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Measurement of Radioactive Concentrations and Determination of Isotopes Using Portable Devices for Radiochemistry Laboratories Al-Tuwaitha Nuclear Site in Iraq

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ABSTRACT

The measurements of radioactive concentrations using portable radiological devices for radiochemistry laboratories at the Al-Tuwaitha nuclear site (section C) were studied, section C consists of three laboratories, C1, C2, and C3 were used, Redeye device to measure the radioactive concentrations of alpha and beta emitters, and the Interceptor™ Specifications device to detect radioisotopes. The results showed the presence of radioactive contamination in Unit C distributed over most of its parts. In the C1 laboratory, the highest radioactive contamination was recorded in HCL2 with a concentration of 113.65Bq/cm^2. In addition, the C2 laboratory recorded the highest radioactive concentration in FH1 with a concentration of 830.14Bq/cm^2 for Beta particle emitters, while the C3 laboratory recorded the highest pollution in FH contamination with a radioactive concentration of 75.26 Bq/cm^2. The results show that location C shows the isotopes detected in the laboratory components, such as Cesium ^{137}Cs, Neptunium ^{237}Np, and Americium ^{241}Am. The results showed the presence of contamination on the laboratory floor in the fourth part, contaminated with Americium ^{241}Am and Lutetium ^{167}Lu isotopes. While location B did not record radioactive contamination in most of its parts except for room B8 which recorded radioactive concentrations of about 1.33 Bq/cm^2. While the location A, that is, no radioactive contamination was recorded, and the readings were within the permissible limits

KEYWORDS: Radioactive concentrations; contamination; radiochemistry laboratories; redeye; Interceptor™ specifications.

INTRODUCTION

In the years leading up to during World War II, nuclear research was primarily focused on creating defense weapons. Later, the researchers were focus on peaceful uses. Nuclear Science and technology and noteworthy application of electricity are generated using nuclear energy. Scientists have successfully used nuclear technology for various applications after years of research and science, medicine, and industry [1]. Because of the impact on the health and safety of operating employees and the general public and environmental protection, the International Atomic Energy Agency (IAEA) has focused on decommissioning nuclear sites. The IAEA began its decommissioning effort in the 1970s and has published hundreds of articles on the safety series since 1980. The radiological characterization is the first step in estimating the danger of accidents and decommissioning nuclear sites. The phrase "radiological characterization" refers to radionuclides' nature, location, and concentration in nuclear power plants in general [2]. Radioactive waste comes from various places, including the nuclear industry, nuclear research centers, nuclear power plant accidents, and diverse uses of radioactive material for human needs, including medicine. The processing of raw materials containing Naturally Occurring Radionuclides Materials (NORMs), such as fertilizer manufacturing, can also result in radioactive waste [3]. Additionally, radioactivity from the oil sector

can be found in sludge and scale's liquid and solid phases. Uranium, thorium, radium, and other natural radionuclides can all be used in the process (NORMs) of radiation and radiation production; these radionuclides in the workplace can increase maintenance personnel's exposure [4]. The regulatory authority must develop and implement safety assessment rules. The person or organization in charge of a facility or activity that poses a radiation risk must complete a proper safety evaluation of that facility or activity [3]. According to the regulating authority, persons or organizations in charge of facilities and activities that pose a radiation risk must complete an appropriate safety assessment. Before receiving authorization, the responsible person or organization must submit a safety evaluation to the regulatory agency for evaluation [5].

In the 1960s, the Al-Tuwaitha Nuclear Research Center (ATNRC) was founded. It is located at 33o 12.57 north and 44o 31.822 east in Baghdad province, Iraq's capital. It is around 1.3 km^2 in size. It's about a kilometer east of the Tigris River and 20 kilometers south of Baghdad. Earthen berms encircled the previous Iraqi Atomic Energy Commission (IAEC) with a 30-meter height around the buildings. The Iraqi Ministry of Science and Technology, represented by the nuclear formations Al-Tuwaitha site, plans to decommission the nuclear sites destroyed. The radiochemistry laboratory was one of 90 structures in Al-Tuwaitha [6]. The Radiochemistry Laboratories (RCL) was founded in 1978 by the SNIA TECHINT–Italy firm as part of the Chemical Research Centre at the former Iraqi Atomic Energy Commission (IAEC nuclear)'s site Al-Tuwaitha. The building, which covers an area of roughly 1000 m^2, was destroyed during the second Gulf War in 1991. The RCL's goals were to extract plutonium isotopes from spent fuel received from the IRT-5000 (Tammuz-14) reactor on a laboratory scale (dissolution, separation, purifying, and other chemical research and analysis (^{239}Pu). Since 1973, the wasted fuel from this facility has been stored. As a result of the fission products of the (^{235}U) isotope, which belong to the fuel rod utilized in these procedures, there are significant amounts of radioactive liquid waste with various radionuclides [6]. Figures 1 and 2 show Iraq map and the Al-Tuwaitha site's location and building plan [7].

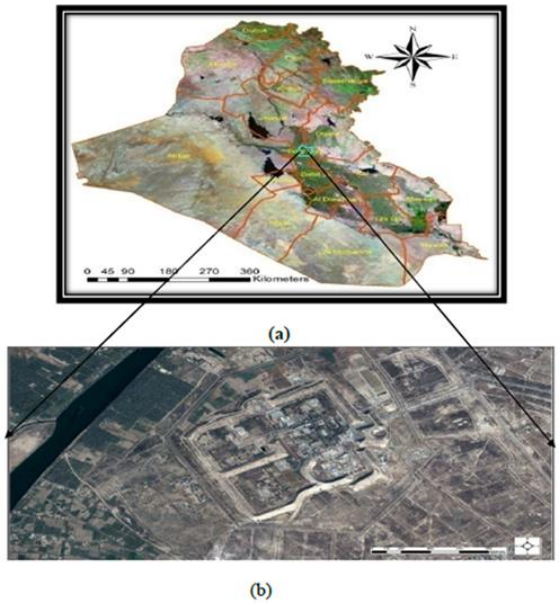

Figure 1. a) Iraq map and b) Al-Tuwaitha site [7].

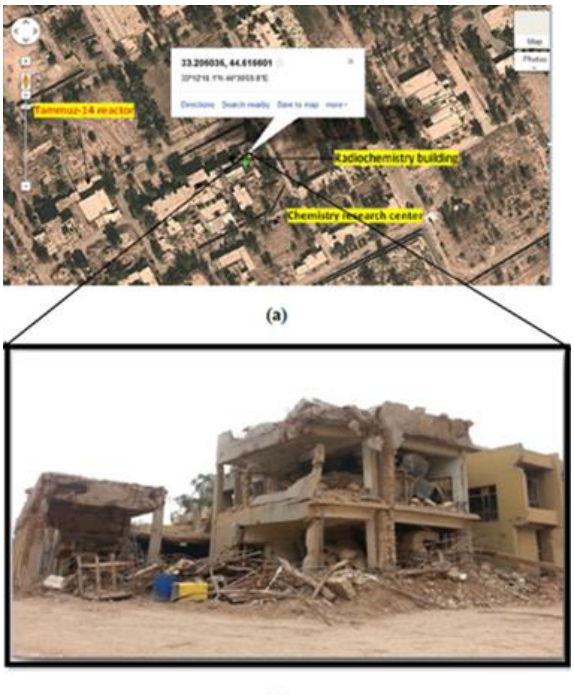

Figure 2. a) The building in the Al-Tuwaitha site, b) Radiochemistry Laboratories RCL building [7].

MATERIALS AND METHODS

Redeye surface contamination measurement device

Thermo scientifically, Germany's Radeye PRD (personal disturbing radiation detector) Figure 3 shows the employed sensitive measurement instrument. The gamma equivalent dosage rate is used to get the overall count rate (in cps). Radiation exposure per hour (in Sv/h) and total

ambient equivalent dose (in Sv), this instrument is also used to locate and detect radiation sources. A highly sensitive NaI (Tl) flash detector is included in the Radeye PRD. It has a small optical multiplier that detects radiation at low levels. The count goes from 10nSv/h to250 nSv/h, with numbers up to 800,000 cps displayed. Twenty mSv/h security alarms before delivery, the manufacturer, determine. Figure 3 shows the Redeye surface contamination measurement device.

Interceptor™ Specifications

Thermo Scientific's Interceptor TM is a hand-held isotope Spectroscopic Personal Radiation Detector (SPRD). The rigid device measures 68mm (W) 122mm (L) 30mm (T) and has a 2.2″ backlit LCD. It is fitted with three Cadmium-Zinc Telluride (CdZnTe) detectors, two for gamma dose rate monitoring and one for nuclide identification. Thermal neutrons are detected using an optional ^{3}He proportional counter. Each of the two dose-rate detectors measures (15× 13 ×5) mm and has a sensitivity (^{137}Cs) of 1.5 cps per R h^{-1} and a dose-rate range response of 5 R hr-1 to 100 mRh^{-1} (±30%). The volume of the high-resolution CdZnTe detector is 7× 7× 3.5 mm, and it is connected to a 1024 channel analyzer with an energy resolution (^{137}Cs) of 2.4%– 3.5% FWHM (crystal dependent) and range 30keV–1.5 MeV) [8] as shown in Figure 4. Unattended Surveillance Mode (USM) and User Attended Mode (UAM) are also options for the detector (UAM). The device can be used as a finder, monitor dosage rate and total dose measured, be set in identification mode, and manually acquire spectra in UAM. The identification method can collect data for one to thirty minutes, depending on how much data is needed. The device's isotope library includes 28 medical, industrial, NORM, and SNM isotopes, with an additional 23 in the extended library. The device can record voice and snap images to document the source measured. In either model, the device can be programmed with warning and alarm levels ranging from $250nSvh^{-1}$ to $50mSvh^{-1}$, or 3.0 to 9.9 times the local background rate. Warnings and alarms are communicated to the user via visual, audio, and vibration notifications. The audio and vibration warnings can be turned off in the settings, allowing measurements to be made without startling the general public [9].

Figure 3. Redeye device.

Figure 4. Interceptor™ Specifications.

Measurements of contamination

Contamination is determined by rubbing a small piece of material, such as filter paper, across a designated region of the component surface (typically 100 – 300 cm^2). This action transmits a portion of the activity to form, which can be counted using counting equipment. There are two approaches to measure total or fixed external surface contamination:

1. One way is to utilize a stationary detector for a specified distance from the surface for a set period. The detector is frequently used with an instrument that calculates a numerical result by integrating the counts across the period selected. Some devices can also store several results for later analysis on a computer. The limiting speed is determined by the detector sensitivity and the type of detector and the instrument's resolving time, as well as the radiation intensity.
2. Scanning the surface is the other method of measurement. The equipment is held close to the surface and moved systematically low enough to detect changes in the radiation field. The detector sensitivity, the kind and intensity of radiation, and the instrument

resolving time all influence the limiting speed.

Radiological characterization in radiochemistry laboratories

Through this study, radiological measurements of radiochemistry laboratories have been evaluated. Included According to the engineering description of the building and radiochemistry laboratories RCL, which consists of Health physics laboratories (B5, B6) which consist of an entrance and a private bathroom to remove radioactive contamination for workers, and health physics laboratories are connected to it and a corridor of length (30m) roughly joined by a group of rooms and small corridors, Figure 5. The C1 laboratory contains three glove boxes (GB13, GB 14, GB 15), a box made of stainless steel with windows made of organic glass with openings for a working glove. The box also contains side spaces to connect it with another box or insert and exit materials. In addition to slots for the disposal of aqueous liquid waste (Aqueous Waste) and organic waste, these openings, in turn, are connected with the pipeline network of the liquid waste system. The C1 laboratory contains two fume hoods (FH1, FH2) intended for dealing with radioactive chemicals when preparing chemical solutions and conducting some simple research on them. Laboratory C2 contains 11 glove boxes (GB1, GB2, GB3, GB4, GB5, GB6, GB7, GB8, GB9, GB10, and GB11) and two fume hoods. Laboratory C3 includes one fume hood [10].

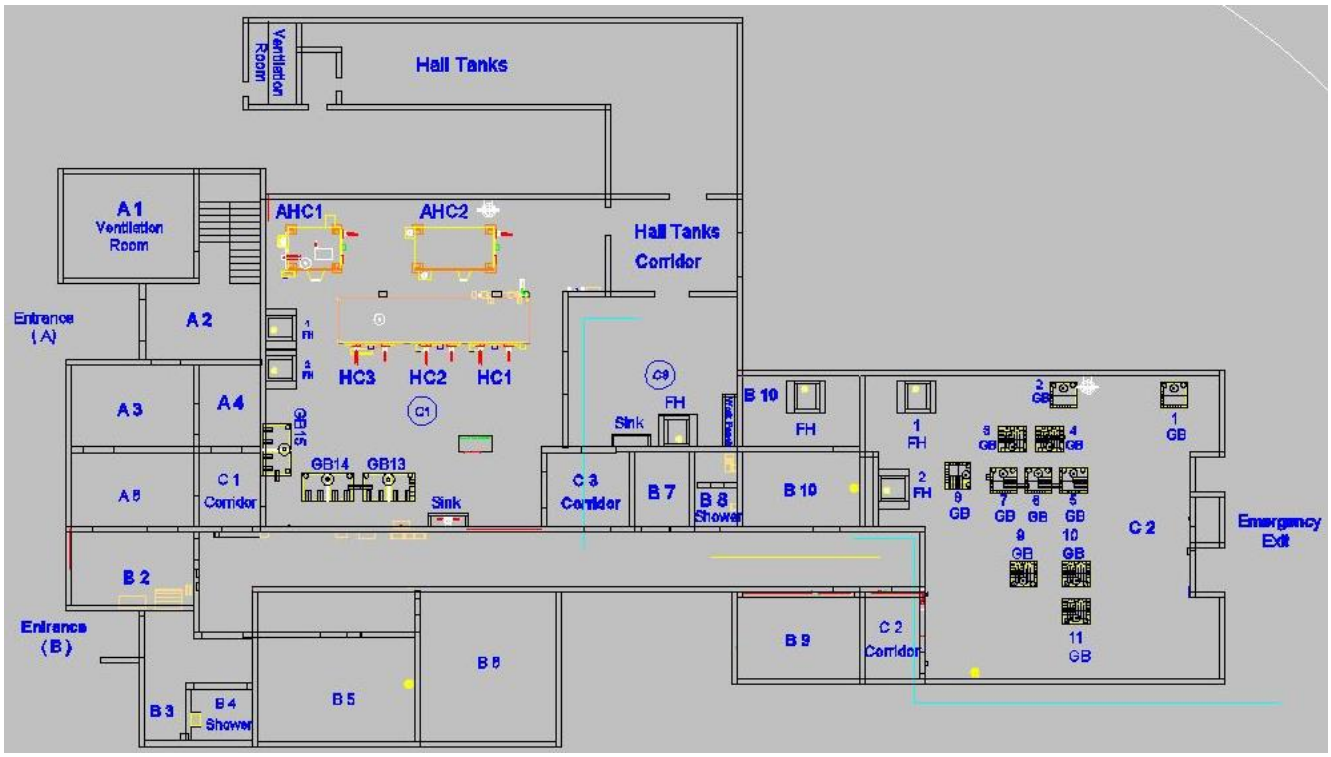

Figure 5. Block diagram of the Radiochemistry Laboratories [7, 10].

Radiological measurements of radiochemistry laboratories

To characterize the radiochemistry laboratories, a characterization plan is required that includes the equipment used in characterization and each unit of the radiochemistry laboratories. This building is divided into three main sections (A, B, and C), and each unit of these laboratories is divided into several grids for the floor, ceilings and walls, (1x1) meters as shown in Figure 6.

Figure 6. Grids distribution ceilings, walls and floor of rooms in the radiochemistry laboratory building.

RESULTS AND DISCUSSION

Results of characterization processes

The location A consists of five rooms (A1, A2, A3, A4, and A6) of varying dimensions, where room A1 represents the ventilation room, and the rest of the rooms are empty. Radiological characterization was carried out using portable devices (activity concentration was measured portable devices Radeye) for each of these rooms, as shows in Table 1. It is within the global permissible limits for both beta particle emitters at a concentration of 0.4 Bq/cm^2 and alpha particle emitters at 0.04 Bq/cm^2 as recommended by ICRP [11]. The location B consists of eight rooms (B2, B3, B4, B5, B6, B8, B9, and B10) of varying dimensions, a private bathroom to remove radioactive contamination for workers and associated health physics laboratories B5 and B6, rooms B4 and B8 connected with shower, B10 contains the fume hood (FH) and the rest of the rooms are empty. Radiological characterization was carried out using portable devices, as shows in Table 2.

Table 1. Activity concentration in the radiochemistry location A.

Location	Activity concentration (Bq/cm^2)			
	β		α	
	Max.	Min.	Max.	Min.
A1	0.29	0.16	0.00	0.00
A2	0.27	0.15	0.00	0.00
A3	0.29	0.17	0.00	0.00
A4	0.29	0.14	0.00	0.00
A6	0.29	0.18	0.00	0.00

Table 2. Activity concentration in the radiochemistry location B.

Location	Activity concentration (Bq/cm^2)			
	β		α	
	Max.	Min.	Max.	Min.
B2	0.18	0.11	0.00	0.00
B3	0.15	0.10	0.00	0.00
B4	0.17	0.12	0.00	0.00
B5	0.17	0.11	0.00	0.00
B6	0.16	0.13	0.00	0.00
B8	1.33	0.12	0.00	0.00
B9	0.22	0.15	0.00	0.00
B10	0.32	0.13	0.00	0.00

Section C consists of three laboratories, C1, C2, C3, and laboratory will be dealt with individually due to the nature of these laboratories. Table 3 shows C1 laboratory the contamination in each of the glove boxes (GB) and fumes hood (FH) are removable, whereas the Hot Cells (HCL) and the analytical cells (AHC) were free of external contamination, and the radioactive contamination originated from the inside. Table 4 shows the measurement of radioactive concentrations with the Redeye device. Radiation measurements of the C3 laboratory were carried out using portable devices, described the fume hood and the laboratory's ground, walls, and ceiling, as shows in Table 5 shows the results of measuring the radiation concentration.

Table 3. Activity concentration of smear test, and isotope type for Laboratory C1.

Code	Activity Concentration (Bq/cm^2)				Isotope type
	β		α		
	Max.	Min.	Max.	Min.	
GB13	2.33	0.10	0.06	0.00	^{137}Cs-^{241}Am
GB14	28.67	0.11	3.23	0.00	^{137}Cs-^{241}Am
GB15	61.22	0.14	4.99	0.00	^{137}Cs-^{241}Am
FH1	5.11	0.12	0.00	0.00	^{137}Cs
FH2	15.6.67	0.11	0.00	0.00	^{137}Cs
HCL1	1.34	0.13	0.00	0.00	^{137}Cs
HCL2	113.65	0.13	0.00	0.00	^{137}Cs
HCL3	2.44	0.10	0.00	0.00	^{137}Cs
AHC1	73.55	0.13	0.00	0.00	^{137}Cs
AHC2	18.98	0.11	0.00	0.00	^{137}Cs

Table 4. Activity concentration of smear test, and isotope type for laboratory C2.

Code	Activity concentration (Bq/cm^2)				Isotope type
	β		α		
	Max.	Min.	Max.	Min.	

GB1	33.57	0.33	1.55	0.00	^{237}Np- ^{241}Am
GB2	101.42	0.22	2.50	0.00	^{137}Cs- ^{237}Np
GB3	1.4	0.10	0.00	0.00	^{137}Cs- ^{237}Np
GB4	65.00	0.45	0.00	0.00	^{137}Cs- ^{237}Np
GB5	1.7	0.2	0.00	0.00	^{176}Lu- ^{237}Np
GB6	5.7	0.23	12.44	0.00	^{137}Cs- ^{237}Np
GB7	12.81	0.43	3.32	0.00	^{137}Cs- ^{237}Np
GB8	18.45	0.16	12.65	0.00	^{137}Cs- ^{237}Np
GB9	17.18	0.17	0.00	0.00	^{137}Cs- ^{241}Am
GB10	34.21	0.13	0.5	0.00	^{137}Cs- ^{241}Am
GB11	73.76	0.76	0.03	0.00	^{137}Cs
FH1	830.14	3.65	149.72	0.00	^{237}Np
FH2	1.2	0.32	0.5	0.00	^{241}Am

Table 5. Activity concentration of smear test for the wall, ground, and celling for laboratory C3.

Code	Activity concentration Bq/cm^2			
	β		α	
	Max.	**Min.**	**Max.**	**Min.**
FH	75.26	0.45	0.6	0.00
W11	0.16	0.14	0.00	0.00
W21	0.18	0.13	0.00	0.00
W31	0.19	0.14	0.00	0.00
W41	0.22	0.18	0.00	0.00
Ground1	0.34	0.19	0.00	0.00
Ceiling1	0.18	0.13	0.00	0.00
W12	0.18	0.15	0.00	0.00
W22	0.19	0.12	0.00	0.00
W32	0.23	0.15	0.00	0.00
W42	0.21	0.12	0.00	0.00
Ground2	0.27	0.13	0.00	0.00
Ceiling2	0.15	0.14	0.00	0.00

CONCLUSIONS

The results show the locations A and B are not radioactively contamination and within the permissible limits for each of the concentration radioactivity. The results show the unit B is not radioactively contaminated and within the permissible limits for each of the concentration radioactivity with the exception of room B8 which contains shower to remove contamination, radioactive concentrations were found above the permissible limits for concentrations of radioactive materials. The B10 laboratory consists of two sections; the first section is considered the closest to the corridor and contains many shelves of chemicals packed in glass flasks; the results of radiological surveys indicated that this section was no radiation contamination. The second section contains a fume hood (FH) containing flasks of different capacities and sizes. The results of the radiological survey of laboratory B10 showed no radioactive contamination, and the results were within allowed limits. Room B8 contains two showers used to remove continuation resulting from the different activities of the workers and the tools used in measurement or work that can remove. These showers recorded radioactive concentrations of about 1.33 Bq/cm^2, which are higher than the permissible limits for concentrations of beta emitters. The results show the unit C shows the isotopes detected in the laboratory components, such as cesium ^{137}Cs, neptunium ^{237}Np and americium ^{241}Am. The results showed the presence of contamination on the laboratory floor in the fourth part, contaminated with americium ^{241}Am and lutetium ^{167}Lu isotopes. The results showed the presence of radioactive contamination in most parts of the C1 laboratory, where the highest radioactive concentration in HCL2 was 113.65 Bq/cm^2, as well as the C2 laboratory recorded high radioactive contamination in FH1 with a radioactive concentration of 830.14 Bq/cm^2, The C3 laboratory showed the presence of radioactive contamination in the fume hood contamination with a radioactive concentration of 75.26Bq/cm^2. The limits radiation concentration of the walls, ground and ceiling were within the limits of the radiation background. These results agreed with the findings of the researcher Radiological Characterization and Safety Assessment of Destroyed Nuclear Facilities at Al-Tuwaitha Nuclear Site in Iraq [10].

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