Assessment of radiological risk in the area around surface disposal at Al -Tuwaitha site

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Abstract

The gamma dose rates and specific activity of ^{137}Cs, ^{60}Co and ^{40}K in samples of soil taken from places near the landfill radiation at Al-Tuwaitha site were measured using a portable NaI(Tl) detector. The results of gamma dose rates in samples were ranged from 52.6 $nGy.h^{-1}$ to 131$nGy.h^{-1}$. Then the specific activity of ^{137}Cs, ^{60}Co and ^{40}K in soil were determined using high pure germanium (HPGe) detector. The specific activities were varied from 1.9 to 115500 Bq. kg^{-1} for ^{137}Cs, from 6.37 to 616.5 Bq. kg^{-1} for ^{60}Co, and from 3 to 839.5 Bq. kg^{-1} for ^{40}K. The corresponding health risk for the annual effective dose equivalent varied from 1.85×10^{-14} to 15.7mSv/y. The results were compared with various international recommendations.

Key words

^{137}Cs, ^{60}Co and ^{40}K, Annual Effective Dose Equivalent.

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تقييم المخاطر الإشعاعية في المنطقة المحيطة بسطح مخازن الطمر الاشعاعي في موقع آلتويثة

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الخلاصة

تم قياس معدلات جرعة اشعة جاما والنشاط الاشعاعي النوعي للنظائر المشعة مثل السيزيوم-137والكوبلت-60 و البوتاسيوم-40 في نماذج من التربة المأخوذة من اماكن بالقرب من مخازن الطمر الاشعاعي في التويثة. أجريت القياسات المباشرة لمعدلات جرعة أشعة جاما باستخدام الكاشف المحمول ايوديد الصوديوم المطعم بالليثيوم (Tl) وتتراوح قيمته بين 52.6$nGy\ h^{-1}$ الى 131$nGy\ h^{-1}$. ثم تم تحديد الفعالية النوعية للنظائر المشعة في هذه التربة باستخدام كاشف الجرمانيوم عالي النقاوة (HPGe). وقد تباينت قيم النشاط النوعي لتلك النظائر فكانت قيمه تتراوح بين 1.9×10^{5} $Bq\ kg^{-1}$ - 1.155×10^{5} $Bq\ kg^{-1}$ للسيزيوم -137 و 6.37 - 616.5$Bq\ kg^{-1}$ للكوبلت -60 و 3 $Bq\ kg^{-1}$ - 839.5 $Bq\ kg^{-1}$ للبوتاسيوم -40. وحسبت المخاطر الصحية المقابلة للجرعة السنوية الفعالة وكانت قيمها تتراوح من 1.85×10^{-14} mSv/y إلى 15.7 mSv/y. وتمت مقارنة النتائج مع مختلف التوصيات الدولية.

Introduction

The Russian cemetery (RC) which was built in the early sixties of the last century at Al-Tuwaitha site, it called Russian Silo too, is a building similar the silo, it was designed for store low radioactive waste. Radioactivity is part of everyday life. Depending on the typology of the source it is possible to divide it in natural and artificial radioactivity. Artificial radioactivity derives from man activity and is generated in different applications, ranging from nuclear installations, nuclear accident or normal radionuclides applications used in

industry, e.g. medical machinery and different kinds of electronic devices. The primary man-made products are ^{90}Sr and ^{137}Cs [1].

Soil contamination is caused by the presence of man-made chemicals or other alteration in the natural soil environment. There are many different ways that soil can become polluted, such as:

• Leakage from a landfill
• Inflection of industrial waste into the soil
• Percolation of contaminated water into the soil
• Rupture of underground storage tanks
• Excess application of pesticides, herbicides or fertilizer
• Solid waste seepage

Estimation of the external exposure due to gamma-ray radiation is important because this may contribute significantly to the total annual individual dose [2]. The term for the absorption of radiation by living organisms is dose. The United States uses the Roentgen Equivalent Man (rem) as the unit of equivalent dose in humans. Rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose, as some forms of radiation are more efficient than others in transferring their energy to living cells [3]. The absorbed dose refers to how much energy is deposited in material by the radiation [4].

Radiological impacts may arise from gradual processes which may cause the facility and its components (e.g. barriers) to degrade, and from discrete events that may affect the isolation of the waste (e.g. earthquakes, tsunamis, floods, fire, inadvertent human intrusion) [5].

There are no studies that identify the leaks that contaminated or discharge of industrial waste from the Russian cemetery to soil surrounding areas. Therefore, this research aims to a considerable amount of detail regarding the contaminated soil, sample data so the determine basis for the estimates of the amount of waste leaked and its source term.

Materials and methods

1. The study area

The RC was used for disposal of low radioactivity and contains around 100 concrete wells of 4 m depth, which means the cemetery was built on top of 1m concrete slab. There are three sections in RC: Square wells, cylindrical wells and two large stainless steels.

The dimensions of the building from the outside are 60m × 10m × 4m. This cemetery is located at Al-Tuwaitha site, a nuclear research center 18 km south of Baghdad. RC is still intact and contains radioactive waste of the sixties, seventies and eighties.

2.In situ gamma dose rates measurement

Ludlum Model 19 Micro R Meter, USA was used to measure the gamma dose rates at 1 meter above the ground of sampling location. The instrument has linear energy responses to gamma radiation between 0.08 and 1.2 MeV [6]. It covered the majority of gamma ray emissions from major sources. The instrument uses scintillator, 2.5 x 2.5 cm (1 x 1 in.) (Dia x L) thick Nal. The survey meters were calibrated at the Malaysian Nuclear Agency, which is recognised by the IAEA as a Secondary Standards Dosimetry Laboratory. The meter display was in microroentgen per hour ($\mu R\ h^{-1}$). The gamma dose rate in unit $\mu R\ h^{-1}$ was converted to unit $\mu Gy\ h^{-1}$ ($1\ \mu R\ h^{-1} = 0.00876\ \mu Gy\ h^{-1}$).

2.1 Samples collection and preparation

A total 13 samples were taken from several locations above and surface surrounding the RC building. The samples were dried in an oven at 120 ^{0}C for 48 hours. The samples were grinded to form powder and then sieved by a sieve of 315 μm. The samples of 500 g kept in a cylindrical container. The samples were stored for a month to get equilibrium between Ra with its daughter.

2.2 Measurements of specific activity

The specific activity of ^{137}Cs, ^{60}Co and ^{40}K were measured using spectrometer with a coaxial high purity germanium detector (GC2018-7500 SL). It has a relative efficiency of 40%, and a resolution of 1.8 keV for 1332 keV gamma ray emission of ^{60}Co. Gamma vision version (6.8) software for gamma spectrum analysis a gamma spectrometer and relevant accessories were supplied by Canberra, USA [7].

The calibration was carried out by counting standard radionuclides of known activities with well-defined energies within the energy range of interest from 60 keV to 2000 keV and used standard source for efficiency calibration of gamma ray spectrometer in measuring large volumes of low specific activity materials [8].

The radionuclides were identified according to their individual photopeak radioactive. The activity of ^{137}Cs was directly determined using its 661.6 keV, 1173.24 keV for ^{60}Co, and 1460.8 keV of ^{40}K photopeak. The concentration of each individual radionuclide was calculated by the following equation [9].

$$W_s = \frac{W_{CRM} \cdot S_s}{M_s \cdot S_{CRM}} \cdot M_{CRM} \quad (1)$$

where W_s is the concentration of the radionuclide in the sample (Bq. kg^{-1}), W_{CRM} is the concentration of the radionuclide in the standard (Bq .kg^{-1}), M_s is the weight of the sample (g); M_{CRM} is the weight of the standard (g), S_s is the counts of the sample (cps) and S_{CRM} is the counts of the standard (cps). An empty cylindrical container of the same volume as the sample was counted to determine the background distribution due to the naturally occurring radionuclides in the environment around the detector area.

Results and discussions

1.External gamma dose rates

Two methods have been used to evaluate external exposures of gamma dose rate in this study area. The first was direct measurement of external gamma dose rates; the reading was taken at 1 m above the ground using NaI gamma detector [10]. The external gamma dose rate ranges from 52.6nGy h^{-1} to 131nGy.h^{-1}as shown in Table 1.

2. Specific activity of ^{137}Cs, ^{60}Co and ^{40}K.

The specific activity of ^{137}Cs, ^{60}Co and ^{40}K samples were measured using HPGe detector and the results are tabulated in Table 2.

Table 1: The direct measurements of gamma dose rate for the samples collected from a surface and above the RC (nGy/ h).

ID	Situ	Dose Rate in µR/h	Measured gamma dose rate (nGy/h)
1	Left side	15	131.40
2	Left side deep 30 cm	12	105.12
3	Back situ	9	78.84
4	Above situ (circular wells)	8	122.64
5	Next to the situ	9	131.40
6	Right side	9	78.84
7	Above situ (square wells)	7	105.12
8	Above situ (square wells)	6	87.60
9	Above situ (square wells)	8	96.36
10	Right side	9	78.84
11	Right side on deep 30 cm	8	70.08
12	Lift side	9	131.40
13	Lift side on deep 30 cm	6	113.88

Table 2: The specific activity of ^{137}Cs, ^{60}Co and ^{40}K in the samples collected from a surface and above the RC

Sample No.	Situ	Specific activity (Bq.kg^{-1})		
		^{137}Cs	^{60}Co	^{40}K
1	Left side	96300	600.3	7.7
2	Left side deep 30 cm	59800	339.9	3
3	Back situ	116000	616.5	10
4	Above situ (circular wells)	104.8	6.37	261
5	Next to the situ	23.19	14.6	326
6	Right side I	65.16	4.8	151.6
7	Above situ (square wells) I	389.2	11.59	137.8
8	Above situ (square wells) II	426.4	8.3	45.5
9	Above situ (square wells) III	269.5	6.5	11.7
10	Right side II	26.86	6.8	839.5
11	Right side on deep 30 cm	4438	6.8	292.6
12	Back left side	59.8	172.8	243.3
13	Back left side on deep 30 cm	1.9	58	7.7

The measured specific activity of ^{137}Cs varies from 1.9 Bq.kg^{-1} to 116000 Bq.kg^{-1} as shown in Fig.1. The highest specific activity of ^{137}Cs was found in the Back situ sample while left side deep 30 cm has the lowest activities.

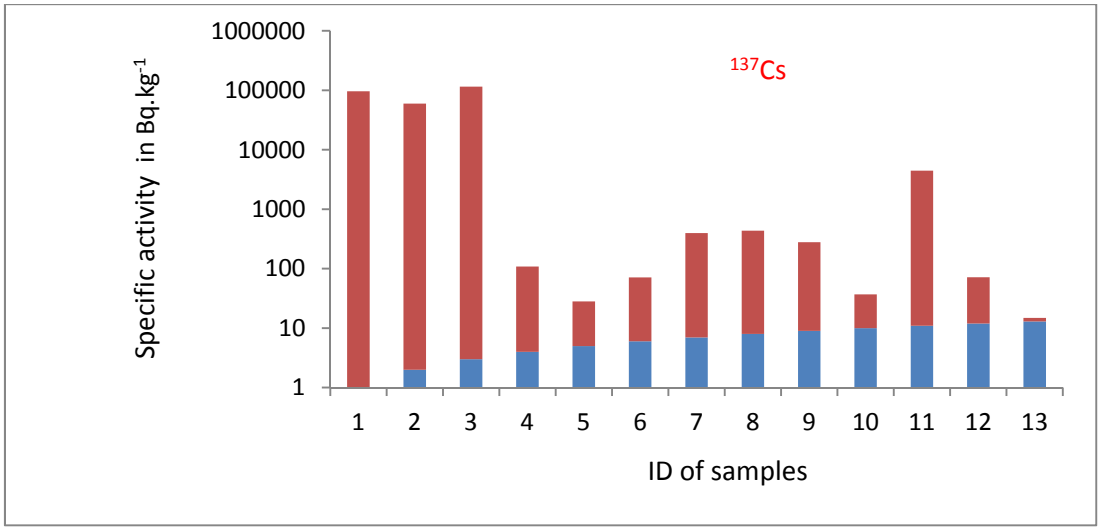

Fig.1: The specific activity of ^{137}Cs in the samples collected from a surface and above the RC.

The specific activity of ^{60}Co varies from 4.8 $Bq.kg^{-1}$ to 616.5 $Bq.kg^{-1}$ as shown in Fig. 2. The highest specific activity of ^{60}Co was found in the Back situ sample.

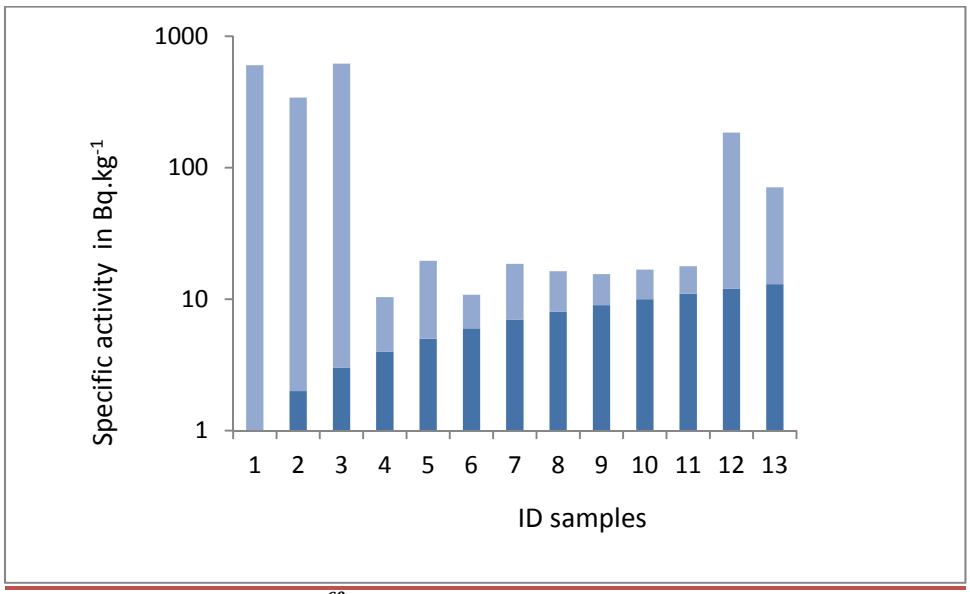

Fig.2: The specific activity of ^{60}Co in the samples collected from an among processing plant.

^{40}K specific activity varies from 3$Bq.kg^{-1}$ to 839.5 $Bq.kg^{-1}$ as shown in Fig. 3. Right side has highest specific activity of ^{40}K while back left side deep 30 cm has the lowest activities.

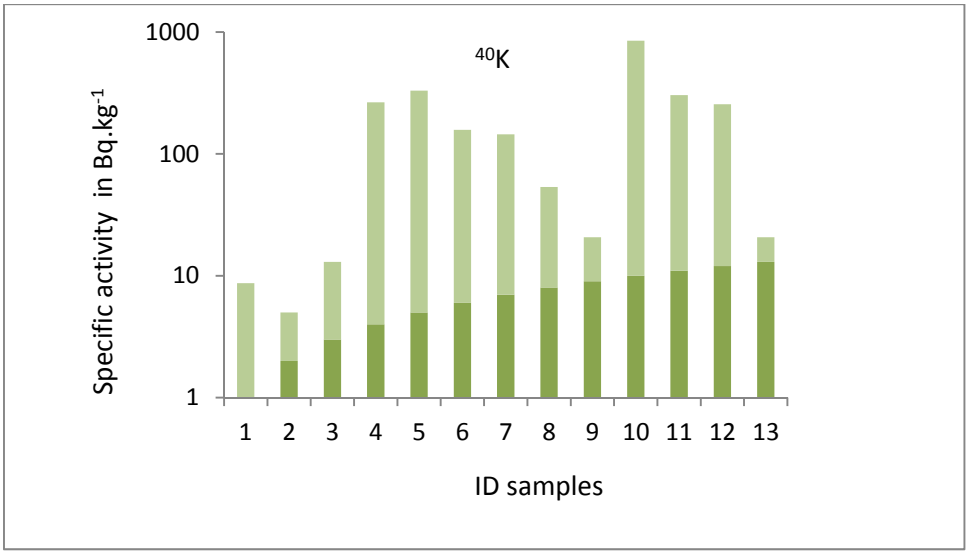

Fig.3: The specific activity of ^{40}K in the samples collected from a surface and above the RC.

Figs. 1, 2 and 3 show that the radioactivity measurements for samples of soil is relatively high for ^{137}Cs and ^{60}Co radionuclides in left and back situ when they compared with other samples while the activity of ^{40}K was increased in the right side.

The absorbed gamma dose rates of the samples were also calculated based on the specific activity of ^{137}Cs, ^{60}Co and ^{40}K in the collected samples as represented in Table 3. The methodology used for the derivation of the gamma dose rates from the activity of ^{137}Cs, ^{60}Co and ^{40}K was adopted from UNSCEAR (2000) using Eq.(2), [11].

$$D_{Medium} = D_{Air} \frac{\mu_m\ (Medium)}{\mu_m\ (Air)} \qquad (2)$$

where D_{medium} – Absorbed dose rate in medium.
μ_m – The mass attenuation coefficient [12].
D_{air} - Absorbed dose rate in air.

Table 3: The absorbed dose rate of ^{137}Cs, ^{60}Co and ^{40}K in the samples collected from a surface and above the RC.

ID	Absorbed dose (^{137}Cs mGy/h)	Absorbed dose (^{60}Co mGy/h)	Absorbed dose (^{40}K mGy/h)	Total absorbed dose (nGy/h)
1	1.11E-02	7.41E-05	5.97E-06	1.12E+04
2	6.28E-03	4.20E-05	2.32E-06	6.32E+03
3	4.13E-03	7.61E-05	7.75E-06	4.21E+03
4	3.75E-06	7.86E-07	2.02E-04	2.07E+02
5	8.31E-07	1.80E-06	2.53E-04	2.56E+02
6	2.33E-06	5.92E-07	1.17E-04	1.20E+02
7	1.39E-05	1.43E-06	1.07E-04	1.22E+02
8	1.53E-05	1.02E-06	3.53E-05	5.16E+01
9	9.65E-06	8.02E-07	9.07E-06	1.95E+01
10	9.62E-07	8.39E-07	6.51E-04	6.53E+02
11	1.59E-04	8.39E-07	2.27E-04	3.87E+02
12	2.14E-06	2.13E-05	1.89E-04	2.12E+02
13	6.80E-08	7.16E-06	5.97E-06	1.32E+01

Fig.4 shows the relation between measured and calculated gamma dose rate in the samples. The correlation coefficient was very good (0.9185) between measured and the calculated gamma dose rates from the radionuclides ^{137}Cs, ^{60}Co and ^{40}K. The significant linear relationship between measured and the calculated gamma dose rates indicate that the calculated or measured gamma dose rates could be used to predict the other.

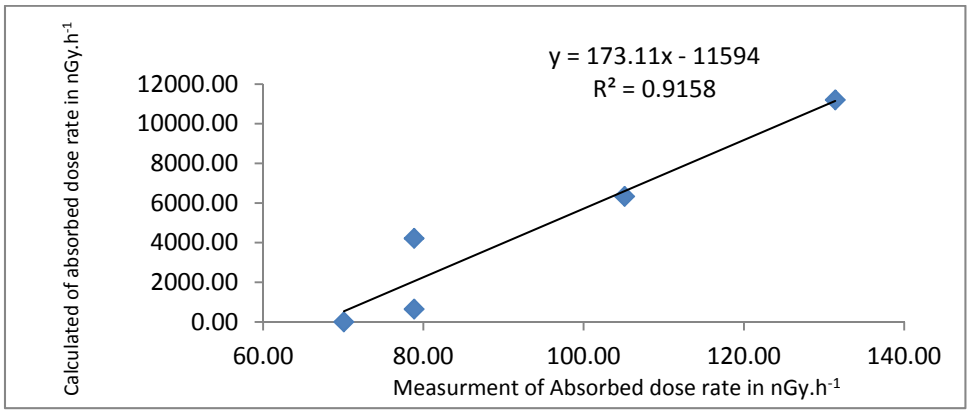

Fig 4: The correlation between measured and calculated absorbed gamma dose rate in the samples.

3. Annual Effective Dose Equivalent (AEDE)

Annual effective dose equivalent (AEDE) was used to assess the external radiological health risk worker. In order to estimate the annual effective dose equivalent, the conversion coefficient, 0.7 Sv Gy^{-1} from the absorbed dose in air to effective dose and the average working time at RC of 2000 h annually were used (ICRP1990). It can be calculated by using Eq. (3) [13].

$$AEDE\ (mSv\ y^{-1}) = D\ (nGy\ h^{-1}) \times 2000\ h\ \times 0.7\ (Sv.Gy^{-1}) \times 10^{-6} \quad (3)$$

The annual effective dose equivalent was calculated for the sample of the soil based on the calculated gamma dose rate. The results were in the range from 1.85E-14 mSv to 1.57E+01 mSv as shown in Table 4. Left side, Left side deep 30 cm and Back situ could pose significant radiological health risk to among workers since the annual effective dose equivalent is greater than the recommended value by ICRP (1991).

Conclusions

The external gamma dose rate and specific activity of ^{137}Cs, ^{60}Co and ^{40}K in the samples collected from the site, were measured to assess the radiological health risk to the workers. The external gamma dose rates were varied from 78.8 to 131 nGy h^{-1} which the highest gamma dose rate was recorded in Left side, Left side deep 30 cm and Back situ. The specific activity of radionuclides ^{137}Cs, ^{60}Co and ^{40}K were varied from 1.9 Bq.kg^{-1} to 116000 Bq.kg^{-1} these values were to have a significant potential to cause elevated radiation exposures to the workers. The mean annual effective dose equivalent was calculated in the range from 1.85E-14 mSv to 1.57E+01 mSv. When compared the results with the ICRP recommendations the calculated annual effective dose equivalent of the samples was low and one can notice don't exist risk in the site.

Table 4: The calculated gamma dose rate from ^{137}Cs, ^{60}Co and ^{40}K and annual effective dose equivalent.

ID	**The calculated gamma dose rate (nGy h^{-1})**	**Annual effective dose equivalent (mSv)**
1	1.12E+04	1.57E+01
2	6.32E+03	8.86E+00
3	4.21E+03	5.91E+00
4	2.07E+02	2.90E-01
5	2.56E+02	3.57E-01
6	1.20E+02	1.68E-01
7	1.22E+02	1.71E-01
8	5.16E+01	7.22E-02
9	1.95E+01	2.73E-02
10	6.53E+02	9.13E-01
11	3.87E+02	5.42E-13
12	2.12E+02	2.97E-13
13	1.32E+01	1.85E-14

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