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Depleted uranium in the food chain at south of Iraq

A.T. Al-Kinani[1, 2*]

[1] College of Medicine, AL-Mustansiriya University, Baghdad, Iraq
[2] Supreme Council for Environment and Natural Reserves, Doha, Qatar

Background: Depleted Uranium (DU) is uranium with low content of ^{235}U produced as a result of uranium enrichment. DU has high density (19.05 g/cm^3), which is 2.54 more than Iron, so it's high penetrating power makes it preferable as emanations with high penetration power. It was used in second Gulf ware in 1991 for first time. The radioactivity of soil, plants, fruit, meat, milk and water is measured using gamma ray spectroscopy. ***Materials and Methods:*** One hundred samples of soil, plants and tomato fruit were selected from the tomato farms near Basra city south of Iraq and 6 control samples from other farms not contaminated with depleted uranium (DU). Also samples of meats, milk and water were collected in January 2003. Radioactivity of these samples was measured using Gamma-ray spectrograph system with high purity Germanium detector with resolution of 2.2 keV at the energy of 1332.3 keV of Co-60. The system is connected to PC Pentium 111 with PCA program. ***Results:*** The measurements show that radiation equilibrium between ^{234}Th and ^{226}R existed with the range between (0.86-1.16) in uncontaminated soil samples. For contaminated soil samples radiation equilibrium between ^{234}Th and Pa-234m existed with the range between (0.928- 0.956). The mathematical equations of Kosovo team were used. Results show that the soils of two farms were contaminated with (DU). The radioactivity of ^{226}R for plants ranging from 5.97 to 7.26 and for tomato fruits samples between 9.16 to 12.4Bq/kg. Comparing these values with the control radioactivity which range between 6.25 to 7.34 for fruits and 13.3 to 13.9 Bq/kg for plants indicate that these samples were not contaminated with DU. ***Conclusion:*** The soil samples of two farms were contaminated with DU but the fruit of these farms was not contaminated with DU may be due to its high molecular weight and not being water soluble. The radioactivity of ^{226}Ra for different kinds of meat and milk for animal grazing near destroyed tanks contaminated with DU, ranges between (0.02-1.1) and (0.01-.0.2) Bq/kg respectively. These values indicated that meat and milk are uncontaminated with DU. The water samples collected from wells in the same region are below the detection limit of the system. All these results indicated that the food chain was not contaminated with DU at the time of measurements.
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Keywords: *Depleted uranium, food chain, soil contamination, south of Iraq.*

INTRODUCTION

As a result of uranium enrichments to use ^{235}U as fuel in the reactors or nuclear weapons, 0.5 million tones of DU are left in the environment. Some of these amounts of DU are used to balance of Buoying aircraft, aircraft wings, shield and fast breeder reactors to produce plutonium. Many options have been suggested for disposal of DU inside the earth or to send it outside into the space. These suggestions cost a lot. Some researches were conducted in 1972 to find a way to get rid of DU by using it as bolts or as shield for tanks; because of its high density and its high penetration power when bombarding solid targets and being fired strongly, causes high pressure and temperature of about 70% of DU transfer to aerosol of ^{238}U which reacts with oxygen at high temperature producing uranium oxides. DU is alpha emitter with radioactivity of 12500 Bq/gm which is about half the activity of natural uranium (25160 Bq/gm) (1). The inhalation of DU aerosol is hazardous to human being (2). During the second Gulf war in 1991, DU ammunition was used by USA and British army to destroy the Iraqi tanks near Kuwaiti border. Farms of Basra province, south of Iraq were contaminated by DU. The Iraqi environmental scientists in the ex-Iraqi atomic energy commotion discovered this contamination in 1994, and in some parts of Iraq especially near Basra, where the tanks battles took place near the border. These areas were heavily contaminated with DU and some health risk began to appear on people living in Basra.

The most important health effects of DU is

Corresponding author:
Dr. Athab Tahir Al-Kinani, Suprême Council for Environment and Natural Reserves, P.O. Box: 7634, Doha, Qatar.
Fax: *+0974 4415246*
E-mail: *drathabalkinani@yahoo.com*

leukemia, the latent period of this disease is 2-5 years [3, 4], the percentage of this disease increased during the recent years in Iraq and reaching to 43% for age range below 15 years.

During the recent years, the percentage of breast cancer in women has increased in spite of its long latency of 25 years. After inhalation or ingestion, uranium can be transported around the body with blood stream; thus, exposing other organs and blood cells to its carcinogenic effect [5]. In inhalation, toxic and radioactive particles are trapped permanently in the lung increasing the risk of cancer, and then travel in the blood stream and deposits in brain, kidneys, bone, reproductive organ, muscle, and spleen [6].

MATERIALS AND METHODS

More than 100 samples of soils, plants and fruit were collected from tomato farms in Basra province, south of Iraq, where many tanks were destroyed with DU ammunition. Portable radiation detector (PCM5, NE-UK) was used to detect DU contamination and any increasing the radiation above the background in the farms near by destroyed tanks. Many samples of soil, roots, plants and tomato fruit were collected inside plastic bags. Also other samples of food chain from the contaminated areas were collected inside air-tight cylindrical containers. All these samples were transported to the laboratory of health physics center in Baghdad. Soil samples were crushed and sieved to get rid of stones. Plants' roots were dried in oven for 24 hours at 80°C. Samples were then cleaned carefully with distilled water and dried. Tomatoes were crushed and mixed with electrical blender. Meat samples were burned to ashes. Each sample with weight of about 1 Kg was put inside a marinelli beaker, and stored inside refrigerator for some 4 weeks prior to counting allowing establishment of secular equilibrium between ^{226}Ra, ^{228}Ra and ^{224}Ra and their decay product. Milk and water samples were concentrated by evaporation. The activity were measured by Gamma-ray spectrum meters using HPGe detector with efficiency of 30% and resolution 2.2 keV at the energy 1.332 MeV of Co-60 (Canberra Company USA). The efficiency calibration was performed using ^{152}EU provided by IAEA.

RESULTS AND DISCUSSION

The activity of some radio nuclides of uranium series was measured and 9 of the samples were selected for the study, since the results were the same. The sample notation and weight are shown in table 1. Their location on map is shown in figure 1. The 186.2 keV photo peak is mixed energy for ^{226}Ra (186keV) and ^{235}U (185.7 keV). The

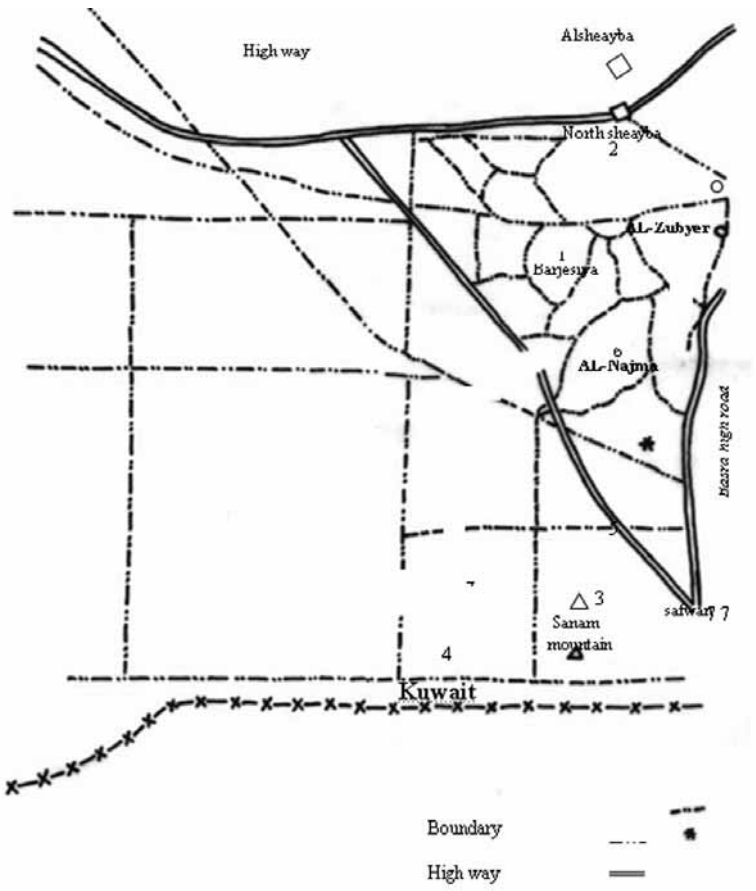

Figure 1. Map of the region with samples location No.

Table 1. Number, location and weight of samples collected from the area under investigation.

Sample no.	Weight (Kg)	Type	Location
1	1	Soil	EAST of ALZUBAYER
	0.230	Plant	
	0.810	Fruit	
2	1	Soil	NORTH of ALZUBAYER
	0.258	Plant	
	0.975	Fruit	
3	1	Soil	SANAM mountain
	0.198	Plant	
	0.972	Fruit	
4	1	Soil	NEAR KWATY BORDER
	0.185	Plant	
	0.860	Fruit	
5	1	Soil	North of SANAM
	0.181	Plant	
	0.712	Fruit	
6	1	Soil	AL-NAJMA
	0.252	Plant	
	0.970	Fruit	
7	1	Soil	SAFWAN
	0.195	Plant	
	0.839	Fruit	
8	1	Soil	AL-NAJAF
	0.260	Plant	
	0.923	Fruit	
9	1	Soil	DYALA
	0.264	Plant	
	0.950	Fruit	

energy difference between the two peaks was about 0.5 keV so the detector couldn't distinguish these two from one another. The radioactivity of ^{235}U was calculated at energy level of 205.3 keV and subtracted from the radioactivity at the energy level of 186.2 keV to get the radioactivity of ^{226}Ra keV only. Table 2 shows the results of radioactivity measurements of soil, plants, and fruit samples. To investigate the contaminations of samples, the mathematical equation of Kosovo team was used [7].

Where:

$$R = \frac{0.72 - 0.52x}{99.274 + 0.5255x}$$

X: Quantity of DU in the samples.

R: the ratio between $^{238}U/^{235}U$ which is equal to 0.0072 (1/R=139) when the concentration of DU = 0% or the ratio=0.0035 when the concentration of DU = 100%.

Table 2 shows $^{234}Th/^{226}Ra$ in soil samples ranged between 0.86-1.16 which proved that radiation equilibriums existed. The plants and fruit samples did not reach the radiation equilibrium, because of the different absorption for different isotopes. The radioactivity of ^{226}Ra in fruits obtained from the farms ranged between 5.79-7.26 Bq/kg and it was less than that of fruit samples in the Najaf and Dyala (control) farms which ranged between 6.25-7.34 Bq/kg. The background in the control area was more than in Basra province. These values indicated that the tomato fruits were not contaminated with DU at the time of measurements. Table 3 shows the percentage of DU, for soil samples. The ratio between $^{235}U/^{238}U$ indicated that the soil samples in locations 6 and 5 were contaminated with DU, because of the obtained percentage (39.979-40.2). This contamination had taken place due to the movements of pollutants from the destroyed tanks to the nearby farms, although soil, plants and fruit were not contaminated with DU. These results have been well in accordance with DU detected in samples when the values of R have been below 0.007, and not detected when the values of R were above 0.007. Similar observations have been reported by other investigators [8]. Comparing the results of $^{235}U/^{238}U$ it was observed that there had been an approximation in the obtained percentage according to International Atomic Energy Agency method and the percentage obtained according to Kosovo method.

The radioactivity of meat and milk of camel, cow and sheep grazing near the destroyed tanks in Basra Region was

Table 2. Radioactivity of soil, plant and fruit $BqKg^{-1}$ samples from interested area and control samples.

Sample NO.	Radioactivity	K^{40}	Pa^{234m}	Bi^{214}	Pb^{214}	U^{235}	$Ra^{226}+Pa^{234}$	Th^{234}
1	Soil	298.7±4.4	-	9.7±0.8	14.2±1.13	-	70.82±1.2	60.77±16
	Plant	247.24±1.6	-	6.54±1.4	9.13±1.8	-	10.7±2.7	43.8±2.8
	Fruit	43.09±2.1	-	2.35±0.7	2.01±0.5	-	5.97±0.6	-
	Ratio*						0.86	
2	Soil	253.11±4.4	-	4.49±0.6	10.3±1.01	-	84.93±15	73.16±20
	Plant	153.11±3.3	-	4.29±0.4	4.9±0.5	-	11.7±0.9	53.06±12
	Fruit	23±3.4	-	2.4±0.34	2.20±0.34	-	6.04±1.1	-
	Ratio						0.86	
3	Soil	182.4±3.8	-	0.6±8.5	11±0.8	-	36.6±11	42.8±15
	Plant	103.4±0.3	-	4.7±0.5	8.1±0.7	-	12.4±0.9	28.6±3.2
	Fruit	44.1±2.7	-	2.9±0.3	2.5±0.4	-	6.7±0.9	-
	Ratio						1.16	
4	Soil	176.1±3.1	-	7.5±0.5	9.7±0.72	-	88.7±9	84.3±11.4
	Plant	115.9±3.5	-	5.2±0.5	6.4±0.7	-	10.3±0.6	55±3.4
	Fruit	66.02±9.9	-	1.1±0.4	1.6±0.2	-	6.0±0.8	-
	Ratio						0.95	
5	Soil	145.6±8.0	-	11.2±1.3	17.6±1.7	-	127.8±22	11.9±28
	Plant	133.9±8.3	-	8.4±1.4	10.2±2.1	-	11.7±0.4	42±3.7
	Fruit	46.7±3.0	-	1.9±0.4	1.6±0.5	-	7.26±1.3	-
	Ratio						0.93	
6	Soil	189±3.9	-	1.04±0.8	15.2±1.3	-	117.3±19	123.7±20
	Plant	141.1±3.3	-	3.2±0.4	4.8±0.6	-	9.2±0.9	31.8±8.2
	Fruit	37.7±2.5	-	1.2±0.2	2.4±0.4	-	6.5±0.8	-
	Ratio						1.05	
7	Soil	126.6±5.2	-	9.6±0.9	14.9±1.3	-	48.8±15	45.7±15
	Plant	221.1±4.3	-	3.1±0.4	4.8±0.6	-	12.3±0.8	30.4±6.5
	Fruit	37.3±2.6	-	0.9±0.2	1.7±0.5	-	6.7±0.6	-
	Ratio						0.93	
NAJAF 8	Soil	255±1.8	-	8.6±0.5	12.4±3.2	-	79.3±11.7	86.5±12
	Plant	366.7±3.1	-	6.5±0.9	10.7±2.2	-	13.3±0.9	43.6±7.9
	Fruit	65±1.6	-	3.4±0.8	3.2±1.1	-	7.3±1.4	-
	Ratio						0.86	
DYALA 9	Soil	150±4.6	-	13.12±0.8	17.3±1.03	-	72.7±11.14	75.3±14.6
	Plant	125±7.6	-	6.2±2.2	9.3±5	-	13.9±0.5	41.3±10
	Fruit	36.8±0.7	-	0.7±0.1	0.8±0.14	-	6.2±1.2	-
	Ratio						1.03	

* Ratio between Th^{234}/Ra^{226}

Table 3. Radioactivity and concentration of U^{238}, ratio between $^{235}U/^{238}U$ and quantity of DU.

Sample No	Radioactivity U-238 Bq.kg^{-1}	Background mg.kg^{-1}	Concentra U-238 mg.kg^{-1}	Concentra DU mg.kg^{-1}	X %	$R = {}^{235}U/_{238}U$	$1/R$
1	60.77±16	66±5	4.90±1.2	0.000	0.000	0.0072	139
2	73.16±20	70±8	5.90±1.6	0.254	4.305	0.0070	142
3	42.8±15	48±5	3.45±1.2	0.000	0.000	0.0072	139
4	84.29±11	73±4	6.79±0.9	0.915	13.402	0.0065	153
5	119.9±28	72±8	9.66±2.2	3.862	39.979	0.0051	196
6	123.7±20	74±6	9.97±1.6	4.008	40.200	0.0051	196
7	45.7±15	46±2	3.68±1.2	0.000	0.000	0.0072	139
8	86.5±12	86.5±12	6.97±0.9	0.000	0.000	0.0072	139
9	75.3±14	75.3±14	6.07±1.1	0.000	0.000	0.0072	139

Table 4. Radioactivity of meat, milk and water of Basra covariant

Sample	Th^{234}	Ra^{226}
Camel meat at ZUBAYER region	0.02	ND*
Camel meat at SAFWAN region	0.04	0.03
Caw meat at SAFWAN	0.03	0.02
Lamb meat at boarder area	1.1	0.9
Milk at ZUBAYER	0.01	ND
Milk at SAFWAN	0.03	0.01
Milk at the grazing area near border	0.2	0.19
All water samples	ND	ND

* ND; Not detected

measured. The results are shown in table 4. The results prove that the radioactivity of ^{234}Th ranging between 0.2-1.1 Bq/kg in meat and 0.01-0.2 Bq/kg in milk had same range as the background radioactivity. The activity of eight samples of well water were under detection limit of Gamma ray detector.

In conclusion, the specific radioactivity for the radionuclides represent contamination in soil samples [5, 6] has been due to the presence of ^{235}U and ^{234m}Pa, giving an indication that the samples were contaminated because of the destroyed vehicles and tanks. These findings well agree with other studies [7]. The measurements showed that there has been a radioactive equilibrium between $^{234}Th/^{234m}Pa$ for the contaminated samples after calculating its specific radioactivity. The percentage between $^{234}Th/^{234m}Pa$ was 0.84-0.99. This percentage gave an indication that there has been a radiation equilibrium state for the first daughters of U-238 series, which is in accordance with other data [8].

The tomato fruits in Basra province were not contaminated with DU because their molecules were not soluble in water and they were not adsorbed to the soil particles; therefore, couldn't have moved through the roots to the plants. These findings have been the same as other studies [9]. DU was detected in samples when the values of R were below 0.007 and not detected when the values of R were above 0.007 [10]. The obtained meat, milk and water from the contaminated areas were not contaminated with Ra^{226}, thus the food chain was not affected by DU contamination.

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