Field Radiological Characterization for Scrap Yards at Al-Tuwaitha Nuclear Site

Yousif M. Zayir Al-Bakhat
Radiation and Nuclear Safety Directorate,
Ministry of Science and Technology

Hazim Louis Mansour **Huda Nassar Karkosh**
Department of Physics, College of Education
Al-Mustansiriyah University

ABSTRACT

In the present study, measurements of alpha/beta contamination and gamma dose rates measurements were carried out in scrap yard contaminated by spillage of sludge contained ^{238}U at Al-Tuwaitha Nuclear Site. Alpha/beta surface soil contamination levels were directly measured in the field at January 2016 using RadEye SX monitor. Gamma dose rates measurements were conducted using RadEye PRD. The results showed that alpha/beta surface soil contamination levels varied from 0.1 for uncontaminated areas and reach 2.8 Bq/cm^2 for contaminated areas, with an average value of 0.8 Bq/cm^2, which is more than 6 times the local natural background level. Results of dose assessment indicate that, the potential radiation doses to on-site workers from site contaminants were estimated to be in the order of 0.036 mSv/y, which was considered within the occupational dose limit of 20 mSv/y recommended in the International Atomic Energy Agency (IAEA) GSR Part 3 (2014). However, the mean dose rate reaches 4.5 times the background level, indicating that remediation of site contaminants is recommended to ensure environmental safety.

Key words: Radiological characterization, scrap yards, Al-Tuwaitha Nuclear Site

1. Introduction

There are number of sites in Iraq which had been used for nuclear activities and which contain potentially significant amounts of radioactive material. Iraq's former nuclear facilities are spread across ten sites in Iraq. Most of these sites suffered substantial physical damage during the Gulf war in 1991 and several have been subjected to looting of materials and equipment as a consequence of the challenging security situation in the country in 2003. Looting has increased the spread of contamination and related health problems among the local residents [1, 2, 3].

Al-Tuwaitha central nuclear complex covers a land area of approximately 1.6 km^2 (1200 m × 1400 m) within the bermed area and was the main site for nuclear researches before 2003. By 1991, Al-Tuwaitha site comprised several facilities dedicated to nuclear researches, nuclear fuel fabrication, radiochemistry, processing facilities, radioisotope production, radioactive waste treatment, waste storage facilities, and biological researches buildings. Objectives of this study include:-

- Perform a hazard assessment to identify and evaluate the consequences of radiological hazards involved in the contaminated scrap yard;
- Verify site compliance with release criteria;
- Determine whether remediation is required and to what extent.

2. Materials and Methods

2.1 Description of the Study Area

There are several tons of metallic scrap at Al-Tuwaitha nuclear site placed in unsecured areas, including some parts of separators, air ducts, filters, abandoned equipment, storage tanks and drums from former Iraqi nuclear program and other metal parts associated with the 1991 bombing of nuclear facilities in Iraq, suspected to be contaminated with radioactive materials. Examples of materials and equipment that may be found in Al-Tuwaitha scrap yards include metals, concrete, tools, equipment, piping, conduit, furniture, and dispersible bulk materials such as trash, rubble, roofing materials, and sludge. Most of this scrap material exists in separate piles. Overall, there are more than 20 distinct piles of scrap in this area. Some of this damaged scrap was brought from Tarmiya site to the scrap yard at Al-Tuwaitha at the request of IAEA inspectors [3]. These piles of debris and rubbles contain miscellaneous contaminated and uncontaminated items.

The period from 1991 till now can be considered a sufficient period of time for migration of contaminants through weather factors (rainfall, wind, etc.) to surface soil or groundwater. In the other hand, there are no published analysis relating specifically to the radiological hazards associated with these scrap yards during normal conditions and during occurrence of events (e.g. loss or theft) although the issue has been raised internationally in the literature.

As for all destroyed nuclear facilities and contaminated areas in Iraq, scrap yards have been targeted for remediation under Ministry of Health and Environment/Radiation Protection Center (MoHEN/RPC) and

International Atomic Energy Agency (IAEA) supervision with the objective of releasing the site from radiological control for restricted or unrestricted use after optimizing radiological protection of workers, members of the public and the environment.

Historical site data collected from personal interviews with knowledgeable former Al-Tuwaitha workers indicates that:-

- There was a spill of ^{238}U contaminated sludge or sediments in the sludge yard of unknown source after 2003;
- The spill causes a contaminated zone of about 210 m^2 (7 m (width) × 30 m (length));
- The scrap yard occupy a surface area of approximately 6050 m^2 (110 m × 55 m) surrounded to the south by earthen berms, to the east by damaged structure, to the north and west by vacant (disused) lands (Figure 1).

Figure 1: Topographic map shows scrap yard located inside Al-Tuwaitha earthen berms

2.2 Field Radiological Characterization

Field radiological characterization surveys were conducted for scrap yard at Al-Tuwaitha nuclear site start from the historical analysis of site operating life and of conditions that could lead to spill contaminations, followed by dose rate measurement and surface contamination measurements on representative components (sludge/sediments in contaminated zone, soil in the areas surrounding the contaminated zone) to evaluate the types; activity levels; and geospatial distribution of surface contamination.

RadEye SX (External Scintillation Detector, Thermo Scientific, Germany) is used for in-situ measurements of surface contamination levels. RadEye SX is a modern compact multi-purpose for external scintillation probes. This radiation detector has been recently developed and marketed enables the in-situ detection of the gross alpha and beta ray emitter. In conjunction with NaI(Tl) (2 inch × 2 inch) area detector, both alpha and beta measurement data can be displaced and recorded simultaneously [4]. RadEye SX is used in the field for measuring surface alpha and beta activities in Bq/cm^2 for the contaminated zone, uncontaminated areas and scrap material. Direct alpha and Beta-emitting radionuclides measurements using RadEye SX detector were taken by placing the instrument at the appropriate distance above the surface (about 5 cm), taking a discrete measurement for a pre-determined time interval (1 min), and recording the reading according to pre-determined grid locations. A one minute integrated count technique is a practical field survey procedure for most equipment and provides detection sensitivities that are below most guideline levels [4]. Over range indication starts at 100 000 cps. Figure 2 shows field survey points.

RadEye PRD (Alarming Personal Radiation Detector, Thermo Scientific, Germany) is used in the field for monitoring gamma radiation dose rates. RadEye PRD is a highly sensitive measuring device used to measure the gross count rate (in cps), the ambient equivalent dose rate of gamma radiation (in µSv/h) and the accumulated ambient equivalent dose (in µSv). The survey instrument is also used to detect and localize radiation sources. RadEye PRD incorporates a highly sensitive NaI (Tl) scintillation detector which is equipped with a miniature photo-multiplier allowing detection of very low radiation levels. The detection for gamma radiation dose range from 10 nSv/h to 250 µSv/h and counts display up to 800 000 cps. A safety alarm of 20 µSv/h is set by the manufacturer before delivery [5]. The selection of the RadEye PRD over other available radiation detectors is primarily based on the RadEye PRD's ability to detect low-energy gamma radiation, which comprises the majority of the gamma radiation from the radionuclides of concern.

Background radiation measurements were conducted in analogous, undisturbed, similar characteristics and non-impacted areas to provide reference data on the natural background and to distinguish between potential contaminations associated with the site from naturally occurring background conditions [6]. The recorded background readings will then be averaged in order to establish the background at the site for the particular instrument.

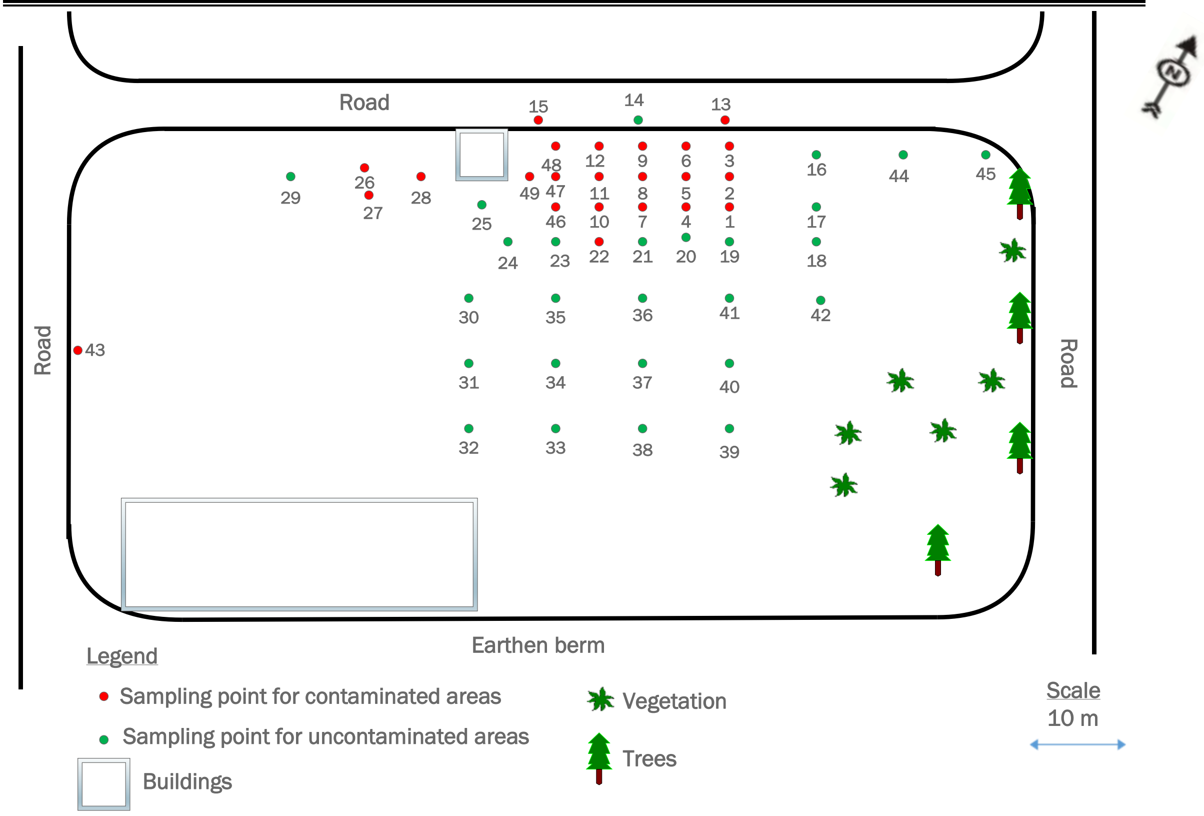

Figure 2: Field survey points

3. Results and Discussion

Field surveys were performed in the contaminated zone, surrounding areas and scrap material using hand-held, direct reading instrument (RadEye SX). The investigated site has been divided into 49 data points (23 in the contaminated zones and 26 in the surrounding areas to detect possible migration of contamination). A minimum of 10 field readings were randomly recorded from various locations according to pre-determined grid locations. The results of α/β surface contamination measurements using RadEye SX and γ dose rates measurements using RadEye PRD displayed in Table 1 were shown in Figure 3. Mean, standard deviation (σ), minimum and maximum observed contamination levels and dose rates registered by the hand-held radiation detection instrument are presented in Table 1. Gamma dose rates and surface α/β soil contamination levels detected for the background area were 0.02 ± 0.005 µSv/h and 0.12 ± 0.01 Bq/cm^2, respectively (Table 1). Surface α/β contamination measurements for areas surrounding the contaminated zone were generally higher than the background level (Figure 4), with 5 identified "hot spots", indicating that migration of contamination from the contaminated zone to the surrounding areas have been occurred as a result of weather factors (wind, rainfall, etc.).

Comparison between surface α/β surface soil contamination levels and γ dose rate measurements for contaminated and uncontaminated zones with the local natural background levels are shown in Figures (3) and (4). The mean observed gamma radiation dose was estimated to be 1 to 4.5 times the local natural background level, while the surface soil contamination levels range from 1 to 19.5 times the local natural background level, indicating that the investigated areas present a significant radiological hazard for the human health and the environment. The mean detected α/β contamination level in the contaminated zone (in excess of the background level) is 1.34 Bq/cm^2. In accordance with the IAEA-TECDOC-8S5 (1996)[7], surface soil ^{238}U contamination at 0.7 Bq/cm^2 is equivalent to 4 Bq/g. Accordingly, surface soil contamination by ^{238}U is estimated to be 7.67 Bq/g, which is considerably higher than the IAEA exemption criteria for radionuclides of natural origin (1 Bq/g) [8]. Surface α/β contamination measurements for scrap material range from 0.1 to 0.12 Bq/cm^2, with a mean value of 0.106 ± 0.008 Bq/cm^2, which is considered well within the measured natural background level for uncontaminated scarp material (0.11 ± 0.01 Bq/cm^2).

Dose and risk assessments require the definition of the exposure pathways and involve the calculations of the exposures that in turn will take into consideration different types of information related to the site surroundings, social economical habits, hydrology, meteorology, etc. The potential radiation dose related to soil contamination is estimated to be 0.039 ± 0.013 µSv/h (range from 0.024 to 0.084 µSv/h). The residual radiation dose rate (in excess of the background level) is estimated to be 0.039 – 0.02 or 0.019 µSv/h. For restricted (occupational) site use (8 hours per day, 5 days per week), the annual dose is estimated to be about 0.036 mSv/y, which is considerably less than the occupational dose limit of 20 mSv/y [9]. The potential radiation dose related to soil contamination after the site release from regulatory control without cleanup is estimated to be 168 µSv/y for unrestricted (public) use, which is well within the IAEA release criterion of 300 µSv/y [10].

Table (1): Results of α/β contamination and γ dose rate measurements:

Sample code	α/β contamination levels (Bq/cm^2)		γ dose rates (μSv/h)	
	Mean ± σ	Range	Mean ± σ	Range
AS1	2.09 ± 0.13	1.8 – 2.4	0.037± 0.008	0.02 - 0.05
AS2	1.79 ± 0.21	1.6 – 2.3	0.03 ± 0.005	0.02 - 0.04
AS3	1.87 ± 0.13	1.6 – 2.1	0.046 ± 0.01	0.02 - 0.06
AS4	2.19 ± 0.21	1.7 – 2.6	0.046 ± 0.008	0.03 - 0.05
AS5	2.23 ± 0.22	1.8 – 2.8	0.04 ± 0.005	0.03 - 0.05
AS6	1.67 ± 0.13	1.4 – 2	0.043 ± 0.006	0.04 - 0.05
AS7	1.59 ± 0.19	1.2 – 2	0.031 ± 0.006	0.02 - 0.04
AS8	1.36 ± 0.08	1.2 – 1.5	0.03 ± 0.006	0.02 - 0.04
AS9	1.3 ± 0.13	1.1 - 1.8	0.04 ± 0.006	0.03 - 0.05
AS10	1.56 ± 0.06	1.4 - 1.7	0.03 ± 0.007	0.02 - 0.05
AS11	1.59 ± 0.1	1.4 - 1.8	0.04 ± 0.007	0.02 - 0.05
AS12	1.36 ± 0.07	1.2 - 1.5	0.03 ± 0.006	0.02 - 0.04
AS13	1.14 ± 0.19	0.8 – 1.4	0.055 ± 0.005	0.05 - 0.06
AS14	0.14 ± 0.01	0.1 – 0.16	0.03 ± 0.008	0.02 - 0.04
AS15	0.83 ± 0.07	0.6 – 0.92	0.056 ± 0.008	0.04 - 0.07
AS16	0.17 ± 0.01	0.15 – 0.18	0.03 ± 0.006	0.02 - 0.04
AS17	0.23 ± 0.01	0.2 – 0.25	0.03 ± 0.003	0.02 - 0.04
AS18	0.16 ± 0.01	0.15 – 0.18	0.03 ± 0.006	0.02 - 0.04
AS19	0.21 ± 0.02	0.17 – 0.24	0.03 ± 0.005	0.02 - 0.04
AS20	0.21 ± 0.01	0.17 – 0.24	0.04 ± 0.006	0.03 - 0.05
AS21	0.19 ± 0.01	0.17 – 0.22	0.037 ± 0.008	0.03 - 0.05
AS22	0.96 ± 0.08	0.89 – 1.2	0.05 ± 0.007	0.03 - 0.06
AS23	0.15 ± 0.01	0.14 – 0.17	0.032 ± 0.007	0.02 - 0.04
AS24	0.17 ± 0.01	0.15 – 0.19	0.043 ± 0.008	0.03 - 0.05
AS25	0.21 ± 0.01	0.18 – 0.24	0.036 ± 0.005	0.03 - 0.04
AS26	1.18 ± 0.11	1.05 – 1.34	0.082 ± 0.008	0.07- 0.09
AS27	0.91 ± 0.05	0.81 – 0.98	0.084 ± 0.005	0.08 - 0.09
AS28	0.46 ± 0.05	0.37 – 0.58	0.067 ± 0.018	0.04 - 0.09
AS29	0.17 ± 0.01	0.15 – 0.18	0.026 ± 0.004	0.02 - 0.03
AS30	0.18 ± 0.02	0.14 – 0.22	0.035 ± 0.007	0.03 - 0.06
AS31	0.17 ± 0.03	0.12 – 0.22	0.035 ± 0.005	0.03 - 0.04
AS32	0.19 ± 0.02	0.17 – 0.22	0.036 ± 0.008	0.03 - 0.05
AS33	0.2 ± 0.01	0.18 – 0.22	0.034 ± 0.006	0.03 - 0.04
AS34	0.15 ± 0.01	0.14 – 0.17	0.029 ± 0.007	0.02 - 0.04
AS35	0.15 ± 0.01	0.11 – 0.17	0.026 ± 0.005	0.02 - 0.04
AS36	0.20 ± 0.008	0.19 – 0.22	0.031 ± 0.003	0.03 - 0.04
AS37	0.18 ± 0.01	0.12 – 0.2	0.035 ± 0.007	0.02 - 0.04
AS38	0.18 ± 0.01	0.15 – 0.21	0.03 ± 0.005	0.02 - 0.04
AS39	0.21 ± 0.01	0.18 – 0.23	0.033 ± 0.004	0.03 - 0.04

AS40	0.22 ± 0.03	0.17 – 0.26	0.035 ± 0.006	0.02 - 0.05
AS41	0.16 ± 0.02	0.14 – 0.2	0.033 ± 0.004	0.03 - 0.04
AS42	2.34 ± 0.09	2 – 2.5	0.04 ± 0.006	0.03- 0.05
AS43	0.4 ± 0.04	0.33 – 0.46	0.024 ± 0.005	0.02 - 0.03
AS44	0.12 ± 0.015	0.1 – 0.15	0.032 ± 0.007	0.02 - 0.04
AS45	0.12 ± 0.02	0.09 – 0.15	0.026 ± 0.005	0.02 - 0.03
AS46	2.28 ± 0.67	0.67 – 2.8	0.07 ± 0.01	0.06 - 0.09
AS47	1.80 ± 0.12	1.7 – 2.1	0.037 ± 0.004	0.03 - 0.04
AS48	1.56 ± 0.17	1.3 – 1.7	0.05 ± 0.01	0.04 - 0.06
AS49	0.36 ± 0.05	0.24 – 0.42	0.048 ± 0.003	0.04 - 0.05
Background	0.12 ± 0.01	0.1 – 0.14	0.02 ± 0.005	0.01 - 0.03

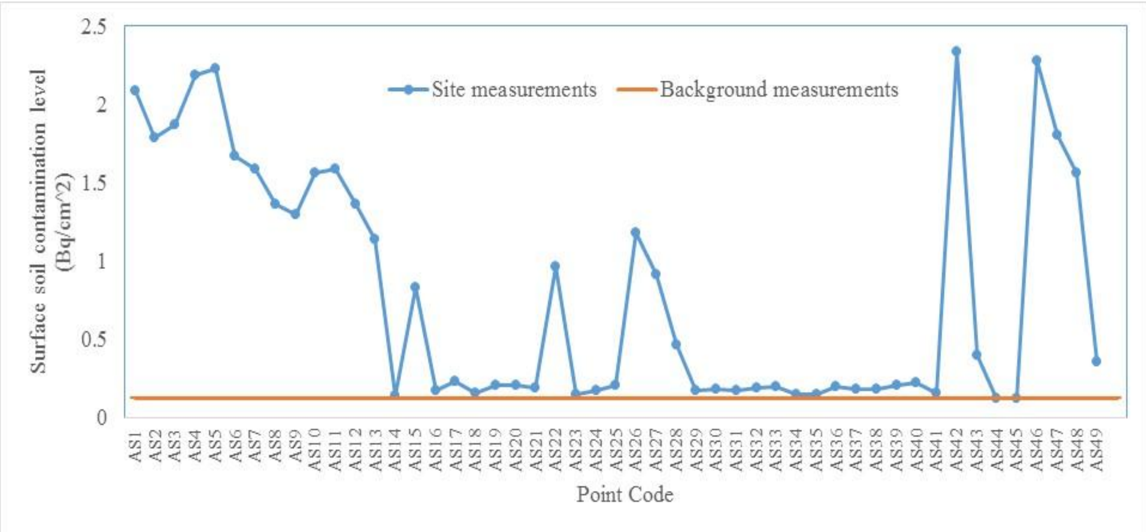

Figure (3): Comparison between α/β surface soil contamination measurements with the background measurements

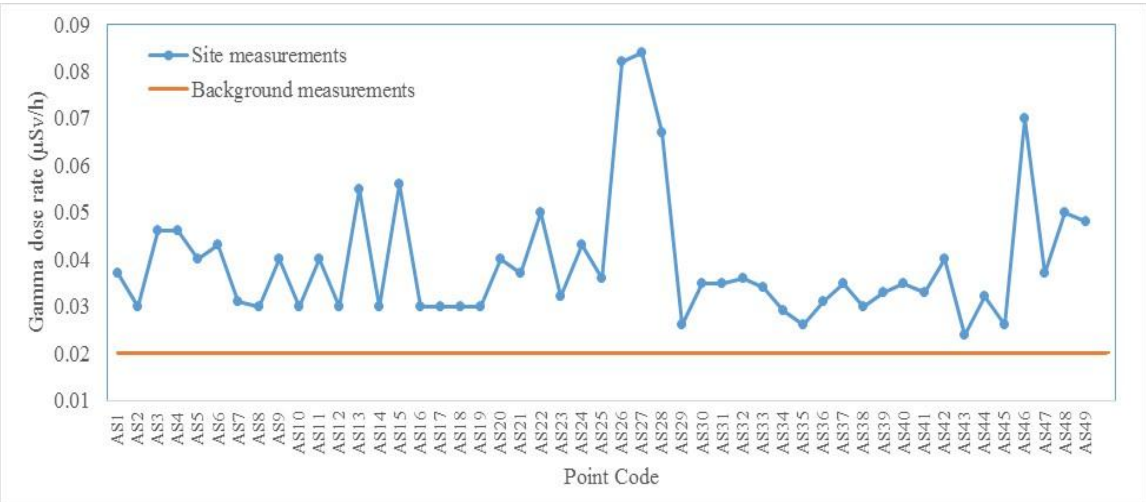

Figure (4): Comparison between γ dose rate measurements with the background measurements

4. Conclusions

The radiological characterization survey conducted for scrap yards at Al-Tuwaitha nuclear site showed that there were radioactively contaminated zones arising from spill of sludge/sediments containing ^{238}U. The estimated radiation doses to onsite workers from site contaminants were estimated in the order of 0.036 mSv/y, which was considered within the occupational dose limit of 20 mSv/y. However, surface soil contamination level is estimated to reach more than 19 times the local natural background levels, while the detected gamma dose rates inferred from direct measurements reached 4.5 times the local natural background levels, indicating that remediation of site contaminants are recommended to ensure environmental safety. It is interesting to mention that, the results of the present study are presented for the first time as far as authors know.

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التوصيف الاشعاعي الحقلي لساحات تجميع الخردة في موقع التويثة النووي

يوسف محسن زاير

مديرية السلامة الاشعاعية والنووية، وزارة العلوم والتكنولوجيا

حازم لويس منصور　　　　**هدى نصار كركوش**

قسم الفيزياء، كلية التربية، الجامعة المستنصرية

الخلاصة

تضمنت الدراسة الحالية اجراء قياسات للتلوث الاشعاعي السطحي لاشعاعات الفا/بيتا وقياسات لمعدلات الجرع الاشعاعية لاشعة كاما في ساحات تجميع الخردة المعدنية الملوثة برواسب تحوي نظير اليورانيوم–238 في موقع التويثة النووي. تم قياس مستويات تلوث التربة السطحي باشعاعات الفا/بيتا حقليا خلال شهر كانون الاول 2016 باستخدام جهاز RadEye SX. اجريت قياسات لجرع اشعة كاما باستخدام جهاز RadEye PRD. بينت النتائج ان مستويات التلوث السطحي باشعاعات الفا/بيتا تتراوح بين 0.10 للمناطق الغير ملوثة وتصل الى 2.8 بكريل/سم^2 في المناطق الملوثة وبمعدل 0.8 بكريل/سم^2 والتي تعتبر اكثر من الخلفية الاشعاعية الطبيعية للمنطقة بـــ 6 مرات. اظهرت نتائج قياسات الجرع الاشعاعية ان الجرعة الاشعاعية المتوقعة للافراد العاملين في الموقع بحدود 0.036 مللي سيفرت بالسنة، والتي تعتبر ضمن حدود الجرع المسموحة للعاملين في حقول الاشعاع البالغة 20 مللي سيفرت بالسنة الموصى بها في تقرير الوكالة الدولية للطاقة الذرية المرقم GSR Part 3 لعام 2014. بالرغم من ذلك، كانت معدل الجرعة الاشعاعية بحدود 4.5 مرة بقدر الخلفية الاشعاعية الطبيعية للمنطقة مما يؤشر ضرورة تنظيف الموقع من الملوثات الاشعاعية حفاظا على السلامة البيئية.

الكلمات المفتاحية: التوصيف الاشعاعي، ساحات تجميع الخردة، موقع التويثة النووي