) to (0.67) in the Ajkira city as illustrate in the (Table 2), It is clearly the value excess the world average value of (0.29 $x10^{-3}$), the profile of (ELCR) in study area of Jalu as shown in (Figure 13). An increase in the ELCR causes a proportionate increase in the rate at which an individual can get cancer of the breast prostate or even blood (Avwiri *et. al*., 2014).

External And Internal Hazard Index

The external hazard index (H_{ex}) defined by the equation (8.0)

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad 8.0$$

Where, C_{Ra}, C_{Th} and C_K are the radioactivity concentration in Bq/kg of ^{232}Th, ^{238}U and ^{40}K. The value of this index must be less than unity for the radiation hazard to be insignificant. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} (370 Bq/Kg), The internal hazard index is calculated by equation (9.0), (Wang *et. al.,* 2015; Ademola *et. al.,* 2014; Beretka and Matthew, 1985).

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad 9.0$$

H_{in} should be less than unity for the radiation hazard to be insignificant. Internal exposure to radon and its daughter products are very hazardous and can lead to respiratory diseases like asthma and cancer. As shown in the **(Table 2)** the mean average of External hazard index (H_{ex}) were ranges from (13.85) in Nafoora pond (A) to (0.17) in Ajkira city as illustrate in **(Figure 14)** the result mean value is excess the dose limit of unity in Nafoora ponds (A and B). but lower than the limit of unity in the other locations. It's important to know if the average size of H_{ex} is greater than 0.3, it will increase the risk up to 30%, therefore people , who are living in that area, must comply with safety principle (UNSCEAR, 2000).

The mean values of internal hazard index (H_{in}) were ranges from (21.77) in Nafoora pond (A) to (0.23) in Ajkira city. The average value is higher than dose limit of unity in Nafoora ponds (A and B), and Jalu pond (A), but lower than in other locations as shown in (Table 2)

and (Figure 15). The quantity of internal exposure to radon and its short – lived decay products is given by internal hazard index (H_{in}). The value of H_{in} must be less than unity to have insignificant hazardous effect of radon and its short – lived decay products to the respiratory organs . (Ramasamy *et. al*., 2014).

Table 1. Average level of radioactivity concentration (Bq/Kg) in study area at Jalu.

location	^{226}Ra	^{228}Ra	^{40}K
Nafoora pond (A)	2936	1512.64	305.79
Nafoora pond (B)	599.36	165.31	153.59
Jalu pond (A)	303.87	23.97	184.28
Jalu pond (B)	49.27	16.96	331.53
Jalu City	19.64	18.96	492.06
Auglia City	61.25	29.26	305.03
Ajkira City	18.99	14.32	322.59
Nafoora field	107.58	22.53	394.6
Max	2936	1512	492.06
Min	18.99	14.32	153.59
Average	**511.99**	**225.49**	**311.18**
World average	**35**	**30**	**400**

Table 2. values of radium equivalent (Ra_{eq}), annual gondal equivalent dose (AGED), gamma index (I_γ), absorbed dose rate (D), annual effective dose equivalent outdoor, annual effective dose equivalent indoor, external life cancer risk, external hazard index and internal hazard index for all study area at Jalu.

Location	Raeq (Bq/Kg)	AGED (mSv/yr)	Gamma ($I\gamma$)	EDEA Outdoor (µSv/y)	AEDE Indoor (µSv/y)	ELCR	Hex	Hin
Nafoora Pond(A)	5123.08	15492.38	34.90	2799.97	11199.92	48.99	13.85	21.77
Nafoora Pond(B)	843.08	2591.26	5.75	1879.83	1879.83	8.22	2.29	3.91
Jalu Pond (A)	352.33	1097	2.39	797.67	797.67	3.49	0.952	1.77
Jalu Pond(B)	99.05	327.22	0.72	230.22	230.22	1.00	0.27	0.40
Jalu City	84.64	294.45	0.65	202.02	202.02	0.88	0.23	0.28
Auglia City	126.58	407.35	0.90	288.36	288.36	1.26	0.34	0.51
Ajkira City	64.307	219.83	0.49	151.93	151.93	0.67	0.17	0.23
Nafoora field	170.18	550.5	1.21	391.88	391.88	1.71	0.46	0.75
Min.	64.307	219.83	0.49	151.93	151.93	0.67	0.17	0.23
Max.	5123.08	15492.38	34.90	11199.92	11199.92	48.99	13.85	21.77
Mean study area	858.468	2622.45	5.876	1892.72	1892.72	8.27	2.32	3.703
Max. Permissible limit	**370**	**300**	**1**	**70**	**450**	**0.029 *10^{-3}**	**≥ 1**	**≥ 1**

Table 3. Comparison of natural radioactivity levels in soil and absorbed dose at different locations of Jalu area - Libya, with those in other countries as given in UNSCEAR (2000) report (15).

	Country Activity concentration (Bq kg^{-1})						Absorbed dose rate (nGy h^{-1})	
	^{238}U		^{232}Th		^{40}K			
Country	**Rang**	**Mean**	**Rang**	**Mean**	**Rang**	**Mean**	**Rang**	**Mean**
Present study	**18.99 - 2936**	**511.9**	**14.22 - 1512**	**225.49**	**152.5 – 492**	**311.18**	**30.97 – 2282.97**	**385.81**
Jordan	—	**56**	—	**29**	—	501	—	—
Turkey	—	21	—	—	37	—	342	—
Italy	57 –71	—	73 – 87	—	580 – 760	—	—	—
Egypt	5 – 64	17	2 – 96	18	29 – 650	320	20 – 133	32
USA	8 –160	40	4 – 130	35	100 – 700	370	14 – 118	47
Japan	6 – 98	33	2 – 88	28	15 – 990	310	21 – 77	53
Malaysia	38 – 94	67	63 –110	82	170 – 430	310	55 – 130	92
Chine	2 – 440	32	1 – 360	41	9 - 1800	440	2 – 340	62
India	7 – 81	29	14 – 160	64	38 – 760	400	20 – 110	56
Greece	1 – 240	25	1 – 190	21	12 – 1570	360	30.109	56
Germany	5 – 200	—	7 – 134	—	40 – 1340	—	4 – 350	50
Spain	6 – 250	32	2 – 210	33	25 – 1650	470	40 - 120	76

Libya (El-kameesy)	4 – 13.5	7.5	2.8 – 6.7	4.2	19 – 39.6	27.5	—	—
Max. permissible limit	**17 – 60**	**35**	**11 – 64**	**30**	**140 – 850**	**400**	**18 – 93**	**60**

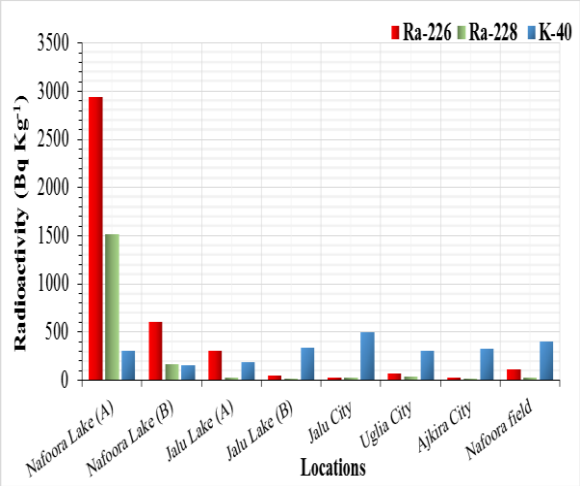

Fig. 7. Average level of the activity concentration values of ^{238}U, ^{232}Th and ^{40}K in the study area of Jalu- Libya

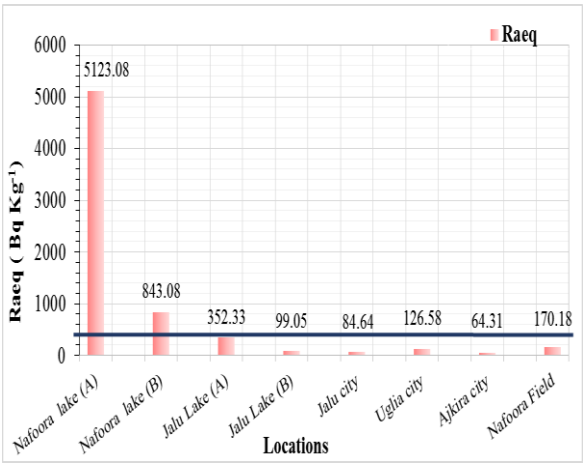

Fig. 8. The Ra_{eq} ($Bqkg^{-1}$) levels along the study area.

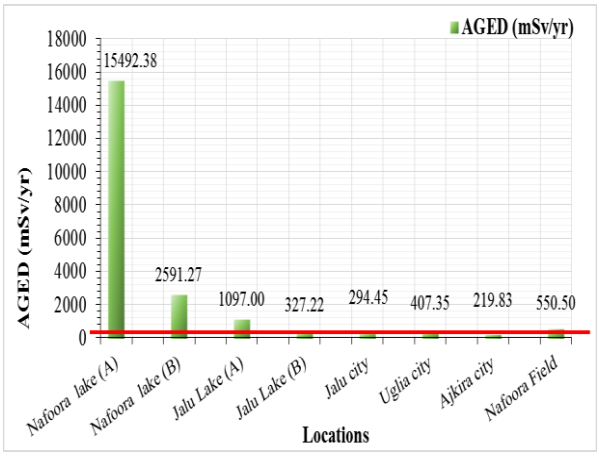

Fig. 9. The AGED (mSv/yr) level along the study area.

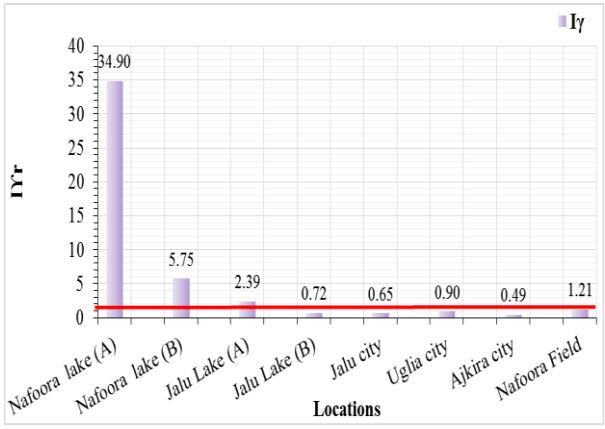

Fig. 10. The representative gamma index levels along the study area of Jalu.

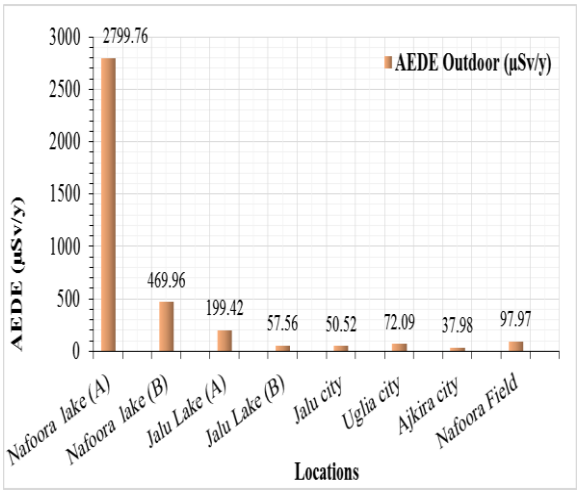

Fig. 11. (AEDE) for outdoor (µSv/y) levels along the study Area.

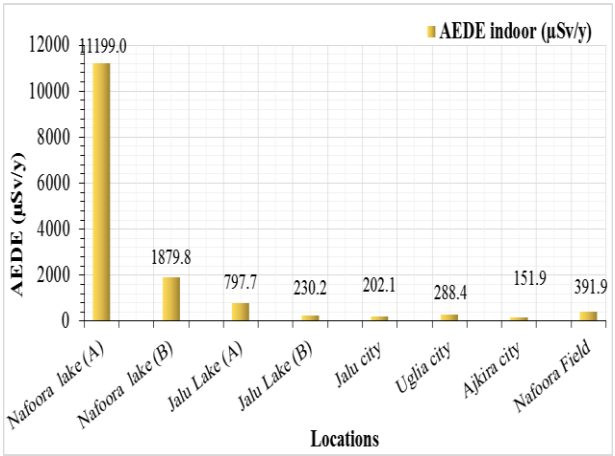

Fig. 12. (AEDE) for Indoor (µSv/y) levels along the study Area.

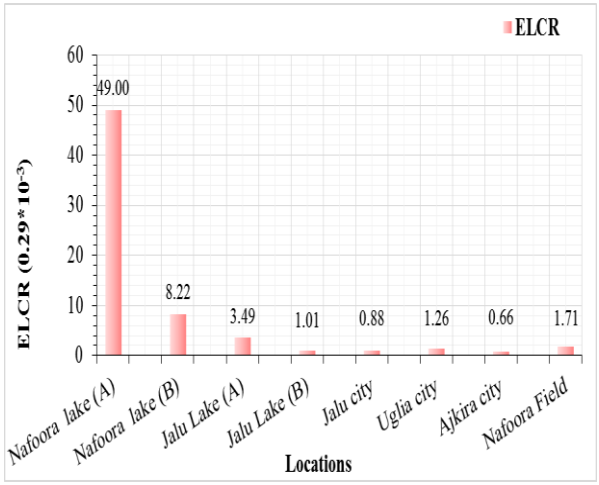

Fig. 13. External life cancer risk levels along the study area.

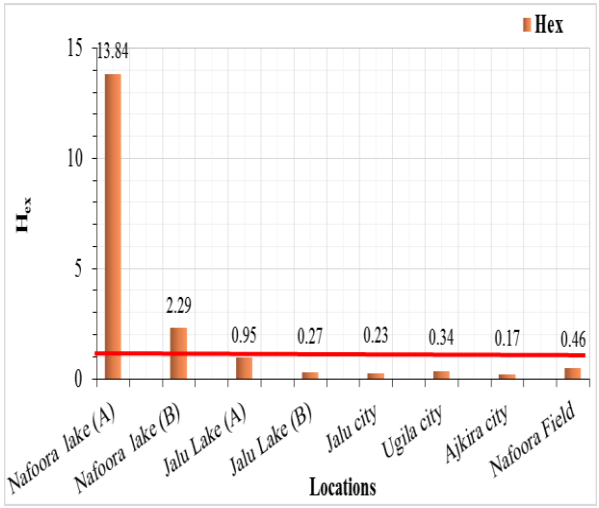

Fig. 14. External hazard index levels along the study sites.

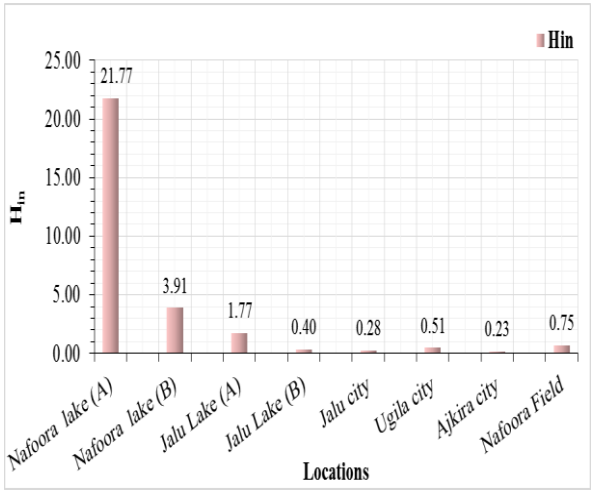

Fig. 15. Internal hazard index levels along the study sites.

CONCLUSION:

During the production oil from the fields around the Jalu area , highly contaminated oil ponds were formed covering a large area surrounded the Jalu, Ajkira and Auglia cities as result of oil present, soil properties including physical, chemical and geotechnical properties were affected negatively. Moreover the contamination levels were sufficiently high compared with clean soil. The level of natural radioactivity in soil and sediment collected from Jalu area of Libya has been evaluated using high resolution gamma-ray spectrometry (HPGe).

- The high radiation values in Jalu area compared to the global average rate and environment protection organization which endangers people and animals through inhalation and ingestion which lead to the spread of diseases such as cancer miscarriage and skin diseases.
- Uncontrolled work activities involving NORM and TENORM can lead to unwanted exposure and dispersal posing a risk to human health and the environment.
- Harmful radiation effects were posed to the population who live in the study area. Higher values of ^{226}Ra, ^{228}Ra and ^{40}K concentrations and radiation hazard levels are observed in Nafoora ponds (A and B), Jalu ponds (A and B) and Nafoora field base samples, notably, this area contains production and oil refining.

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