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Management of Radiation Contaminated Solid Wastes Aggregated from Radioactive Experimental Analysis

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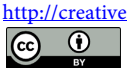

Abstract

Radiation-contaminated solid wastes are normally generated in the laboratory as a result of radioactive experimental and analytical processes. Aggregates of solid wastes in the laboratory were placed in three small plastic bags, each weighing 600 g, and labeled 1, 2, and 3. The three smaller bags are subsamples from one the larger bins containing waste materials generated from a laboratory radiological experiment. The gamma spectrometer, RadEye B20-ER dose meter, and Radiacode 110 were utilized for surface contamination measurements. The resulting spectral peaks and the activity concentration from the gamma spectrometer measurements indicate the presence of low-level gamma-emitting radioisotopes. Analysis of the results from all measurements shows low contamination levels and poses no radiological risk to humans and the environment.

Keywords

Radioactive, Solid Waste, Experiment, Contamination, Activity

1. Introduction

Radioactive solid wastes are dry, radioactive-contaminated materials, such as paper, plastic, microcentrifuge tubes, glassware, empty vials, and gloves [1]. They may contain small amounts of damp materials, but solid wastes may not contain any pourable liquids. Metals, lead pigs, sealed sources, sharps, etc., must not be present in solid wastes. Wastes are generated in the laboratory when carrying out

experiments that include radioactive isotopes (e.g., Uranium-238, Thorium-232) [2]-[4]. Radioactive solid wastes are segregated according to the half-life of the isotope (short-lived vs long-lived). Short-lived (decay in storage) isotopes have a half-life of less <90 days, while long-lived isotopes have a half-life of >90 days [5]-[7]. The wastes are packaged by affixing a sticker on the outside of the container labelled as "Caution: Radioactive Materials". They are stored in a waste container lined with a plastic bag, with the container having its own disposal record. Waste disposal records should be updated each time waste is added to the container. When waste is no longer being added to that container, the filled/ sealed date will be recorded. Before disposal of short-lived isotopes, they are held in the laboratory for ten half-lives from the filled/sealed date [8] [9]. After ten half-lives, an appropriate survey meter is used to confirm that the waste has decayed to an acceptable regulatory standard. Waste Disposal Record must be approved by the Radiation Protection Officer before disposal. The Radiation Safety Unit collects the long-lived isotopes for disposal and ensures that all records and information on the containers are correct and up to date before contacting the Radiation Safety Unit [10]-[12].

Appropriate information should be provided on the management of radioactive waste generated during analytical processes. Regulatory bodies should adopt stringent laws to regulate radioactive waste and impose severe punishments for violations. The management of waste in compliance with such regulations is, therefore, critical to the laboratory's sustained operations. A laboratory waste management plan that details procedures for managing radioactive waste should be implemented before radioactive materials are accepted for processing [13] [14].

The types of waste generated and the waste management issues encountered in the laboratory are determined by the analytical processes used and the characteristics of the samples analyzed [15] [16]. A laboratory that performs only one or two analytical processes may produce only a few waste streams, while a multi-service laboratory that performs a variety of processes may produce many waste streams [15]. Waste streams generated by radio-analytical procedures can include both radioactive and nonradioactive waste. A laboratory waste stream is defined as all wastes that are produced by a given analytical process. Laboratory processes that generate radioactive wastes include analytical processes, radioactive standards, radioactive solutions, dry waste, aqueous waste, etc. [17]-[19]. Many countries have experience in handling low-level radioactive wastes, such as burnable or combustible waste and scrap metals for melting. The treatment of various kinds of ion-exchange resins can be done in a pyrolysis facility using the THOR-process. The advantage of incineration of combustible waste as well as of ion-exchange resins by pyrolysis is the vast volume reduction, which minimizes the cost for final storage and results in an inert end-product that is feasible for safe final disposal [20]. The amount of uranium in the waste to be incinerated has an impact on the quality of the resulting ash [21]-[24]. The uranium content can be reduced by leaching through a chemical process before and after incineration. The incin-

eration of combustible waste as well as of ion-exchange resins by pyrolysis has the advantage that the waste volume reduction, which minimizes the cost for final storage, results in an inert end-product that is feasible for a safe final repository.

Uranium-contaminated solid waste mainly emanates from nuclear fuel fabrication facilities, and as concerns its treatment, the recycling of uranium is of course also attractive both commercially and environmentally [2] [25] [26]. Some researchers in Sweden have developed a chemical process for the leaching of uranium residues having low uranium content from uranium fuel fabrication [27]-[29]. The base of the treatment is the process used for the leaching of uranium during the mining of aluminum shales. The different types of residues processed from uranium fabrication include filters, ashes, ion exchange resins, and burnable materials [30] [31]. The process starts with a pre-treatment, such as milling or disintegration. Leaching with sulfuric acid takes place either as agitation leaching or as percolation leaching. In liquid-liquid extraction equipment, the uranium is separated and precipitated as ammonium diuranate. The handling and treatment of uranium-contaminated burnable low-level waste (LLW) has been done for many years with different modes of treatment with regard to pre- and post-treatment [32] [33]. It has been proven that the lower the temperature during incineration and the lower the amount of uranium in the burnable waste, the better the quality of the ash, *i.e.*, finer ash with homogeneous distribution of the fissile component [23] [34]-[38].

Laboratory-contaminated radioactive wastes in a university setting are normally not sent off campus but rather collected and disposed of in a designated area on campus, as per the Environmental Health and Safety radioactive waste processing procedures [39]. The wastes are collected every month in cans, disposal bags, waste tags, tape, carboys and secondary containers, solvent bottles, portable meters, and standard PPE. Control measures are implemented by avoiding the handling of radioactive materials or contaminated items, utilizing secondary containment for liquids whenever possible, and labeling radioactive or contaminated materials with the word "Radioactive" [40] [41]. It is advisable to wear personal protective equipment, such as a laboratory coat, gloves, eye protection, and full shoes. The responsible officer must make sure that all materials are properly tagged before making a waste collection request. Hazardous wastes in the institutional laboratories are produced as a result of their work, study, or operational activities. It is the responsibility of all individuals at the University to store and handle the generated hazardous waste in a manner that protects people, property, and the environment. This work highlights the experimental analysis in the management of uranium-contaminated solid wastes in the laboratory. All hazardous materials will be accepted for disposal provided that they meet the regulatory requirements. The waste disposal program should be convenient, flexible, and easy to use. It is recognized that there will always be unique situations that will require the assistance of the specialists.

2. Materials and Methods

2.1. Materials

The materials utilized in this work are contaminated waste bins (containing uranium contaminated wastes generated from radiation experimental research), a gamma spectrometer, a RadEye B20-ER hand-held contamination monitor, a Radiacode 110 Portable radiation detector and spectrometer, bin bags, protective gloves, and an electronic weighing scale. The instruments were each calibrated ensure accurate data.

2.2. Methodology

The method was carried out by first sorting out solid contaminated wastes into three primary bin bags. One of these bins was further subdivided into three smaller bin bags, labelled 1, 2, and 3, with each containing approximately 600 grams of solid waste. The three labelled bags were then transferred to the Gamma Spectrometer room for radiation measurement. A lead brick was placed within the spectrometer compartment to provide shielding and ensure measurement accuracy. Measurement from the bag to the detector was taken at the surface and one meter (1) for background measurements. The gamma spectrometer was first exposed for 85989.2 seconds to measure the background activity level as the baseline. This was then followed by measuring the radiation levels of the three labelled samples of bags containing 600 g of solid waste. Bag 1 was exposed for 84568.3 seconds, and the process was repeated for bags 2 and 3. Additionally, RadEye B20-ER dose meter and Radiacode 110 were also utilized for surface contamination measurements. The Radiacode was set at the spectrometric mode and measured the gamma emission from the contaminated bins. The Radiacode was passed through each bin bag, the dose rate in count per second (cps), and the picks were noted. The readings from the RadEye B20-ER dose meter are shown in counts per second (cps), while Radiacode 110 was also used to measure activity levels present in the waste bins. Both the background and contamination measurements were noted and documented for analysis. Figure 1 is a display of the three different instruments utilized to carry out the radiometric measurements.

3. Results and Discussions

3.1. Analysis of Data from Gamma Spectrometer Measurements

The pick from all three graphs (Figures 2-5) is located around the 500 units mark on the x-axis, and the pick intensity is located around the 700 units on the y-axis. It's noted that the pick starts rising from around 10 units and sharp increase around 300 to 500 units on the x-axis. This shows the presence of inactive gamma emitting radionuclide with a strong signal around 700 unites on the y-axis. The gradual falling of the pick indicate the present of a low-level gamma emitter radioisotope. The consistency of the spectral peaks across all samples confirms the presence of a low-level gamma-emitting isotope, with no significant variation in

energy levels. These results validate the classification of the waste and support its safe disposal under hazardous waste protocols. Table 1 shows the data obtained from the gamma spectrometer measurements carried out on the three solid waste containing bags.

Figure 1. Display of instrumental setup for radiation dose measurements.

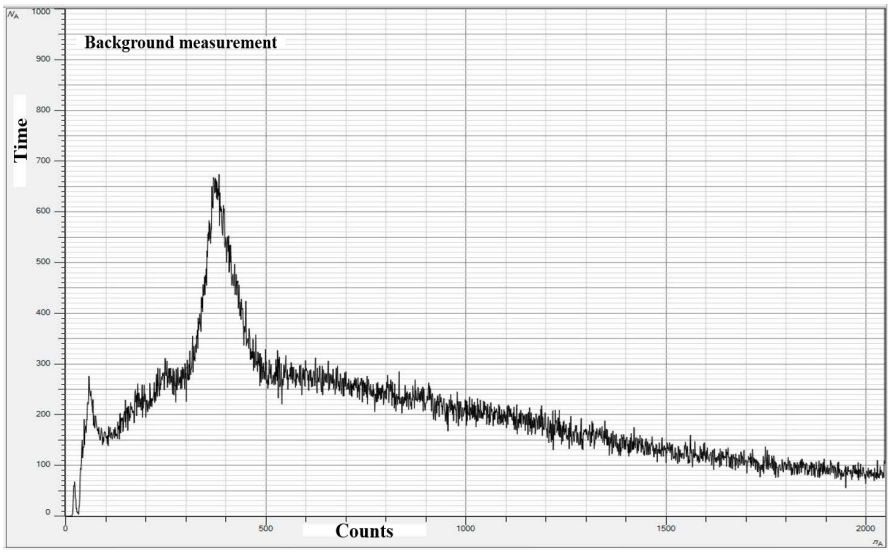

Figure 2. Spectral illustration of background measurement of waste samples.

Table 1 shows the activity (Bq) of gamma radiation measurements determined from the pulse counts and time (s). It should be noted that the lead brick was only used for shielding. The pulse counts displayed from the background radiation measurement are 607,609 at a rate of 85989.2 seconds. These values were used to determine the activity of background radiation by simple mathematical division

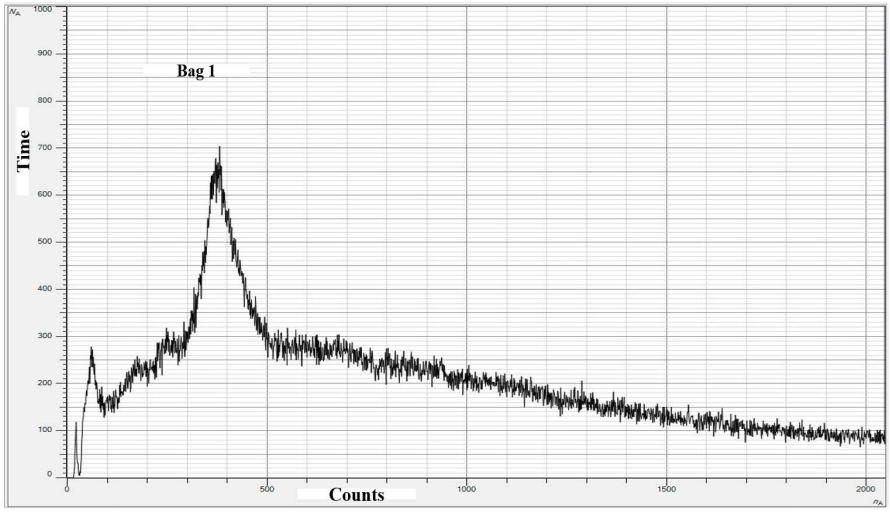

Figure 3. Spectrum of activity measurements of waste samples in bag one.

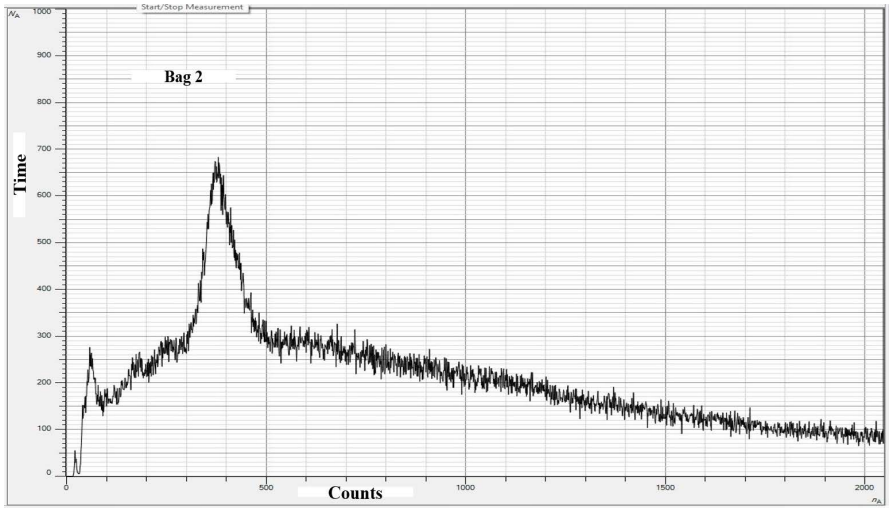

Figure 4. Spectrum of activity measurements of waste samples in bag two.

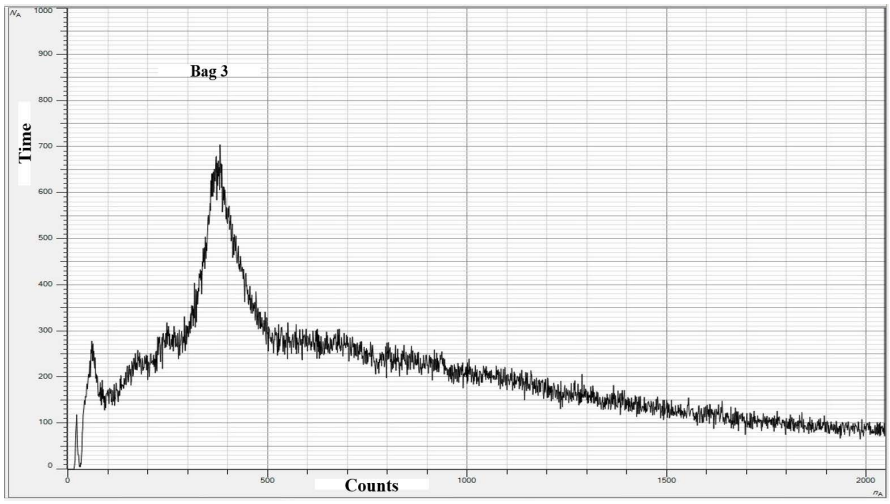

Figure 5. Spectrum of activity measurements of waste samples in bag three.

Table 1. Gamma spectrometer measurements.

Samples	Weight (g)	Counts	Time (s)	Activity (Bq)	Total Activity Concentration per weight (Bq/g)
Lead Brick (background)	600	607609	85989.2	7.07	0.011
Bag 1	600	610266	84568.3	7.22	0.012
Bag 2	600	621131	87558.2	7.09	0.011
Bag 3	600	621131	87258.2	7.09	0.011

$\left(\frac{\text{counts}}{\text{time}}\right)$ resulting to 7.07 Bq. This was then followed by taking dose measurements of the three solid waste containing bags from the top, bottom and side views of both three bags. The pulse counts for bags 1, 2, and 3 according to the results are 610,266, 621,131, & 621,131 and their corresponding rate (time in seconds) are 84568.3 seconds, 87558.2 seconds, and, 87258.2 seconds respectively. The computed radiation dose activities in bequerrels for bags 1, 2, and 3 are 7.22 Bq, 7.09 Bq, and 7.09 Bq respectively. The activity concentration was then determined by simply dividing each activity by the weight of it bag. As earlier stated in the methodology above, each of the bags weigh 600 g. The resulting activity concentrations for each of the three bags are 0.012 Bq/g, 0.011 Bq/g, and 0.011 Bq/g.

3.2. Data from RadEye B-20-ER Portable Contamination Monitor

A RadEye B-20-ER was set to measure radiation contamination rate in counts per second (cps) and the recorded values are shown in Table 2.

Table 2. RadEye B20-ER monitor dose measurement.

Bin Number	Side dose (cps)	Top dose (cps)	Bottom dose (cps)	Average dose (cps)
Bag 1	1.92	0.42	1.92	1.42
Bag 2	1.69	1.84	1.65	1.72
Bag 3	0.90	4.01	9.28	4.73

Rdiation measurements was taken from the top, bottom and side views of the three bags each at a time. The average doses in counts per seconds (cps) recorded for bags 1, 2, and 3 are 1.42, 1.72, and 4.73 cps respectively. Results shows elevated radiation doses at certain locations of each of the bags during measurements.

The activity of each bag was determined by converting the counts per second (cps) to becquerels (Bq) where 1 Bq is equivalent to 1 disintegration per second (1 Bq = 1 dps). The activity was then computed by simply dividing the counts per second by detection efficiency ($\frac{\text{cps}}{\text{Detection efficiency}}$). The detection efficiency for a uranium alpha emitter ranges from 5% - 10% (0.5 to 0.10) and for better

emitter ranges from 5% - 15% (0.5 to 0.15). Table 3 outlines the activity in Becquerel (Bq) and the activity concentration in Becquerel per gram (Bq/g) computed for bags 1, 2, and 3. Result analysis from all measurements shows low contamination levels and poses no radiological risk to both human and the environmental, hence can be disposed as a non-radiological hazardous waste through Hazardous Material Facility.

Table 3. Activity concentration (Bq/g) computed from RadEye B-20-ER portable contamination monitor measurements.

Bin No.	Average dose (cps)	Approx. Detection Efficiency	Activity Bq (cps ÷ Detec Efficiency)	Activity in gram (Bq/g)
Bag 1	1.42	0.12	14.2	0.0142
Bag 2	1.72	0.12	17.2	0.0172
Bag 3	4.73	0.12	47.3	0.0473

3.3. Data from Radiacode 110 Portable Radiation Detector

Figure 6 shows the results of the spectral analysis of waste samples in bags 1, 2, and 3 using Radiocode 110. It reveals the count rate, dose rate, and hardness from the side view measurement of each bag. Table 4 shows the average doses computed from the side, top, and bottom measured doses.

Figure 6. Radiacode 110 spectra for bags 1, 2, and 3 containing wastes.

Table 4. Radiacode 110 dose measurement.

Bin No	Side dose (cps)	Top dose (cps)	Bottom dose (cps)	Average dose (cps)
Bag 1	13.5	13.7	13.3	13.50
Bag 2	13.7	13.6	15.01	13.77
Bag 3	13.3	5.94	14.90	11.35

The count rates for bags 1, 2, and 3 are 13.5 cps, 13.7 cps, and 13.3 cps respectively. The dose rates of the three bags are 9.11 μR/h, 8.75 μR/h, and 8.11 μR/h while the hardness are shown to be 0.68, 0.64, and 0.61. It is observed that the count rates which determines the activity of the samples has no significant variation from bags 1 to 3. Referring to similar conversion done in the sections above [Detection Efficiency for Uranium α-emitter = 5% - 10% (0.5 to 0.10) and β-emitter 5% - 15% (0.5 to 0.15)], the calculated activity levels for each of the radiation waste containing bags are displayed in Table 5.

Table 5. Activity concentration (Bq/g).

Bin No.	Average dose (cps)	Detection Efficiency	Activity Bq (cps÷ Dec. Efficiency)	Activity in gram (Bq/g)
Bag 1	13.50	0.12	135	0.135
Bag 2	13.77	0.12	137.7	0.1377
Bag 3	11.35	0.12	113.5	0.1135

The exemption or clearance for disposal of radiation contaminated waste is 1 Bq/g according to IRR-19, Ireland jurisdiction. Therefore, all Radiacode110 contamination measurements show that the contamination levels are low and pose no environmental risk. This aligns with the IAEA General Safety Requirements Part 3 (GSR Part 3).

4. Handling Contaminated Solid Wastes Generated in the Laboratory

See Figure 7.

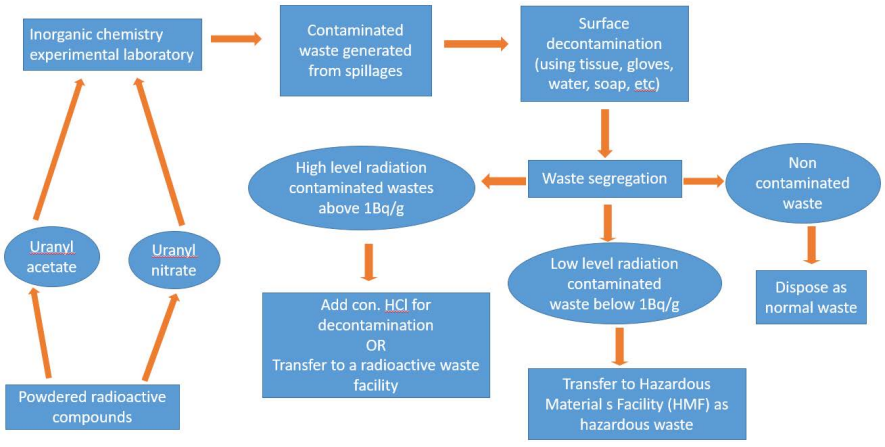

Figure 7. A simplified disposal workflow showing local institutional procedure for handling wastes.

5. Conclusions

A laboratory radiological analysis was conducted to determine the radiation con-

tamination levels in waste generated during laboratory radiological activities. Three subdivided waste bins, each containing 600 g of waste materials, were tested for radiation doses. Measurements were carried out using a gamma spectrometer, a RadEye B20-ER dose meter, and a Radiacode 110 to determine the radiation doses. The research successfully characterized the gamma radiation levels of solid contaminated wastes. The gamma spectrometer revealed consistent peaks around 500 keV across all samples, indicating the presence of a low-level gamma-emitting radionuclide. Background radiation was minimal, confirming the reliability of the measurements. Surface contamination readings obtained via the RadEye B20-ER dose meter were within acceptable safety limits, supporting the classification of the waste as hazardous rather than radioactive. These findings enabled safe handling and disposal procedures in accordance with regulatory guidelines.

The consistency of results across the samples reinforces the conclusion that the waste poses low radiological risk and can be managed under standard hazardous waste protocols. This approach ensures both environmental safety and compliance with waste management standards. Since the bins radiation activity levels are less than 1 Bq/g, which is the Ionizing Radiation Regulation (IRR19) exemption limits for Uranium-238 and Thorium-based compounds, the solid waste bins can be disposed of through Hazardous Materials Facility (HMF) without further notification. However, all wastes must be placed in a clear bin bag with no radiation trifold labels attached before transferring the bags to the Hazardous Materials Facility for final disposal.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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