Searching for Abandoned Radioactive Sources in Scrap Yards at Al-Tuwaitha Nuclear Site

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ABSTRACT

In the present study, the scrap yards (located within the latitudes 33° 21' 613" to 33° 21' 290" North, and longitudes 44° 51' 299" to 44° 50' 904" East) at Al-Tuwaitha nuclear site were scanned for the period from January to February 2016 using hand-held radiation detectors with the intent of locating radioactive sources thrown within piles of scrap material. Only one ^{137}Cs radioactive source has been found with an estimated activity of 6.3×10^{8} Bq, which was found to be considerably less than the "dangerous quantity" D-value of 1×10^{11} Bq. Assessment of the potential radiological consequences arising from exposure to the source during normal conditions has been conducted using Rad Pro Calculator Version 3.26 (2009). The potential radiological dose arising from normal occupational exposure situation was estimated to be 139 mSv/y at 1 meter distance from the source, which was considerably higher than the occupational dose limit of 20 mSv/y recommended in the International Atomic Energy Agency (IAEA) GSR Part 3 (2014), indicating that this source must be removed and treated as radioactive waste.

Key words: Abandoned radioactive sources, scrap yards, Al-Tuwaitha Nuclear Site

1. Introduction

Al-Tuwaitha Nuclear Research Center, currently owned by Ministry of Science and Technology (MoST), served as the foundation of nuclear research and development in Iraq from 1967 until 2003. 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, such as nuclear fuel fabrication, radiochemistry, processing facilities, radioisotope production, radioactive waste treatment, waste storage facilities, and biological researches

buildings [1]. Most of these sites suffered substantial physical damage during the Gulf war in 1991 and several have been subject 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 [2-4].

The so-called "orphan source" phenomena is a serious national problem and significant potential threat in Iraq as sources showing up unexpectedly in scrap yards, border crossings, or numerous other public locations. Radioactive sources and substances can become associated with scrap metal in various ways and if not discovered they can be incorporated into steel and non-ferrous metals through the melting process. This can cause health hazards to workers and to the public as well as environmental concerns and it can also have serious commercial implications. Numerous incidents have occurred in recent years involving the discovery of radioactive sources in scrap metal and, in some cases, in metal from the melting process. These incidents have proved to be very costly in relation to the recovery and clean-up operations required but also in terms of the potential loss of confidence of the industry in scrap metal as a resource. This has led the scrap metal industry to seek ways of managing the problem on the international level [5].

Radioactive source can be defined as a source containing radioactive material that is used as a source of radiation. Sealed sources commonly consist of concentrated radioactive materials encapsulated in small metal containers. The radioactive material in a sealed source is permanently sealed in a capsule, or closely bonded and in a solid form [6]. The radiation emitted from these sources is quite intense, requiring heavily shielded containers for their safe use, transportation and storage.

The objectives of this study were:

- Verify whether there were abandoned (orphan) radioactive sources in scrap yards at Al-Tuwaitha Nuclear Site through performing field scanning survey using hand-held radiation detectors.
- Evaluating the radiological consequences of found radioactive sources during normal conditions.

2. Materials and Methods

2.1 Description of the Scrap Yards

There were several tons of metallic scrap at Al-Tuwaitha nuclear site placed in unsecured areas readily accessible by the public (Figure 1), 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, sludge and possibly radioactive sources. Most of these scrap materials exist in separate piles. Overall, there were more than 30 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 [4]. These piles of debris and rubbles contain miscellaneous contaminated and uncontaminated items.

Figure 1: Topographic map shows scrap yard located outside Al-Tuwaitha earthen berms (Reference: Google maps).

2.2 Survey Approach

The investigation of scrap yards at Al-Tuwaitha nuclear site (located within the latitudes 33^{o} 21’ 613” to 33^{o} 21’ 290” North, and longitudes 44^{o} 51’ 299” to 44^{o} 50’ 904” East) where radioactive sources were present or suspected to be presented were undertaken for the period from January to February 2016 in several phases. The three main investigation phases include (historical information study, walkover survey, and field investigation using hand-held radiation detectors). Radiation detectors used for searching radioactive sources are described below:-

- identiFINDER ICx (digital hand-held gamma spectrometer with radionuclide identification, Germany) has been used for searching, localizing and identification of gamma and neutron-emitting radioactive sources. identiFINDER ICx can be described as a small but powerful computer further equipped with dedicated detectors for gamma and

neutron radiation plus some auxiliary sensors such as a receiver for the Global Positioning System (GPS) [7].

- RadEye PRD (Alarming Personal Radiation Detector, Thermo Scientific, Germany) 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. The 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 [8].
- RadEye SX (External Scintillation Detector, Thermo Scientific, Germany) is used in the field for searching alpha/beta sources in surface soil. The 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) detectors, both alpha and beta measurement data can be displaced and recorded simultaneously [9].

For scrap yards long ago abandoned and showing obvious signs of disorder and dilapidation, visual indicators of the presence of radiation sources may be difficult to employ. The basic operating procedure used to search for radioactive sources in scrap yards was adopted according to the guidance provided by the IAEA Technical Document 804 [10] and the guidance provided in the identiFINDER ICx User Manual [7]. This operating procedure is illustrated below:

- Background measurements for identiFINDER ICx, RadEye PRD and RadEye SX detectors were conducted in place where radiation levels considered normal. Background measurements were used as a guideline for detection of areas or spots with excessive alpha, beta or gamma radiation;
- The survey instruments were moved around the site and across the suspected surfaces (sediments, soil, vegetation, scrap material, rubble piles) with the intent of locating radioactive source at transect lines 3 meters apart (as terrain and vegetation permit (Figure 2)), while observing the detectors display. The 3 meters distance will provide thorough coverage of the area [11]. Normally, measurements were made at heights of (0.02–1) meter above ground level. Where an

elevated measurement is indicated, measurement close to the ground will be performed to enable locating the anomaly, which may indicate a buried radiation source. Look for physical appearance of the radiation sources was kept constantly in mind by the search team;

- When an elevated reading is identified from observing the detectors display, the complete dose rate distribution around the elevated spot is determined by scanning the area with a series of parallel routes. When the presence of a radiation source is confirmed from visual inspection, the ICx identiFINDER's Finder Mode will be used to determine the exact location of the radioactive source;
- After locating the position of the radiation source by surveying the ambient dose rate, the ICx identiFINDER's Identification Mode will be used to find out the nuclide the radiation is originating from.

Rad Pro (Radiation Protection) Calculator Version 3.26 (2009) (developed by Ray McGinnis, US Department of Energy (DOE)) was used to quantify the activity of the radioactive sources, based on measured dose rate and the known nuclide composition of the radioactive sources. Rad Pro Calculator performs many nuclear calculations that are useful to the health physicist, radiological researcher, radiochemist, radiation safety officer.

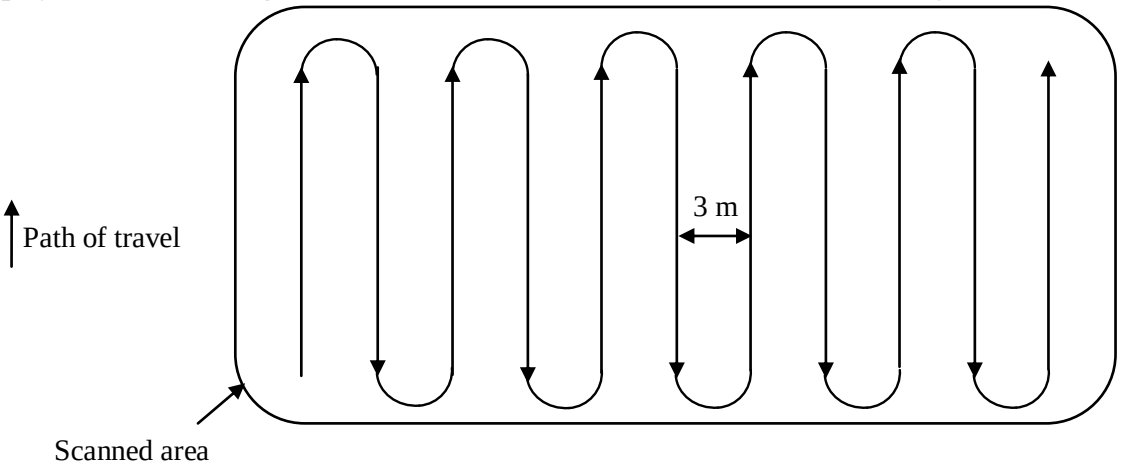

Figure 2: Scanning survey for detection of orphan sources in scrap yards

2.3 Categorization Criteria for Radioactive Sources

A radioactive source categorization system (Table 1) is used to provide a risk informed ranking and grouping of the sources and their applications, which in turn are of direct relevance to the regulatory measures, safety measures, management options, national registry of sources, import/export controls, labeling of sources, and emergency preparedness and response [12]. Symbol (A) in Table 1 represents the

activity of the radioactive material in the source, and D is the dangerous quantities of radioactive material.

The radioactive sources that will be found at scrap yards in Al-Tuwaitha Nuclear site is categorized in five categories in accordance with the guidance provided in the relevant International Atomic Energy Agency (IAEA) safety guides and standards [12]. On the basis of this categorization, risk informed decisions can be made, in a graded approach to the regulatory control of radioactive sources for the purposes of safety and security. Category 1 sources could lead to the death or permanent injury of individuals who are in close proximity to the source for a short period of time (minutes to hours). Category 2 sources could lead to the death or permanent injury of individuals who are in close proximity to the source for a longer period of time than for Category 1 sources. Category 3 sources could lead to the permanent injury of individuals who are in close proximity to the source for a longer period of time than Category 2 sources. Category 4 sources could lead to the temporary injury of individuals who may be in close proximity to the source for a longer period of time than Category 3 sources. Category 5 sources could, but are unlikely to, cause minor temporary injury of individuals.

Table 1. Categorization system of radioactive sources used in common practices [12]:

Category	Activity ratio (A/D)
1	$A/D \geq 1000$
2	$1000 > A/D \geq 10$
3	$10 > A/D \geq 1$
4	$1 > A/D \geq 0.01$
5	0.01 > A/D and A > exempt level

3. Results and Discussion

During field survey campaign in scrap yards, an unnoticed ^{137}Cs source has been identified in surface soil with dose rate, measured using identiFINDER ICx range from 19000 to 20000 µSv/h, with a mean value of 19500 ± 707 µSv/h at about 5 cm distance from the radioactive ^{137}Cs source. Surface α/β activities, measured using RadEye SX range from 1023 to 1487 Bq/cm^2, with a mean value of 1255 ± 328 Bq/cm^2. Activity estimation of the source was made using Rad Pro Calculator. Based on the measured dose rate at 5 cm distance from the source, the activity of the source is estimated to be 6.3×10^8 Bq (about 17 mCi, range from 16.7 to 17.6 mCi). No other radiation source has been identified in scrap yards, as shown in Figures (3) and (4), since the entire observed gamma dose rates

and α/β surface soil activities for most of the investigated points were slightly exceed the local measured natural background level (0.02 µSv/h, 0.12 Bq/cm^2), and reached more than twice the measured background level in some points due to presence of surface soil contaminants.

According to the IAEA guide on categorization of radioactive sources, the identified source is category 5 (A/D = 6×10^{-3} < 0.01, where A is the activity of the radioactive material in the source (6.3×10^{8} Bq), D-value = 0.1 TBq (1×10^{11} Bq) for ^{137}Cs [12]). Accordingly, this source could cause minor temporary injury for individuals with no lethal or severe consequences.

For normal (occupational) exposure scenario (6 hours per day, 5 days per week, indoor occupancy factor of 80% with building shield (25 cm concrete) and outdoor occupancy factor of 20% without building shield), the annual dose arising from the found source is estimated to be about 139 mSv/y at 1 meter distance from the source using Rad Pro Calculator Version 3.26 (2009), which is considerably higher than the occupational dose limit of 20 mSv/y [12]. 76% of the estimated dose arising from outdoor exposure, while the remaining 24% arising from exposure to the source inside building.

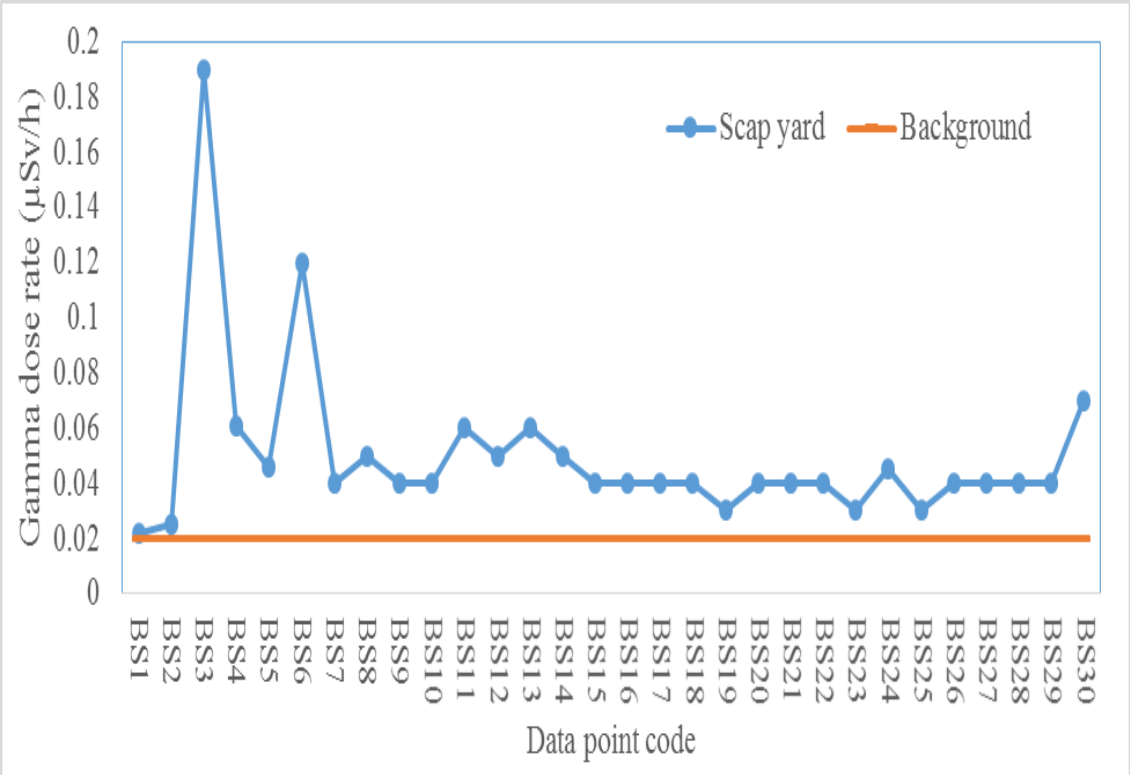

Figure 3: Results of direct dose rates measurements using RadEye PRD detector

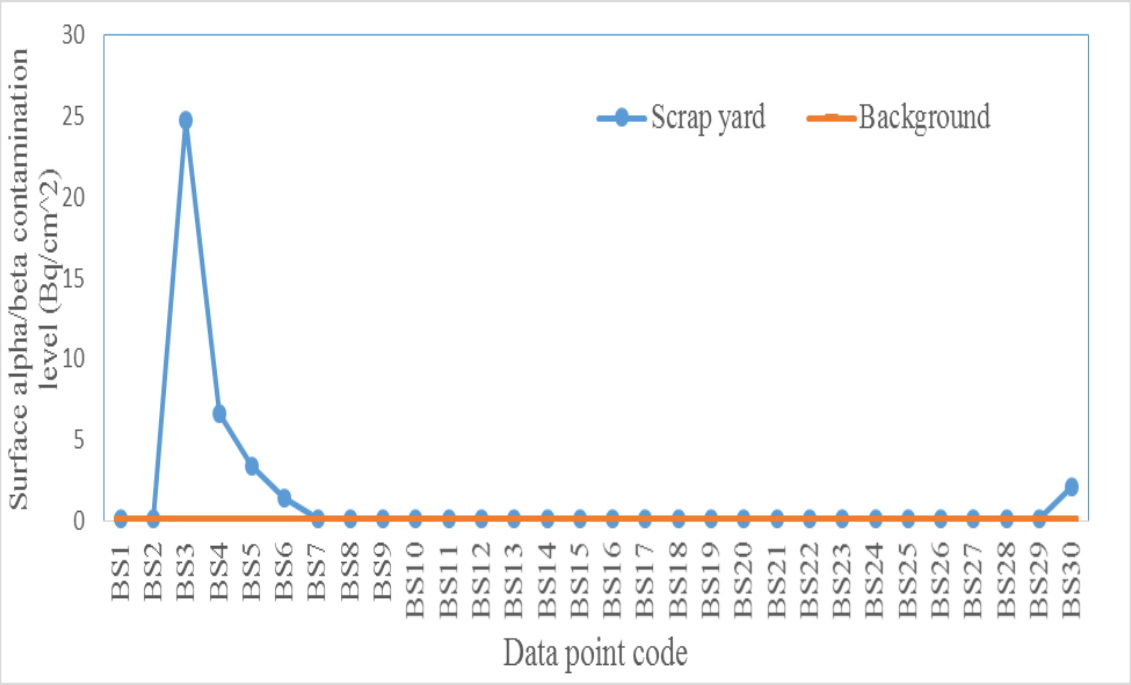

Figure 4: Results of direct alpha/beta contamination measurements using RadEye SX

4. Conclusions

This study presents the findings of radiological survey conducted for scrap yards at Al-Tuwaitha Nuclear Site with the intention to search for abandoned (orphan) radioactive sources within piles of scrap material and evaluating the radiological impact of found sources during normal conditions.

Only one ^{137}Cs source has been found with activity of 6.3×10^{8} Bq, which is considerably less than the "dangerous" D-value of 1×10^{11} Bq. However, due to relatively large amount of radioactive content estimated in the source, this source is completely unsafe under normal occupational exposure conditions.

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البحث عن المصادر المشعة المتروكة في ساحات تجميع الخردة في موقع التويثة النووي

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الخلاصة

تم في الدراسة الحالية اجراء مسح اشعاعي لساحات الخردة المعدنية (الواقعة ضمن الاحداثيات 33^{o} 21' 613" الى 33^{o} 21' 290" شمالا و 44^{o} 51' 299" الى 44^{o} 50' 904" شرقا) في موقع التويثة النووي خلال الفترة من كانون الاول لغاية شباط 2016 باستخدام اجهزة كشف الاشعاع المحمولة بهدف البحث عن المصادر المشعة المفقودة والمرمية ضمن اكوام الانقاض والحطام. تم العثور على مصدر مشع واحد لنظير السيزيوم–137 وبنشاط اشعاعي مقدر بـــ 630 مليون بكريل، والذي يعتبر اقل من الكمية الخطرة المحددة بـــ 1×10^{11} بكريل. تم تقدير الجرعة الاشعاعية المتوقعة في حالة التعرض الطبيعي للمصدر المشع باستخدام حزمة Rad Pro البرمجية الاصدار 3.26 لعام 2009، وكانت الجرعة الاشعاعية المحتملة الناجمة عن التعرض المهني للمصدر المشع بحدود 139 مللي سيفرت بالسنة على مسافة متر واحد من المصدر، والتي تعتبر اعلى من حدود الجرع الاشعاعية للافراد العاملين في حقول الاشعاع البالغة 20 مللي سيفرت بالسنة الموصى بها في تقرير الوكالة الدولية للطاقة الذرية المرقم GSR Part 3 لعام 2014، مما يؤشر ضرورة ازالة ذلك المصدر المشع ومعاملته كنفايات مشعة.

الكلمات المفتاحية: المصادر المشعة المتروكة، ساحات تجميع الخردة، موقع التويثة النووي