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The radiological effects of dust storms in Baghdad- Ramadi area

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Abstract

Twelve storm dust samples were collected from three cities in Iraq. The samples were collected in the same time during big storms which hit Iraq in summer, 2012 and 2013. The deposited dust on 4 by 4 nylon sheet on surfaces of selected buildings in cities of Baghdad, Fallujah and Al-Ramadi were collected. Each sample was put in sealed Marinilli beaker and kept for 4 weeks to reach the equilibrium state between radium and its short half-life daughters. Gamma spectrometry system based on HPGe was used for analysis of natural and artificial radionuclides in the dust. The activities of natural radionuclides were found to be ranged between 13-19 Bq/kg, 9-14 Bq/kg and 200-240 Bq/kg for Ra-226, Th-232 and K-40 respectively, while Cs-137 was found in all the samples to be ranged between 3-10 Bq/kg. The current study includes the estimation of doses caused by external and internal exposure and inhalation dose of these radionuclides and discusses the potential sources of these relatively elevated concentrations of radionuclides

Keywords: dust, storms, radionuclides, dose, Iraq.

التأثيرات الاشعاعية للعواصف الترابية في منطقة بغداد–الرمادي

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الخلاصة

جرى تجميع اثنتا عشرة عينة من غبار العواصف من ثلاث مدن في العراق. تم جمع العينات في نفس الوقت من غبار عواصف ضربت العراق في صيف 2012 و 2013 بعد ترسبها على قطع من النايلون بقياس 4*4 م موضوعة على سطوح البنية مختارة في مدن بغدان الفلوجة والرمادي. يوضع كل نموذج في حاوية مارمللي ويغلق جيدا ويحفظ لمدة لا تقل عن اربعة اسابيع لغرض الوصول الى حالة الاتزان بين الراديوم و وليداته قصيرة نصف العمر. استخدمت منظومة تحليل اطياف كاما المستندة الى عداد الجرمانيوم عالي النقاوة في القياس والتحليل للنويدات المشعة الطبيعية والصناعية في العينات اعلاه. تراوح النشاط الاشعاعي بين 13–19 بكريل/كغم، 9–14 بكريل/ كغم و 200–240 بكريل/كغم لكل من الراديوم–226 والثوريوم–232 والبوتاسيوم–40 على التوالي بينما كان النشاط الاشعالي للسيزيوم يتراوح بين 3–10 بكريل/كغم. تضمنت الدراسة الحالية تخمين الجرع الاشعاعية المتسببة عن التعرض الخارجي والداخلي وجرع الناجمة عن استنشاق النويدات اعلاه ومناقشة المصدر المحتمل لهذه التراكيز المرتفعة نسبيا في غبار العواصف منطقة الدراسة

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Introduction

The radionuclides are included in dust particles as unattached clusters and as aerosol-attached clusters with different particles size from fraction of a micron to several hundreds of microns [1] and of different origin; cosmogenic, decay product and artificially products produced due to nuclear weapons tests, reactors accident and mining works [1,2]. Many researchers have investigated the origin of long range transported dust particles using radionuclides as tracers [3-5] and recognized that main source of theses radionuclides are due to the global nuclear weapon test [6].

Saharan dust and Asian dust contribute of the largest part of the annual global dust which estimated to be 1000 to 3000 Tgy^{-1}[7-8]. These Aeolian dust have been found to be of significant influence in human health [9-12].

Iraqi surface soil has been contaminated by global fallout and nuclear accidents, e.g. Chernobyl, especially at the northern and the western parts of Iraq [13-14].

The concentration of Cs-137 in surface soil in Iraq was estimated to be ranged between below detection limits to 175 Bq/kg dry soils [15]. Furthermore desertification has increased the frequency of dust storms [16], which also would be expected to lead to increase ^{137}Cs deposition in Iraq.

The current study, attempts to investigate the radionuclides and their radiological effect in the dust storms which hit Iraq during summer season, 2012-2013.

Study area and literatures review

The study area (Ramadi, Fallujah and Baghdad) is located within the Western Desert and alluvial Plain, according to the four main geographic regions of Iraq (Figure-1). The desert is almost dry expecting few rainy days within winter, its soil consists mainly of fine sand and gypsum which lead to presence some sand dunes in this region [17]. While Baghdad region represents alluvial plain. Its surface soil consists mainly of clay deposits derived from the Tigris River and the Euphrates River.

Dust storms count among the most common natural hazards in Iraq. Dust-plumes cover sky of Iraq many times every year during summer's months coming from W-North, West and South-West of Iraq. The biggest storms occurred in Jully, 4, 2009, April, 16, 2009, June , 2 and 30,2011, June ,2 and April, 19, 2012 and on March, 23, 2013. Plate-1 represents NASA's satellite images for a dust plumes extending roughly north-south throughout Iraq [18].

Studied of dust storm in Iraq concluded that dust storms and dusty days could be reached up to 300 events/year within the next 10 years [19] neighboring countries are involved in these increasing numbers of dust storms[20-22]. Mohammed and Alomari [17] concluded that in Baghdad area, the greater effect on the occurrence of dust storm are dryness and wind speed. So in addition to the wind speeds which mostly exceed 4 m/s in the area, the condition and direction of the dominant wind are effective factors that determine the source of the storms.

Figure 1- physiographic map of Iraq

In Iraq, dust and sand storms occur when two seasonal wind, the sub-tropical jet stream and a polar front jet stream are combined and create more dynamic weather, especially the strong northwesterly "shimal" winds [23]. Mohammed and Alomari [17] identified dust sources by using satellites images (Aqua and Terra). They tracked a dust storm dated 17-18/June/2009 and they observed that an indication of Al-shimal wind effect. They believe that the main source of dust storms in Iraq is from Al-Jezirah part of Iraq in addition to Jordan, Syrian Desert.

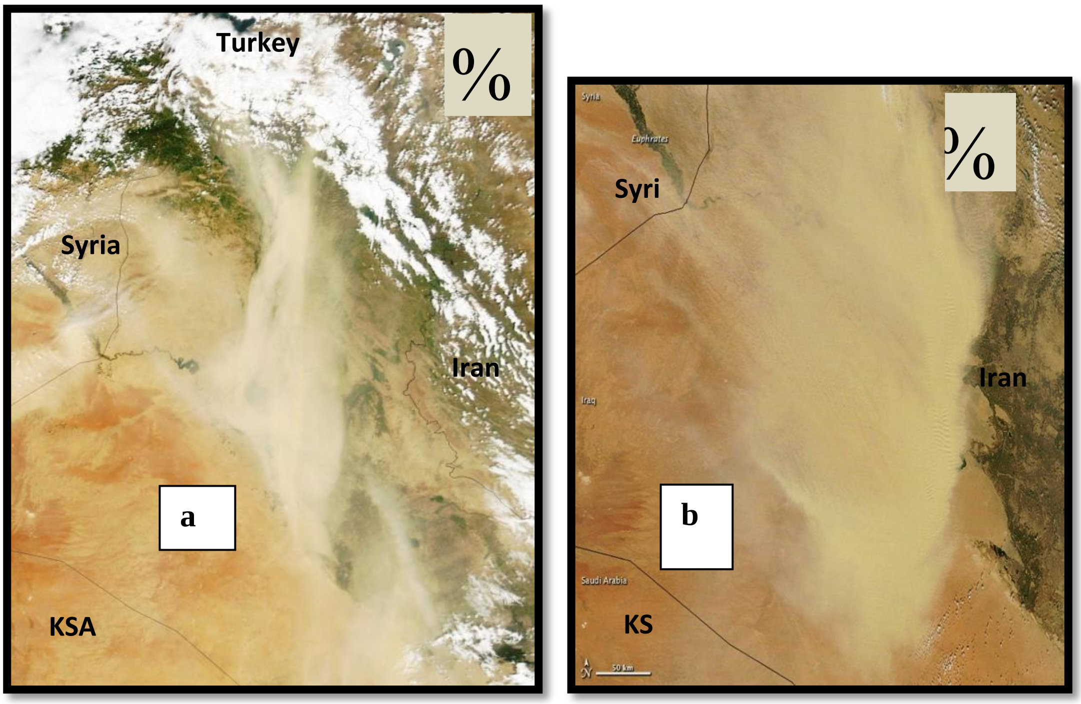

Plate -1 NASA's satellite image for a dust plume hit Iraq (a) in March, 23, 2013. (b) April, 19, 2012

Meteorological data of Iraq

Arid and semi-arid climate is predominant in most parts of Iraq, especially in the western and south western of Iraq. The amount average of precipitation is about (147 mm), with wind speed ranging from (2.4-4 $msec^{-1}$). Winds blow over Iraq in two main directions; predominant direction is W and NW almost hot and dry in summer the other is southern and southeasterly wind called [24]. The climate is influenced by subtropical aridity of Arabian Desert area and the subtropical humidity of Arabian Gulf. Temperatures range from 5℃ in January to more than 35℃ in August. 70% of the rainfall in the country falls between November and March.

Materials and methods:

Sampling and measurement of radionuclides

Twelve dust samples were collected for the period February, 2012 to September, 2013. The deposited dust on 4 by 4 nylon sheet on surfaces of selected buildings in cities of Baghdad, Fallujah and Al-Ramadi were collected. Five samples collected from the city of Ramadi, 2 samples from the city of Fallujah and 5 samples from Baghdad. 500 to 1000 g of each sample was put in Marinilli beaker. To reach the equilibrium between radium and its short half-life daughters the samples were kept sealed for four weeks before analysis using Gamma spectrometry system based on HPGe. Concentration in Bq/kg of Radium-226, Th-232, K-40 and Cesium-137 were measured in all samples. The specific activities 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 to determine the specific activity of ^{226}Ra.while the gamma-ray lines of 338.4 keV, and 911.2 keV from ^{228}Ac, 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 662.2 KeV of ^{137}Cs is used for measuring the specific activity of Cs-137. The energy calibration and efficiency was calibrated by using a standard source of a multi energy made by the American Canberra Company. The Marinilli geometrical shape was used to measure the activity of the samples

Dose assessment:

Inhalation dose

The dose (Sv/year) due to inhalation of the dust in current study is calculated using the following equation:

Committed effective dose (Sv/y) = C x F x R ……………..(1)

C is concentration of the nuclides in the dust (Bq/m^3), F is inhalation dose conversion factor (Sv/Bq) published by IAEA and ICRP[25-28] (3.6 x 10^{-7}, 1.1 x 10^{-4}, 2.1 x 10^{-9}, and 4.6 x 10^{-9} for ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs, respectively) and R is, breathing rate assumed to be 10512 (m^3/y), according to assumption that breathing rate for an adult is 0.02 m^3/s [25,27, 28].

The maximum average concentration of particles in dust in Iraq was recorded to be 2241.1 μg/m^3 air [29]. This value was used in the current study to convert the concentration of the radionuclides in units of Bq/kg dust to the concentration of the radionuclides in the dust in Bq/m^3 air.

Absorbed dose rate

The absorbed dose rate is calculated by converting the natural radionuclides concentration, ^{226}Ra, ^{232} Th and ^{40} K in the dust samples using the conversion factor given by UNSCEAR[30] as in the following equation:

D (nGy/h) = $0.462C_U + 0.604C_{Th} + 0.0417\ C_K$ ………………(2)

Where D is the absorbed dose rate in $nGyh^{-1}$ and $C_{U,}$ C_{Th}, and C_K are the measured concentration of U-238, Th-232 and K-40 in the dust samples in Bq/kg respectively.

Results and discussion

Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K and ^{137}Cs and inhalation doses

The activity concentration in Bq/kg of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs radionuclides in the dust storms samples of the current study were represented in Table-1.

Table 1- concentration of radionuclides (Bq/kg) in storms dust in Iraq and the committed equivalent doses (Sv/y) caused by inhalation.

sample ID	Sampling Location	^{226}Ra	^{2332}Th	^{40}K	^{137}Cs	Committed equivalent doses (Sv/y)				
						^{226}Ra	^{2332}Th	^{40}K	^{137}Cs	Total
1	Baghdad	13	9	237	3	1.36E-07	2.00E-05	2.64E-07	9.28E-11	2.04E-05
2	Baghdad	15.2	11	215	5.2	1.86E-07	2.98E-05	2.18E-07	2.79E-10	3.02E-05
3	Baghdad	14	13.1	201	4.1	1.58E-07	4.23E-05	1.90E-07	1.73E-10	4.27E-05
4	Baghdad	18.7	10.4	200	7.9	2.82E-07	2.67E-05	1.88E-07	6.43E-10	2.71E-05
5	Baghdad	16.1	11	225	10	2.09E-07	2.98E-05	2.38E-07	1.03E-09	3.03E-05
6	Ramadi	17	12.4	222	9.1	2.33E-07	3.79E-05	2.32E-07	8.54E-10	3.84E-05
7	Ramadi	18.5	13.9	240	3.4	2.76E-07	4.76E-05	2.71E-07	1.19E-10	4.82E-05
8	Ramadi	19	14	231	7.4	2.91E-07	4.83E-05	2.51E-07	5.65E-10	4.89E-05
9	Ramadi	13.3	13.2	216	8.5	1.43E-07	4.30E-05	2.20E-07	7.45E-10	4.33E-05
10	Ramadi	15.2	9	201	8.1	1.86E-07	2.00E-05	1.90E-07	6.76E-10	2.03E-05
11	Fallujah	17.4	13.5	214	6.9	2.44E-07	4.49E-05	2.16E-07	4.91E-10	4.54E-05
12	Fallujah	16.5	12.1	217	8.1	2.20E-07	3.61E-05	2.22E-07	6.76E-10	3.65E-05
Average		16.2	11.9	218.3	6.8	2.14E-07	3.55E-05	2.25E-07	5.29E-10	3.60E-05
Max		19	14	240	10	2.91E-07	4.83E-05	2.71E-07	1.03E-09	4.89E-05
Min		13	9	200	3	1.36E-07	2E-05	1.88E-07	9.28E-11	2.03E-05
SD		2.1	1.8	13.5	2.3	5.36E-08	1.01E-05	2.79E-08	3.03E-10	1.02E-05

The radium-226 activities (or ^{238}U activities for the samples assumed to be in radioactive equilibrium) range from 13 Bq/kg to 19 Bq/kg with an average of 16.2 ±2.1 (Bq/kg). The activities of ^{232}Th range from 9 Bq/kg to 14 Bq/kg with an average of 11.9 ± 1.8 (Bq/kg), the activity concentration of ^{40}K ranges from 200 (Bq/kg) to 240 Bq/kg with an average of 218.3 ± 13.5 Bq/kg. Finally the concentrations range of ^{137}Cs is 3 Bq/kg to 10 Bq/kg with average 6.8 ± 2.3 Bq/kg. These results are comparable with those reported by Ali et al. [31] for Iraqi soil and within the activity range of ^{137}Cs in the surface soil in Iraq [15]. The activity concentration of ^{137}Cs in surface soil, of middle and western Iraq, ranges between 7-175 Bq/kg [15]. Also the results are comparable with the results measured by Al-Hamidawi[32] in Najaf, western Iraq (^{226}Ra :21.5, ^{232}Th :5.4 and for ^{40}K: 308) Bq/Kg and with those obtained by Al-harbi and El-Taher [33] in Qassim, middle of Saudi Arabia (10, 8, 306)Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K, respectively.

Committed equivalent doses (Sv/y) caused by inhalation of those radionuclides were tabulated in Table-1.

The maximum effective dose by inhalation of individual radionuclide was caused by the Ra-226 (4.83E-05 Sv/y) while the total effective dose caused by inhalation of all radionuclides (^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs) that measured in the dust was 1.02E-05 Sv/y. These values just represent very small fraction from the recommended effective dose (1 mSv/y) to public from inhalation of radionuclides from all sources of radiation [34].

Absorbed dose rate

Absorbed dose rate was estimated to be ranged from 20.84 nGy/h to 26.95 nGy/h with average of 23.7±1.9 nGy/h(Table-2). The radionuclides concentration in the dust causes an additional dose (23.7±1.9 nGy/h) to that the dose due to the exposure to the ambient gamma rays from the natural occurring radionuclides in the surface soil at the sampling location. For comparison, the range of absorbed dose rate due to the natural radionuclides in surface soil of the western part of Iraq is (5-299) nGy/h [7].

Table 2 calculated absorbed dose, and the Ra_{eq} in the dust in the current study.

Sample No.	Absorbed dose D(nGy/h)
1	21.32
2	22.63
3	22.76
4	23.26
5	23.46
6	24.60
7	26.95
8	26.87
9	23.12
10	20.84
11	25.12
12	23.98
Min	20.84
Max.	26.95
Average	23.74
SD	1.90

Concentration of cesium

In previous studies, concentration of cesium in the surface soil in the study area was found to be ranged between below detection limit (BDL about 0.5 Bq/kg) to 20 Bq/kg [15] (Figure-2) or between 0.5 to 14.5 Bq/kg [35]. In this study, the concentration of cesium in dust storm samples was found to be ranged between 2.3 to 10 Bq/kg. Concentrations of Cs-137 in the air (Bq/m^3) due to resuspension from the soil in the study area (Table-1) were estimated using the resuspension factor for cesium in normal conditions $10^{-6}m^{-1}$ [36]. The values were found to be ranged between $1.15x10^{-5} – 3.34x10^{-4}$ Bq/m^3 air. The concentrations of cesium which were measured in the dust storms' samples in the current study range between $6.72x10^{-3}$- $2.241x10^{-2}$ Bq/m^3 air. It is clearly notes that in dust storm conditions, concentration of cesium is hundred folds more than that in normal condition caused due to resuspention. Moreover, the minimum measured concentration of cesium in dust storm samples was 2.3 Bq/kg which is more than that in soil surface (BDL) in study area. These values indicate that the sources of cesium, consequently, the sources of dust storms are from surrounding areas such as western parts of Iraq and Al-Jazerah which have more concentration of cesium in their soil surface 175 Bg/kg as appear in Figure-2 [15]. Also, it is easy to notes that the study area located in downwind of the prevailing wind direction in Iraq (Figure-3). This conclusion corresponding with the conclusion by Mohammed and Alomari [17] who believe that the main source of dust storms in Iraq is from Al-Jezirah part of Iraq in addition to Jordan and Syrian Desert.

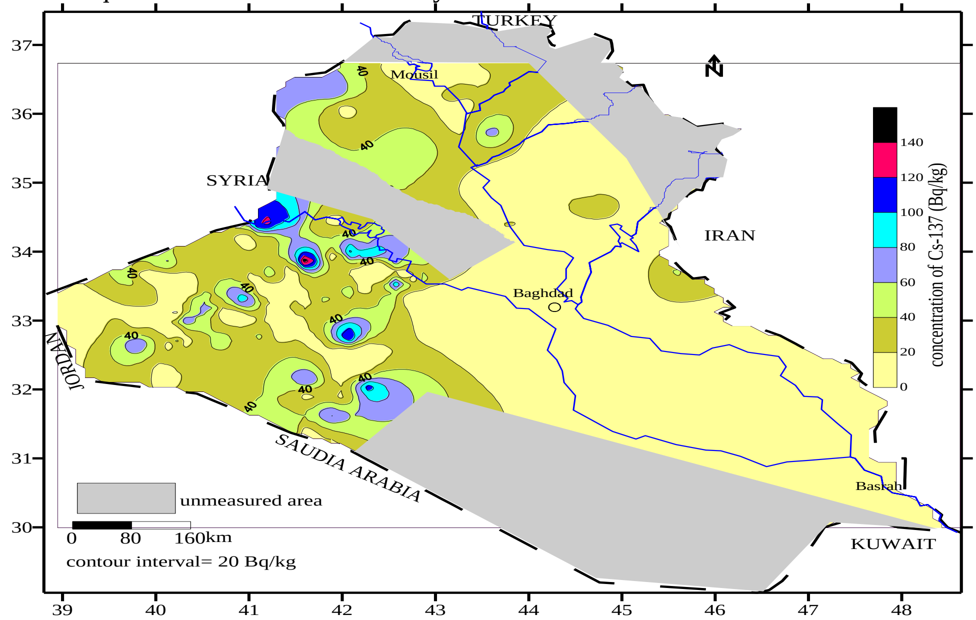

Figure 2- Cesium distribution in the surface soil in Iraq[16].

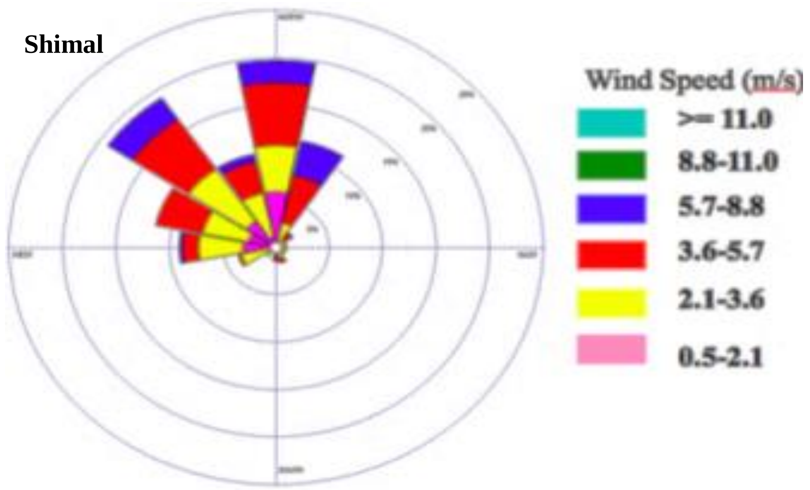

Figure 3- Wind rose for Baghdad city, Iraq for May to June 2010 [37].

Conclusion:

The dust storm is considered as one of natural sources which effects on the humans and environment. Current study has estimated the radiological effects of some dust storms in Iraq. The concentration of natural occurring radionuclides such as radium, thorium and potassium in addition to the artificial radionuclide, cesium were found to be comparable to that in surface soil in the study area and other areas in Iraq. Those radionuclides caused an additional doses by inhalation estimated to be as maximum as 1.02E-05 Sv/y. These doses just represent very small fraction from the permissible value recommended by IAEA caused by background radiation. Also, concentration of these radionuclides in the dust causes an additional average dose rate about 23.7±1.9 nGy/h which is comparable to the absorbed dose rate due to the natural radionuclides in surface soil of the western part of Iraq. In present study we may conclude that it is reasonable to find measurable concentration of radionuclides in dust storms but its radiological effects may be insignificant. Also, this study concludes in simple way but not rigid that the sources of dust storm in study area are not far away from the study area and may be from the Western Desert of Iraq or Al-Jazerah region. The conclusion needs to be verified.

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