ASSESSMENT OF NATURAL RADIOACTIVITY IN SOIL AND ROCK SAMPLES ROUND EL-OBEID REFINERY, SUDAN

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Abstract: This Study is primarily conducted around El-Obeid refinery, North Kordofan State to contribute overall strategic national programme of radiation monitoring to create a radiation map for country, to be useful as a reference in the any case of environmental impacts. The measurements soil and Rock samples were performed measured by Gamma Spectrometry with Nal(TI) detector. The average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K determined were 30.11±4.49, 28.19±5.82 and 301.28±62.95 Bq/kg, respectively in soil samples. On the other hand the activity concentration of radionuclides ^{226}Ra, ^{232}Th and ^{40}K in rock samples were 23.80±6.40, 25.82±5.37 and 315.37±94.40 Bq/Kg, respectively. The absorbed dose rates and annual effective dose were estimated. However, the absorbed dose rates was found to be 32.03±4.04 nGy/h and 29.42±6.52 nGy/h for soil and rock samples, respectively and the corresponding annual effective dose to the population due to exposure to natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) for soil and rock samples were 39.31±4.96 and 36.11±8.00 µSv/y, respectively. However, the results showed that the radioactivity level in area under consideration were less than the global data reported in the UNSCEAR publications for normal background areas.

***Key words*:** Natural Radioactivity, Soil and Rock samples , El-Obeid refinery-Sudan.

1. Introduction

Natural radioactivity is widespread in the earth environment and it exists in various geological setting, such as earth crust, rocks, soils, plants, water and air [1]. Natural radionuclides in soil generate a significant component of the background radiation exposure of the population. The radioactivity caused by radionuclides can transfer from soil, water and air to agricultural plants, and other biological elements and finally to human body[2].So natural radioactivity in soil contributed radiation dose to dwellers that originate from ^{238}U,^{232}Th and ^{40}K , and the higher radiation levels are associated with igneous rocks, such as granite and lower levels with sedimentary rocks[3]. For health and environmental safety purposes there is need to measure and evaluate the level of radioactivity in the environment regularly and estimation of the radiation dose distribution is vital in assessing the health risk to a population and serves as a reference for documenting changes in environmental radioactivity due to anthropogenic activities [4]. The radiological survey is important for each country, to establish a data base for environmental purposes, and for future variation in radiation level due to one reason or another. The data generated in this study will complement a few other studies, which were conducted at different locations in Sudan to initiate creation of radiation map for the country and provide a useful reference for radiation Protection.

2. Materials and methods

Sample Collection and Preparation

A total of 28 soil and 16 rock samples have been collected randomly around El-Obeid refinery, which is situated about 10km on the East El-Obeid, capital North Kordofan State, Sudan. The samples were separately crushed using a jaw crusher and then ground to veryfine powder and homogenized by passing through 2mm sieve. The formed powder samples (500g) were sealed in standard Marinelli beakers (0.5 L) for approximately four week before counting by gamma- ray spectroscopy to allow secular equilibrium between ^{226}Ra and ^{232}Th and their progenies.

Gamma - Spectrometric measurements

Activity measurements was performed by using gamma – ray spectrometry system equipped with NaI (Tl) detectors of [3"×3"] inch crystal detector system, coupled to PC-MCA Canberra. To reduce the gamma background, a cylindrical lead shield (100mm thick) with affixed bottom and movable cover shielded the detector. The lead shied contained an inner concentric cylinder of copper (0.3mm thick) in order to absorb X-rays generated in the lead. In order to determine the background distribution in the environment around the detector, an empty sealed beaker was counted in the same manner and in the same geometry as the samples. The measurement time of activity or background was 10800s.The background spectra were used to correct the net peak area of gamma rays of measured isotopes .A dedicated software program .The (351.9 keV) gamma line of ^{214}Pb and (609.2 keV) of ^{214}Bi were used to calculate the activity concentrations of ^{226}Ra, while the gamma lines of ^{228}Ac (911keV)and ^{208}Tl (583.2keV), were used for estimating the activity concentration of ^{232}Th. The single 1460KeV gamma line was used to determine ^{40}K activity concentration.

Calculation of element concentration

Activity concentrations of the radionuclide contents and their activity levels in the samples were measured using a calibrated NaI (NI) detector. The activity concentration (A) of each radionuclide in the samples was determined by using the net count (CPS), weight of the sample, the photo-peak efficiency and the gamma intensity at a specific energy as [1] (B. M. R. Faisal et al., 2014).

$$A = CPS / E \times I \times W \quad (1)$$

Where, A = Activity concentrations of the sample in Bq/kg,
CPS = the net counts per second = cps for the sample- cps for the background value,
E = the counting efficiency of the gamma energy, I = Absolute intensity of the gamma ray and
W = Net weight of the sample (in kilogram).

Calculation of Absorbed Dose Rate and Annual Effective Dose from measured activity concentrations

The activity concentrations of ^{226}Ra and ^{232}Th and ^{40}K obtained in the soil and rock samples was converted into air absorbed dose rate (D) at a height of 1m above the ground level using Dose Rate Conversion Factors (DRCFs) given in the UNSCEAR (2000).

$$D\ (nGyh^{-1}) = 0.0.604A_{Ra} + 0.0417A_{Th} + 0.462A_{k} \quad (2)$$

Where:$D(nGyh^{-1})$ represents the total air absorbed dose rate due to the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K ($Bq.kg^{-1}$), respectively, at 1.0 m above the ground surface.

The estimated absorbed dose rate in air (D) was converted into annual effective dose (H) using the conversion formula:

$$H\ (\mu Svy^{-1}) = D\ (nGyh^{-1})\ x\ 24\ h\ x\ 365.25d\ x\ 0.2\ x\ 0.7\ Sv\ Gy^{-1}\ x\ 10^{-3} \quad (3)$$

Where: the conversion coefficient from absorbed dose in air to effective dose received by an individual is 0.7 $SvGy^{-1}$ and the outdoor occupancy factor is 0.29 [2,5,6,7] .

Table 1. Activity concentration of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K Bq/kg)in soil samples, corresponding total absorbed dose rate in air at a height of 1.0m (nGy/h), and the annual effective dose (μSv/y).

Sample Code	^{266}Ra	^{232}Th	^{40}K	nGy/h	μSv/y
S1	29.78	17.46	429.08	35.02	42.98
S2	31.80	30.45	369.01	36.16	44.38
S3	34.53	30.86	326.10	35.58	43.66
S4	23.94	26.39	377.59	32.28	39.62
S5	34.93	33.29	240.28	32.59	40.00
S6	30.60	31.26	360.43	35.47	43.52
S7	35.20	32.08	317.52	35.76	43.89
S8	35.53	30.86	334.68	36.37	44.64
S9	34.68	32.16	326.10	35.93	44.09
S10	36.07	31.02	283.19	34.43	42.25
S11	35.12	28.83	300.36	34.27	42.06
S12	27.28	41.01	343.26	35.46	43.51
S13	32.18	30.05	446.24	39.56	48.55
S14	32.73	30.45	351.85	35.83	43.97
S15	31.47	23.14	266.03	29.98	36.80
S16	27.92	21.52	308.94	29.95	36.76
S17	21.49	20.71	248.87	24.45	30.00
S18	34.06	34.11	240.28	32.40	39.76
S19	27.53	22.33	231.70	26.65	32.70
S20	27.37	26.47	240.28	27.86	34.19
S21	34.23	30.98	274.61	33.26	40.82
S22	25.58	24.77	317.52	30.04	36.87
S23	20.76	31.30	317.52	29.42	36.11
S24	25.00	31.26	300.36	30.49	37.42
S25	31.53	32.48	214.54	29.86	36.64
S26	25.07	12.18	248.87	24.09	29.57
S27	26.31	23.96	223.12	26.12	32.05
S28	30.45	28.03	197.38	27.67	33.96
Mean	30.11	28.19	301.28	32.03	39.31
STD	4.49	5.82	62.95	4.04	4.96
Min	20.76	12.18	197.38	24.09	29.57
MAX	36.07	41.01	446.24	39.56	48.55

Table 2: Activity concentration of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K Bq/kg) in rock samples, corresponding total absorbed dose rate in air at a height of 1.0 m (nGy/h), and the annual effective dose (μSv/y).

Sample Code	^{226}Ra	^{232}Th	^{40}K	nGy/h	μSv/y
R1	27.55	28.02	308.94	31.23	38.33
R2	35.17	32.08	369.01	37.96	46.59
R3	34.69	34.63	386.17	39.06	47.94
R4	27.20	25.17	583.55	42.26	51.86
R5	22.05	23.96	291.77	27.25	33.44
R6	26.05	25.58	343.26	31.53	38.69
R7	24.92	22.33	266.03	27.01	33.14
R8	21.97	23.14	214.54	23.71	29.10
R9	18.34	17.46	188.80	19.80	24.30
R10	21.07	19.90	180.21	21.14	25.94
R11	17.65	23.14	326.100	26.66	32.72
R12	18.82	19.08	334.68	26.64	32.69
R13	24.16	23.55	317.52	29.17	35.80
R14	14.17	28.83	274.61	24.22	29.73
R15	15.24	35.33	291.77	26.85	32.95
R16	31.73	30.86	369.01	36.23	44.46
Mean	23.80	25.82	315.37	29.42	36.11
STD	6.40	5.37	94.40	6.52	8.00
Min	14.17	17.46	180.21	19.80	24.30
MAX	35.17	35.33	583.55	42.26	51.86

Comparison of the average activity concentrations in soil, rock samples, of the study area with published data.

Country	^{226}Ra	^{232}Th	^{40}K	Reference
Taiwan	30.0	44.0	431	Yu-Ming [8]
Australia	51.5	48.1	114.7	Beretka and Mathew [9]
Nigeria	42.4	64.5	298	Joshua [10]
India	37	24.1	432.2	Kumar [11]
Amman, Jordan	56.4	28.8	501	Ahmed [12]
Istanbul, Turkey	21.0	37.0	342	Karahan and Bayulken[13]
Sudan	30.11	28.19	301.28	Present study
Global average	35	30	400	UNSCEAR [5]

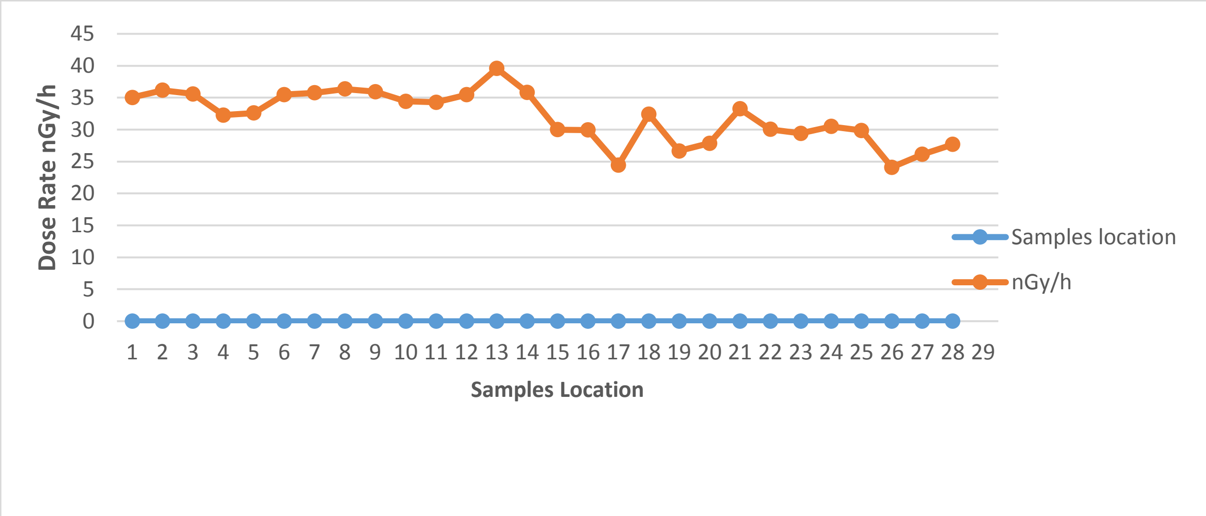

Fig .1: absorbed dose rate in air (nGy/h) in Soil samples around El-Obeid refinery.

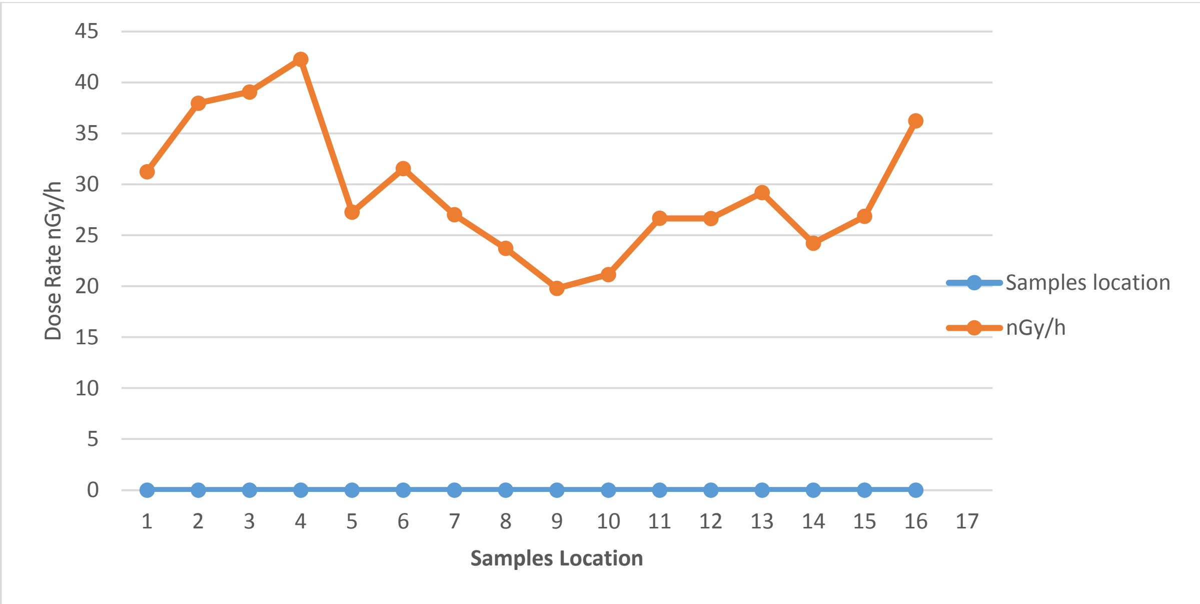

Fig. 2. Absorbed dose rate in air (nGy/h) in rock samples around El-Obeid refinery

3. Results and Discussion

The mean values of measured activity concentration of selected radionuclides of ^{226}Ra,^{232}Th, and ^{40}Kinsoil and rock samples collected around El-Obeid refinery were presented in table 1,2 respectively. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil samples were ranged from 20.76 to 36.07 with an average value of (30.11±4.49) Bq/Kg, and 12.81 to 41.01 with an average value of (28.19±5.82) Bq/Kg and from197.38 to 446.24 with an average value of (301.28±62.95)Bq/Kg, respectively. Similarly, activity concentrations in rocks samples were to be in the range 14.17 to 35.17 with an average value of (23.80±6.40) Bq/Kg for ^{226}Ra, while for ^{232}Th it is in the 17.46 to 35.33 with an average value of (25.82±5.37) Bq/Kg and On the other hand, the activity of ^{40}K was found to be in the range583.55 to 180.21 with an average value of

(315.37±94.40) Bq/Kg. However, the measured activity concentrations of ^{226}Ra, ^{232}Th, and^{40}Kwere compared with the values reported worldwide [8,9,10,11,12,13,5] as shown in Table 3. It is found that the measured activity concentrations of all radionuclides in this study are lower than most of the reported values from other countries as well as the world's average values.

Environmental exposure situations resulting from gamma-emitting radionuclides often expressed by absorbed dose rate in air at a height of 1.0 m from the surface [14]. The estimated absorbed dose in soil and rocks samples were ranged from 24.09 to 39.56 with a mean of (32.03±4.04) nGy/h, and from 19.80 to 42.26 with a mean of (29.42±6.52) nGy/h (Table 1,2) & (Fig 1,2) respectively. The average absorbed dose rate reported in this study was lower than the worldwide average value of 60 nGy/h estimated UNSCEAR, (2000). The corresponding annual effective dose to the population due to exposure to natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) for soil and rocks samples were ranged from 29.57 to 48.55 with an average value of (39.31±4.96) μSv/y and ranged from 24.30 to 51.86 with an average value of (36.11±8.00) μSv/h, the overall annual effective dose were lower than allowable limit set by ICRP 1$\mu Sv y^{-1}$.However, the data generated from consideration area was reported the area is below world-wide average characteristics for normal background areas. Also the results from the study will serve as a baseline data in data bank for the Radiation Protection Board of Sudan, as part of a national programme to establish data on environmental radioactivity in Sudan.

4. Conclusion

The average concentrations of the radionuclides in soil and rock samples collected around El-Obeid refinery, North Kordofan State,are at the normal environmental levels and they are similar with the concentrations obtained in the surroundings countries.

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ОЦЕНКА ЕСТЕСТВЕННОЙ РАДИОАКТИВНОСТИ В ОБРАЗЦАХ ПОЧВЫ И СКАЛЫ ВОКРУГ НЕФТЕПЕРЕРАБАТЫВАЮЩЕГО ЗАВОДА ЭЛЬ-ОБЕЙДА, СУДАН

Ноорлдин Фадол, Эльфадил Махмуд Юсеф

Резюме: Это исследование в основном проводится на нефтеперерабатывающем заводе в Эль-Обейде, штат Северный Кордофан, для внесения вклада в стратегическую национальную программу радиационного мониторинга для создания радиационной карты для страны, которая будет полезна в качестве справочной информации в случае любого воздействия на окружающую среду. Измерения проб почвы и горных пород проводились гамма-спектрометрией с помощью детектора Nal(TI). Средняя концентрация активности ^{226}Ra, ^{232}Th и ^{40}K в образцах почвы была определена, 30,11±4,49, 28,19±5,82 и 301,28±62,95 Бк/кг соответственно. С другой стороны, концентрация активности радионуклидов ^{226}Ra, ^{232}Th и ^{40}K в образцах пород составляла 23,80±6,40, 25,82±5,37 и 315,37±94,40 Бк/кг соответственно. Оценены мощности поглощенной дозы и годовая эффективная доза. Однако было установлено, что уровень поглощенной дозы составляет 32,03±4,04 нГр/ч и 29,42±6,52 нГр/ч для образцов почвы и горных пород и соответствующая годовая эффективная доза для населения из-за воздействия естественных радионуклидов (^{226}Ra, ^{232}Th и ^{40}K) для образцов почвы и горных пород составляли 39,31±4,96 и 36,11±8,00 мкЗв/г соответственно. Однако, результаты показали, что уровень радиоактивности в рассматриваемой области были меньше, чем глобальные данные о которых сообщалось в публикациях НКДАР ООН для нормальных фоновых областей.

Ключевые слова: природная радиоактивность, образцы почвы и горной породы, нефтеперерабатывающий завод Эль-Обейд-Судан.

SUDAN, EL-OBEID NEFT EMALI ZAVODU ƏTRAFINDA TORPAQ VƏ QAYA NÜMUNƏLƏRININ TƏBII RADIOAKTIVLIYININ QIYMƏTLƏNDIRILMƏSI

Nooreldin Fadol, Elfadil Mahmoud Yousef

Xülasə: Tədqiqat, ilk növbədə, ölkənin radiasiya xəritəsini yaratmaq üçün radiasiya monitorinqinin ümumi strateji milli proqramına yardım etmək məqsədi ilə Şimali Kordofan əyalətindəki El-Obeid neft emalı zavodunun ətrafında aparılır və hər hansı bir ətraf mühitə təsir halında istinad kimi faydalıdır. Torpaq və qaya nümunələrinin ölçüləri Nal (TI) detektoru vasitəsilə Qamma Spektrometriyası ilə həyata keçirilmişdir. Torpaq nümunələrində ^{226}Ra, ^{232}Th və ^{40}K orta aktivlik konsentrasiyaları müvafiq olaraq 30.11±4.49, 28.19±5.82 və 301.28±62.95Bq/kq olmuşdur. Digər tərəfdən qaya nümunələrində ^{226}Ra, ^{232}Th və ^{40}K radionuklidlərin aktivlik konsentrasiyası uyğun olaraq 23.80±6.40, 25.82±5.37 və 315.37±94.40 Bq/kq təşkil etmişdir. Udulma doza dərəcələri və illik effektiv doza hesablanmışdır. Torpaq və qaya nümunələri üçün udulma doza dərəcələri müvafiq olaraq 32.03 ± 4.04 nGy /s və 29.42±6.52 nGy /s olmuşdur. Təbii radionuklidlərin (^{226}Ra, ^{232}Th və ^{40}K) təsiri nəticəsində əhali üzrə illik effektiv doza torpaq və qaya nümunələri üçün müvafiq olaraq 39.31±4.96 və 36.11±8.00μSv/y təşkil etmişdir. Bununla belə, nəticələr göstərdi ki, nəzərdə tutulmuş ərazi üzrə radioaktivlik səviyyəsi UNSCEAR-ın (Atom Radiasiyasının təsirlərinə dair Birləşmiş Millətlər Təşkilatının Elmi Komitəsi) standart fon sahələri üçün dərc edilmiş qlobal məlumatlarından daha azdır.

Açar sözlər: Təbii Radioaktivlik, torpaq və qaya nümunələri, Sudan, El-Obeid neft emalı zavodu