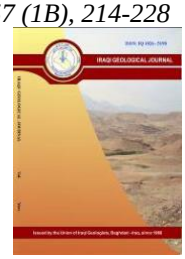
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Natural and Artificial Radionuclides Distribution in Surface Soil in Baghdad International Airport Region

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Abstract

This is the first time that radiological assessment achieved in the Baghdad International Airport (BIA) in Iraq. Twenty-three sites were sampled from upper 5 cm of the surface soil within the BIA to be analyzed for the radioactivity of natural radionuclides Ra-226, Th-232 and K-40 and the artificial radionuclide, Cs-137 using gamma spectroscopy based on Hyper pure Germanium detector (HPGe). Ten samples out of the 23 samples were analyzed for U-238, U-235 using the Neutron Activation Analysis method. To determine the percentage of DU [DU (%)] which is calculated from the $^{235}U/^{238}U$ isotope ratio. The study showed that there is a possibility of slight contamination with depleted uranium in two sites out of the 23 sites that were examined. The average activities of Ra-226, Th-232, and K-40 in the study area are within the limits of world averages, while there are evidences that new feeding of Cs-137 in the region, reaches about 19 Bq/kg, from the new global fallout after Chernobyl accident. The measured and calculated absorbed doses in the study area were within international limits and no need for farther monitoring. Annual effective dose equivalent due to resuspension of Ra-226 is estimated to be 1.0E-10Sv, and this value is negligible compared with 1 mSv permissible value for public recommended by ICRP.

Keywords: Radioactivity; Radiation Dose; BIA, Surface soil, Resuspension

1. Introduction

According to its origin, two types of radioactive contaminations may be found in the surface soil, contamination by naturally occurring radioactive materials (NORM) and/or artificial radionuclides. NORM includes U-238, U-235, Th-232 series, and single radionuclides such as K-40 and Rb-87. The artificial (industrial) contamination caused by radionuclides added to the environment due to the operations of nuclear reactors, nuclear explosion tests, and nuclear accidents. Cesium-137 and I-130 are the most famous and most productive in nuclear tests or nuclear accidents among the others (Eisenbud & Gesell, 1997). Other types of artificial radionuclides come from the use of waste radioactive materials (depleted uranium (DU)) resulting from the enrichment of uranium in nuclear reactors (IAEA, 2009).

Depleted uranium was used twice by the US and allied forces against Iraqi troops and personnel in 1991 and 2003 (Gerdes et al., 2004). The potentially contaminated sites are all shielded building and army sites, all armor camps, and other sites of special importance. It appears approximately 100 to 200 metric tons was shot at tanks, trucks, buildings and people in largely densely populated areas (Fahey, 2003)

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Cesium-137 deposited from the atmosphere may contaminate the surface soil of Baghdad City (Ali and Marouf, 2011). Because of its solubility and close physicochemical similarity to potassium, cesium can be considered one of the most hazardous radionuclides in the environment and one of the dangerous products of nuclear fission. It is a source of gamma radiation and also is a carcinogen (UNSCEAR, 1988; IAEA, 1996; UNSCEAR, 2000).

Internationally, many researches have been conducted to investigate the effect of DU in Kosovo, Serbia–Montenegro, Bosnia, and Herzegovina, Kuwait, and Iraq during wartime in Kosovo (Danesi et al., 2003; Salbu et al., 2003), Serbia–Montenegro (McLaughlin et al., 2003), Bosnia and Herzegovina (UNEP, 2003), Kuwait (Salbu et al., 2005) and Iraq (Fahey, 2003; Gerdes et al., 2004). At all sites, a part of the DU contamination was identified as DU particles except in Iraq where no information on particles appears to be available. Although there is little known about the actual quantities of DU released or the locations of contamination in Iraq, it appears approximately 100 to 200 metric tons was shot at tanks, trucks, buildings and people in largely densely populated areas (Fahey, 2003). In April 2003, UNEP, (2003) published a desk study on the Environment in Iraq. One of the issues identified in the study was the impact of the use of depleted uranium (DU) during the Gulf war conflict. The report accordingly recommended that a comprehensive field assessment have to be conducted in Iraq to investigate the use of DU and its residual impacts.

Some studies in Iraq concerning DU are unpublished thesis such as Al-Hilli (1998); Al-Saji (1998); Al-Temimi (2003); and Al-Bayati (2004). Others are reports or published researches such as Al-azzawi et al. (1997; 1998; 1999). Almost those studies deal with the modeling of dispersing of DU in soil, water, and air in southern Iraq. May be the last study achieved by Al-Ttai, 2007, titled: assessment and treatment of DU concentration of soil selected from some Iraqi locations. This study focused on treating contaminated soil. Husain (2004) studied the concentration of depleted uranium and the radiation pollution in selected soils in Saladin Governorate. He concluded that a very low concentration of DU is found in the soil of the studied area. Al- azzawi (2006) reported detail study regarding du in Iraq and she confirmed that DU projectiles were used against Iraq during wars 1991 and 2003. Al-Ubaidi (2006) studied natural and industrial radioactive pollutants in the environment of Baghdad city using Gamma Spectrometry and Solid-State Nuclear Track Detector CR-39. Abojassim and Rasheed (2021). Achieved a study on the natural radioactivity of soil in the Baghdad governorate. Most of the area in the current study was not included. They concluded that the average values of specific activity of terrestrial gamma radiation (^{238}U, ^{232}Th and ^{40}K) for soil samples in the Karkh and Rasafa districts in Baghdad Governorate were lower than the world average values according to UNSCEAR (2008). Essa et al. (2021) studied the contamination with DU in soil samples collected from Al-Nahrwan site south of Baghdad, the reached that there is no evidences for DU in the studied area and the ratio of $^{235}U/^{238}U$ less than the value in natural case.

With regard to cesium, several studies have been carried out to investigate the distribution of cesium-137 in the soil in Iraq. The important research achieved by Ali and Marouf (2011) shows that the cesium content in the soil of Iraq is attributed to the global and regional fallout from the nuclear weapon tests and nuclear accidents. The activity of Cs-137 in surface soil in Iraq ranges between below detection limit (BDL) (about 0.5 Bq/kg for Cs-137) to 175 Bq/kg. The activity in Baghdad Region not exceeds 7 Bq/kg.

In this study, soil samples were collected from selected sites in Baghdad International Airport (BIA) that were potentially contaminated with natural occurring radioactive materials or DU or subjected to other artificial radioactive pollutants especially Cs-137. The aim of this study is a radiological assessment then health risk and radiological hazards would be estimated. This is the first time that a radiological assessment has been studied at BIA.

The study area represents the BIA region within the city of Baghdad (Fig.1). It represents the floodplain mostly horizontally with an elevation of 18-29m above sea level. The upper part of the soil

in the study area is non-homogenous, characterized by great lateral and vertical variations. These soils seem to have been highly affected by seasonal floods of the Tigris River, but now human activities are the main influence. The area covers with Quaternary sediments of Pleistocene and Holocene age (Ali, 2012). The upper layer of the soil characterizes by the presence of clay sediments changes in some locations to silt as a result of irrigation channels in the region. The analysis of the sediments of the study area showed that the sediment consists of calcite, dolomitic, and clay sediments in different proportions (Rashid, 2001).

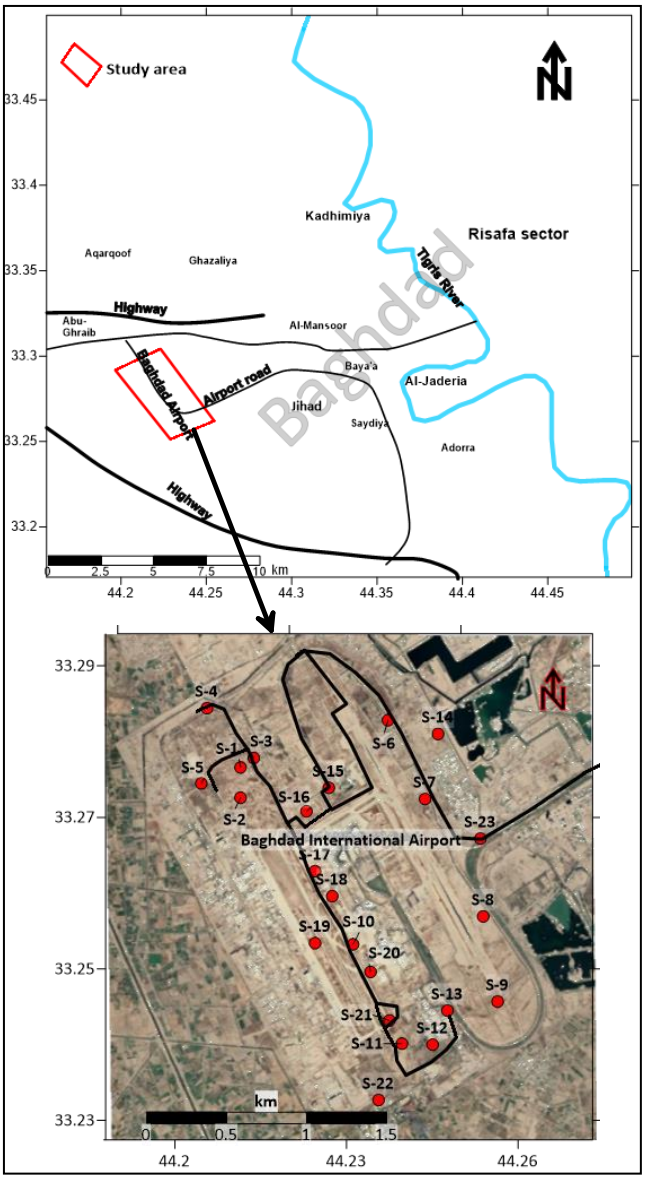


Fig.1. The study area. The upper part shows the city of Baghdad, the lower part is a zoom of Google map for BIA region with sampling locations indicated with red solid circles and samples ID.

2. Materials and Methods

2.1. Radioactivity Measuring in Soil Sample

Twenty-three soil samples (given the ID: S-1 to S-23) (Fig.1) were selected from upper 5 cm of the surface soil within the BIA to be analyzed for gamma emitters to measure the radioactivity of natural radionuclides Ra-226, Th-232 and K-40 and the artificial radionuclide, Cs-137 using gamma spectroscopy based on Hyper pure Germanium detector (HPGe). The measurements were done in the

laboratories of the Radiation Protection Center (RPC), Ministry of Health and Environment and the laboratories of the Iraqi Radioactive Sources Regulatory Authority (IRSRA) in Iraq. The concentrations of Ra-226 representing U-238, Th-232, and potassium-40 in Bq/kg were measured. To determine the specific activity of ^{226}Ra, the gamma-ray lines at 186.2 of Ra-226 and/ or at 295.2 keV and 351.9 keV from ^{214}Pb and at 609.3 keV and 1764.5 keV from ^{214}Bi were used. The gamma-ray lines of the 727.3 keV from ^{212}Bi and 583.2 keV, and 2614.5 keV from ^{208}Tl were used to determine the specific activity of ^{232}Th. The specific activity of ^{40}K was measured directly by its own gamma-ray line at 1460.8 keV and the energy gamma line of 662 keV is used for measuring the activity of Cs-137. The activity (*A*) of a radionuclide in Bq/kg is calculated according to equation (1).

$$A=TC-BG/ \varepsilon . \gamma . t.m \quad (1)$$

Where TC: total count of area under peak of energy of the radionuclide in the samples, BG: background area under peak of the radionuclide in absence of the sample, ε: efficiency of the detector at the energy of the radionuclide, γ : the intensity of the gamma rays emitted by the radioactive source at that energy, t: spectrum collection time, (equal to 10800s in this study), m : mass of the sample and equal to 0.5 kg.

Ten samples (S1-S6, S8, S11, S13. and S15, Fig. 1) were analyzed for U-238, U-235 using the Neutron Activation Analysis method (NAA). The analyses were achieved in Bureau Veritas Laboratories/ Canada, refer to Alfassi (1990) for the method of analysis. These analyses are used to determine the percentage of DU [DU (%)] which is calculated from the ^{235}U/^{238}U isotope ratio as follows (UNEP, 2003).

$$DU[\%] = 100x\ (R_u\text{-nat-}R_m/R_u\text{-nat-}R_{DU}) \quad (2)$$

Where $R_{U\text{-}nat}$ Isotope ratio ^{235}U/^{238}U of natural U (= 0.00725), R_{DU} Isotope ratio ^{235}U/^{238}U of depleted U (= 0.002), R_m measured isotope ratio ^{235}U/^{238}U of the samples

2.2. Total radiation absorbed dose rate

The Ambient gamma radiation absorbed dose rate in μSv/h (or nGy/h) was measured in the study area using portable and/or car-mounted devices. The measurements include all the sampling points. InSpector™ 1000 Digital HandHeld Multichanne (Canada) or MONA ENVINET's mobile spectroscopic detection and survey system was used in land vehicles in current study. The MONA system is a combination of a high sensitive detector unit and a ruggedized laptop as control unit. It is able to detect smallest amounts of artificial radiation in the environment, coming from potential threats like nuclear incidents or accidents, non-authorized usage of radioactive sources, etc. or is used to measure the radiation dose rate. MONA uses a high sensitive 4 liter NaI (TI) scintillation detector and the dose rate of the gamma spectrometer. The devises were recorded readings for the ambient absorbed doses almost close in all sites (Fig. 2), and so both readings were adopted complementing one another in the locations where the readings for one of them were not taken.

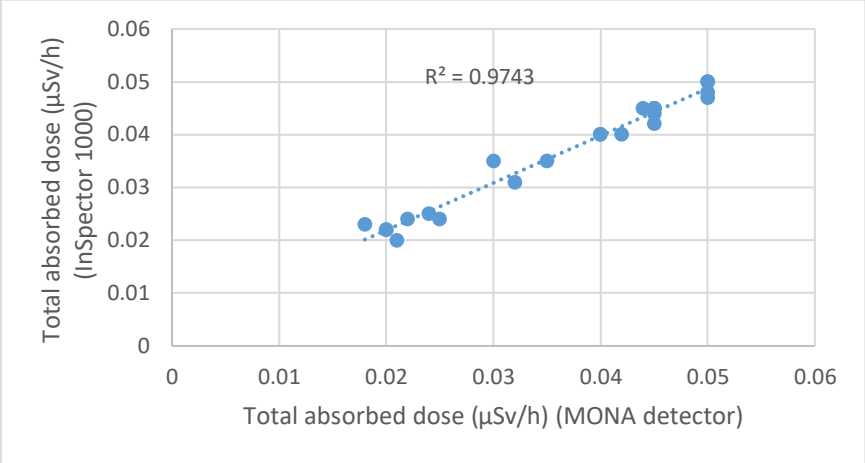


Fig.2. Strong correlation between dose readings with mobile MONA detector and portable InSpector - 1000 detector

2.3. Ambient absorbed dose

in the air one meter above the surface of the earth resulting from the presence of natural radionuclides such as ^{226}Ra, ^{232}Th, ^{40}K, in soil samples, which can be calculated from the following equation (Beretka and Mathew, 1985;UNSCEAR, 2008).

$$D(nGy/h)=0.462\ ARa + 0.604ATh + 0.0417AK \quad (3)$$

Where: ARa, ATh, and AK: are the concentrations of radium, thorium, and potassium, respectively, 0.462, 0.604 and 0.0417: are conversion coefficients from specific radioactivity concentration to absorbed radioactive dose in units of (nGy kg / Bq.h).

3. Results and Discussion

3.1 Radioactivity in Soil Samples

The activity of Ra-226, Th-232, K-40 and Cs-137 in all soil samples selected in this study are shown in Table-1. The table includes the measured absorbed doses (µSv/h) in the same locations. These results obtained using gamma spectrometry system. Isorad maps were plotted for the three radionuclides Ra-226, Th-232, K-40 and Cs-137within BAI as shown in figs. 3a-d respectively.

Fig. 3a shows that the activity of Ra-226 in the soil of BAI ranges between 21.5 Bq/kg to 53.8 Bq/kg with an average of (36.9±11) Bq/kg. The average activity of radium in the soil of BAI is close the average of Ra-226 in the soil in the worldwide which about 32 Bq/kg (UNSCEAR, 2010). It is worth noting that most of the sites within BAI from which the samples were selected have higher radioactivity than the global average for radium in the soil. The max. activity of Ra-226 is recorded in near site of S-6 (Qasr Al-Melh), while the min. activity is in S-18 near the runway within the BAI.

The distribution of Th-232 (Fig. 3b) shows that Th-232 most likely has the same distribution pattern as radium, increasing in the areas around the runway and decreasing in the center of the airport. The range of Th-232 is 14.1 - 45 Bq/kg. The maximum value is found in S-6 (Qasr Al-Melh) while the minimum value is in S-18. The average of Th-232 in the soil of the BAI is 29.1 ± 9 Bq/kg which is below the worldwide average 45 Bq/kg (UNSCEAR, 2021). On the other hand, some locations have Th-232 concentration as the same level of the worldwide average as in S-6 (Qasr Al-Melh).

While the K-40 concentrations ranged between 208.6 and 520.1 Bq/kg, at an average of 339.7±78.7 Bq/kg (about 1.2 % total potassium), Potassium is a major element and the eighth most abundant in the earth's crust (Ding et al., 2023). The highest activity in BAI soil is in S-11 near Radwaniya check point.

Fig. 3c shows the distribution of K-40 in the soil of the BAI. The concentrations of potassium are below the international averages, where the total content of potassium in the soil ranges between 0.05% and 9.5% at an average of 1.68% (Fischer, 1975), 0.04-3% (Helmke and Sparks, 1996) or between 0.3% and 4.5% (Eisenbud and Gesell, 1997). The Potassium content in soil differs depending on the clay minerals in soils with a high content of sulfates and grain size of the soil (Fischer, 1975).

The distribution of Cs-137 in study area is presented in contour map shown in Fig. 3d. The activity of Cs-137 ranged between below detection limit (BDL) and 19.4 (Bq/kg). Most of the samples gives BDL of Cs-137, two locations within BAI (S-1 and S-11) contain relatively high concentration of Cs-137. Generally, except these two points, activity of Cs-137 in all the other samples within the average value in city of Baghdad and below the activity of Cs-137 in other locations in Iraq (Ali and Marouf, 2011) (0.5-175 Bq/kg), the activity of 175 Bq/kg were recorded in the Western Desert in Iraq.. The activity of Cs-137 in the soil of Iraq is a result of the global fallout due to the nuclear explosions or as a result of accidents in nuclear reactors. The Chernobyl accident in Ukraine in 1986 is considered the largest and most important accident that affected most regions of the world, especially the neighboring European countries. This incident led to the pollution of areas in the northern part of Iraq (Marouf et al., 1992) other parts of Iraq influenced with less level of Cs-137 (Ali and Marouf, 2011).

Ali and Marouf (2011) in their study for the period from 1999-2003, they found that cesium concentrations in Baghdad do not exceed 7 Bq/kg, while in the current study there are sites with relatively elevated radioactivity (19.1 Bq/kg). This indicates that the soil surface is still fed by radioactive fallout from new sources, perhaps the Fukushima accident is the most important of these sources. This conclusion is confirmed by other researchers in the region (Aba et al., 2021). Or that these concentrations were transferred from other regions during the redistribution processes through the dust storms that occur in the region, where Ali and Al-Shijeri (2019) found that the dust storms in Baghdad and the neighboring areas carry with them concentrations of cesium. The distribution of cesium-137 was not homogeneous, and it did not cover the study area completely with the same concentrations. Two locations appear as hot spot within the BAI.

Table 1. Activity of Ra-226, Th-232, K-40 and Cs-137 in soil samples selected from BIA and the corresponding absorbed dose recorded by portable dosimeters. Sampling location as shown in Fig.2

Sample ID	Radioactivity (Bq/kg)				Dose (µSv/h)	Location
	Ra-226	Th-232	K-40	Cs-137		
S-1	42.8	23.1	360.0	19.4	0.045	BIA (near a destroyed tank)
S-2	44.8	25.4	401.5	2.2	0.05	BIA
S-3	49.0	44.2	284.0	BDL	0.045	BIA (near destroyed plane)
S-4	52.6	28.4	251.1	13	0.045	BIA (near Kuwait Co.)
S-5	48.2	34.1	323.5	BDL	0.044	Near the anti-aircraft weapon
S-6	53.8	45.0	370.0	1.5	0.045	Qasr Al- Melh
S-7	41.7	43.2	501.2	BDL	0.05	BIA
S-8	42.6	42.0	399.0	BDL	0.045	BIA
S-9	45.4	14.1	330.0	6	0.05	BIA
S-10	38	29.0	288.0	8	0.04	Runway
S-11	42.6	26.0	520.1	16.4	0.05	Radwaniya check point
S-12	41.2	32.8	270.0	5	0.045	BIA
S-13	49.0	43.8	378.1	6	0.042	airport exit
S-14	22.4	21.6	310.3	1.2	0.03	Near Qasr Al-Melh
S-15	24.8	25.8	301.1	5.2	0.031	Near runway
S-16	24.3	25.6	480.9	BDL	0.036	BIA

S-17	24.0	26.6	421.4	BDL	0.033	BIA
S-18	21.5	18.2	297.8	BDL	0.025	BIA
S-19	26.7	22.6	380.0	BDL	0.035	BIA
S-20	24.6	21.0	370.2	1.2	0.03	BIA
S-21	22.9	25.1	379.5	BDL	0.031	BIA
S-22	36.9	30.3	410.1	1.2	0.035	BIA
S-23	28.6	21.9	314.4	BDL	0.025	Entry Checkpoint
Min	21.5	14.1	251.1	1.2	0.025	
Max	53.8	45	520.1	19.4	0.050	
Average	36.9	29.1	362.7		0.039	
SD	11.0	9.0	72.6		0.001	

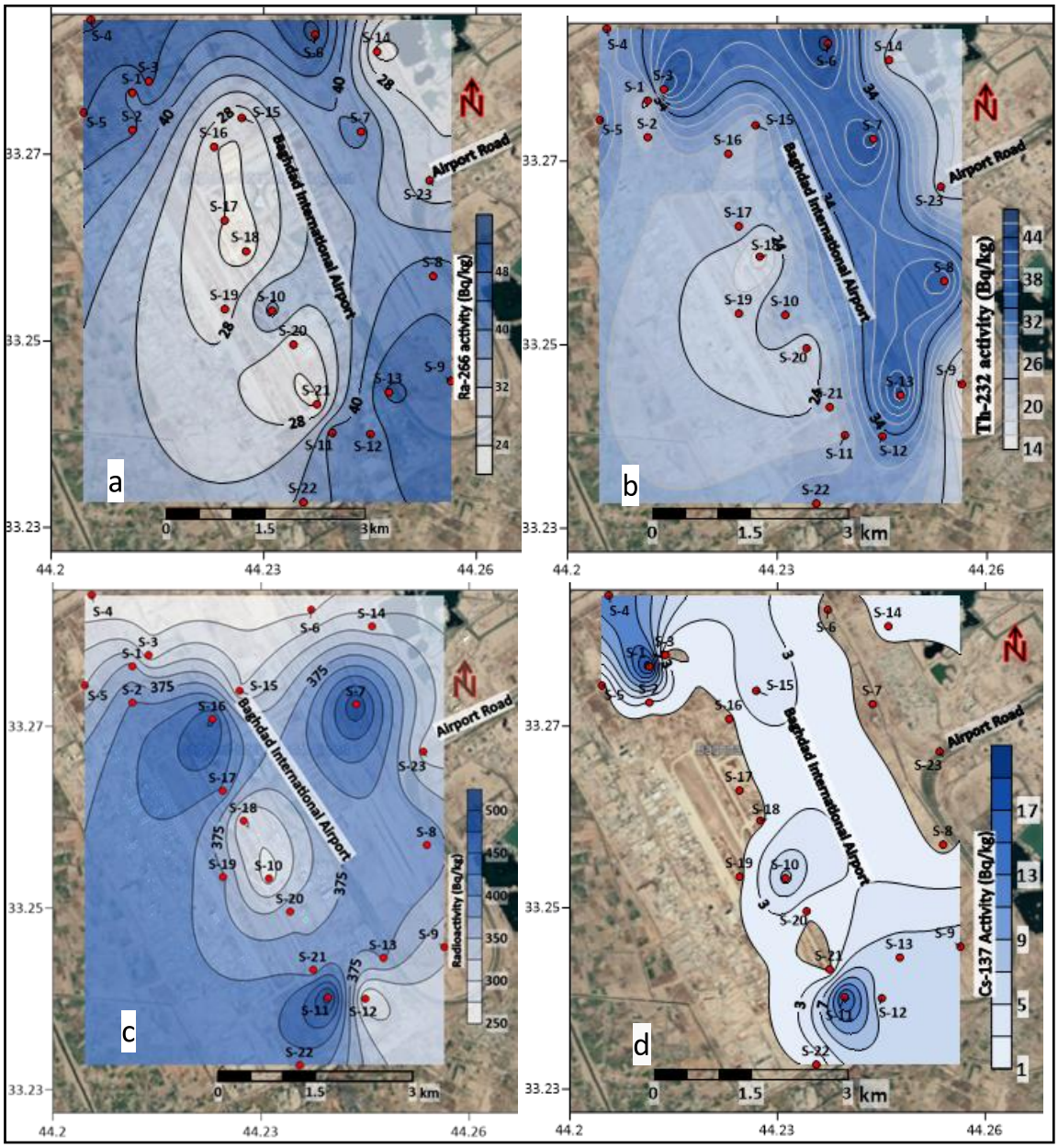


Fig.3. pattern distribution of Ra-226, Th-232, K-40 and Cs-137 (Bq/kg) in soil samples in BAI. Red solid circles are the sampling locations with their ID.

3.2 Calculation of DU in Soil Samples in BIA

The percentage Rm% in equation (2) was calculated for each sample from the mass concentration of ^{235}U and ^{238}U according to (UNEP, 2003).

$$Rm\% = (CU\text{-}235/CU\text{-}238) \times 100\% \quad (4)$$

Where CU-235 and CU-238 are the concentrations in ppm for ^{235}U and ^{238}U in the soil sample and are calculated using the following equations.

$$CU_235 = (AU\text{-}235)/80.01 \quad (5)$$

$$CU_238 = (AU\text{-}238)/12.45 \quad (6)$$

where AU-235 and AU-238 are the measured concentrations of the activities in the soil in Bq/kg and 80.1 and 12.4 are the specific activities of ^{235}U and ^{238}U, respectively, in Bq/mg of each isotope.

The results (Table 2) showed that Rm% ranges between 0.68% and 0.92% (0.0068- 0.0092), which means that most of the samples have %Rm matches its percentage of ^{235}U in the natural uranium isotopic composition. However, samples S-3 and S-12 have relatively Rm% less than that in the natural uranium which may be contaminated with DU of about 3.4% and 8.4%, while the other locations have underestimated levels of DU%.

Table 2. Radioactivity of uranium isotopes U-235 and U-238 in the soil samples in BIA using NAA and the calculated DU in these samples

Sample ID	Radioactivity (Bq/kg)			
	U-235	U-238	Rm%	%DU
S-1	1.0	19	0.82	-17.9
S-2	0.8	17	0.73	-1.4
S-3	1.0	22	0.71	3.4
S-4	1.0	19	0.82	-17.9
S-5	1.0	20	0.78	-10.1
S-6	1.1	23	0.74	-3.7
S-8	0.9	18	0.78	-10.1
S-12	0.7	16	0.68	8.4
S-13	1.0	18	0.86	-26.6
S-14	1.0	17	0.92	-36.3

3.3 Total measured radiation absorbed dose rate

The total absorbed dose rates in the study area were recorded to be between (0.025-0.05) µSv/h (Table 2) corresponding to 35.7-71.4 nGy/h (multiply by factor $0.7 SvGy^{-1}$, UNSCEAR, 1993) with average value of 0.039± 0.01 µSv/h or 55.7±7 nGy/h. This value is close to the worldwide average dose rate of 58 nGy/h recorded by UNSCEAR (UNSCEAR, 2000). Classed post map for the total doses was plotted for BIA as shown in Fig. 4. About 70% of the area with total dose between 0.034 and 0.05 µSv/h and more than 52% of the area with total doses above 0.042 µSv/h corresponding to 60 nGy/h which is above the wide world average.

3.4 Calculated Ambient Absorbed Dose

The ambient absorbed doses in nGy/h due to presence of Ra-226, Th-232 and K-40 in the surface soil of the study area were calculated according to equation-3. The range of Dc is 33.5-66.6 nGy/h corresponding to 0.21-0.41 mSv/y with average value of 49.8 ±9.8nGy/y, 0.3±0.06mSv/y, which is below the worldwide average value 58 nGy/h (UNCEAR, 2008). In the report of the UNSCEAR (2000), stated that the level of the gamma dose rate in the world ranges between 10 and 200nGy/h. However,

there is some locations in BAI have Dc higher than the worldwide average such as location (S3, S6, S7, S8 and S13) as shown in Fig.5.

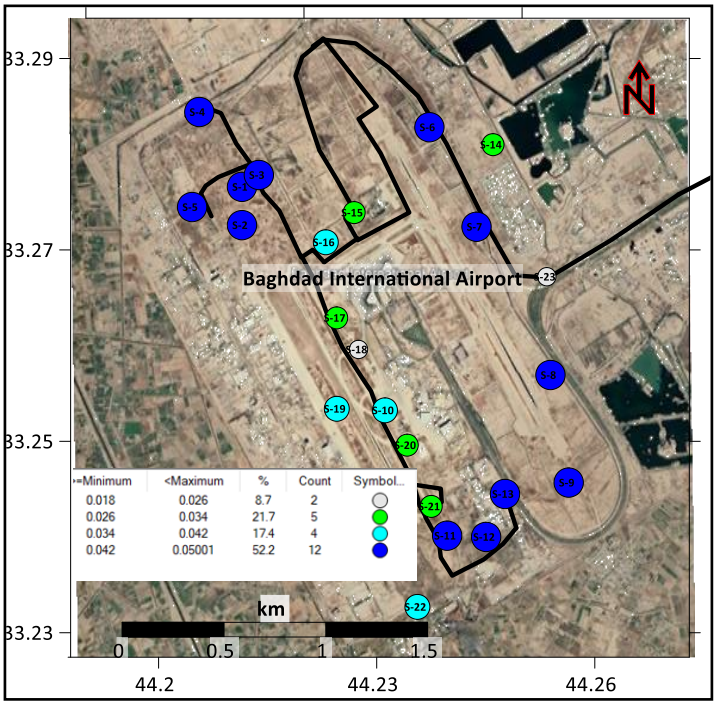


Fig. 4. Classed post map for total measured absorbed dose in BAI line. More than 52% of the points (solid blue colored circles) have doses more than 0.042 µSv/h.(60 nGy/h).

It is known that the Dc value is related to the difference in the of radionuclides content in the soil which in turn is related to the chemical composition and the origin of the soil. The order of the three radionuclides according to the contribution to the total gamma absorbed doses is Ra-226> Th-232 > K-40 in the samples S1 –S10, (Fig. 6a) while the contribution of thorium and potassium is the highest in the rest of the samples. However, the contribution of each of the radionuclides to the total dose is approximately the same (Fig. 6b).

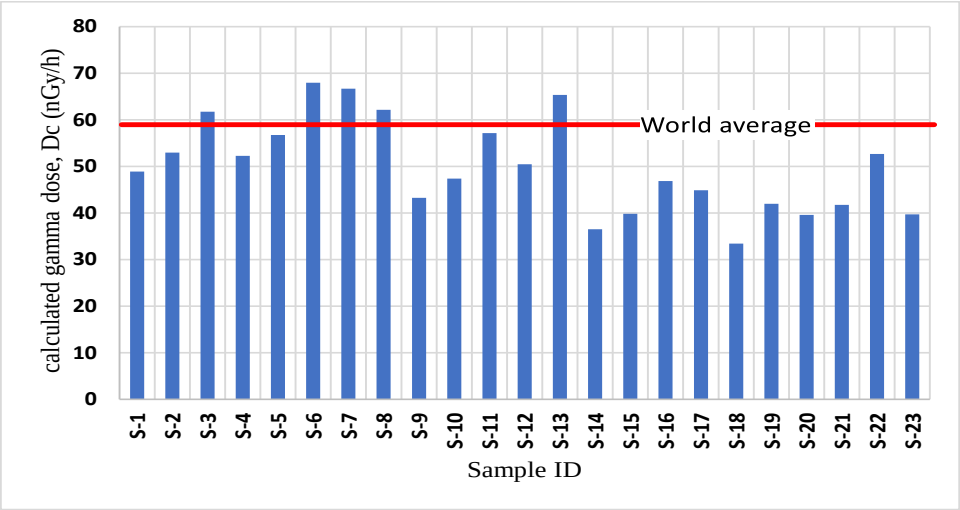


Fig. 5. Absorbed gamma dose calculated from the activity of Ra-226, Th-232 and K-40 is the soil samples in the study area. Solid red line is the worldwide average (58 nGy/h).

The relationship between the total annual absorbed gamma dose rates (Dm in mSv/y)) measured in the field in the study area with the calculated annual absorbed dose rates (Dc in mSv/y)) due to the

radioactivity of Ra-226, Th-232 and K-40 in soil samples selected from the same locations of the measuring absorbed dose is shown in fig. 7. The relationships represented by the formula Dm= 0.91 Dc + 0.1 with R^2= 0.57. The amount 0.1 in the equation represents the dose effect due to cosmic ray and other radiation sources.

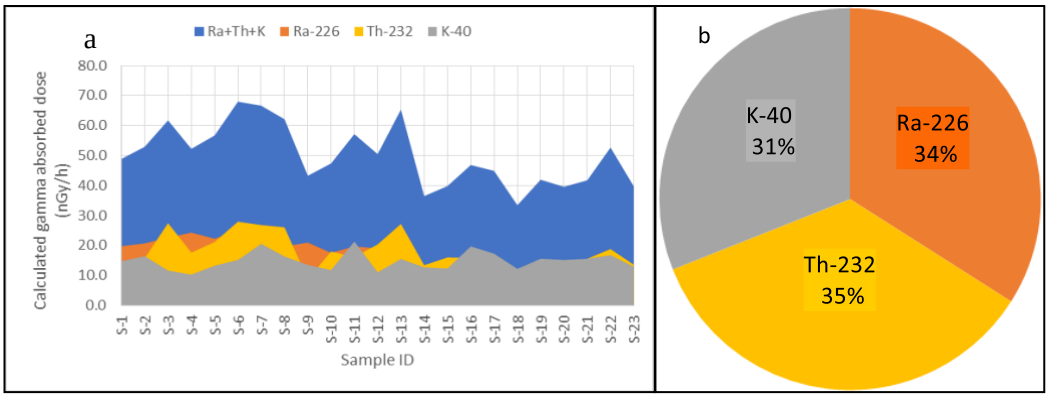


Fig. 5. (a) Contribution of Ra-226, Th-232 and K-40 in the total absorbed doses calculated from the radioactivity of the three nuclides. (b) The contribution percentage of each radionuclides in the total calculated gamma absorbed doses.

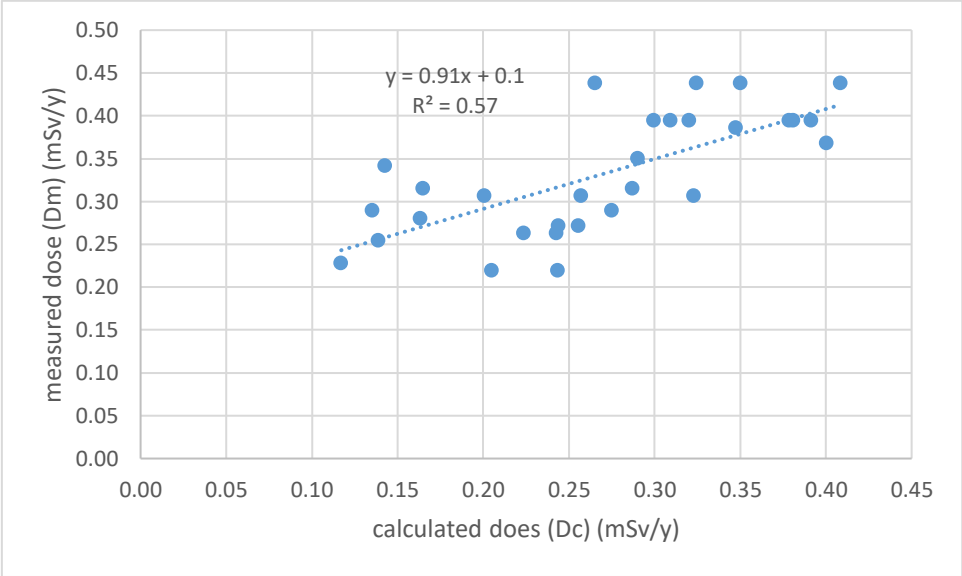


Fig. 7. relationship between calculated dose causing by the activity of Ra-226, Th-232 and K-40 in the soil samples in study area and the absorbed dose measured by the dosimeters in current study at the same locations of sampling.

3.5. Dispersion Model for Radioactive Pollutants in the Study Area

In this section, we will examine the dispersion of radium-226 in the study area, as it is among the most dangerous and influence of natural on the environment and the population (Eisenbud and Gesell, 1997; IAEA, 2010). Hotspot model was used in application. Hotspot version 3.0.3, 2013 was developed by LLNL (Lawrence Livermore National Laboratory, USA) and recommended by NARAC (National Atmospheric Release Advisory Center) (Homann, 2011).

The following data were used for Ra-226: Max activity: 6.2 kBq/m^2 at location: S-6, Wind speed: 4.1 m/s, (Ali and Shejiri, 2019; IMOS, 2022). Resuspension Factor: 1 x 10^{-6}, (Sehmel, 1980; IAEA, 1980). Atmospheric class: C slightly unstable, deposition velocity: 0.3 cm/s and Receptor height: 1.5m

and other parameters used as default in the Hotspot. The concentration in Bq/kg should be converted to kBq/m^{-2} taking an area of 1 m^2 to depth 1cm, which covers an area of about 20 m radius.

The behavior of plume total effective dose equivalent (TEDE) as a function of downwind distance according to the data above is shown in Fig. 8. The TEDE value at site S-6 slightly above 1E-8 Sv then it decreases with downwind distance to be about 1E-10 Sv after 1 km along the plume centerline. The value of TEDE represents very small fraction comparison with the permissible annual effective dose for public 1mSv (1E-3 Sv) (ICRP, 1991). This indicates that the resuspension of Ra-226 from this site (S-6) in BIA is not a significant issue. This value is very small contributed to two reasons the first that the concentration of Ra-226 is not high value and resuspension factor of Ra-226 (1E-6 m) is too small due to the strong binding of radionuclides by adsorption on the surfaces of the clay and silt grains (IAEA, 1990).

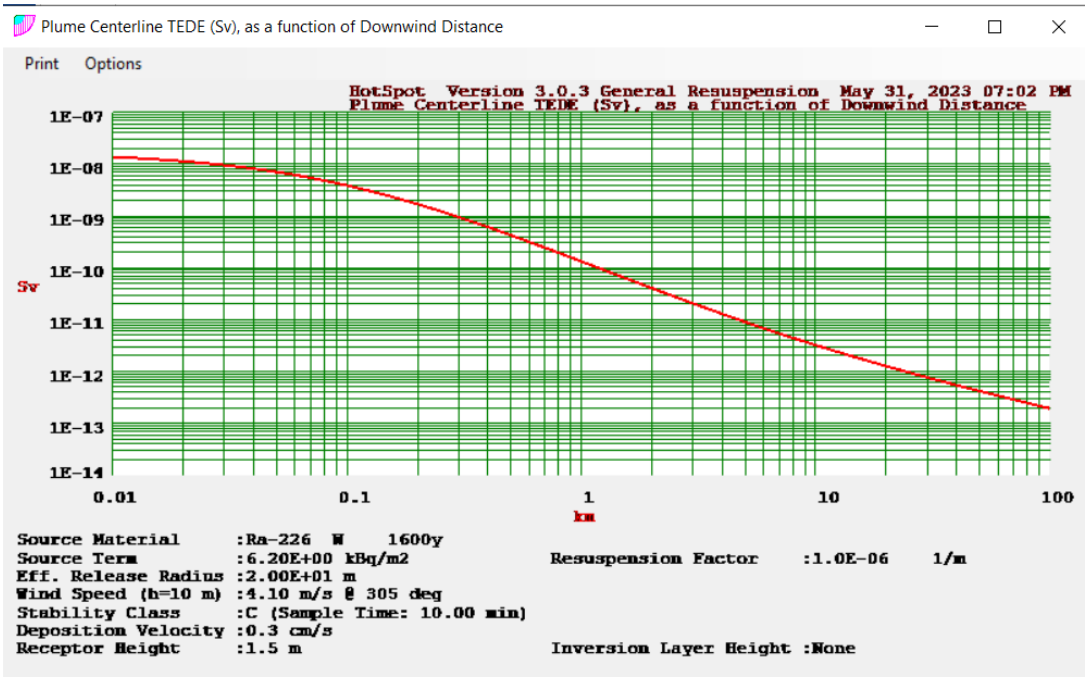


Fig. 9. Total effective dose equivalent due to resuspension of Ra-226 from the soil of BAI at S-6 as a function of downwind distance. After 1km the TEDE decreases from 1E-08 at the release source to about 1E-10 Sv.

The dispersion of Ra-226 due to resuspension from the max concentration in site S-6 in BIA is shown in fig. 9. The dispersion of radium takes a direction from the NW towards the SE according to the prevailing winds in the city of Baghdad throughout the year. It is worth noting that the pollutant covers a small area that does not exceed 0.025 km^2, with concentrations not exceeding 1x10-12 kBq/m^2, which represents very low concentration that does not pose a significant threat to the environment. As for the areas farther than that, it will certainly be less important in terms of radioactive contamination.

As a result of this dispersion and deposition of Ra-226 the dose contour map in the same area was plotted as shown in Fig. 10. The area of max radiation dose represented by red contours has value 1.0E-10Sv covers an area of 0.21 km^2. This value is negligible compared with 1 mSv permissible value for public recommended by ICRP (1991).

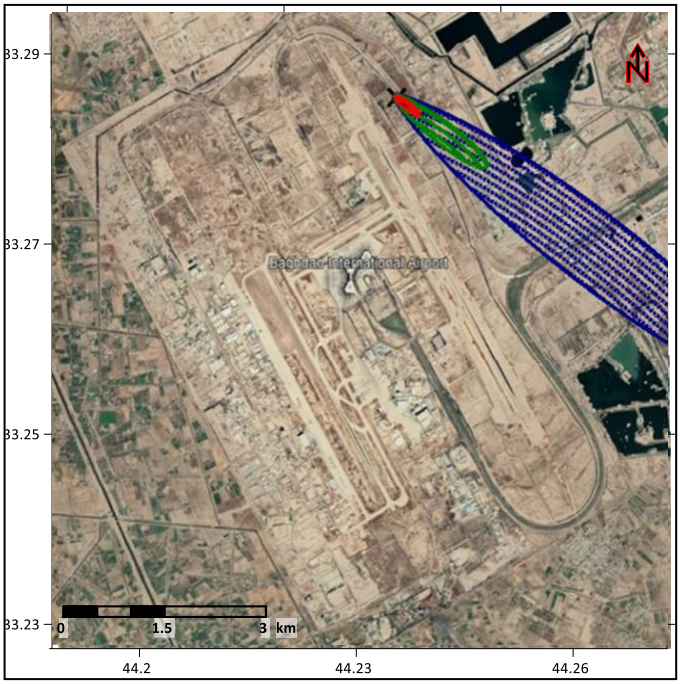


Fig. 10. Deposition contours due to resuspension and deposition of Ra-226 in BAI from location S-6. Inner contour 1.00E-12 kBq/m^2 (0.025km^2). Middle contour 1.0E-13 kBq/m^2 (0.29 km^2). Outer contour 1.0E-14 kBq/m^2 (3.7 km^2).

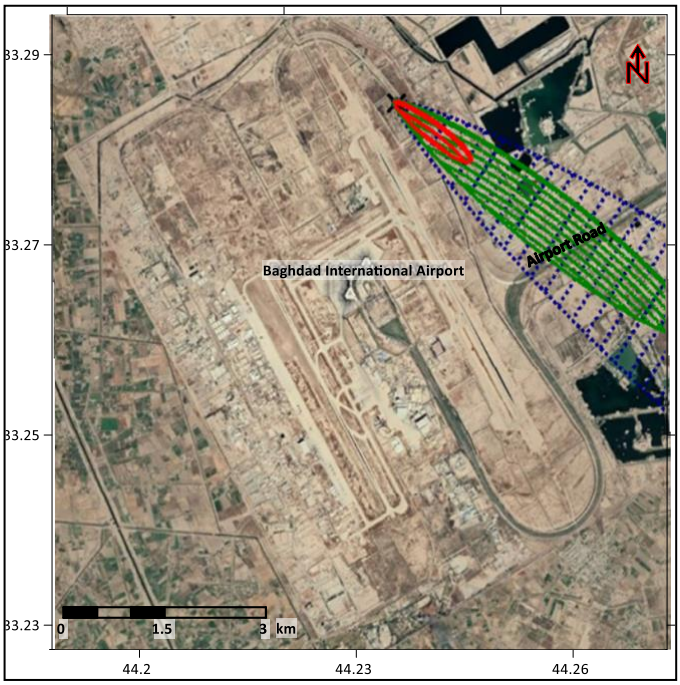


Fig. 11. TEDE contours due to presence of Ra-226 in BIA soil location S-6 corresponding with the predominant wind direction. Inner contour 1.0E-10Sv (0.21 km^2), middle contour 1.0E-11 Sv (2.6 km^2), Outer contour 1.0E-12 Sv (44 km^2)

4. Conclusions

The city of Baghdad and the study area in addition of whole of Iraq were exposed during the war of 1991 and 2003 to bombing with different types of projectiles, including depleted uranium projectiles (Fahey, 2003; Gerdes et al., 2004). Therefore, the current study, for the first time, is an attempt to assessment of the radioactivity in an important area in Baghdad, which is the Baghdad International Airport area (BIA).

In this study, the natural radioactivity represented by the activity of radium-226, thorium-232 and potassium-40 was assessed in addition to the radioactivity of cesium-137 as a representative of industrial radionuclides. The following conclusions can be summed up. With regard to depleted uranium, the study showed that there is a possibility of slight contamination with depleted uranium in two sites (S-3 and S-12) out of the 23 sites that were examined.

The fact that we did not obtain clear and conclusive evidence of the contamination of the area with depleted uranium, because the area is an effective area with a wide activity, therefore, as a result of the rehabilitation of BIA and its vicinity which caused the burial of the contaminated areas with new soil transferred. Perhaps one of the ways to deal with radioactive contamination is to bury the areas contaminated with radionuclides with new clean soil.

With regard to natural radioactivity, although some of the sites in BIA have higher radioactivity than the worldwide averages, the average activities of Ra-226, Th-232, and K-40 in the study area are within the limits of world averages, and there are no abnormal anomalies that require more monitoring and studies.

Most of the investigated sites have Cs-137 activity below the detection limit of the analysis system (within the range of 0.5 Bq/kg), but there are sites that recorded higher cesium radioactivity than what was recorded in previous studies in the city of Baghdad. This indicates the possibility of feeding the region with new cesium from new radiation sources, including nuclear accidents such as Fukushima accident-2011.

The total absorbed dose that measured in the field or which is calculated due to the presence of concentrations of Ra-226, Th-232 and K-40 in the surface soil in BIA were within international limits and there is nothing to worry about.

Dispersion of Ra-226 due to resuspension from the site that has max concentration of radium covers an area not exceeds 0.025 km^2 with concentration 1.00E-12 kBq/m^2 causing an annual effective dose equivalent of 1.0E-10Sv covering an area of 0.21 km^2. This value is negligible compared with 1 mSv permissible value for public recommended by ICRP (1991).

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