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# Cobalt-60 And Cesium-137 Soil Contamination In Al Tuwaitha Nuclear Site, Using GIS Technique

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## ABSTRACT

In this paper, the author aims to introduce the hazard contamination in Al Tuwaitha nuclear site using GIS technique. The contamination level of $^{137}$Cs and $^{60}$Co, 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 of $^{137}$Cs and $^{60}$Co indicates a relatively asymmetrical distribution tailing slightly towards higher concentration. However, the activity level of $^{137}$Cs and $^{60}$Co in the soil samples of the study area exhibit large variability. Which were above the suggested normal environmental levels.

**Keywords:** Al Tuwaitha nuclear site; Iraq; GIS technique.

# تلوث التربه بعنصر الكوبلت 60 والسيزيوم 137 في موقع التويثه النووي باستخدام نظم المعلومات الجغرافيه

## الخلاصة

في هذه البحث، ويهدف الباحثون إلى تعريف التلوث الخطر في موقع التويثة النووي باستخدام تقنيات نظم المعلومات وقد اخذت عينات للتربه لعنصري الكوبلت 60 والسيزيوم 137 حول المفاعلات وقورنتمع المعايير العالميه للجنه الامم المتحدهUNSCEAR لسنه 2000 . وقد اظهرت النتائج توزيع عنصر السيزيوم 137 والكوبلت 60 بشكل غير متكافئ ومختلف في التراكيز العاليه.مع ذلك نجد ظهور نشاط عنصر السيزيوم 137 في عينات التربهالمحلله هي الاكثر تغيرا , مع ذلك نجد ان نشاط عنصر الكوبلت 60 في عينات التربه لمنطقه الدراسه قد تغيرت ايضا نتيجه اختلاف الأنشطة النووية وتقدمها , والتي هي اعلى من المحددات البيئيهالطبيعيه .

## 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



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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 Figure (1).

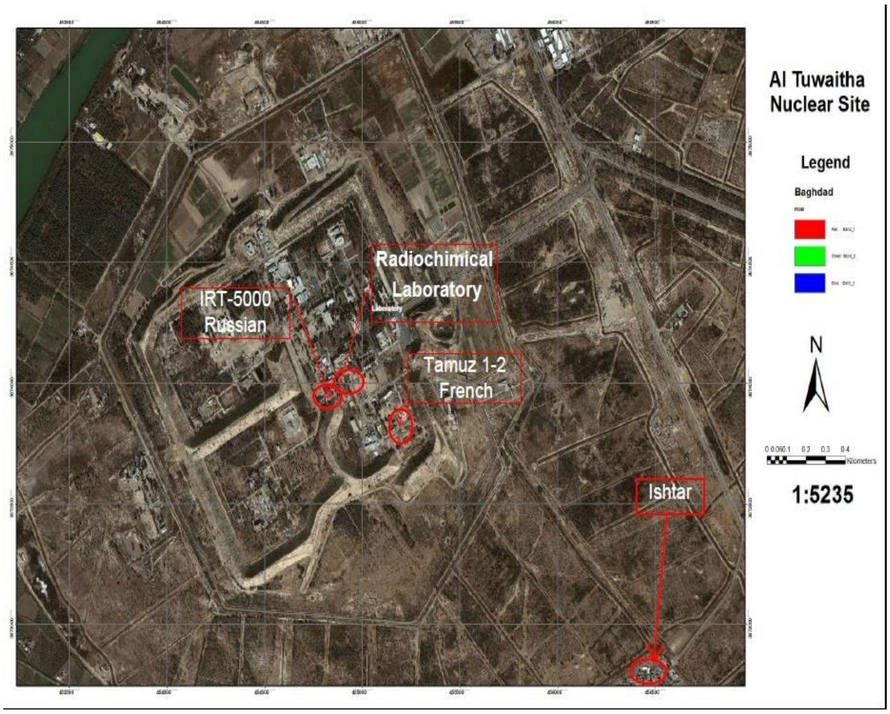


**Figure (1). Map of Al Tuwaitha nuclear site facilities (2012)**

As a result of the Osiraq and IRT-5000 reactor bombardment, long-lived of $^{137}$Cs and $^{60}$Co, 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.

## 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, [1, 2]. The nuclear research facilities at Al

Tuwaitha were built by various companies during the development of the Iraq's peaceful nuclear program. 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 [2]. Iraqi civilians looted perimeter storage areas at Al Tuwaitha and dumped more than 200 barrels of uranium compounds in the form of yellow cake near the village of Ishtar. The barrels, still containing more than 10 kilograms of yellow cake 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 yellow cake by June 2003. Furthermore, 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 [2].

## Materials and Methods

In this paper, total of 201 soil samples were analyzed. The radioactivity data samples used in this paper were collected in 2009 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 (Fig. 2).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 for exposures dose radioactive maps were created by additive interpolation method of the geographical information system using the integration between ArcGIS 9.3 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 represent 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. [3-6].

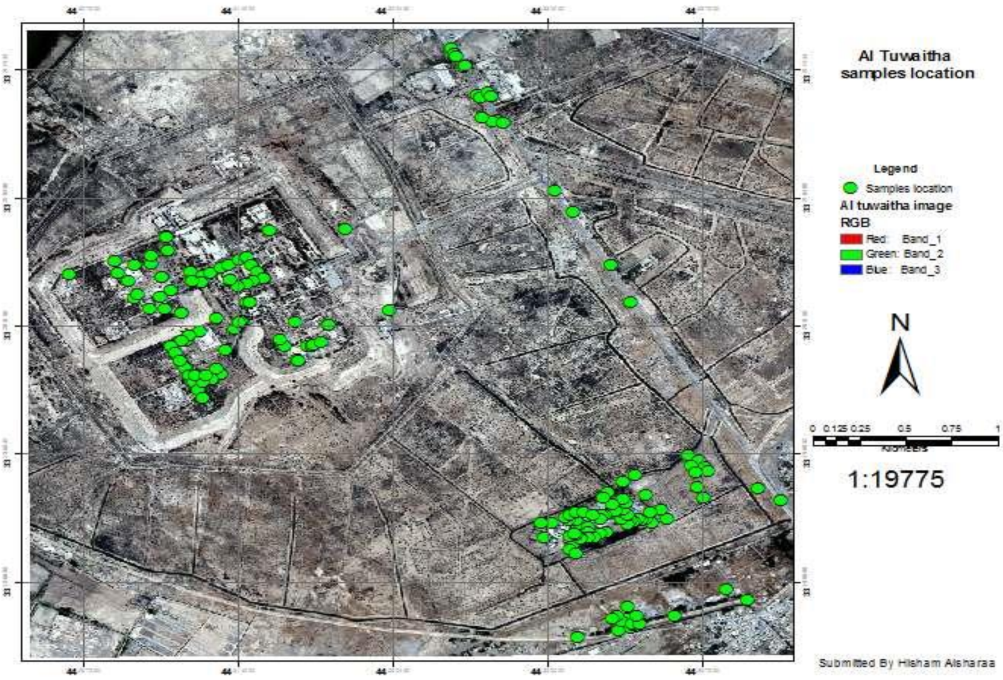


**Figure (2). Soil samples locations**

## Results and Discussion

The statistical summary of activity levels of $^{137}$Cs and $^{60}$Co in the soil samples collected from different locations of Al-Tuwaitha is given in Table 1. The activity of $^{137}$Cs and $^{60}$Co indicates a relatively asymmetrical distribution tailing slightly towards higher concentration. However, the activity level of $^{137}$Cs in the soil samples' exhibit higher variability and ranged between 0.0000274-76.9474 Bq/g with an average value of 0.728 ± 6.513 Bq/g. Similarity, it is observed that the activity level of $^{60}$Co in the soil samples of the study area also exhibits large variability and ranged between 0.02-250.0472 with mean values of 1.264 ± 17.636. Whereas, indicating that the activity level of $^{137}$Cs and$^{60}$Co in the soil samples was above the normal environmental levels suggested by UNSCEAR (2000).

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

| Elements | Min | Max | Mean | Standard Deviation | Criteria |
|---|---|---|---|---|---|
| $^{137}$Cs | 0.0000274 | 76.947 | 0.728 | 6.512 | 0.02 |
| $^{60}$Co | 0.02 | 250.047 | 1.264 | 17.635 | 0.05 |

The obtained values of $^{60}$Co level exceed the permitted level by 5000 times and for $^{137}$Cs by 3850 times. However, the activity level of $^{137}$Cs in the soil samples' exhibit higher variability and ranged from the normal level to 76.947 Bq/g with an average value of 0.728 ± 6.512 Bq/g. Similarity, it is observed that the activity level of $^{60}$Co in the soil samples of the study area also exhibits large variability and ranged between 0.02 to 250 Bq/g with mean values of 1.264 ± 17.635 Bq/g. indicating that the activity level of $^{137}$Cs and $^{60}$Co in the soil samples was above the normal environmental levels of the UNSCEAR (2000) as shown in Figures 3 and 4 as contour and mountain range plots.

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, and radiocesium were as follows: $^{137}$Cs = 0.0081 ± 0.003 Bq/g. Some radionuclide’s found in environmental samples at Al Tuwaitha were not detected in control samples. These radionuclide’s and their detection limits were:$^{60}$Co = 0.021 Bq/g.

Twenty five of the 201 soil samples (12.4 %) 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. The characteristics of all samples containing of $^{137}$Cswere detected in 16 of the 201 sampling localities (8%). The highest $^{137}$Cs levels were found in areas adjacent to the IRT-5000 and in the vicinity of the Russian silos that were used to store radioactive waste. $^{137}$Cs was found together with other radionuclides in 16 of the 29 samples; $^{137}$Cs was found in nine samples that also had elevated natural uranium, and it was found in seven localities in combination with high activities of $^{60}$Co. 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. Samples containing solely $^{137}$Cswere found outside of the waste processing and storage facilities. Such contamination may have resulted from improper disposal and dispersal of radioactive sources used in medical applications or research. Except for contamination by looting, all releases of radiation appear to be confined within the berm area of the nuclear research center. Although 35 of the 201 (17.6 %) sampled show significantly elevated values for at least one radionuclide. $^{137}$Cs and $^{60}$Co were found in significantly elevated activities primarily in the vicinity of the IRT-5000, the radioactive source shed, and the radioactive waste storage tanks located at the Russian silos. Presume that environmental contaminations near the IRT-5000 and the source shed was the result of spillage of sources and 1AW (is waste raffinate from solvent extraction) waste during the consolidation of radioactive sources follows 1991 military action. The highest concentrations of 1AW waste were found adjacent to the access doors of the metal tank used to house spent fuel and wastes from the IRT-5000. This structure was embedded into the soil in late 1991 by Al Tuwaitha personals. Small areas of $^{137}Cs$ and $^{60}Co$ contamination found alongside the access doors to the radioactive source storage shed, Variation of the activity levels and radionuclide content in the soil samples surrounding the Russian silos imply that contamination could not the result of a single source.

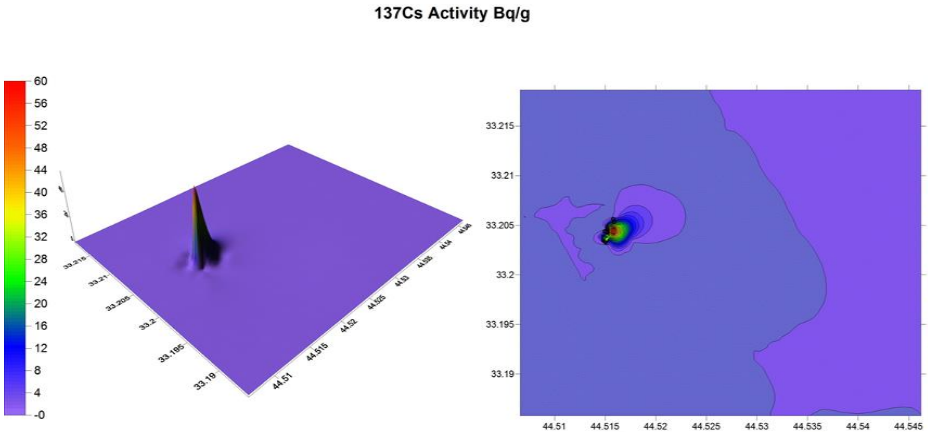


**Figure (3): $^{137}Cs$ concentration contour and 'mountain range' plots**

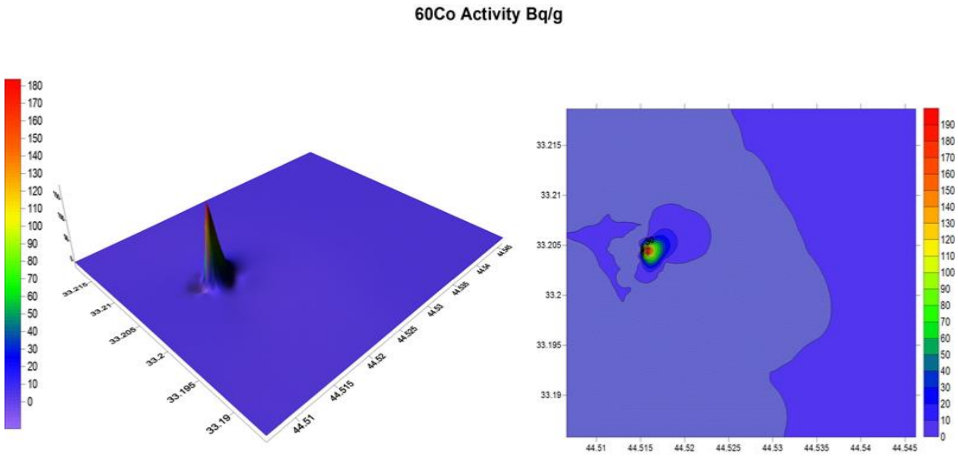


**Figure 4: $^{60}Co$ concentration contour and 'mountain range' plots**

## CONCLUSION

It is concluded that radiation doses in Al Tuwaitha nuclear site region surveyed was found As a result of the Osiraq and IRT-5000 reactor accident, long-lived of

$^{137}$Cs and $^{60}$Co are still eminent in the environment, predominantly in the surface soil; it can see very high contamination activity in spent fuel storage as radioactive waste in this area. The $^{60}$Co level exceeds the permitted level by (5000) times and for $^{137}$Cs by (3850) times over the UNSCEAR (2000) regulation very high contamination activity was found near spent fuel storage area. 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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