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Araştırma Makalesi - Research Article

Radiological Doses Assessment of NORM Waste for Soil Samples in Some of the Oil Fields

Radyolojik Dozlar Bazı Petrol Sahalarındaki Toprak Numuneleri için NORM Atıkların Değerlendirilmesi

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ABSTRACT

Naturally Occurring Radioactive Material (NORM) wastes are generated during oil production operations and the unjustified radiation exposures resulting from it represent challenges facing many countries, including Iraq. This research deals with an evaluation of the absorbed dose rates and the total annual radiation dose resulting from this waste in the study area. The activity concentrations of radionuclides in 13 soil samples were measured by using the Falcon 5000 system containing an HPGe detector. For which, the samples were placed at a distance of 5 cm from the detector surface for 3 hours. Then, the radiation dose rates were calculated. It is found that the values of the average absorbed dose is 23.42 nGy/h and the average total annual effective outdoor and indoor doses are 0.029 mSv/y and 0.115 mSv/y, respectively. These values are lower than the limits set by the International Atomic Energy Agency (IAEA) GSR Part3 standards and the recommended values in UNSCEAR 2000. The outputs of RESRAD-ONSITE software showed that the total dose values are 3.24 μSv/y , which is less than the permissible values for the total radiation dose for workers in the radiation field. The research recommended conducting continuous monitoring of absorbed dose rates and total annual effective doses for workers in work areas and continuous radiation evaluation of NORM waste sites through the use of appropriate radiation monitoring devices and taking samples to make the necessary measurements and spreading radiation awareness among workers in work areas.

Keywords- NORM, Absorbed Dose, Soil Samples, Annual Dose, Dose Assessment

ÖZ

Petrol üretim operasyonları sırasında Doğal Olarak Oluşan Radyoaktif Madde (NORM) atıkları üretilmekte ve bundan kaynaklanan haksız radyasyona maruz kalma, Irak dahil birçok ülkenin karşılaştığı zorlukları temsil etmektedir. Bu araştırma, çalışma alanında absorbe edilen doz oranları ve bu atıklardan kaynaklanan toplam yıllık radyasyon dozunun değerlendirilmesini içermektedir. 13 toprak örneğindeki radyonüklitlerin aktivite konsantrasyonları, HPGe dedektörü içeren Falcon 5000 sistemi kullanılarak ölçüldü. Bunun için numuneler 3 saat boyunca dedektör yüzeyinden 5 cm mesafeye yerleştirildi. Daha sonra radyasyon doz oranları hesaplandı.

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Ortalama absorbe edilen doz değerlerinin 23.42 nGy/h olduğu ve ortalama toplam yıllık etkili dış ve iç ortam dozlarının sırasıyla 0.029 mSv/y ve 0.115 mSv/y olduğu bulunmuştur. Bu değerler Uluslararası Atom Enerjisi Ajansı (IAEA) GSR Part3 standartlarında belirlenen limitlerin ve UNSCEAR 2000'de önerilen değerlerin altındadır. RESRAD-ONSITE yazılımının çıktıları, toplam doz değerlerinin 3.24 µSv/y olduğunu gösterdi; bu, radyasyon alanında çalışanlar için toplam radyasyon dozu için izin verilen değerlerden daha azdır. Araştırma, çalışma alanlarındaki işçiler için emilen doz oranlarının ve yıllık toplam etkin dozların sürekli izlenmesini ve uygun radyasyon izleme cihazları kullanılarak NORM atık sahalarının sürekli radyasyon değerlendirmesinin yapılmasını ve gerekli ölçümlerin yapılması için numunelerin alınmasını ve çalışma alanlarındaki işçiler arasında radyasyon bilincinin yayılmasını önermiştir.

Anahtar Kelimeler- NORM, Emilen Doz, Toprak Örnekleri, Yıllık Doz, Doz Değerlendirmesi

I. INTRODUCTION

Oil and gas production processes are always accompanied by the generation of Natural Radioactive Materials (NORM) as these materials are found within the Earth's crust [1]. These materials are characterized by their richness in radionuclides from the decay series of the elements U-238 and Th-232, in addition to potassium isotopes (K-40) at different concentrations. Because these nuclides have long half-lives, they have been present within the Earth's crust for a long time [2], [3]. These natural radioactive materials are extracted with oil from the ground and placed on the inner walls of pipelines and oil separation or storage tanks [4].

Exposure levels resulting from these radioactive wastes require great monitoring and attention, as external and internal exposure (inhalation and ingestion) resulting from K-40 and nuclides within the U-238 and Th-232 decay series are the most common [5]. Mostly uranium-series elements are radium and radon. Radioactive radon, which is the product of the disintegration of 226Ra is found in some underground waters at very high concentrations [6]. Radon exposure is also an issue with NORM waste. It should be noted that all work related to NORM that is not subject to control and supervision results in undue exposure to radiation [5].

NORM sources can cause high radiation exposure among workers at work sites at levels above the normal exposure level, in addition to the risks they cause to the environment, but they do not constitute a cause for concern [7]. There are a number of activities that need to be monitored by the competent regulatory authorities, in addition to the need to take measures to address the inaccuracy and uncertainty in assessing the radiation doses resulting from these wastes and the extent of their impact on human health and the environment [8].

These materials are in the form of raw materials, final or by-product products, intermediate materials, or process wastes, in addition to being liquid, solid, gaseous, or a mixture of them [9].

A number of IAEA conferences have addressed the issue of NORM waste and related issues such as radiation exposure, prevention, and management of these highly radioactive wastes. Despite the many conferences and meetings that have been held and discussed this topic, the problem of this waste is still long-standing and cannot be easily addressed without arriving at a correct understanding of its management [10].

This study used a RESRAD-ONSITE program (computer code) designed by Argonne National Laboratory - USA, with the aim of assessing radiation doses, in addition to the risks of cancer to an individual present on soil contaminated with radiation. The software inputs include important information in order to calculate pollution properties, such as the properties of the surface and subsurface layers, as well as the atmospheric, hydraulic and hydrogeological properties of the site. The program user has the freedom to choose all or some of the inputs. [11]

The importance of this study comes in order to evaluate the radiation doses resulting from NORM waste generated during oil production operations in some oil fields in Iraq.

II. THE STUDY PROBLEM

Iraq is considered one of the oil-producing countries and, like the rest of the world, suffers from the problem of NORM waste due to the absence of legislation that regulates the correct management of this waste. Uncontrolled practices related to this waste cause unjustified radiation exposure that poses risks to the health of workers and the public, as well as the environment.

III. MATERIALS AND METHOD

During this study, 13 soil samples of NORM waste were collected and prepared for measurement using the Falcon 5000 measurement system within the laboratory of the Iraqi Radioactive Sources Regulatory Authority (IRSRA) and then the results were analyzed using the relevant computer programs, as shown below:

A. Collection and Preparation of Samples

Soil Samples of NORM waste were collected from some Iraqi oil fields in the governorates of Baghdad, Maysan, and Basrah in the middle of October, and the number of samples reached 13 soil samples, as shown in Table 1, then it was prepared in the laboratory according to the context followed in it for preparing samples by drying, grinding, and sifting them, then filling them and placing them in special containers. After that, the weights of the samples were measured, and then they were left for 30 days to achieve balance.

Table 1. Soil Samples Characteristic

No.	Sample Code	Sample Depth (m)	Geological Structure	Color	GPS	Location
1	MCN1	2648	Al-Khasib Formation (Carbonite rocks) (Limestone)	Mixed Black & Gray	33.346437° , 44.567712°	Al-Nahrawan district (Baghdad)
2	MCN2	2650				
3	MCN3	2658				
4	MCN4	2652				
5	MCN5	2680		Dark Gray	33.34662° , 44.56136°	
6	MCL1	1200		Gray	33.13695° , 44.81602°	Al-Laj district (Baghdad)
7	MCL2	1000		Brown		
8	MCM1	3250	Nahr Omar Formation (Sandstone)	Gray	32.06027° , 47.43696°	Buzurgan field (Maysan Governorate)
9	MCM2	3100		Beige		
10	MCB1	4600	Al-Yamamah Formation (Carbonite rocks) (Limestone)	Gray	30.916390° , 47.322440°	West Qurna-1 field (Basra Governorate)
11	MCB2	3820				
12	MCB3	4624				
13	MCB4	3828				

B. Samples Measurement

The Falcon 5000 system, which includes a high-purity germanium (HPGe) detector with size 60×30 mm, was used to measure the activity concentrations of radionuclides. Through the values of activity concentrations of radionuclides as shown in Table 2, the absorbed radiation dose and the annual effective dose resulting from these nuclides were calculated using the equations shown below: [12], [13] and [15]

Table 2. Activity Concentration of (U-238, Th-232, Ra-226 & K-40) in Soil Samples

No.	Samples Code	Activity Concentration (Bq/kg)		
		K-40	Ra-226	Th-232
1	MCN1	329 ± 0.44	28.7 ± 0.022	3.92 ± 0.02
2	MCN2	10.57 ± 0. 034	15.1 ± 0.003	1.44 ± 0.019
3	MCN3	180 ± 0.056	70 ± 0.046	17.6 ± 0.032
4	MCN4	10.2 ± 0.022	25.9 ± 0.031	29.6 ± 0.04
5	MCN5	35.9 ± 0.014	24.7 ± 0.007	15.1 ± 0.01
6	MCL1	223 ± 0.15	6.59 ± 0.007	21.5 ± 0.006
7	MCL2	45.24 ± 0.02	6.23 ± 0.001	20.1 ± 0.007
8	MCM1	113 ± 0.16	1.03 ± 0.001	17.8 ± 0.01
9	MCM2	11.9 ± 0.024	22.6 ± 0.01	25.1 ± 0.042
10	MCB1	41.8 ± 0.023	12.84 ± 0.013	39.7 ± 0.03
11	MCB2	53.94 ± 0.021	12.6 ± 0.01	13.7 ± 0.03
12	MCB3	49.5 ± 0.031	11.5 ± 0.01	7.84 ± 0.01
13	MCB4	23.4 ± 0.001	23.12 ± 0.04	13.2 ± 0.016
	Min.	10.2 ± 0.034	1.03 ± 0.001	1.44 ± 0.019
	Max.	329 ± 0.44	70 ± 0.046	39.7 ± 0.032
	Average	86.72 ± 0.12	20.07 ± 0.012	17.43 ± 0.014
UNSCEAR report 2000		400	35	30

$$D = 0.462\ A_{Ra} + 0.694\ A_{Th} + 0.0417\ A_{k} \quad (1)$$

$$AEDE_{outdoor} = D \times 8760 \times 0.7 \times 0.2 \times 10^{-6} \quad (2)$$

$$AEDE_{indoor} = D \times 8760 \times 0.7 \times 0.8 \times 10^{-6} \quad (3)$$

Where D is the absorbed radiation dose, A is the radioactivity concentration of Ra-226, Th-242, and K-40. AEDEoutdoor and AEDEindoor are the equivalent annual effective dose of radionuclides.

In addition, the RESRAD-ONSITE program (version 7.2) was used to calculate the total radiation dose resulting from external and internal exposure (inhalation and ingestion) up to more than 500 years in the future, using the activity concentration values obtained from samples measured with the Falcon 5000 system. Two calibration processes are performed for the Falcon 5000, energy calibration using a standard source placed in front of the detector, and the source energy curve is matched with the energy curve stored in the system. Efficiency calibration uses a file attached in the system through which the calibration process is carried out using the Genie 2000 software program.

IV. RESULT AND DISCUSSION

The samples were measured using the HPGe system and the values of activity concentrations of radionuclides (K-40, Ra-226, Th-232, and U-238) were obtained. It was shown in Table 2 that the average values of activity concentration for the radionuclides were less than the recommended values in UNSCEAR 2000[16]. Using these values in the aforementioned equations, both the absorbed dose rate and the annual effective dose were calculated.

A. Absorbed dose rate (D) and annual effective dose equivalent (AEDE)

Both the absorbed dose rate and the annual effective dose were calculated using Eq.(3.1) for soil samples, where the maximum value for soil samples was 50.48 nGy/h, the minimum value was 8.287 nGy/h and the average value was 23.42 nGy/h. The values of the annual effective dose equivalents for outdoor and indoor for soil samples were calculated using equation Eq. (3.2) and Eq. (3.3) and the maximum value of AEDEoutdoor was 0.062 mSv/y for MCN3, the minimum value was 0.01 mSv/y for MCN2 and average value was 0.115 mSv/y. The maximum value of AEDEindoor was 0.25mSv/y for MCN3, the minimum value was 0.041 mSv/y for MCN2 and the average value was 0.029 mSv/y. The results showed that they are less than the limits recommended in UNSCEAR 2000[16]. Table 3 and Figures 1, 2 and 3 shown all values of the D and AEDE.

Table 3. Absorbed dose rate and the annual effective dose in Soil Samples

No.	Samples Code	D (nGy/h)	$AEDE_{outdoor}$ (mSv/y)	$AEDE_{indoor}$ (mSv/y)
1	MCN1	29.35	0.036	0.144
2	MCN2	8.29	0.01	0.041
3	MCN3	50.48	0.062	0.25
4	MCN4	22.03	0.03	0.11
5	MCN5	22.03	0.027	0.11
6	MCL1	25.33	0.031	0.12
7	MCL2	16.91	0.021	0.083
8	MCM1	15.94	0.019	0.078
9	MCM2	26.1	0.03	0.13
10	MCB1	31.7	0.04	0.16
11	MCB2	16.35	0.02	0.08
12	MCB3	12.11	0.015	0.06
13	MCB4	19.63	0.024	0.096
	Min.	8.287	0.01	0.041
	Max.	50.48	0.062	0.25
	Average	23.42	0.029	0.115
	UNSCEAR 2000	55	0.07	0.41

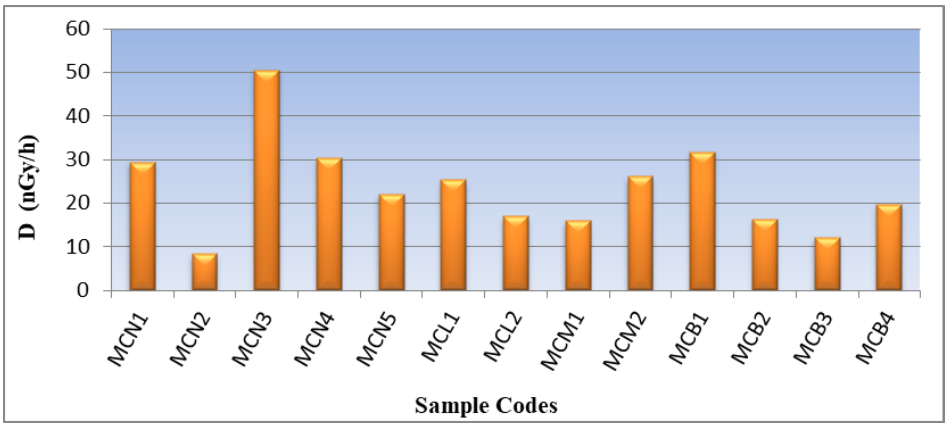

Figure 1. Absorbed Dose Rate (nGy/h) for Soil Samples

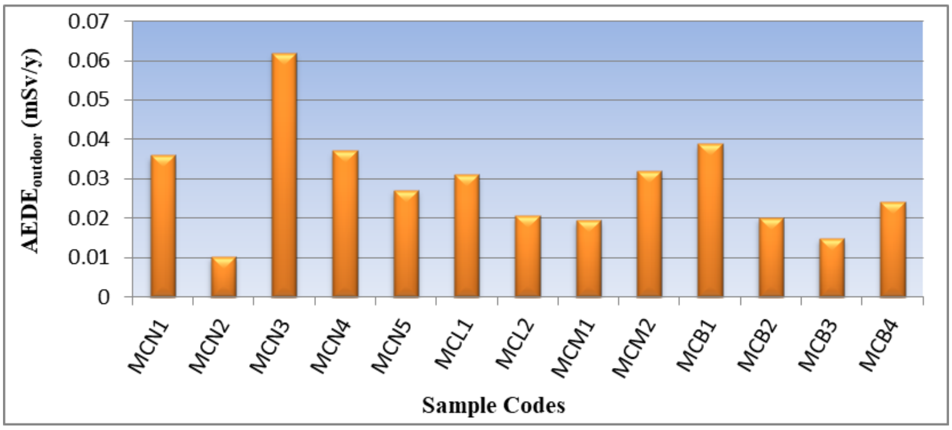

Figure 2. Annual Effective Dose Equivalent outdoor (mSv/y) for Soil Samples

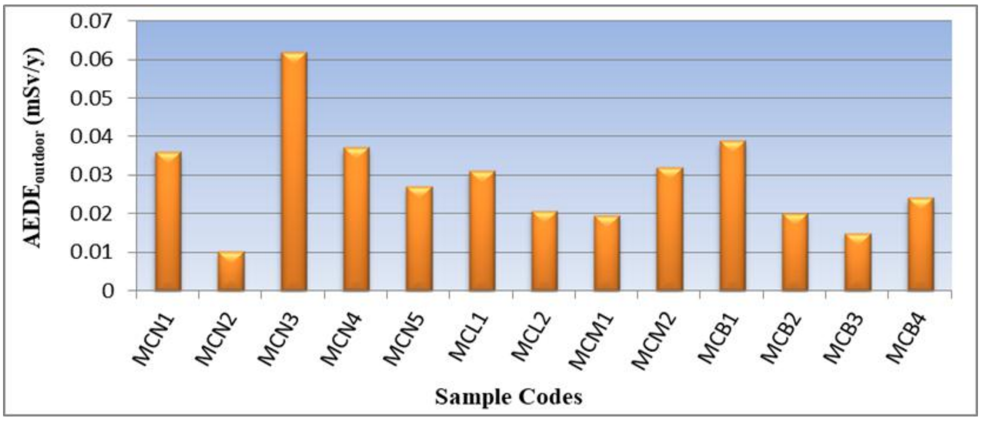

Figure 3. Annual Effective Dose Equivalent indoor (mSv/y) for Soil Samples

B. Total Dose using RESRAD-ONSITE Software Program

The RESRAD-ONSITE version 7.2 software program was used, which is considered one of the specialized programs in the field of environmental risk assessment, as it estimates environmental risks as well as the risks resulting from exposure to radioactive materials inside the site.

The total radiation dose to the workers was calculated and compared to local and international standards, as the program depends on several parameters, which represent the type of radioactive isotope, its activity concentration, the area of the study area, the depth of the contaminated area, in addition to the time spent by the workers in the study area, taking into account other environmental factors.

The results showed that the radiation dose resulting from external exposure is 3.22 µSv/y equal to 0.003 mSv/y. The total dose value represented by the external and internal dose (inhalation and ingestion) is 3.24 µSv/y.

The results of RESRAD-ONSITE software program shown in Table 4 and Figure 4 are considered less than the permissible limits for the total annual radiation dose to workers according to international atomic energy agency general safety requirements GSR-Part3 [17].

Table 4. Total Dose Measured with RESRAD for the Samples

	External	Inhalation	Ingestion	Total
		(μSv/y)		
Dose	3.22	0.019	0.001	3.24

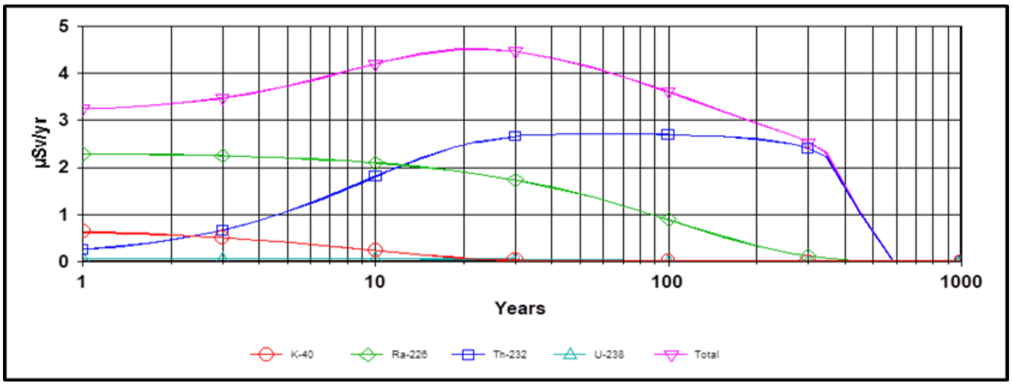

Figure 4. Total Dose measured by RESRAD-ONSITE software program for all nuclides

V. CONCLUSION

According to the results, we conclude that the absorbed dose and the total annual dose values are less than the recommended limits in UNSCAER 2000, meaning that there are no risks threatening human health and the environment. However, this waste cannot be overlooked when imagining the large quantities generated by the oil industry annually.

The results obtained using the RESRAD-ONSITE software program are considered less than the annual dose limits for workers according to the standards of the IAEA GSR Part3, as the highest value for the total dose was recorded at 20 years of value 0.0045 mSv/y.

VI. RECOMMENDATIONS

Through this study, in order to reduce the radiation risks resulting from this waste, the following must be done:

1- Conduct continuous monitoring of the absorbed dose rates and annual effective doses for workers working in the study areas.
2- Continuous radiation evaluation of NORM waste collection sites using radiation monitoring devices to ensure that there are no radiation risks that threaten human health and the environment.
3- Spreading awareness and knowledge among workers regarding the risks of radioactive materials and following occupational safety standards while working.

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