The Nucleus **48**, No. 4 (2011) 295-300

The Nucleus
A Quarterly Scientific Journal of Pakistan
Atomic Energy Commission
NCLEAM, ISSN 0029-5698

DETERMINATION OF GAMMA-EMITTING RADIONUCLIDES IN DUHOK CITY, IRAQ

*K.M.S. ABDULLAH[1] and R.A. RAMADHAN[2]

[1] Department of Water Resources, College of Engineering, University of Duhok, Iraq

[2] Department of Physics, College of Science, University of Duhok, Iraq

(Received July 14, 2011 and accepted in revised form November 18, 2011)

The present study assesses for the first time, the level of background radiation and the environmental radioactivity concentration in Duhok city using both gamma spectroscopy and dosimetry. The objective is to establish a baseline radiation level of the region. The city is located in the northwest in Kurdistan region of Iraq. Using gamma scout radiation meter (dosimetry), the average outdoor dose rate found in the field is 0.16 μSvh^{-1}. Using shielded well type NaI (TI) detector for 30000 sec, the calculated absorbed dose rate in air from terrestrial radiation and ^{137}Cs ranges 21.09-72.14 $nGyh^{-1}$ with an average of 44.05±1.34 $nGyh^{-1}$ which is below the world average value**.** The corresponding average annual effective dose rate is 0.054±0.002 $mSvy^{-1}$. The mean deposition activity concentration of ^{137}Cs is 9.17±0.47 $Bqkg^{-1}$ and 17.25 $Bqkg^{-1}$ for the non-intervened locations. Taking the non-intervened value, the expected contamination of the ^{137}Cs fallout from the Chernobyl accident in 1986 is 30.2 $Bqkg^{-1}$. Regarding the depleted uranium (DU) it is found that there is no significant DU trace at 20 sampling locations. Compared with other measurements in different countries we can conclude that the environment of the city is clean and suitable for living.

Keywords: Environmental radioactive sources, Soil samples, Annual effective dose rate

1. Introduction

The primary radioactive elements found in the earth's crust are uranium, thorium, their radioactive decay products and potassium. These elements emit alpha and beta particles, associated with gamma rays. Natural radioactivity is common in rocks and soil that make up our planet, in water and oceans and in our building materials and homes [1].

One of the reasons of pollution is the spread of radioactive materials in soil and water. The biggest percentage of radioactive pollution came from nuclear tests and the nuclear reactor accidents. Every explosion from such a kind is to be accompanied by the development of a cloud of radiated dust that transferred by the currents of air for thousands of kilometers to settle on the surface of the earth sphere for many years [1]. The long lived fission products ^{134}Cs, ^{137}Cs and ^{238}U, ^{222}Rn, $^{239\text{-}240}Pu$ and ^{241}Am released into the environment has increased the probability for the human to be exposed undesirably [2].

The radiological pollution monitoring started in Iraq right after the accident of Chernobyl in 1986. The United States forces used depleted (fertilized) uranium weapons for the first time during the second gulf war against Iraq in 1991 as shields that contributed to raise pollution level in Iraq [3]. It is of no doubt that the ionization radiation causes a great damage not only to man health but it also creates effects that are lethal or harmful to humans [4]. Among the Iraqi areas suffered was the Duhok city which was attacked by four undefined aircraft projectiles.

For the first time, a verification of radioactivity pollution is conducted in Duhok region. Specified locations of the city have been selected for such job. This research has been done to show the activities, percentages of the radioactive concentration and doses of the long lived terrestrial radioisotopes such as ^{238}U, ^{232}Th and ^{40}K as well as ^{137}Cs released to the atmosphere from Chernobyl accident and transferred by the air masses all over the world [5].

* Corresponding author : khairi_ms51@yahoo.com

2. Study Area

Duhok governorate is located at the north-western part of Iraq as a third governorate of Kurdistan region. It is confined by Turkey from the north, Syria from the west, Arbil from the east, and Nineveh from the south. It is mountainous region having physiographic diversity from the middle and south of Iraq [6].

Duhok city is capital of the governorate; it is located at the intersection of longitude 43°00' to the east and the latitude 36°52' in the north. Geographically the city is blockaded between two mountains, Duhok Mountains (Shindokha) from southern site and White mountains (Bekhir) from northern site. The permeability of soil throughout investigation is classified as soil of a very low permeability and the average mass density of 1800 Kg/m^3. The population of the city is about 300,650 persons [7].

The climate of the city is dominated by Mediterranean Sea and the semi-dry climate of (Savanna). It is characterized by moderate wet winter (cold and rainy accompanied by snow) and dry hot summer. The city has three major types of winds, northern, northeastern and western. The western wind is dominant throughout the year. The general average rate of rain precipitation record (400-800) mm between October and March [7, 8].

3. Field and Laboratory Work

The dose rates in the 20 locations were measured first by the gamma scout radiation meter (dosimeter) processed by Gamma Toolbox software installed on a personal computer [9]. The measurements were carried out at one meter above the ground level with a period of three hours for each location with logging interval of one hour to store three different measuring per site. The choice of a specific area within each site (location) is based on the undisturbed soil for the last few years.

A total of 20 surface soil samples were collected, for each site, an area of about (0.4×0.4) m^2 was marked and carefully cleared of debris, and a soil sample depth (0-10) cm is collected, depending on a standard methodology [10]. Collected soil samples were air-dried, sieved to remove stones and pebbles, heated-up with an oven at about 150 C$^\circ$ for 30 minutes to remove the moisture contents then grinded and crushed to pass through a fine mesh sieve 2 mm to homogenize. Finally, a part of each prepared soil sample was packed in a standard 1000-ml Marinelli beaker that was hermetically sealed, dry-weighed and stored for more than four weeks prior to counting to ensure equilibrium between decay products [11].

Gamma spectroscopic system was consisted of a NaI(Tl) well type detector, which was housed in a cylindrical lead shield of thickness ~6 cm which is suitable for limiting the gamma background. A Multi-Channel Buffer (MCB) used is a PC-based plug in PCI card consisting of more than 8k Analog Digital Convertor (ADC) with sophisticated WINDOWS based control and analysis software MCDWIN to analyze the γ-ray spectrum [12].

Under the assumption that secular equilibrium has been reached between decay products of ^{232}Th and ^{226}Ra. The concentration of ^{232}Th was determined from the average concentrations of ^{212}Pb and ^{208}Ti in the samples, and that of ^{226}Ra from ^{214}Pb and ^{214}Bi decay products. Thus, an estimation of radionuclide concentration of ^{232}Th and ^{226}Ra was obtained after subtracting the background determined prior, whereas a direct measurement of ^{40}K and ^{137}Cs concentration was achieved.

Following the spectrum analysis, count rates for each detected photo-peak, the activity for each of the detected nuclides were calculated as:

$$A_{Ei} = \frac{N_{Ei}}{\varepsilon_E \times t \times f_\gamma}(Bq) \quad (1)$$

Where ε_E is the detection photo-peak efficiency at energy E, N_{Ei} is the photo-peak counts determined by the area f_γ is a gamma decay fraction and t is the live time of the measurements (30000 sec). Their activity concentrations C_e (activity per unit mass) will be.

$$C_e = \frac{1}{M_s \times n}\sum_{i=1}^{n} A_{Ei}(BqKg^{-1}) \quad (2)$$

The absorbed dose rate, D (nGyh^{-1}), in air at 1m above the ground level due to the presence of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs in the studied samples was calculated using the following equation [13].

1. $$D = a.C_U + b.C_{Th} + c.C_K + d.C_{CS} \quad (3)$$

Table 1. Dose rate (μSvh^{-1}) in Duhok city.

Sample site	Dose rate μSvh^{-1}	Sample site	Dose rate μSvh^{-1}	Sample site	Dose rate μSvh^{-1}	Sample site	Dose rate μSvh^{-1}
DH1	0.18	DH6	0.18	DH11	0.18	DH16	0.15
DH2	0.16	DH7	0.17	DH12	0.16	DH17	0.16
DH3	0.15	DH8	0.16	DH13	0.16	DH18	0.14
DH4	0.15	DH9	0.16	DH14	0.13	DH19	0.17
DH5	0.14	DH10	0.15	DH15	0.16	DH20	0.19

Table 2. The activity concentration of the ^{226}Ra, ^{232}Th-series, ^{40}K and ^{137}Cs.

Sample site	Activity concentrations ($BqKg^{-1}$)			
	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
DH1	20.44±0.92	34.95±0.78	610.49±4.83	10.03±0.53
DH2	23.29±1.07	20.32±0.79	396.82±4.54	ND*
DH3	10.30±1.10	15.13±0.47	475.82±3.99	19.28±0.50
DH4	22.78±1.28	23.41±0.78	502.76±4.17	1.42±0.16
DH5	16.28±1.33	16.10±0.76	359.11±4.97	12.04±0.58
DH6	18.35±1.36	44.45±1.22	646.40±4.33	14.37±1.23
DH7	21.59±0.84	33.66±0.71	515.33±3.68	4.08±0.45
DH8	17.61±0.39	16.10±0.88	346.54±4.92	ND
DH9	15.86±0.43	27.68±1.43	400.41±4.29	2.04±0.34
DH10	16.24±1.34	18.48±1.37	423.75±9.91	4.43±0.37
DH11	18.71±0.72	29.09±0.65	574.58±5.49	ND
DH12	15.65±1.09	27.94±0.73	581.76±8.58	ND
DH13	22.51±1.19	28.41±2.20	538.67±5.69	ND
DH14	11.62±0.63	13.41±0.67	182.66±3.07	ND
DH15	23.72±1.12	21.35±1.01	412.98±6.05	ND
DH16	12.61±0.63	19.48±1.03	412.98±3.16	23.30±0.14
DH17	16.96±1.70	22.62±1.72	436.32±4.20	9.71±0.53
DH18	17.78±0.90	14.05±0.58	215.47±2.73	0.99±0.05
DH19	14.01±0.90	31.31±0.93	484.80±5.55	9.06±0.55
DH20	25.92±1.57	50.77±1.29	682.31±5.24	8.41±0.64
Average	18.11±1.03	25.44±1.00	460.00±4.97	9.17±0.47
Range	10.30 - 25.92	13.41 - 50.77	182.7 - 682.3	0.99 - 23.30

* Not Detected

Where a = 0.462, b = 0.604, c = 0.0417 and d = 0.1243 are the coefficients for conversion of activity concentration to absorbed dose rate in air ($nGyh^{-1}/Bqkg^{-1}$) of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs respectively adapted from UNSCEAR (2000).

The annual effective dose rate in units of μSvy^{-1} is calculated using the following formula [13].

$$AEDE(\mu Svy^{-1}) = D(nGyh^{-1}) \times 8766h \times 0.7SvGy^{-1} \times 0.2 \times 10^{-3} \quad (4)$$

4. Results and Discussion

The results of dose rate μSvh^{-1}, using Gamma scout radiation meter, is shown in Table 1. The exposure rates in the area ranged between (0.13-0.19) μSvh^{-1} and the average is $0.16\mu Svh^{-1}$.

Table 3. The dose rate of the ^{226}Ra, ^{232}Th-series, ^{40}K and ^{137}Cs in $nGyh^{-1}$.

Sample site	Dose rate ($nGyh^{-1}$)				
	^{226}Ra	^{232}Th	^{40}K	^{137}Cs	Total
DH1	9.44 ± 0.43	21.11 ± 0.47	25.45 ± 0.2	1.25 ± 0.07	57.26±1.16
DH2	10.76 ± 0.49	12.27 ± 0.48	16.55 ± 0.19	ND	39.58±1.16
DH3	4.76 ± 0.51	9.14 ± 0.28	19.84 ± 0.17	2.4 ± 0.06	36.14±1.02
DH4	10.52 ± 0.59	14.14 ± 0.47	20.96 ± 0.17	0.18 ± 0.02	45.81±1.26
DH5	7.52 ± 0.61	9.72 ± 0.46	14.97 ± 0.21	1.5 ± 0.07	33.72±1.35
DH6	8.48 ± 0.63	26.85 ± 0.74	26.95 ± 0.18	1.79 ± 0.15	64.07±1.70
DH7	9.97 ± 0.39	20.33 ± 0.43	21.49 ± 0.15	0.51 ± 0.06	52.30±1.03
DH8	8.14 ± 0.18	9.72 ± 0.53	14.45 ± 0.21	ND	32.31±0.92
DH9	7.33 ± 0.2	16.72 ± 0.86	16.7 ± 0.18	0.25 ± 0.04	41.00±1.28
DH10	7.5 ± 0.62	11.16 ± 0.83	17.67 ± 0.41	0.55 ± 0.05	36.89±1.91
DH11	8.64 ± 0.33	17.57 ± 0.39	23.96 ± 0.23	ND	50.17±0.95
DH12	7.23 ± 0.5	16.88 ± 0.44	24.26 ± 0.36	ND	48.37±1.30
DH13	10.4 ± 0.55	17.16 ± 1.33	22.46 ± 0.24	ND	50.02±2.12
DH14	5.37 ± 0.29	8.1 ± 0.4	7.61 ± 0.13	ND	21.09±0.82
DH15	10.96 ± 0.52	12.9 ± 0.61	17.22 ± 0.25	ND	41.08±1.38
DH16	5.83 ± 0.29	11.77 ± 0.62	17.22 ± 0.13	2.9 ± 0.02	37.71±1.06
DH17	7.84 ± 0.79	13.66 ± 1.04	18.19 ± 0.18	1.21 ± 0.07	40.90±2.07
DH18	8.21 ± 0.42	8.49 ± 0.35	8.98 ± 0.11	0.12 ± 0.01	25.81±0.89
DH19	6.47 ± 0.42	18.91 ± 0.56	20.22 ± 0.23	1.13 ± 0.07	46.73±1.28
DH20	11.98 ± 0.73	30.67 ± 0.78	28.45 ± 0.22	1.05 ± 0.08	72.14±1.80
Average	8.37 ± 0.47	15.36 ± 0.60	19.18 ± 0.21	1.14 ± 0.06	44.05±1.34

Table 4. The average dose rate and effective dose compared to other world locations.

Country	Dose rate ($nGyh^{-1}$)	Effective dose rates ($mSvy^{-1}$)	Reference
Duhok city, Kurdistan, Iraq	44.05	0.054	Present work
World average value	57	0.5	[13]
Nigeria	45.21	0.39	[14]
India	86.54	0.11	[11]
Iran	158.0	-	[15]
Palestine	18	-	[16]
Cameroon	29	0.036	[17]
Nigeria	56.06	0.069	[18]
Turkey	-	0.055	[19]
Egypt	43.58	0.05	[20]
Cyprus	14.7	0.018	[21]

The activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs for 20 soil samples are calculated by eq.1 and eq. 2 and shown in Table 2. The mean activity concentration is 18.11±1.03 Bqkg^{-1} for ^{226}Ra, 25.44±1.0 Bqkg^{-1} for ^{232}Th, 460±4.97 Bqkg^{-1} for ^{40}K and 9.17±0.47 Bqkg^{-1} for ^{137}Cs in all locations.

The outdoors dose rates in air are calculated from the activity concentrations of all radionuclides using Eq.3. The calculated values ranged from (21.09±0.82-72.14±1.80) nGyh^{-1} with an average of 44.05±1.34 nGyh^{-1} as shown in the last column of Table 3. This is in consistent with the world value 57 nGyh^{-1} [13].

The resulting average annual outdoor effective dose estimated according to Eq.4 is 0.054±0.002 mSvy^{-1} and is ranged from 0.26±0.001 (DH14) mSvy^{-1} to 0.089±0.002 (DH20) mSvy^{-1}.

For comparison with the worldwide areas, Table 4 shows our average values with many published investigations, which shows our extracted values nicely fit to these results [14]**.**

5. Conclusion

The results of activity concentrations and dose rate show that the distribution is not uniform, but agrees well in terms of distribution with the field measurements.

For ^{137}Cs, the mean deposition or accumulation activity concentration is 9.17±0.47 Bqkg^{-1} from all samples and 17.25 Bqkg^{-1} from the non-intervened locations DH16, 3, 6 and 5. Therefore, taking the non-intervened value and considering the relaxation length 6 cm, the contamination density is 1.9 KBqm^{-2} at present time. Accordingly the estimated contamination due to the deposition of ^{137}Cs from Chernobyl in 1986 was 30.2 BqKg^{-1} and 3.3 KBqm^{-2}. A comparison with the recorded value of contamination at that time in Turkey (4.0 KBqm^{-2}) by UNSCEAR (1988), prove without any doubt that the region was subjected to contamination from Chernobyl accident.

It is worthwhile to mention that in none of the 20 measured spectra was a significant peak at 1001.03 KeV line. Because any DU production started only after 1940, only the ^{234}Pa and ^{234}Th isotopes are in equilibrium with ^{238}U after a few months. We have a typical but weak 1001.03 KeV line in the decay of ^{234m}Pa that can be used for the selective determination of DU. Accordingly we can state with good confidence that there is no DU present at our 20 sampling points in Duhok city.

Finally the specific activity of radionuclides in Duhok city soil samples is within the permissible range. The activity concentrations, therefore, do not pose any threat to public health in the study area where the observations were made.

References

[1] J. P. Koplan, Toxicological Profile for Ionizing Radiation, Agency for Toxic Substances and Disease Registry, Atlanta, Georgia (1999).

[2] K. Froehlich, Environmental Radionuclides: Tracers and Timers of Terrestrial Processes, a companion series to the Journal of Environmental Radioactivity, Volume sixteen, Elsevier B.V. (2010).

[3] D. Williams, independent researcher, Eos, UK, "UNEP Key issues for UN uranium testing in Iraq, Implications of UNEP recommendations for Depleted Uranium studies in Iraq", Copyright © Eos (2003).

[4] S. F. Al-Najar, The Risk of Environmental Radiological Pollution Consequences of the use Radiological Depleted Uranium in South of Iraq, M.Sc. Thesis, College of Science, Mosul University, Iraq (2001).

[5] UNSCEAR (1988) Ionizing Radiation Sources and Biological Effects. United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General Assembly, New York (1988).

[6] K.A. Tawfiq Aga, Determinants of Investment Climate in the Iraqi Kurdistan Region, M.Sc. Thesis, College of administration and economics, Duhok University (2008).

[7] A. I. Abdy, A Study of Some Engineering Properties of (undisturbed and remolded) desiccated Soils in Duhok Governorate, M.Sc. Thesis, College of Engineering, Duhok University (2003).

[8] S. A. Faqeeh, Areal Expansion for Duhok City Studying in City Geography, M.Sc. Thesis, College of Arts, Slah Al. Deen University (1999).

[9] Gamma-Scout radiation detection, product of gamma-scout Ltd. http://www.gamma-scout.com.

[10] M. Pöschl and L. M. L. Nollet, Radionuclide Concentrations in Food and the Environment, Taylor & Francis Group, LLC, USA (2007).

[11] S. Singh, A. Rani and R. K. Mahajan, J. Radiat. Meas. **39** (2005) 431.

[12] MCD-2, Dual Input Multi-scalar/Multichannel Analyzer user Manual, FAST ComTec Communication Technology GmbH, D-82041 Obreaching, Germany (2002).

[13] UNSCEAR, Sources, Effects and Risks of Ionization Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General Assembly, with Annexes, New York (2000).

[14] A. Manzoor, W. Mohammad, A. Mohammad, Z.J. Hussain, A. Yasir and S. Farhan, Health Physics **98**, Suppl. 2 (2010) S69.

[15] AVWIRI and G.O, J. Appl. Sci. Environ. Mgt. **9**, No.3 (2005) 27.

[16] S. A. Husseini, J. Appl. Sci. **7**, No.20 (2007) 3091.

[17] A. Lahham, H. Al-Masri and A. Judeh, J. Radiat. Protect. Dosim. **135** (2009) 0144.

[18] M. Ngachin, M. Garavaglia, C. Giovani, M.G. K. Njock and A. Nourreddine, J. Environ. Radioactivity **99** (2008) 1056.

[19] I.C. Okeyode and A.M. Oluseye, J. Phys. International **6,** No.1 (2010) 1.

[20] O. Kilic, M. Belivermis, S. Topcuoglu, Y. Cotuk, M. Coskun, A. Cayir and R. Kucer, J. Radiat. Protect. Dosim. **128,** No.3 (2008) 324.

[21] A. Nada, T.M. Abd-El Maksoud, M. Abu-Zeid Hosnia, T. El-Nagar and S. Awad, J. Appl. Radiat. Isot. **67** (2009) 643.

[22] M. Tzortzis and H. Tsertos, Gamma-ray Measurements of Naturally Occurring Radioactive Samples from Cyprus Characteristic Geological Rocks, Department of Physics, University of Cyprus, Nicosia (2002).