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Uranium$^{235, 238, 234}$ soil contamination in Al Tuwaitha nuclear site, using Geomatics techniques

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Abstract
In this paper, the authors aims to introduce Uranium contamination in Al Tuwaitha nuclear site using Geomatics techniques. The contamination level of Uranium (235, 238, 234) , from different soil samples of the nuclear reactor surrounding areas has investigated and compared to the international standards of UNSCEAR 2000,. The results show that distribution indicates a relatively asymmetrical distribution tailing slightly towards higher concentration. However, the activity level of Uranium in the soil samples exhibits higher variability. $U^{238,\ 235,234}$ concentration level exceed the permitted level by (75) times over the UNSCEAR (2000) regulation in spot near Ishtar village and many other uranium contamination inside Al Tuwaitha nuclear research center, location C and Ishtar village. The contaminated area above normal concentration of U sum in soil having about 65% from total contaminated area (0.87 km2) between (0.08-0.2) Bq/g, 23% between (0.2-0.4) Bq/g, 6% between (0.4-0.7) Bq/g, 5% between (0.7- 2.5) Bq/g and 1% between (2.5-4.5) Bq/g as the highest concentration level.

Keywords: Al Tuwaitha nuclear site; Iraq; GIS techniques.

1. Introduction
There are many of sites in Iraq, which have been used for nuclear activities and, contain potentially significant amounts of radioactive material. The principal nuclear site is Al Tuwaitha nuclear research center who contains about 18 facilities, including research reactors, hot cells, waste treatment and storage facilities. Al Tuwaitha site considered as unique case most of its facilities suffer substantial physical damage during the Gulf Wars and have been subjected to subsequent looting. Despite the long history of nuclear programs at Al Tuwaitha, no significant radioactive contamination as a result of normal operations has been officially reported for the site or surrounding communities Radionuclide's are present in the environment and within the remaining structures. Locations of these facilities are shown in Figures 1 and 2, [1].
As a result of the Osiraq and IRT-5000 reactor accident, long-lived of Uranium 235, 238, 234, is still eminent in the environment, predominantly in the surface soil. Therefore, the aim of the present work is to assess the radioactivity contamination level of the soil samples taken at different points from the surrounding areas of the research reactor of Al-Tuwaitha site. The risk of these other effects is much less

than the risk of developing cancer due to radiation exposure. The contaminated area was investigated and determined by using the integration of Geographic Information Systems (GIS) and statistical software.

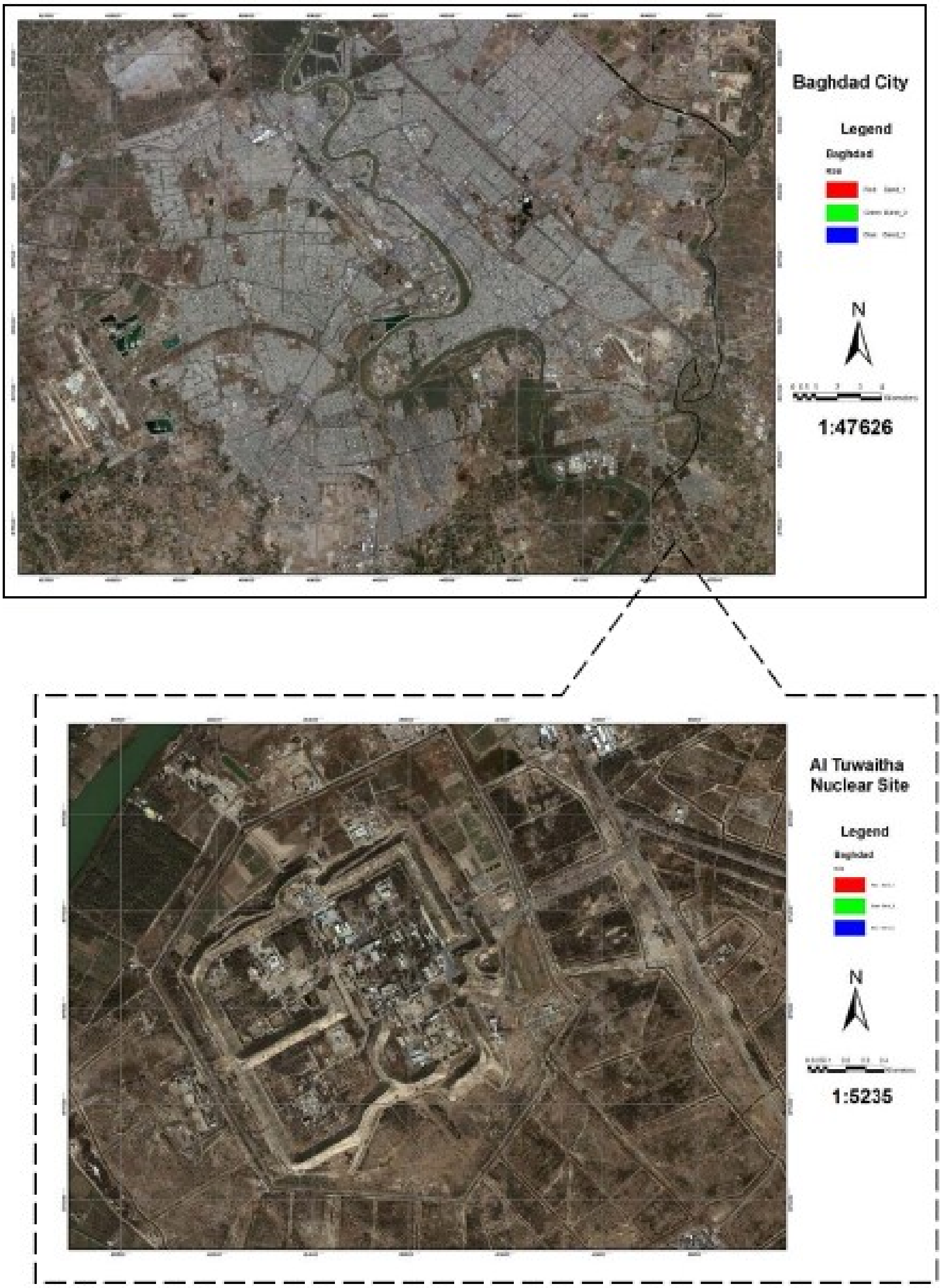

Figure 1. Al Tuwaitha nuclear site location.

2. Al Tuwaitha site description

Al Tuwaitha Nuclear Research Center covers an area about 1.3 km^2 and is located approximately 1 km east of the Tigris River 18 km south of Baghdad. This site is fortified by large earthen beams around the key facilities which cover over one km^2 which includes two research reactors (Osiraq and IRT-5000) a fuel fabrication facility, plutonium separation uranium enrichment, waste storage facilities and many other facilities [2]. The nuclear research facilities at Al Tuwaitha were built by various companies during the development of the Iraq's peaceful nuclear program as shown in Figure 2. Therefore, the area inside the earthen beam is divided into many sectors. French, Italian, and Russian sectors are so named according to the nationality of the companies that designed and built the nuclear research facilities. At gulf wars, the IRT 5000, Tammuz-2, radiochemistry and nuclear physics laboratories, fuel fabrication laboratories, the radioactive waste treatment station, and nuclear material stores were seriously destroyed. In late-April 2003, a documented radioactive dispersal occurred [3]. Iraqi civilians looted perimeter storage areas at Al Tuwaitha and dumped more than 200 barrels of uranium compounds in the form of yellowcake near the village of Ishtar. The barrels, still containing more than 10 kilograms of yellowcake residue, were transferred to nearby villages and used for household storage. Uranium residue from the looted barrels was likely dumped in residential areas prior to recovery of the containers. Coalition forces, IAEC hazmat teams, and others recovered most of the barrels and dumped yellowcake by June 2003. Also, they recovered numerous cesium and cobalt sources that possessed acute danger to surrounding communities. Subsequently, all high-level radioactive materials at the site were secured and transported out of Iraq. Remaining sources and unsecured radioactive materials were consolidated into on-site bunkers and storage buildings [4].

Figure 2. Map of Al Tuwaitha nuclear site Facilities.

3. Materials and methods

In this paper, total of 201 soil samples were analyzed. The radioactivity data samples used in this paper were collected in 2010 was provided by Ministry of Science and Technology (MOST). They were collected locations with effective gamma and beta dose rates were measured (1-meter height) at same locations, they were collected from inner and outer perimeters of Al-Tuwaitha complex, storage location and the ditches along the outer perimeter highway (Figure 3). While the background level is defined from samples collected within Baghdad city 18 km far from Al-Tuwaitha site. The output digital map layer includes contours maps were created by additive interpolation method of the geographical information system using the integration between ArcGIS 10.1 and golden surfer. With ArcMap and Surfer spatial analysis extension and, DATA of subareas values can be imported to GIS through grid cells. These grid cells which have been classified in various ways and different colors are chosen for each class; the colors represent the progression of values for specified data. It is achieved after the raster themes are converted into a shape file, which includes radioactivity and information that represents sub grade characteristics. Data are interpolated by kriging method to introduce a continuous surface as visual display by using spatial interpolation which is the process of using points with known values to estimate values at other unknown points. In GIS, spatial interpolation of these points can be applied to create a raster surface with estimations made for all raster cells.

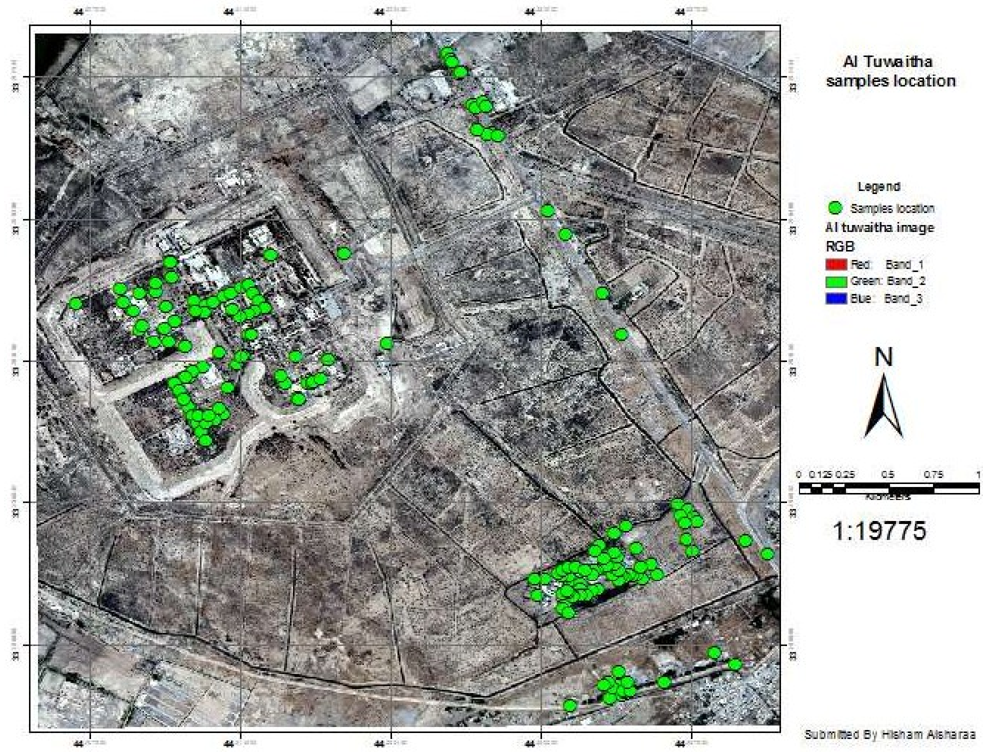

Figure 3. Soil samples locations.

4. Results and discussion

The statistical summary of activity levels of U-sum in the soil samples collected from different locations of Al-Tuwaitha is given in Table 1.

Table 1. Activity concentrations of radionuclides in soil samples (Bq/g).

Elements	Min	Max	Mean	Standard deviation	Criteria
U-sum	0.01994	6.12042	0.08259	0.43572	0.040

This approach may be thought of as an upper limit, recognizing that both the contaminant mean and overall distribution particularly the higher concentrations due to hotspots are important parameters for demonstrating that the cleanup has achieved the release criteria. Thus, it is necessary to have an overall understanding of the contaminant distribution to make this determination on hot spot acceptability.

One difficulty in this approach is a large number of samples are required to adequately characterize the upper tail of the distribution. That is, with relatively few data, the uncertainty in the upper percentiles of distributions is great.

Sixty-three samples (17.6 %) Figure 3 were found to have one or more radionuclides with activities significantly greater than background. Background estimates for total uranium. Some radionuclide's found in environmental samples at Al Tuwaitha were not detected in control samples. Twenty five of the 201 soil samples (12.4 percent) from the vicinity were determined to have natural uranium activities significantly higher than background. Significant uranium activities were seen in all areas, the administration and research sectors. Seven samples are interpreted to be the remnants of 1AW radioactive waste products, generated by the first uranium solvent extraction of fuel reprocessing by the PUREX method. This waste is characterized by the presence of fission products and induced-activity isotopes (^{137}Cs, ^{60}Co) but without significant uranium activities. The combination of ^{137}Cs and uranium probably originates from other radioactive waste products not involved in the uranium extraction process. As a result of the Osiraq and IRT-5000 reactor accident, long-lived of Uare still eminent in the environment, predominantly in the surface soil. 238,235,234 U concentration level exceed the permitted level by (75) m times over the UNSCEAR (2000) regulation in spot near Ishtar village and many other uranium contamination inside Al Tuwaitha nuclear research center, location C and Ishtar village. Figure 4 shows uranium concentration contour and 'mountain range' plots.

The contaminated area above normal concentration of U sum in soil having about 65% from total contaminated area (0.87 km2) between (0.08-0.2) Bq/g, 23% between (0.2-0.4) Bq/g, 6% between (0.4-0.7) Bq/g, 5% between (0.7-2.5) Bq/g and 1% between (2.5-4.5) Bq/g as the highest concentration level (Figure 5).
Sensitivity analyses allow studying the contribution of individual risk factors to the variance of the target forecast. The results indicated that risk in the hotspots 1, 2, 3 and 4 as shown in Figure 6; was mostly influence by U sum with 98%. The correlation plots shows that the hotspot 1 best fit for uranium with correlation 0.98(98%) (Figure 7).

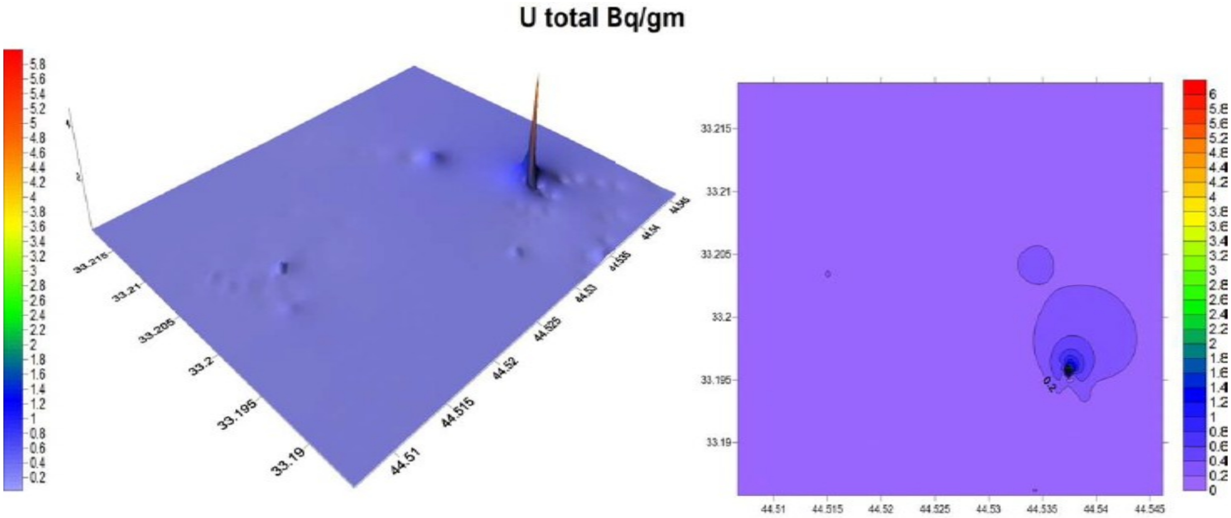

Figure 4. Uranium concentration contour and 'mountain range' plots.

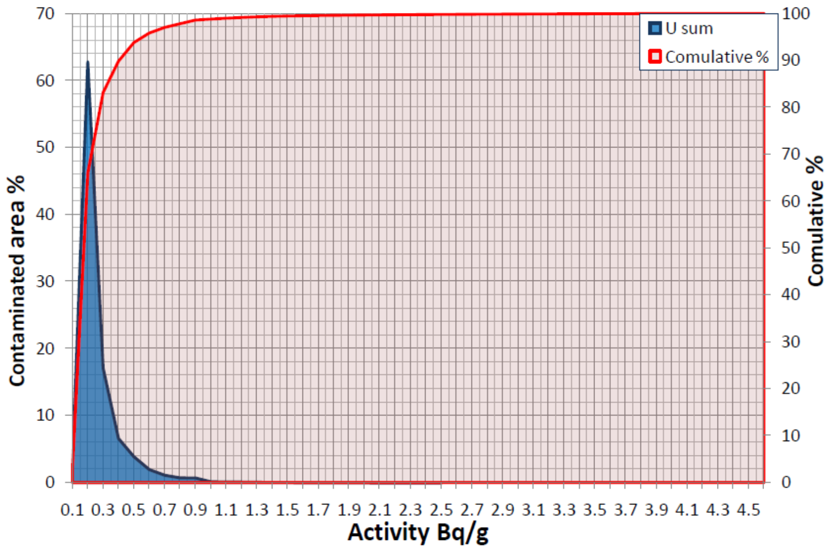

Figure 5. Contaminated area with uranium.

5. Conclusion

It is concluded that 238,235,234 U concentration in Al Tuwaitha nuclear site region surveyed was found As a result of the Osiraq and IRT-5000 reactor accident, long-lived 238,235,234 U concentration level exceed the permitted level by (75) times over the UNSCEAR (2000) regulation in spot near Ishtar village and many other uranium contamination inside Al Tuwaitha nuclear research center, location C and Ishtar village. Sensitivity analyses allow studying the contribution of individual risk factors to the variance of the target forecast. The results indicated that risk in the hotspots 1, 2, 3and 4 was mostly influence by U sum with 98%, The correlation shows that the hotspot 1 best fit for uranium with correlation 0.98(98%).More research on the effect of this site should be done. Ongoing monitoring of health status of visitors and worker in this site should also be done.

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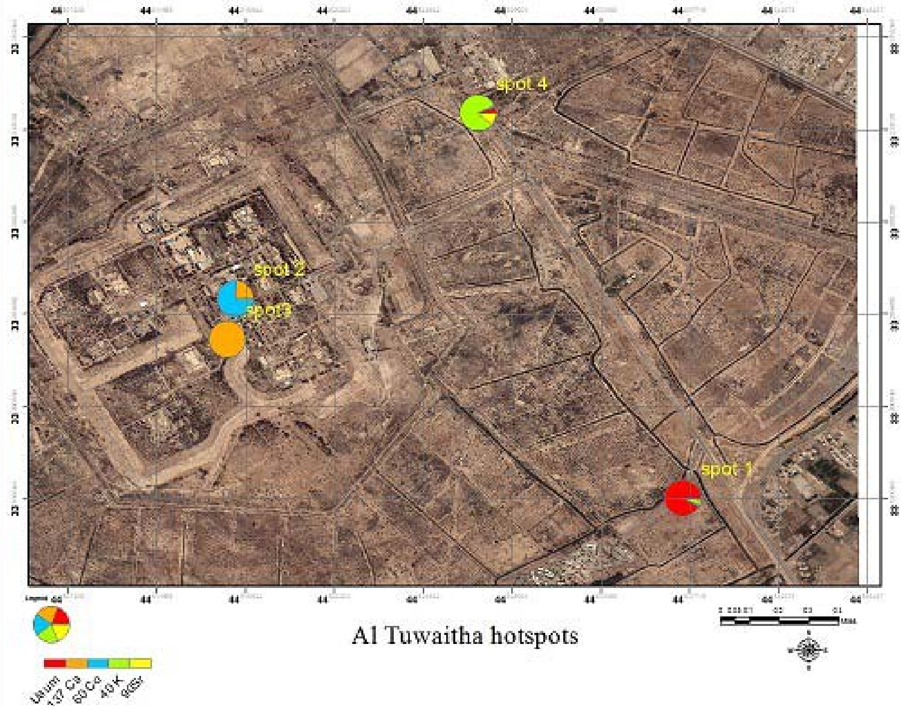

Figure 6. The contaminated hotspots.

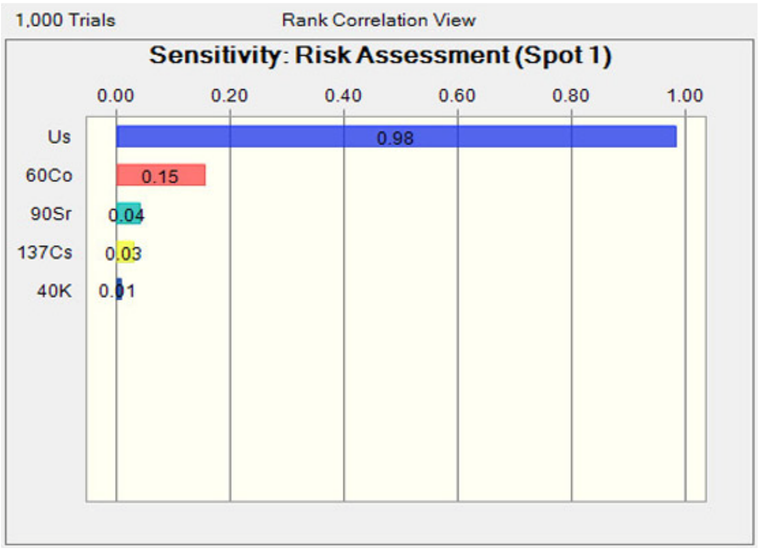

Figure 7. Sensitivity analysis for the contaminated hotspot (1).

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