Risks assessment for the retrieval of radioactive waste from the old Russian cemetery Al -Tuwaitha site

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Abstract

In this work the radioactive wastes in the Old Russian Cemetery Al -Tuwaitha site were classified according to risks for workers who are involved in the retrieval process. The exposure assessment results expressed as estimates of radionuclide intakes by inhalation and ingestion, exposure rates and duration for external exposure pathways, and committed effective dose equivalents to individuals from all relevant radionuclides and pathways. Results showed the presence of natural radionuclides Ra-226, Th-234 and K-40, as well as the produced radionuclide Cs-137 and Eu-152 in the cemetery wells. The absorbed doses from the waste were classified to two categories; exempt waste and low level waste according to absorbed dose value. This studied site does not pose a radiological hazard for the workers.

Keywords

radioactive wastes, exposure assessment, natural radionuclides.

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تقييم المخاطر عند استرجاع النفايات المشعة من موقع الطمر الروسي القديم في منطقة التويثة

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الخلاصة

تم في هذا العمل تصنيف النفايات المشعة المطمورة في المخزن الروسي القديم في منطقة التويثة وفقا للمخاطر التي يتعرض لها الاشخاص الذين يعملون في عملية استرداد النفايات المشعة.أوضحت نتائج التعرض للجرع الاشعاعية التي تؤخذ عن طريق الاستنشاق والابتلاع عن تقديرات ومعدلات التعرض ومدة ومسارات التعرض الخارجية، ووضعت قيم مكافئ الجرعة الفعالة المسموح بها للأفراد من جميع النويدات المشعة. وأظهرت النتائج وجود العناصر المشعة الطبيعية الاتية: راديوم-226 وثوريوم-234 و بوتاسيوم-40، وكذلك النويدات المشعة المصنعة سيزيوم-137 واليوربيوم-152 في آبار الطمر. وصنفت الجرعة الممتصة من النفايات وحسب قيمها إلى فئتين؛ النفايات التي لاتؤدي الى اي مخاطر صحية والنفايات ذات مستوى منخفض وفقا لقيمة الجرعة الممتصة. وتدل نتائج البحث ان هذه المنطقة التي تحتوي على ابار الطمر لا تشكل خطرا إشعاعيا على العمال المتواجدين فيها.

Introduction

A health risk is generally thought of as something that may endanger health. Scientists consider health risk to be the statistical or mathematical probability that lead to radiation injury. Instead, most of us consider the health risk of a particular action in terms of whether we believe that particular action will, or will not, which caused us some harm. The intent of this appendix is to provide estimates of, and explain the bases of radiation risk for occupational radiation exposure. Risk can be easily quantified in terms of the probability of a health effect per unit of dose received. When ionizing radiation interacts with living materials, they may deposit enough energy to cause biological damage in the cells. The interaction is depending upon the type of radiation and its energy. Radiation can cause several different types of events such as tiny changing of molecular structure, removal of electrons from atoms and molecules. When deposited energy of radiation in living tissue is high enough, biological damage could occur as a result of breakage of chemical bonds leading to damaged or death of the living cells. These effects can result in observable clinical analysis. The radioactive waste is generated in enormous quantities throughout the wide usage and applications of radioactive materials in the modern life.RW should be managed properly throughout the whole series of activities and processes of handling, transporting, treatment, conditioning and eventually proper disposal of the waste that's ensure high measures of protection and safety for radiation workers, environment, any number of the public and eventually our future generations[1]. The RW is mostly classified as low, intermediate or high-level waste and as short-lived or long-lived waste, depending upon the radiation activity, half-life of radionuclides, type of emitted, radiation and heat if any, generated during the radioactive decay process.The absorbed dose refers to how much energy is deposited in material by the radiation [2,3]. The dose equivalent is the product of the absorbed dose and the quality factor of the radiation. In the case of presence several radiation types, and total dose equivalent is the sum of its determined individual amounts. 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. A risk assessment consists of four distinct steps: data collection and evaluation, exposure assessment, toxicity assessment, and risk characterization. The outcome of a risk assessment is either a set of chemicals, pathways, media, and/or scenarios of concern for which an appropriate action must be undertaken or a determination that no action is required. All individuals exposed to hazardous waste are potentially at risk, including those within health-care establishments that generate hazardous waste, and radiation workers at nuclear facilities such as radioactive waste management workers who are in direct touch with these waste [4].

The photon attenuation coefficient μ is an important parameter characterizes the penetration and diffusion of gamma rays in composite materials such as waste; RW may contain different radionuclides in different concentrations or activities. The effects of different parameters on the attenuation coefficients of waste were discussed in several studies. An extensive data on mass attenuation coefficients μ/ρ of gamma rays in compound and mixtures of dosimetric interest have been studied by Hubbel1[5] in the energy range of 10keV to 100 GeV, an updated version of attenuation coefficients for elements having atomic number from 1-92 [5].

Experimental work

The RC in Al-Twiatha site is a very big above ground concrete block of 16 ×50 × 5 m. It contains around 91 concrete wells of 4 m depth, which means the cemetery was built on top of

1 m concrete slab. All the waste in RC is unidentified, without documents or inventory history. Retrieving the RW from the wells of the RC is a complicated and risky process due to the loss of the integrity of the plastic containing bags or due to the aging of the waste material itself. Accordingly, a system of classification and characterization has to be identified according the International Atomic Energy Agency classification system for the purpose of evaluating the risks of radiation for workers whom are involves in the retrieval process of the RW and other subsequent management processes. A drum characterization system was utilized for these processes. The system consists a circular rotating for holding and rotating the drums at revolutionary speed of 1 revolution per minute, the second part is the germanium detector holder and its moving upward and downward according to the adjusted height of the barrel. The maximum height will be no more than 85 cm which takes around 15 minutes scanning time. The system is adjusted to repeat the scanning when the detector is moving downward to enhance the measurements and counting statistics. High-purity germanium detector from ORTEC was used to provide gamma ray spectroscopy for the RW gamma spectroscopy analysis. The equipment provided with a neutron and *GM*detectors, *GPS* system and gamma vision version (*6.8*) software for gamma spectrum analysis. The usage of this equipment enabled the characterization and identifying all radionuclides of the RW without mentioned difficulties and avoiding all the radiation hazards and risks.

1. Energy calibration of HPGe detector

The energy calibration of HPGe gamma-ray spectrometer is performed by means of one liter Marinelli beaker mixed nuclide standard radioactive sources and "internal calibration" approach. The spectrometer system often shows non linearity by a channel or two over a full range of several thousand channels. This is achieved by carrying out energy calibration of the detection system. The energy calibration of HPGe gamma-ray spectrometer is performed by counting the peak of the standard radionuclides of the mixed nuclides of the standard source with well-defined energies within the energy range of interest from 60 keV to 2000 keV, and the calibration curve is shown in Fig. 1.

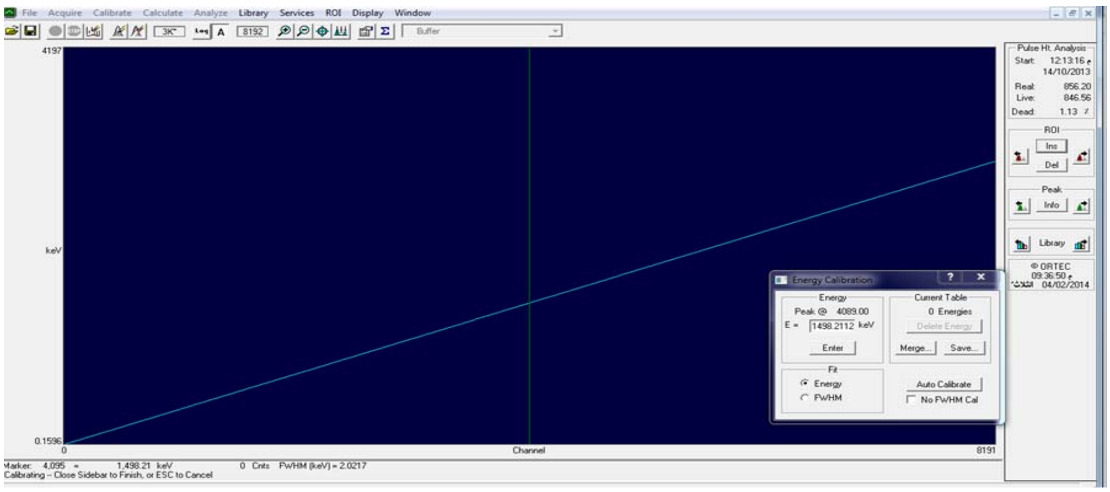


Fig.1: Energy calibration curve using mixed standard radionuclides in a one liter Marinelli beaker.

2. Efficiency calibration

Appropriate radionuclides must be selected for use as standards in efficiency calibration [6]. The detector efficiency (η(E))can be calculated using:

$$\eta(E) = \frac{N_T - N_B}{P_E * A_{STD} * T_{STD}} \quad (1)$$

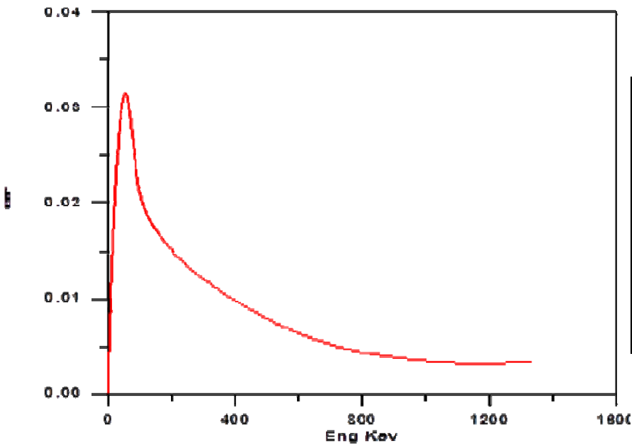
where; P_E is gamma emission probability for energy (E),

N_T is the total counts under a photopeak.

N_B is the background count.

A_{STD} is the activity (Bq) of the radionuclide in the calibration standard at the time of calibration,

T_{STD} is the counting time of the standard.



Radionuclide	Energy keV	Efficiency
	0	0
Am-241	59.5	0.031096
Cd-109	88	0.023606
Co-57	122	0.018691
Cs-137	661.6	0.0055875
Co-60	1332.3	0.0033904

Fig.2: Efficiency calibration curve using mixed standard radionuclides in a one liter Marinelli beaker.

3. Working method

RW sample were taken out of the wells and used four standard steel drums for spectrometry analyzing. Each drum was measured and analyzed for individual nuclide activity, total activity and total dose rates resulting from the radioactive materials presented in the sample. Samples and measuring system are shown in Fig.3.

The activity concentrations of the location samples were calculated using the following analytical expression as shown in Eq.2 [6]:

$$A = \frac{\frac{N}{t} - B.G}{I\% * \eta(E)\% * m} \quad (2)$$

where:

N/t - is the net count or net area under the peak.

I - is the intensity.

t - is the counting time for each sample.

m - is the mass of sample =1 kg.

B.G - is the background.

Fig.3: Wells and some samples in the drum and drum characterization system.

The calculation of radiation dose equivalent by using the following Eq.(3):

$$D_{eq} = \frac{\Gamma \times A}{d^2} \qquad (3)$$

where

D_{eq}- is the equivalent dose rate in μSv/h

Γ - is the gamma factor (dose rate constant) in $\mu Svm^2/(MBqh)$.

A- is the activity of the source in MBq.

d- is the distance in meters from the source [7].

The measured activities of the sample dose note represent the actual activity value due to the loss of some photons in the passage of the photons through the steel material of the barrel. Accordingly the measured activity value have to be corrected for the linear attenuation coefficient of the steel [5] to extract the μ value for each radionuclide in the sample as shown in Fig.4.

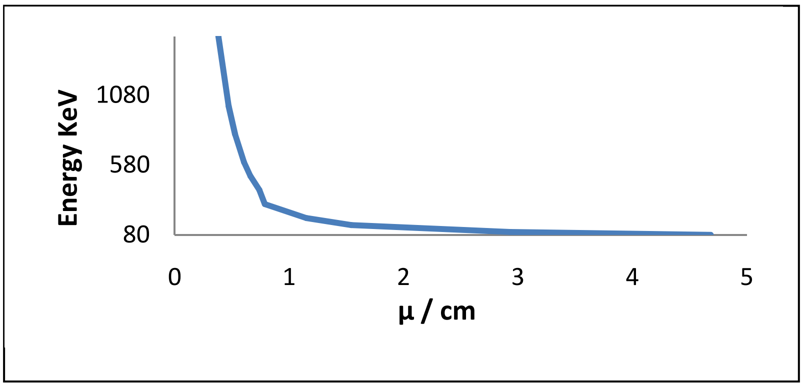


Fig.4 : The relation between energy and linear attenuation coefficient.

The attenuation of gamma rays, that dependent through a drum wall, is calculated as shown in Table 1. Classification of radioactive waste depending on the dose of radiation using the report of the International Atomic Energy Agency[8].

Results and discussion

The activity concentrations of radionuclides in waste samples from the RC in Al-Tuwaitha were determined by gamma spectrometry. Results showed the presence of natural radionuclides Ra-226, Th-234 and K-40, as well as the produced radionuclide Cs-137 and Eu-152 (from the nuclear fission and made man). As shown in Table1, the results of the activity concentrations in the waste samples collected from the studied location are presented and expressed in Becquerel. Analysis of waste streams, Table 1 and compare with Table 2 [8]. shows that more of the waste will be low activity waste (Category I). Waste that is above exemption levels, but with limited amounts of long lived radionuclides, such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities.

Table 1: Experimental and theoretical values of scaled linear absorption coefficient μ′ in cm^{-1} of iron and the all measurement.

Drum no	Type of Radionuclide's	Energy(keV)	Activity after attenuation	Half life	Attenuation coefficients 1/cm	Activity before attenuation in Bq	Dose of radionuclide in μSv/hr
1	Eu-152	121.7	1164.39	13.5 y	2.3	1552.237	0.000235239
	Eu-152	344.3	2075.42	13.5 y	0.78	2287.966	0.00098025
	Cs-137	661.6	238.84	6.70 h	0.58	256.799	0.000211448
	Eu-152	778.9	2326.56	13.5 y	0.52	2482.850	0.002406582
	Eu-152	964. 07	1980.47	13.5 y	0.47	2100.308	0.002519806
	Eu-152	1089.7	1983.31	13.5 y	0.45	2098.068	0.00284513
	Eu-152	1112.07	2152.07	13.5 y	0.44	2273.749	0.003146804
	Eu-152	1408	2350.63	13.5 y	0.39	2468.062	0.004324484
2 cloth	Th-234	92.8	2290.92	24.1 d	3.4	3504.169	0.000404677
	Ra-226	186.1	155.77	7.0E+08 a	1.27	182.569	4.22815E-05
	Bi-214	609.3	38.62	0.332 h	0.6	41.6278	3.15644E-05
	Cs-137	6616	640.66	30.07 y	0.58	688.833	0.000567184
	Ac-228	968.9	10.77	535.6	0.48	11.435	1.37898E-05
	Pa-234M	1001	3333	6.70 h	0.47	3534.680	0.004403244
3 Nylon	Pb-212	238.6	6.17	821.9y	1	6.991	2.07622E-06
	Bi-214	609.3	33.42	0.332 h	0.6	36.022	2.73144E-05
	Cs-137	661.7	30.19	30.07 y	0.58	32.460	2.67276E-05
	Ac-228	911.2	16.02	6.15 h	0.47	16.989	1.92651E-05
	K-40	1461	294.39	535.6	0.38	308.710	0.000561278
4	Th-234	92.8	2494.83	24.1 d	3.4	3816.068	0.000440697
	Eu-152	121.7	2412.83	13.5 y	2.3	3216.520	0.000487459
	Ra-226	186.1	1639.19	1.60E+03 a	1.27	1921.204	0.000444934
	Eu-152	344.3	3498.6	13.5 y	0.78	3856.896	0.001652439
	Cs-137	661.7	378.26	30 y	0.58	406.702	0.000334878
	Eu-152	688.7	2539.42	13.5 y	0.58	2730.366	0.002339989
	Eu-152	778.9	3198.19	13.5 y	0.52	3412.977	0.003308191
	Eu-152	964.07	3141.32	13.5 y	0.48	3335.568	0.004001787
	Pa-234M	1001	7105.87	6.70 h	0.47	7535.846	0.009390134
	Eu-152	1089. 7	3684.49	13.5 y	0.45	3897.682	0.005285534
	Eu-152	1408	3049.46	13.5 y	0.39	3201.804	0.00561017
	Eu-152	121.7	4845.6	13.5 y	2.3	6459.623	0.000978303

Table 2: Classification of radioactive waste by dose rate [8].

	Category	Dose Rate
Low active waste	Category I	< 2 mGy/h
Medium activity waste	Category II	2–20 mGy/h
High activity waste	Category III	> 20 mGy/h
Long lived waste	Category IV	> 4000 Bq/g of alpha emitters and other long lived beta emitters

Conclusions

This work presented the measured results of radioactivity levels for the extracting radioactive waste from RC located in the Al-Tuwaitha region. It can be concluded from overall results that the activity concentrations of waste, province does not pose a radiological hazard for the workmen. The risk assessor should compile the supporting documentation to ensure that it is sufficient to support the analysis and to allow an independent duplication of the results.

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