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ORIGINAL ARTICLE

Risk Assessment for AL-Nahrawn Site that Contaminated with Depleted Uranium in Baghdad

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KEYWORDS

AL-Nahrwan;

Risk assessment;

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ABSTRACT: Activity concentrations of (^{238}U series), (^{226}Ra), (^{232}Th) and (^{40}K) in some soil samples in AL-Nahrawan site 52 soil samples were determined and evaluated. The measurements were carried out using high purity germanium (HPGe) detector. The mean activity concentrations in soil samples were (76019.61, 16.634, 11.693 and 147.55) Bq Kg^{-1} for ^{238}U ,^{226}Ra, ^{232}Th and ^{40}K, respectively. The concentration of 238U more than of accepted limited of clearance level according to IAEA and that mean AL-Nahrawan site is radioactive contaminated site. The risk assessment that calculated for AL-Nahrawan site appear the most of dose that calculated from different pathways such as ingestion ,inhalation ,drinking water and meat is coming from external dose and most of it from ^{238}U than another radio nuclides such as (^{226}R, ^{232}Thand ^{40}K). The total dose for the contaminated area that calculated by RESRAD code (7.2) dose from all nuclides all pathways summed in AL-Nahrawan is (1.46 mSv / year) and that more the accepted limit for dose limit exposure to public (1 mSv/A) according the IAEA and that mean the public have limit use and action for this site. The high purity germanium analysis appears AL-Nahrawan site contaminated with Du depended on the ratio between ^{235}U and ^{238}U radio nuclides. The cancer risk from all nuclides calculated by RESRD code for AL-Nahrawan site is (2.2) ×10^{-3}This value is above the global average of 0.29×10 $^{−3}$ and 1.16×10 $^{−3}$ reported by UNSCEAR.

INTRODUCTION

Resrad is mean Residual radioactivity and software program used to assess the radiation risks resulting from radiation pollution and exposure and compare them with international ratios. The risks resulting from radioactive contamination with depleted uranium for the Nahrawan site. Uranium is the first radioactive element that was discovered, and it is a natural nuclide [1].Uranium metal is one of the heavy elements found in the outer layer of the earth [2]. Natural uranium consists of isotopes of uranium238 U, 235 U and 234U with weight ratios of 99.28%,0.71% and 0.0055% respectively [3].where the assessment includes risks(external doses, soil pollution, risks resulting from inhalation and ingestion of pollutants, as well as the adequacy of pollutants transmission in groundwater, plants, meat and livestock milk, and comparing them with global ratios [4]. Uranium is considered a dangerous mineral due to its ability to affect a living cell, which may lead to mutation or cancer [3]. To reduce the risks of harmful radiation to workers and members of the public through radiation practices, the dose limit must be adhered to, which is; the upper permissible limit for the radiation dose. Dose level The amount of the radiation dose limit may not be increased [3, 5]. The scientific studies looking at uranium concentrations in soil and water are of great interest in studying biology and the environment because of its

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radioactivity [6]. There is a study of the relationship between exposure to radiation and biological effect and through the Biological Effect of Ionizing Radiation (BEIR) in agreement with the United Nations Scientific Committee on the Impact of Atomic Radiation (UNSCEAR) and the International Committee on Radiation Protection ICRP. To avoid undue exposure causing the biological effects of radiation to radiation workers and the general public, all doses should be kept as low as possible according to the ALARA- As Low As Reasonably Achievable (ALARA) principle with the dose limits recommended by the International Commission on Radiological Protection ICRP [2, 6, 7].

Health hazards of uranium

There are a lot of health effects are associated with human exposure to radiation from uranium. Because all uranium isotopes such as (Ra-226,U-235 and Th-232) gnarly emit alpha particles that have little penetrating ability, the main radiation hazard from uranium occurs when uranium compounds are ingested or inhaled. At the exposure levels typically associated with the handling and processing of uranium, the primary radiation health effect of concern is an increased probability of the exposed individual developing cancer during their lifetime. The probability of developing a radiation-induced cancer increases with increasing uranium intakes [8].

Risk assessments for contaminated area in AL-Nahrawan site

By conducting a radiological survey using portable devices RadEye AB100 (ZnS(Ag) scintillation detector Alpha-Beta for surface activity measurements from thermo from Germany and Geiger miler Inspector from USA for radiation dose survey measurements in AL-Nahrawan site see the Figure 1 that explain the location of AL-Nahrawan site in Baghdad, the investigation founded the surface activity and radiation dose measurements average value more higher than the of the background radiation average value in clean area in the same site as shown in the Table 1. According to the results of samples that were measured with a gamma spectrometer by using high purity germanium from Ortic USA and analysis 52 samples taken from deferent location in AL-Nahrawan site see the Figure 2 The mean activity concentrations in soil.

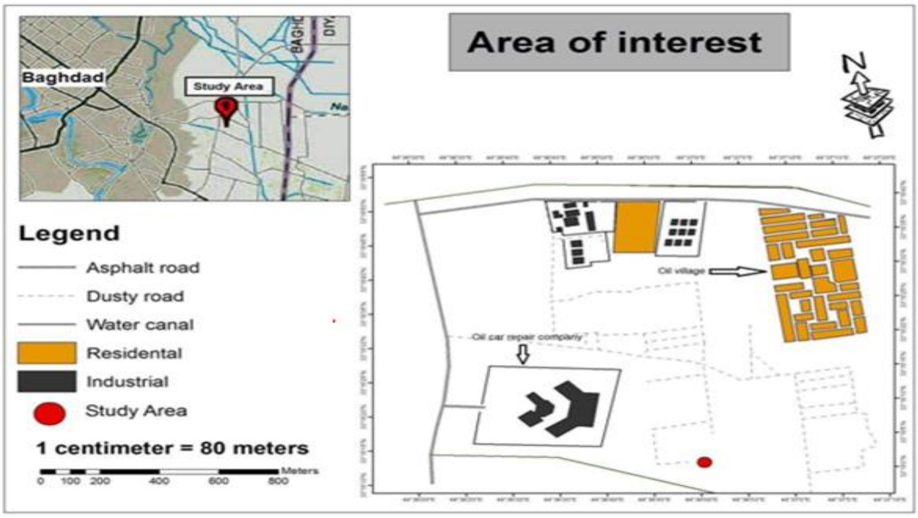

Figure 1. Show the AL-Nahrawan site location.

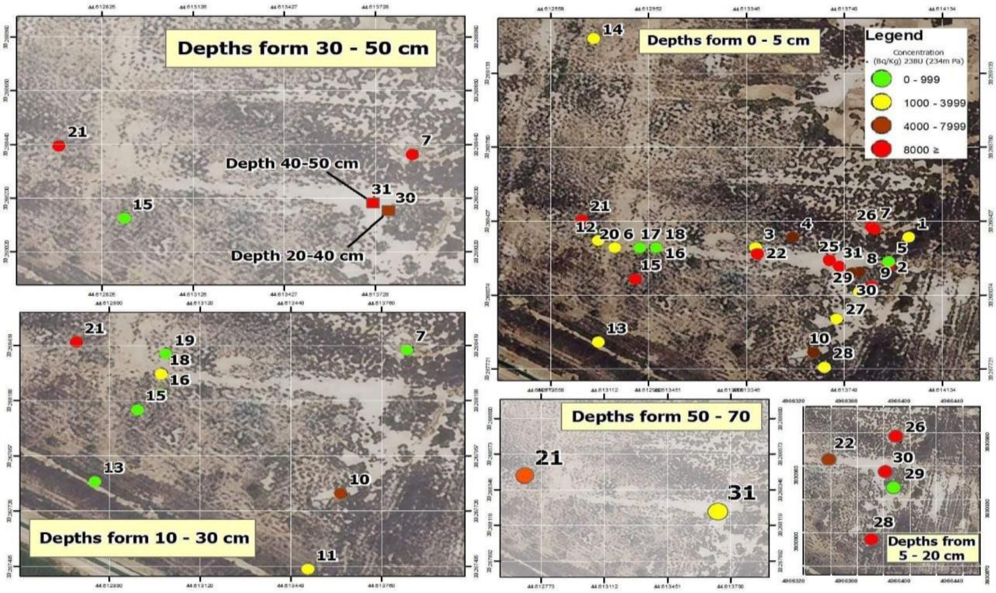

Figure 2. Concentration of radionuclide for ^{238}U (^{234m}Pa) of the contaminated site by use coordinates.

smples were (76019.61, 16.634 , 11.693 and 147.55) Bq Kg^{-1} for ^{238}U ,^{226}Ra, ^{232Th} and ^{40}K, respectively compeering with radionuclide concentration in Baghdad for nuclides ^{226}Ra, ^{232}Th and ^{40}K are (25.81, 21.74 and 434.67) Bq Kg^{-1} respectively [9]. Another study to specific activity for soil samples at different location in Baghdad by using high purity germanium founded that, the specific activity of the ^{238}U, ^{232}Th, ^{40}K ranged from (12.3 to 22.1, 8.2 1 to 21.2, 226.3 to 1325) Bq kg^{-1} respectively [4, 10]. The result of analysis appears high concentration of ^{238}U and ^{235}U radio nuclides and have average concentration value 76019.61, 259.5) respectively and from calculated the average value ratio between (^{238}U and ^{235}U) is 0.0035408. The radiological survey for AL-Nahrawan site appear there are contaminated area about 3000 m^2. A scenario was applied to both resident and suburban farmers in order to assess their doses and risks. First, the area surrounding the contaminated site included areas of more potential arising in which members of the public could be present. Second the resident farmer is expected to produce the highest expected dose than others.

The Table 2 show the average values of radio nuclides concentration in contaminated area in Al-Nahrawan site. Table 3 shows the values of the input parameters for RESRAD code that are used to calculate the radiation dose and risk of these areas for two scenarios. Table 4 show RESRAD results in Table 5 shows the global acceptable limits of radio nuclides in soil and water and Table 6 show the external cancer risk calculated by RESRAD for all nuclides in AL-Nhrwan site .

Table 1. Show the average value of surface activity and radioactive dose for AL-Nahrawan site in clean area.

	Surface Contamination average Bq cm$^{2-1}$	Dose rate ave mR/hr	GPS	Measurements at position
Ave	0.21	0.011	N33.271588 E44.602709	Clean area
Ave	2.889	0.104	N33 16.056 E044 36.495	In contaminated area

Table 2. Show the average value of radioactive concentration for AL-Nahrawan site.

	Specific activity (concentration) Bq Kg^{-1}						
	^{40}K 1460 KeV	$^{232}Th(^{228}Ac)$ 911.2 KeV	$^{226}Ra(^{214}Bi)$ 609 KeV	^{212}Pb 238.6 KeV	^{235}U 205keV	^{238}U (^{234m}Pa) 1001 KeV	^{235}U / ^{238}U
Ave Bq Kg^1	147.55	11.693	16.634	8.667	259.5	76019.61	0.0035408

Table 3. The input parameters for RESRAD software and calculate the dose and risk of contaminated area.

Parameter	Unit	Resident Farmer Value Bq gm^{-1}		Suburban Resident Value Bq gm^{-1}			References
Mean radionuclide concentration	**Bq gm^{-1}**	**^{238}U**	**^{235}U**	**^{238}U**	**^{235}U**	**^{40}K**	Current study
		76.091	0.295	76.091	0.295	0.147	
Contaminated area	m^2	3000		3000			Current study
Thickness of contaminated	m	0.3		0.3			Current study
Cover depth	m	0		0			Current study
Fraction of time indoors	_	0.50		0.50			
Inhalation rate	$m^3\ yr^{-1}$	8400		8400			
Fruit, vegeTable, and grain	Kg yr^{-1}	160		160			
Milk	L yr^{-1}	92		92			
Meat and poultry	Kg yr^{-1}	63		63			
Fish	Kg yr^{-1}	5.4		5.4			

Table 4. The RESRAD results (output) calculations of dose and risk for study area scenario.

Study area	Scenario	Total dose (mSv yr^{-1})	Risk from pathway						Risk from all nuclide
			External	Inhalation	Plant	Meat	Milk	Soil Ingest	
Nahrawan site	Resident Farmer	1.46342	1.49×10^{-3}	5.2782×10^{-2}	6.6294×10^{-3}	4.7064×10^{-3}	2.28284×10^{-4}	1 5.3677×10^{-2}	2.2×10^{-3}

Table 5. Value of acceptable limits concentration of radionuclide in Soil and water [11-13]

Radio nuclides	K-40	Ra-226	Th-232	Pb-212	U-235	U-238
Activity concentration Bq Kg^{-1} in soil	10000	1000	1000	1000	1000	1000
Activity concentration Bq L^{-1} in water	*	1	1	1	1	1

Table 6. External cancer risk for all radionuclide's

External cancer risk	Cancer Risk all nuclides		
	^{238}U	**^{235}U**	**^{40}K**
1.49×10^{-3}	1.46×10^{-3}	2.07×10^{-6}	3.7×10^{-6}

* K-40, a radionuclide that occurs naturally in a fixed ratio to stable potassium, is not included. This is because potassium is an essential element for humans and its concentration in the body is controlled by metabolic processes. If the screening level of 1 Bq L^{-1} for gross beta activity concentration is exceeded, a separate determination of total potassium is made and the contribution of 40K to beta activity is subtracted. Table 4 The results of the RESRAD calculation for the contamination site. The results of the scenario calculation for resident farmers showed that the total dose for the contaminated area is (1.4) mSv / year, the risk of cancer (2.2×10^{-3}), and the total dose for the resident farmers in the scenario doses coming from pathways such as external, inhalation, plant water independent, meat water Independent, and the soil ingestion doses are (0.922676, 5.27822×10^{-2},31.2182×10,1.04342×10^{-2} and 15.3677×10^{-2}) respectively see Table 2, Figures 3 and 4. The radiation dose (0.25 mSv/year) shall be as a limit in clean soil or site decontamination the U.S. Department of Energy (DOE) and the U.S. Nuclear Regulatory Commission (NRC). The dose should not exceed (1mSv/year) mSv /year from another way the radiation exposure from an individual facility via the exposure pathways of waste water and exhaust air must not exceed 0.3 mSv / year for either pathway [14, 15]. It exceeded the permissible limit of public exposure dose limit according the Radiation Protection and Safety of Radiation Sources International Basic Safety Standards IAEA that acceptable limit for public radiation exposure is 1 mSv/year [9]. The cancer risk from contaminated area exceeded the acceptable risk limit for dose, contributions of all nuclides come from all pathways is (2.2×10^{-3}) and cancer risk from all nuclides come from external dose calculated by RESRD code for AL-Nahrawan site is(1.49×10^{-3}) all this values are above the global average of 0.29×10^{-3} and 1.16×10^{-3} reported by UNSCEAR see the Figures 5and 6 [3, 16].

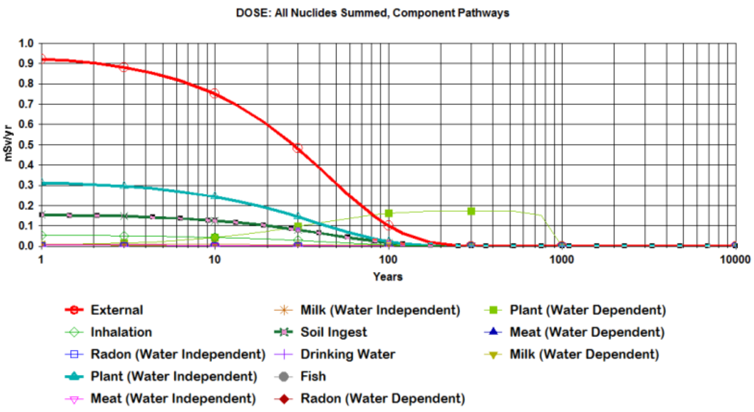

Figure 3. Dose all nuclides summed, component pathways in AL-Nahrawan site for resident farmer scenario.

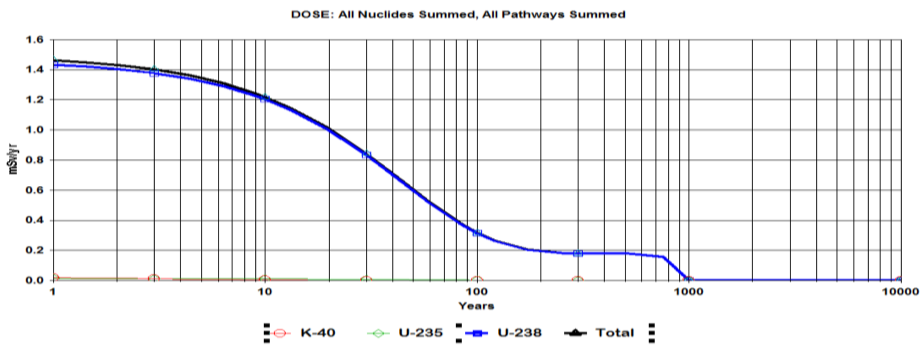

Figure 4. Dose from all nuclides all pathways summed in AL-Nahrawan site for All nuclides.

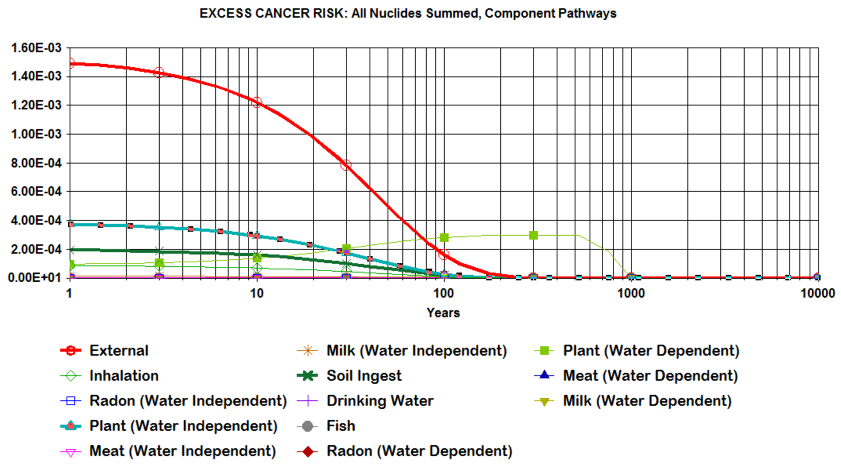

Figure 5. The excess cancer risks All nuclide summed component pathways of the AL-Nahrawan site for suburban resident scenario.

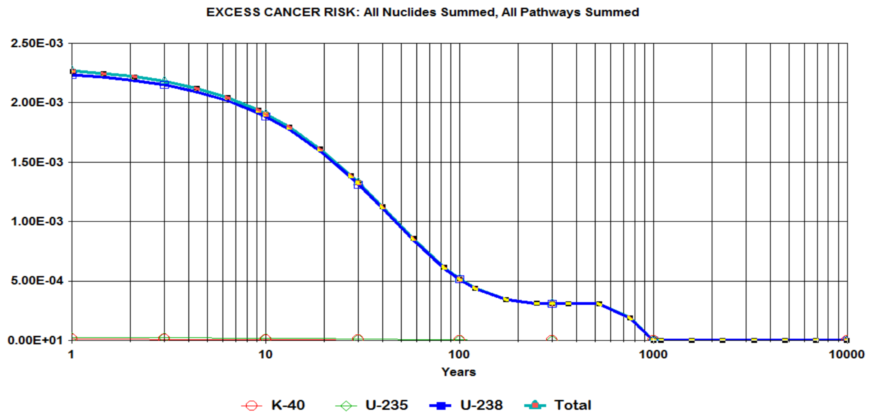

Figure 6. Excess cancer risk all nuclides summed all pathways summed for AL-Nahrawan site for resident farmer scenario.

X-Ray diffraction analysis (XRD) in soil contaminated with DU.

XRD results of the clean and contaminated with Du soil samples. The clean soil sample papered diffraction peaks can be indexed to SiO_2 dependent on JCPDS file PDF number 46-1441, $Ca_6(SiO_4)SiO_3O_{10}$ dependent on PDF number 46-1479 and Fe_5Si_3 dependent on PDF number 38-0438 and all phases appear in contaminated soil samples . The contaminated soil samples with Du appear another phase not found in clean soil sample Uranium silicate hydrate $(UO_2)(SiO_4)$. $2H_2O$ dependent on PDF number 35-0491 and this phase will be have more intensity with increase of ^{234m}Pa 4982 Bq Kg^{-1} sample P10S2concentration in soil samples P21S4 in and have ^{234m}Pa 756623.8 Bq Kg^{-1} see Figure 7 concentration in sample .Their formation through transformation of result of the geochemical conditions under which the penetrators chancing .

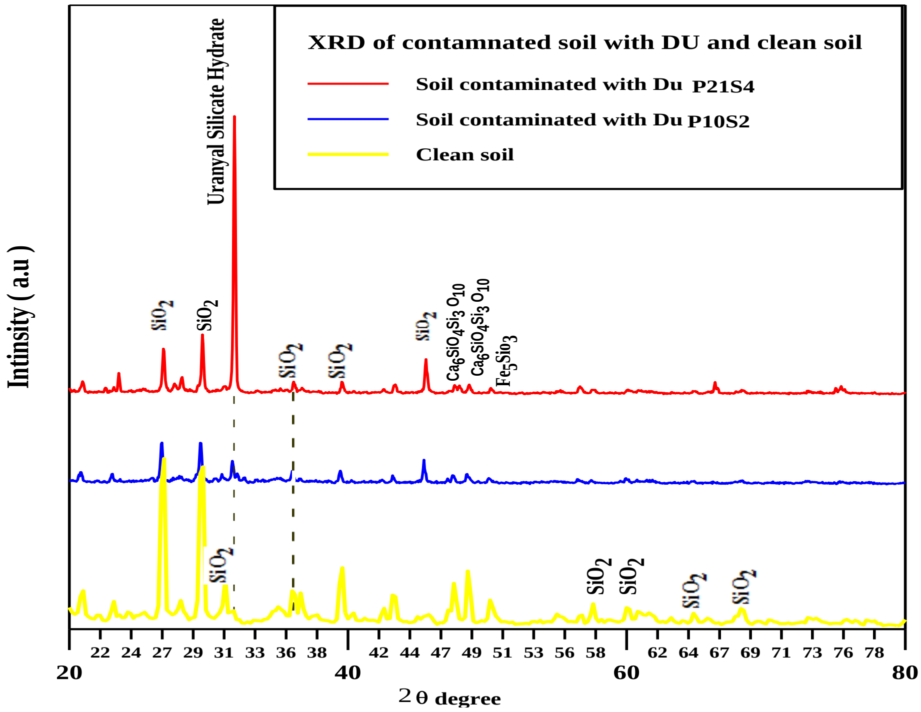

Figure 7. XRD for contaminated soil sample with DU.

Scanning Electron Microscope (SEM) for soil samples

Soil samples are examined by (SEM type Inspect model S50) as shown. A device has Haig resolution power (5 nm), provide heating, coaling stage, EDX detectors for elements analysis. This technique sometimes called energy dispersive X-ray analysis (EDXA) or energy dispersive X-ray microanalysis (EDXMA), is an analytical technique used for the chemical characterization or elemental analysis of a sample or small area. A sample is exposed to an electron beam inside SEM, these electrons collide with electrons within the sample, causing some of them to be knocked out of there orbits. The vacated positions are filled by higher energy electrons which emit X-ray in the process. The number and energy of the X-rays emitted from a specimen can be measured by an energy-dispersive spectrometer EDS. the Magnification power for ESEM device used in this study 10 to 500,000 X. Figures 8 and 9 shows the RF and SEM images of the clean soil sample , Figure 10 the EDX for it , Figures 10 and 11 show the XRF and SEM image for contaminated soil sample with Du and in image map Figure 12 of SEM appear the Uranium as small particle have homogenized distribution in surface of soil sample.

EDX

The XRF analysis investigation for clean and contaminated soil with Du. From EDX analysis for clean soil sample and contaminated soil sample with Du we founded new elements appear in contaminated soil sample that not appear in XRF for clean soil sample see Figure 8 and Table 7. The elements the detection in The EDX analysis for contaminated soil samples are appear Uranium, Cobalt, Niobium and Molybdenum in contaminated soil sample elements and this element not founded in EDX analysis for clean soil sample in the same site and that mean come from using DU weapon in war 2003 see the Figure 10, Tables 7 and 8.

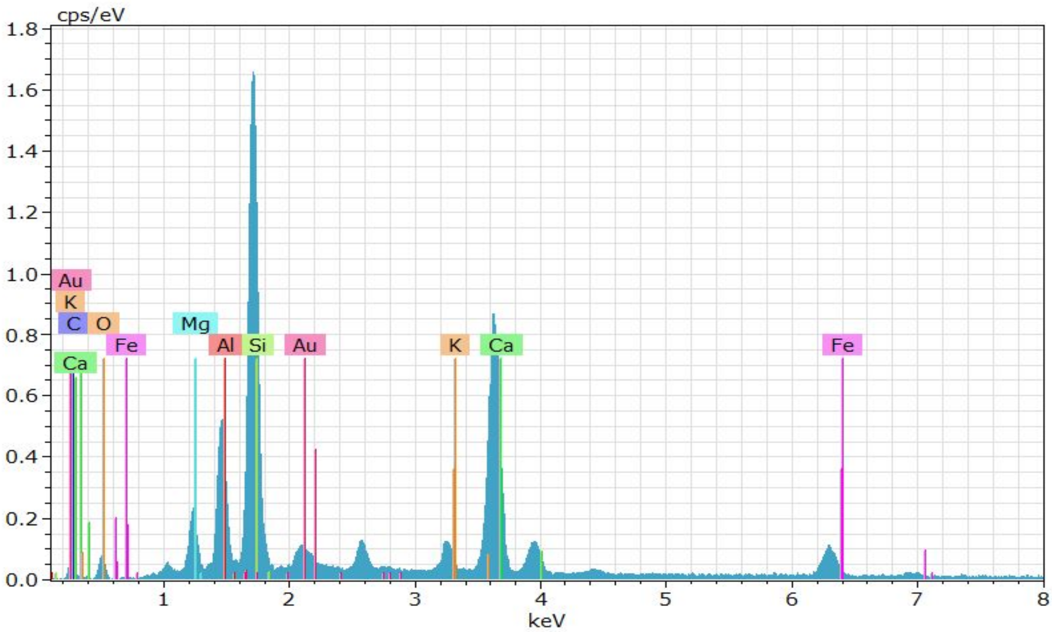

Figure 8. XRF analysis for clean soil sample.

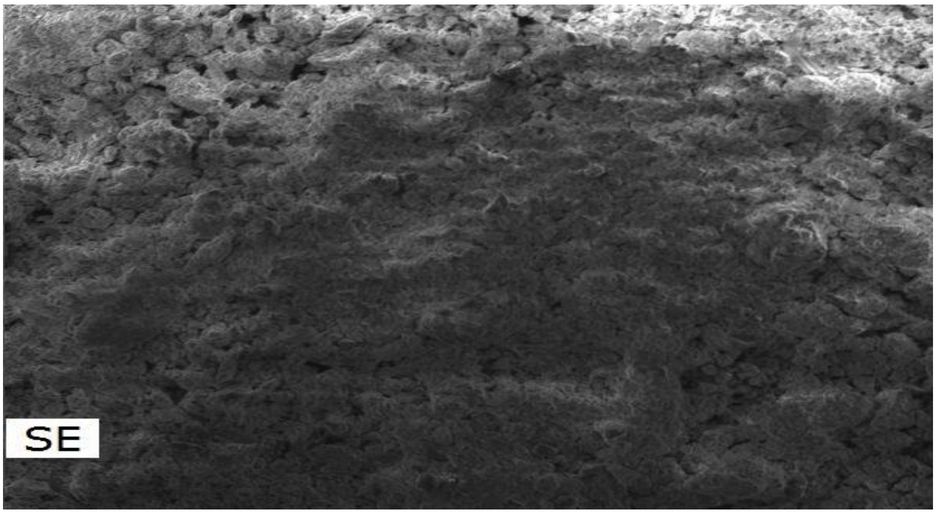

Figure 9. SEM Image show the clean soil sample**.**

Table 7. EDX analysis for clean soil sample elements.

Element	norm. wt.
Silicon	39.9131
Antimony	20.43958
Calcium	129831
Aluminium	7.455858
Carbon	5.994553
Iron	3.570496
Magnesium	3.129527
Oxygen	2.409577
Sum	100

Table 8. EDX analysis for contaminated soil sample elements.

Element	norm. wt.%
Silicon	24.74728
Antimony	18.06293
Calcium	8.868256
Aluminium	6.482585
Carbon	4.350725
Iron	4.397836
Sodium	6.377205
Magnesium	5.552889
Oxygen	3.275445
Molybdenum	12.91868
Niobium	1.897147
Uranium	1.80077
Cobalt	1.268248
Sum	100

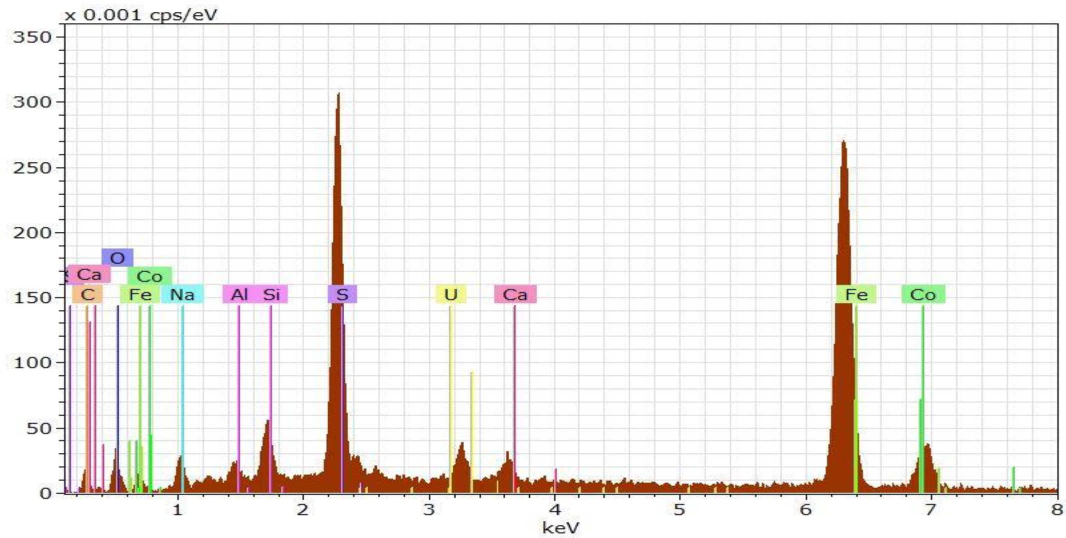

Figure 10. XRF analysis for contaminated soil with du sample.

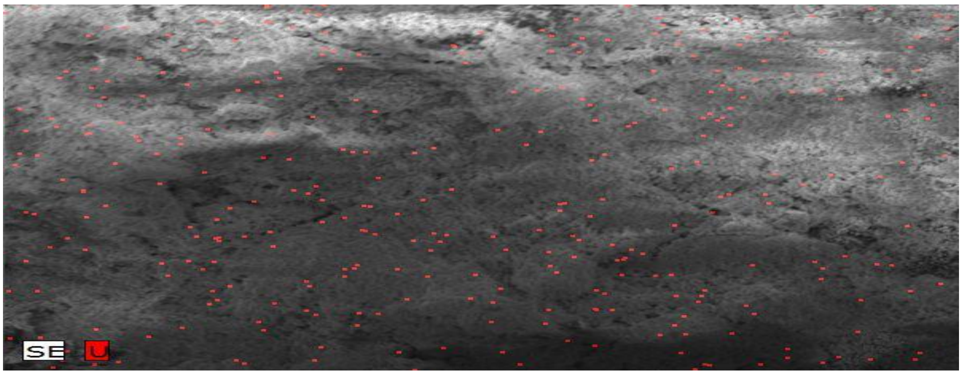

Figure 11. SEM Image show the map (red cooler) distribution of uranium in soil samples contaminated with Du.

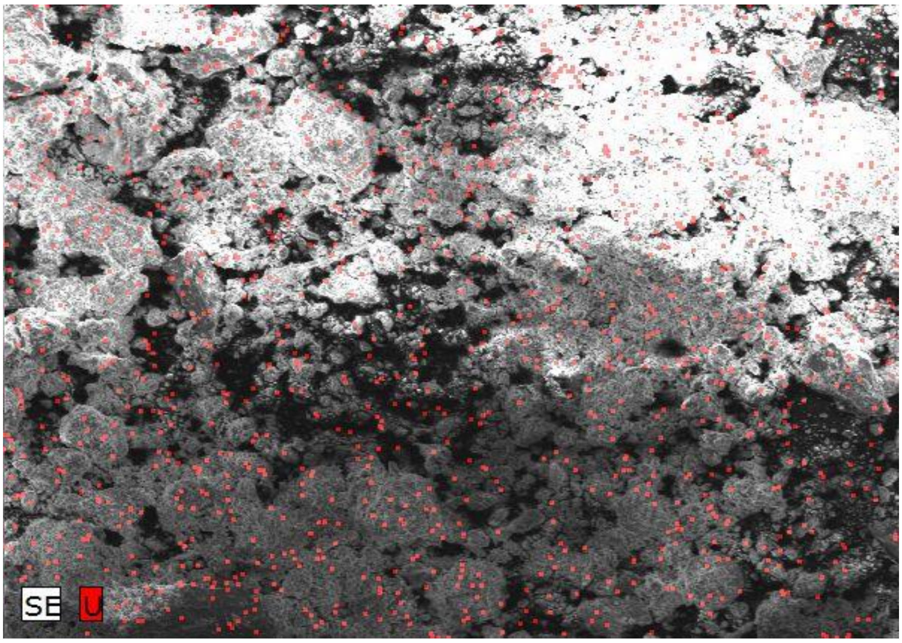

Figure 12. SEM Image show the particle sizes (red cooler) distribution of uranium in soil samples contaminated with Du**.**

RESULTS AND DISCUSSION

1-The contaminated area the detection in AL- Nahrawan site is 3000 meters square contaminated with depleted uranium approved by (HPGe) analysis for samples taken from the site. The radiological characterization for site appears high values for surface activity and have average value (2.88 Bq /cm^2) and recognizing high radiation dose in Al-Nahrawan Site have average value (0.10 mR / hr) cumbering with natural background in clean area in the same site and it is having average value for radiation dose 0.011 mR / hr and and average value surface activity 0.21 Bq cm$^{2-1}$.

2-The specific activity (concentration) of the Nahrawan site (the study site) is the range of the value for ^{238}U, ^{226}Ra, ^{232}Th, and ^{40}K from (180.1-756623.8, 0.86-106.3, 0-124 and 8.5-295.9) Bq Kg^{-1} respectively with the average value of (76019.61, 16.634, 11.693 and 147.55) Bq Kg^{-1} respectively. The range of worldwide specific activity of concentrations are ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K are (16-110, 17-60, 11-64 and 140-850) Bq Kg^{-1} respectively with average the specific activity (concentrations) is 33, 32, 45. And 420 Bq Kg^{-1}, respectively. We have high radioactive concentration for ^{238}U radio nuclide coming from indicated his daughter ^{234M}Pa in AL- Nahrawan Site. As for the rest Radionuclide concentration such as (^{226}Ra, ^{232}Th and ^{40}K) within the permissible limits and it's average radio nuclides values within acceptable global levels. The average radio concentration of ^{238}U 76019.61 more high from accepted clearance level 1000 Bq Kg^{-1} according IAEA

[4] and that mean AL-Nahrawan Site is contaminated with DU and need to decontamination process.

3-The ratio of ^{235}U / ^{238}U has different values from 0.0041 to 0.00588 indicating the presence of the percentage of depleted uranium, the percentage of abnormal uranium and the values from 0.002 to 0.0039 and that approved using USA forces DU in war 2003.

4- From XRD analysis for clean and contaminated soil samples with Du appearing phase not found in clean soil sample Uranium silicate hydrate $(UO_2)(SiO_4).2H_2O$ dependent on PDF number 35-0491 and this phase will be have more intensity with increase of radionuclide ^{238}U concentration in contaminated soil samples with Du.

5-From XRF analysis to samples that contaminated with Du and clean soil sample the elements the detection in on contaminated soil samples are Uranium, Cobalt, Niobium and Molybdenum and this element not detection in clean soil samples and that mean come from using DU weapon in war 2003.

6- From SEM analysis for soil samples that are contaminated with Du and clean soil sample show the contaminated soil sample with Du and in image map of SEM appear the Uranium as small particle have homogenized distribution in surface of contaminated soil sample.

7- The risk assessment that done by RESRAD calculation for the contamination site

Appear that the total dose for the contaminated area is (1.46 mSv / year) and it is higher than the dose allowed to the public, which is (1 mSv/year) according the IAEA and that mean the public have limit use and action in AL – Nahrawan site and the most dose coming from external dose for contaminated area is 0.92 mSv / yr and has the most dose value compared with all pathways. The result of risk assessment that calculated by RESRAD code appear the ^{238}U and ^{235}U radio nuclides have the large value of external radiation exposure dose comparing with another radio nuclides and this value have high ratio in cancer risk comparing with another pathway such as Inhalation, Plant, Meat, and the soil ingestion doses, Radon, drinking water and soil ingest.

8- The cancer risk from all pathways calculated by RESRD code for AL-Nahrawan site is 2.2×10^{-3} This value is above the global average of 0.29×10^{-3} and 1.16×10^{-3} reported by UNSCEAR.

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Conflict of interests

The author declares no conflict of interest.

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