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Estimation the annual dose for residents in the area around the berms of Al-Tuwaitha nuclear site using RESRAD software

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Abstract

RESRAD is a computer model designed to estimate risks and radiation doses from residual radioactive materials in soil. Thirty seven soil samples were collected from the area around the berms of Al-Tuwaitha site and two samples as background taken from an area about 3 km north of the site. The samples were measured by gamma-ray spectrometry system using high purity germanium (*HPGe*) detector. The results of samples measurements showed that three contaminated area with ^{238}U and ^{235}U found in the study area. Two scenarios were applied for each contaminated area to estimate the dose using RESRAD (onsite) version 7.0 code. The total dose of resident farmer scenario for area A, B and C are 0.854, 0.033 and 2.15×10^{-3} mSv.yr^{-1}, respectively. While suburban resident scenario for area A, B and C are 0.807, 0.031 and 2.04×10^{-3} mSv.yr^{-1}, respectively.

Key words
Annual dose, RESRAD, Al-Tuwaitha nuclear site.

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تخمين الجرعة السنوية للمقيمين في المنطقة حول سواتر موقع التويثة النووي باستخدام برنامج RESRAD

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الخلاصة

RESRAD هو نموذج حاسوبي مصمم لتقدير المخاطر والجرعات الإشعاعية من المواد المشعة المتبقية في التربة. سبعة وثلاثون نموذج جمع من المنطقة المحيطة بسواتر موقع التويثة وأنموذجان كخلفية اشعاعية اخذت من منطقة تبعد حوالي 3 كم شمال الموقع. النماذج قيست بواسطة نظام قياس طيف أشعة غاما بأستعمال كاشف الجرمانيوم عالي النقاء (HPGe). نتائج قياس العينات بينت بأن هناك ثلاثة مناطق ملوثة باليورانيوم-238 و اليورانيوم-235 وجدت في منطقة الدراسة. تم تطبيق سيناريوهان لكل منطقة ملوثة لتقدير الجرعة باستخدام RESRAD (onsite) الإصدار 7.0. الجرعة الكلية لسيناريو المزارع المقيم للمناطق A وB و C كانت 0.854 و0.033 و 2.15×10^{-3} ملي سيفرت لكل سنة على التوالي، بينما سيناريو المقيم في الضاحية للمناطق A وB وC كانت 0.807 و 0.031 و 2.04×10^{-3} ملي سيفرت لكل سنة على التوالي.

Introduction

One of the most important steps in protecting human health in the contamination areas with radioactive matirail is to determine how these radionuclides may eventually reach people and thus cause them harm [1]. Evaluation of the impact of radionuclide releases on humans and on the environment is important, both to quantify the risks which arise from radionuclides present in the environment due to past human activities and to predict the possible future risks. The risks from these releases arise as a result of the transport of radionuclides in air, water, soils, or food from their release point to human [2]. Given that calculations for risk and dose assessments are complex, they are best done on a computer. RESRAD is a computer model designed to estimate risks and radiation doses from residual radioactive materials. RESRAD (short for residual radioactivity) was first released in 1989 and developed by Argonne national laboratory. It is a multifunctional tool to assist in developing cleanup criteria and assessing the risk and dose associated with residual radioactive material in soil [3]. The exposure pathways considered by RESRAD include (1) external radiation, (2) inhalation of radon or other gaseous radionuclides and contaminated dirt, (3) ingestion of contaminated plants, meat, aquatic foods, and soil, and (4) drinking contaminated water and milk [1].

The studied area

Al-Tuwaitha nuclear research center is considered the biggest and most complex nuclear facility in Iraq. It is located about 1 km east of the Tigris River and 3 km south of the southern edge of Baghdad**.** The facilities in Al-Tuwaitha cover approximately 1.2 km^2 and surrounding by earthen security berm with an approximately 4.6 km long and 30 m high and contain three gaps which allow for vehicle access. In 1991 and during the Gulf War, most of these facilities were extensively destroyed [4]. The area around the berms of Al-Tuwaitha site involved an area approximately 12 km^2. It is contained Ishtar village, military barracks, farms and a wide area not occupied by people. Therefore, it is important to evaluate the annual dose for those populations who resident in present time and those will resident in future. The dose for this area should not exceed the limits for public which recommendation by regulatory control.

Collection samples

Two soil samples were taken from the area located approximately 3 km north of the site in order to establish background level. 37 soil samples were collected from the area around the berms of Al-Tuwaitha site. Fig.1 shows the location of samples in the area around the berms of Al-Tuwaitha site and background samples. The samples were taken at 15 cm depth from the top surface soil layer to make approximately 1.5 kg weight per sample, using trowel tool. Each soil sample is filled into secure polyethylene bag with sealable tops to prevent cross contamination and sent to the laboratory. The soil sample is contained label recorded in it the information about the sample such as code, sample type, data of collected, location and GPS coordinates. The samples dried, grinded, sieved, filled into 500 ml Marinelli beakers and stored for about one month to obtain the radioactive secular equilibrium between parent and their daughter radionuclides. Samples were measured by gamma-ray spectrometry system using high purity germanium (HPGe) detector with relative efficiency 65%. To determine the radionuclides in soil samples, the energy 1001.03 keV (^{234m} Pa) used for ^{238}U, 911.20 keV (^{228}Ac) for ^{232}Th, 609.31 keV(^{214}Bi) for ^{226}Ra, 163.76 and 205.31 keV used for (^{235}U), ^{40}K at 1460.81 keV and ^{137}Cs at 661.65 keV were used.

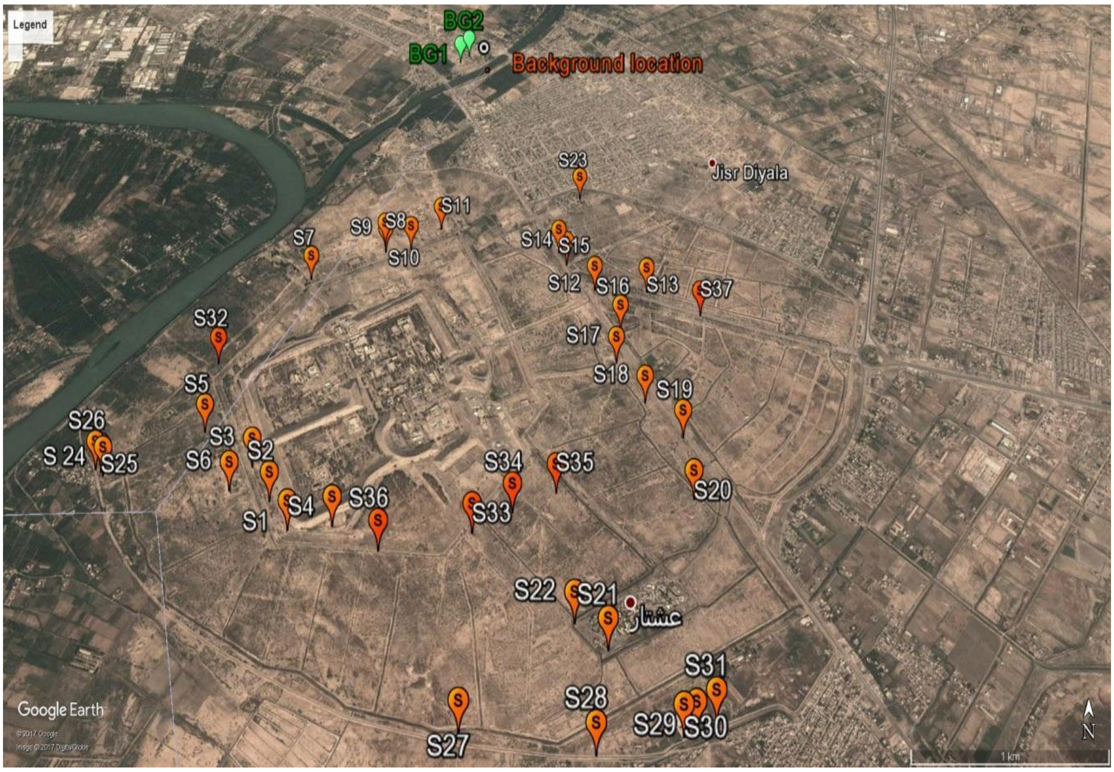

Fig.1: The location of samples in the area around the berms of Al-Tuwaitha site and background samples.

The radionuclide concentration in the soil sample

The specific activity of ^{238}U, ^{235}U, ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs for all soil samples are given in Table 1. According to results of the samples measured in gamma spectrometer.

There are three areas contaminated with uranium component (^{238}U and ^{235}U) which considered clearly above background concentrations were found in the area around the berms and divided according to their location to area A, B and C. Fig. 2 shows the location of contamination areas.

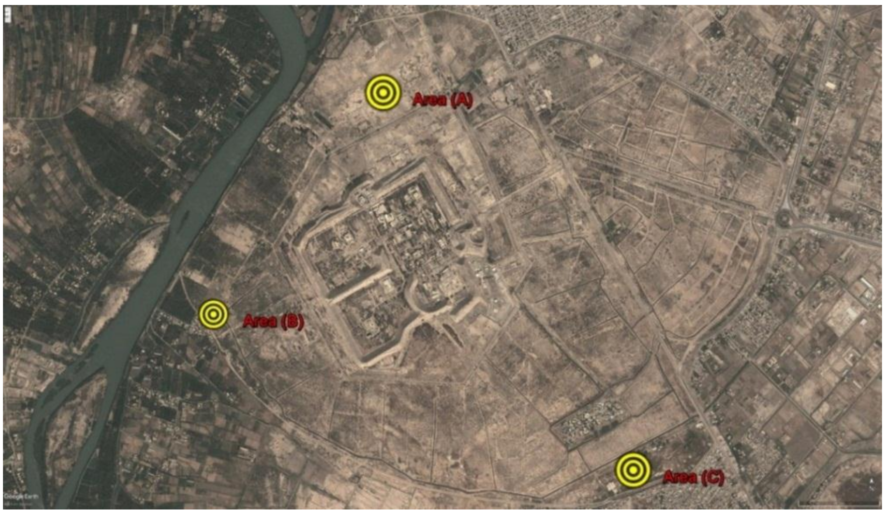

Fig. 2: Location of contamination areas in yellow circles which are clearly above background concentration. Area A includes samples S-8 and S-9, area B includes samples S-24, S-25and S-26, and area C includes samples S-29, S-30 and S-31.

Table1: The measurements of radionuclides activity in the soil samples.

N	**Sample code**	**Activity Concentration (Bq.kg^{-1})**					
		^{238}U (^{234m}Pa)	**^{235}U**	**^{232}Th(^{228}Ac)**	**^{226}Ra(^{214}Bi)**	**^{40}K**	**^{137}Cs**
1	S-1	<MDA	<MDA	19.95±1.75	18.16±2.63	383.44±10.35	3.84±0.49
2	S-2	<MDA	<MDA	15.52±1.63	18.12±2.5	372.39±10.49	<MDA
3	S-3	<MDA	<MDA	16.74±1.5	16.54±2.28	348.6±9.5	<MDA
4	S-4	<MDA	<MDA	18.67±1.67	18.26±1.54	341.4±9.62	5.92±0.49
5	S-5	<MDA	<MDA	18.62±2.81	19.11±2.41	409.65±21.53	<MDA
6	S-6	<MDA	<MDA	17.65±1.71	17.53±1.7	402.92±9.94	<MDA
7	S-7	<MDA	<MDA	15.5±1.49	19.59±1.82	364.56±10.08	1.35±0.34
8	S-8	50674±847.5	1959.5±29.2	19.19±5.65	19.02±1.74	345.63±24.9	<MDA
9	S-9	7523.6±152.25	272.54±5.23	15.9±1.67	17.24±1.5	289.9±8.95	<MDA
10	S-10	<MDA	<MDA	15.05±1.63	17.6±1.4	357.67±9.85	1.29±0.3
11	S-11	<MDA	<MDA	16.22±1.65	18.73±1.2	326.76±9.7	2.95±0.4
12	S-12	<MDA	<MDA	18.2±3.9	16.32±2.11	339.5±20.8	<MDA
13	S-13	<MDA	<MDA	19.14±3.6	16.82±1.9	398.9±22.58	3.24±1.009
14	S-14	<MDA	<MDA	11.4±2.44	12.78±2.75	261.1±16.7	1.11±0.5
15	S-15	<MDA	<MDA	16.87±3.5	18.12±1.4	299.67±19.32	<MDA
16	S-16	<MDA	<MDA	18.4±4.1	18.4±2.5	414±23.07	<MDA
17	S-17	<MDA	<MDA	23.2±3.85	16.69±2.3	392.22±23.6	2.86±1.04
18	S-18	<MDA	<MDA	14.88±3.61	17.46±2.1	343.75±20.5	<MDA
19	S-19	<MDA	<MDA	16.64±3.2	16.13±2.3	332.7±20.6	<MDA
20	S-20	<MDA	<MDA	16.15±3.6	16.35±1.95	371.49±22.1	<MDA
21	S-21	<MDA	<MDA	16.69±1.63	19.84±1.32	380.95±10.2	1.62±0.41
22	S-22	<MDA	<MDA	11.26±0.7	17.53±1.32	365.4±10.49	10.7±0.63
23	S-23	<MDA	<MDA	15.72±1.66	16.08±1.2	339.8±10.41	<MDA
24	S-24	196.69±14.37	9.34±0.68	16.37±1.7	19.39±1.7	406.09±10.54	<MDA
25	S-25	1931.3±79.19	71.03±3.2	19.26±1.8	23.05±1.8	378.4±10.2	1.84±0.3
26	S-26	1428.2±167.3	54.4±2.7	19.1±3.9	16.26±2.8	389.24±21.4	2.05±0.84
27	S-27	<MDA	<MDA	20.15±2.1	18.19±1.1	412.2±10.96	<MDA
28	S-28	<MDA	<MDA	19.13±1.6	19.49±1.5	393.59±9.88	1.48±0.3
29	S-29	28.4±3.8	3.2±0.3	19.07±1.7	18.74±1.4	381.49±10.15	6.35±0.5
30	S-30	78.8±34.8	5.7±0.9	17.12±1.6	18.69±1.7	341.96±10.6	<MDA
31	S-31	80.04±25.02	7.1±0.8	17.24±1.7	16.32±2.3	368.2±9.8	0.65±0.2
32	S-32	<MDA	<MDA	16.48±3.4	18.54±1.9	370.28±21.7	<MDA
33	S-33	<MDA	<MDA	16.19±3.7	17.39±2.6	410.33±22.39	2.2±0.7
34	S-34	<MDA	<MDA	19.5±3.3	19.02±2.1	422.3±22.9	4.28±0.96
35	S-35	<MDA	<MDA	21.02±3.7	18.52±2.2	393.9±22.3	2.66±0.91
36	S-36	<MDA	<MDA	20.9±3.6	16.35±1.9	359.34±21.7	<MDA
37	S-37	<MDA	<MDA	17.56±3.6	16.63±2.1	359.8±22.12	2.25±0.8
38	BG-1	<MDA	<MDA	17.75±1.3	19.7±2.6	395.48±25.3	2.35
39	BG-2	<MDA	<MDA	15.48±1.4	17.97±2.3	323.73±19.5	<MDA

The input parameters of RESRAD

Resident farmer and suburban resident scenario applied for each contaminated area to evaluate the dose using RESRAD (onsite) version 7.0 codes created in 2014. The Table 2 showed the input parameters values of RESRAD which used to calculate the annual dose of these areas for two scenarios.

Results and discussions

Table 3 shows the results of RESRAD calculations. The total dose of resident farmer scenario for area A, B and C are 0.854, 0.033 and 2.15×10^{-3} $mSv.yr^{-1}$, respectively. The large contribution of total dose comes from external, plant and soil ingest dose with 88, 6 and 4 %, respectively.

Table 2: The input parameters for RESRAD used to calculate the dose of contaminated area.

parameters	unit	Area(A)		Area(B)		Area(C)	
		Resident Farmer	**Suburban Resident**	**Resident Farmer**	**Suburban Resident**	**Resident Farmer**	**Suburban Resident**
Mean radionuclide concentration @	Bq/gm	29.098 for ^{238}U 1.115 for ^{235}U	29.098 for ^{238}U 1.115 for ^{235}U	1.185 for ^{238}U 0.044 for ^{235}U	1.185 for ^{238}U 0.044 for ^{235}U	0.06256 for ^{238}U 0.0053 for ^{235}U	0.06256 for ^{238}U 0.0053 for ^{235}U
Contaminated area@	m^2	1250	1250	500	500	1000	1000
Thickness of contaminated@	m	0.15	0.15	0.15	0.15	0.15	0.15
Cover depth@	m	0	0	0	0	0	0
Average annual wind speed [7]	m/s	3.1	3.1	3.1	3.1	3.1	3.1
Precipitation[8]	m/yr	0.152	0.152	0.152	0.152	0.152	0.152
Fraction of time indoors[3]	_	0.50	0.50	0.50	0.50	0.50	0.50
Fraction of time outdoors[3]	_	0.25	0.25	0.25	0.25	0.25	0.25
Plant food[3]	_	0.5	0.1	0.5	0.1	0.5	0.1
Milk[3]	_	0.1	Not used	0.1	Not used	0.1	Not used
Meat[3]	_	0.1	Not used	0.1	Not used	0.1	Not used
Aquatic food[3]	_	0.5	Not used	0.5	Not used	0.5	Not used
Soil ingestion[3]	g/yr	36.5	36.5	36.5	36.5	36.5	36.5
Drinking water intake[3]	L/yr	510	Not used	510	Not used	510	Not used
Duration exposure[3]	yr	30	30	30	30	30	30
Inhalation rate[3]	m^3/yr	8400	8400	8400	8400	8400	8400

@ Current study

The total dose for suburban resident scenario for area A, B and C are 0.807, 0.031 and 2.04×10^{-3} $mSv.yr^{-1}$, respectively. The large contribution of total dose comes from external, soil ingestion and plant dose with 93.7, 3.87 and 1.25%, respectively. According to IAEA safety standard [5, 6], the total dose of area A for resident farmer scenario and suburban resident scenario were exceed the dose constraint for soil cleanup or site decontamination from all pathways which is 0.3 $mSv.yr^{-1}$ above background. The total dose of area B for resident farmer scenario and suburban resident scenario were below the dose constraint but is stilled above of the dose for clearance material of order 10 $\mu Sv.yr^{-1}$, which means that the optimization less than 10 $\mu Sv.yr^{-1}$ might not be warranted on radiological protection grounds. The total dose of area C for both scenarios were below the dose for clearance material 10 $\mu Sv.yr^{-1}$, which means that, the dose of area C is unwarranted on radiological protection grounds and can be release from regulatory control [6]. Figs.3-6 showed the total dose over the time and the contributions pathways of all nuclides to total dose of area A for both scenarios. From Figs.3-6, the dose appears reduction over the time until reach the zero value, but in resident farmer scenario (Figs. 3-4) the value arises slightly after many years and then back reduces again. The reason of the dose reduction attributed to the dilution of the activity concentrations of radionuclide in the soil contaminated. This dilution may come from some factors such as change in thickness of cover contaminated area, leaching and also radionuclide decay, but in case of uranium contaminated which has long half-life 4.5×10^{10} year, the reduction belong to decay is negligible in comparison to the other two. After hundreds years, when radionuclides adsorbed in soil leached by infiltrating water (precipitation water or irrigation water) from the contaminated zone and reached to groundwater used from public, the total dose is starting rise slightly with time (as in Figs.3-4). This behavior only appears in resident farmer scenario because the groundwater contamination used from public and the dose of drink water will be large contribution to total dose.

Table 3: The results of RESRAD for calculations the dose of area A, B and C for both scenarios.

Area	Scenario	Total dose ($mSv.yr^{-1}$)	Contributions pathways to total dose ($mSv.yr^{-1}$)					
			External	Inhalation	Plant	Meat	Milk	Soil Ingest
(A)	Resident Farmer	0.854	0.747	1.032×10^{-2}	0.05156	1.608×10^{-3}	4.096×10^{-3}	3.883×10^{-2}
	Suburban Resident	0.807	0.747	1.032×10^{-2}	1.033×10^{-2}	-	-	3.883×10^{-2}
(B)	Resident Farmer	0.033	0.029433	3.81×10^{-4}	2.097×10^{-3}	6.54×10^{-5}	1.6663×10^{-4}	7.897×10^{-4}
	Suburban Resident	0.031	0.029433	3.81×10^{-4}	4.194×10^{-4}	-	-	7.897×10^{-4}
(C)	Resident Farmer	2.15×10^{-3}	1.912×10^{-3}	2.27×10^{-5}	1.16×10^{-4}	3.61×10^{-6}	9.19×10^{-6}	8.71×10^{-5}
	Suburban Resident	2.04×10^{-3}	1.912×10^{-3}	2.27×10^{-5}	2.31×10^{-5}	-	-	8.71×10^{-5}

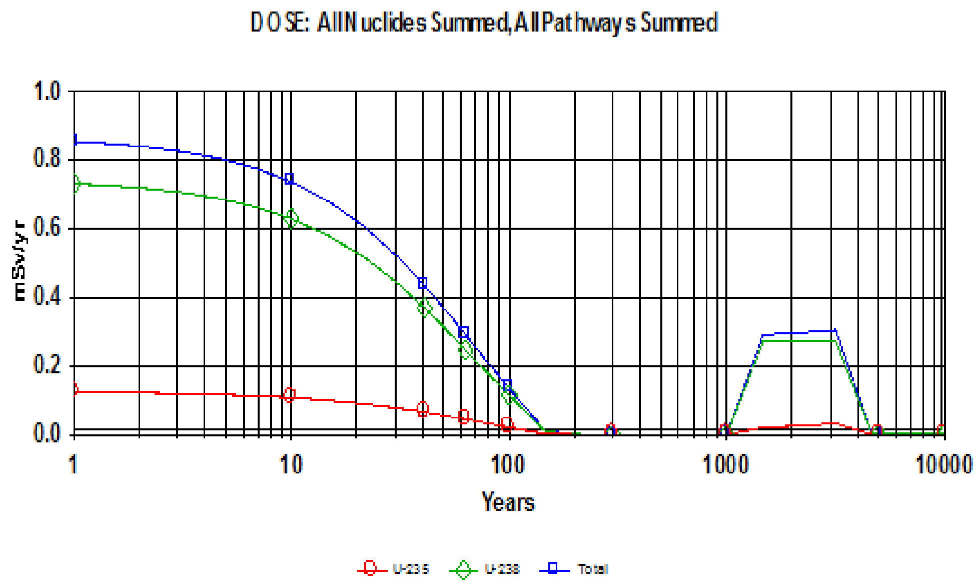

Fig.3: Annual dose over the time of area (A) for resident farmer scenario.

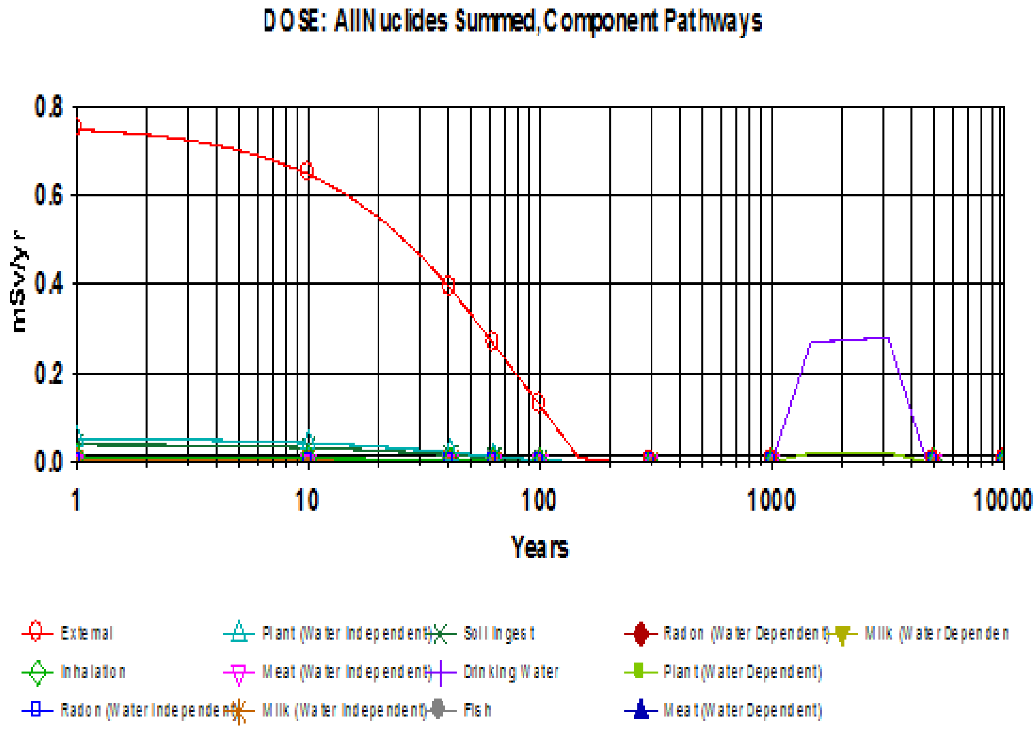

Fig.4: The contribution pathways of all nuclide to total dose of area (A) for resident farmer scenario.

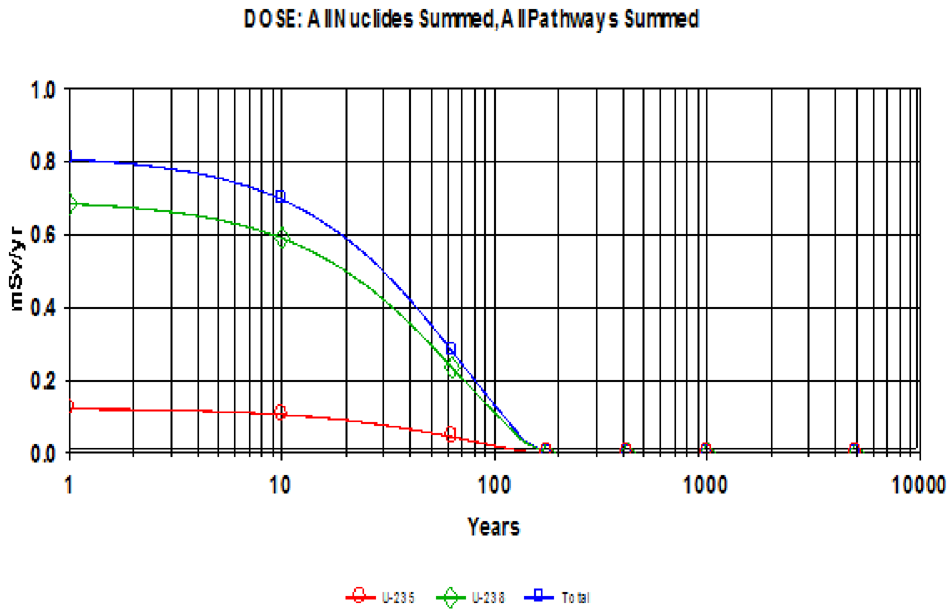

Fig.5: Annual dose over the time of area (A) for suburban resident scenario.

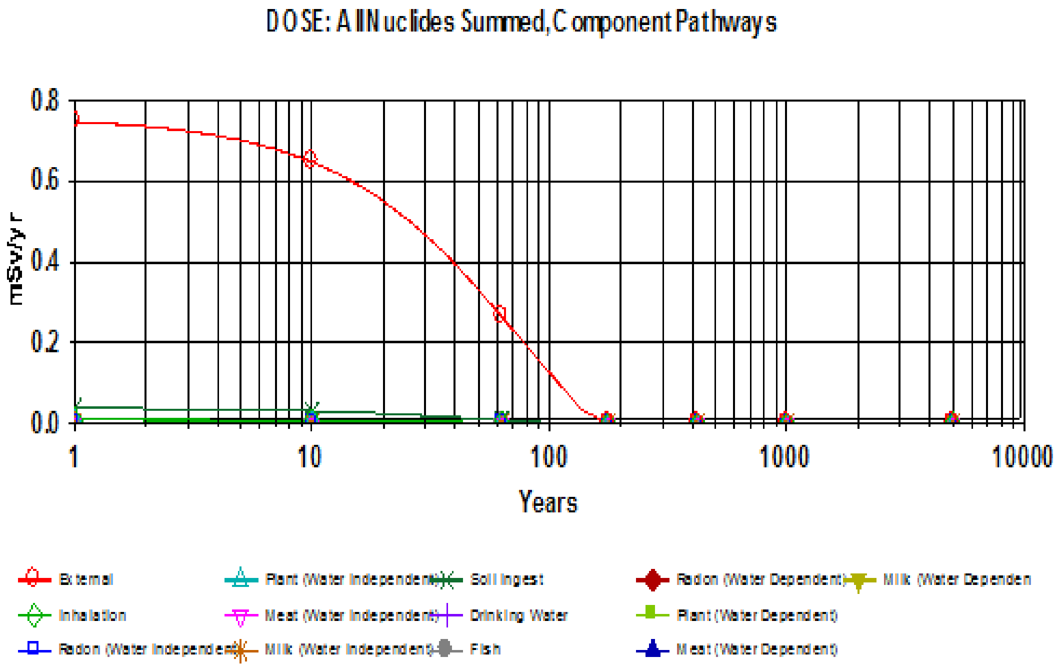

Fig.6: The contribution pathways of all nuclide to total dose of area (A) for suburban resident scenario.

Conclusions

The total dose of resident farmer scenario is higher than suburban resident scenario because it includes all environmental pathways. The early major pathway is external and the later major pathway is drink water. The total dose of area A for both scenarios was exceeded the dose constraint which is 0.3 mSv.yr^{-1}, the total dose of area B for both scenarios was below the dose constraint but it is stilled above the dose for clearance material which is 10 µSv.yr^{-1}, while the total dose of area C for both scenarios were below the dose for clearance material, that means the dose of area C is unwarranted on radiological protection grounds and can be release from regulatory control.

References

[1] Brice Smith. A Community Guide to Estimating Radiation Doses from Residual Radioactive Contamination. 15, 4. (2008).

[2] International Atomic Energy Agency (IAEA). "Validation of models using Chernobyl fallout data from southern Finland", IAEA-TECDOC-904, (1996).

[3] C.Yu, A.J. Zielen, J. J. Cheng, D.J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III, W.A. Williams, H. Peterson., "User’s manual for RESRAD version 6". Environmental Assessment Division. United States. (2001).

[4] R.K. Chesser, B. E. Rodgers, M. Bondarkov, E. Shubber, C. J. Phillips, Bulletin of the Atomic Scientists, 65, 3 (2009) 19-33.

[5] International Atomic Energy Agency (IAEA)." Disposal of radioactive waste". sefety standerds No.SSR-5, Vienna, (2011).

[6] International Atomic Energy Agency (IAEA). "Release of site from regulatory control on termination of practices", Safety Guide. IAEA Safety Standards Series No.WS-G-5.1, Vienna, (2006).

[7] S. Al-Noori and A. Al-Sakini, Journal of the College of Basic Education for Educational and Human Sciences, Babel University, 18 (2004) 372-357.

[8] A. Al-Adili, and S. Ali, Tenth International Water Technology Conference, IWTC10 2006, Alexandria, Egypt, (2006) 1049-1055.