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# Verification of Calculated External Radiation Dose Rates for Radioactive Waste Container using Microshield Computer Code

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## ABSTRACT

According to the law No.7/2010, Egyptian atomic energy authority (EAEA) represented in the hot laboratories and waste management center (centralized waste facility, HLWMC) has the responsibility of collecting, conditioning, storing and management of all types of radioactive waste from all Egyptian territory including spent radioactive sealed sources (SRSSs). Conditioning and packaging procedure for two of the most common SRSSs (Cs-137 & Co-60) have been performed into 4 drums in HLWMC as mentioned in reference one of this paper. The inspector may wish to check and makes shore that all data and information listed on the waste package label are correct. In this paper MicroShield computer code, RadProCalc software and direct manual measurements has been performed to ensure that the dose rate on the surface, at 1 meter and 2 meter of the waste package container (100L drum) is complying and identical with the IAEA safety standard that addressed the maximum dose rate on the surface of waste container should be lower than 200 mrem/h (2 mSv/h).

Keywords: dose rate, disused sealed sources, conditioned waste, Cs-137, Co-60, MicroShiled

## Introduction

Radioactive waste management activities are hazardous as concern both contamination and external exposure. Therefore strict regulations are applied for radiation protection in the field of handling process of radioactive waste. Dose rate in the vicinity of the waste container has to be kept below certain constraints throughout entire treatment and conditioning process. Also, during transportation and for the final storage, the dose rate should meet acceptance criteria stated by the safety regulations.

There are many types of sealed sources are widely used in Egypt for many applications; oil exploration, industry, agriculture, medicine, research and education. The risk posed by these sources vary widely, depending on the amount of activities, the characteristics and chemical form of radionuclide, toxicity, ..etc.

In Egypt, radioactive sealed sources should be declared as spent sources by the user who should confirm the centralized waste facility by an official letter includes all the source data (type of radionuclide, surface dose rate, initial activity, production date, serial number,.... etc).

The sustainable option to reduce the safety and security risks for accidents with spent radiation sources is the disposal, but in case of no disposal facility available, the conditioning or immobilization of these sources in a matrix like concrete is preferred.

Conditioning of spent radioactive sealed sources is important to facilitate the transportation process and to protect the workers from the exposure risk of such sources. The method has the advantage of using unsophisticated technology and material and equipment which are easily available [1]. The selected sources are firstly dismantled to a prefabricated cask which is designed to host the activity of the dismantled sources to a permissible limits [1, 2, 3]. The final product package (200 L drum) is stable for a long time under interim storage conditions. By proper conditioning of a spent sealed source in concrete, the source is transformed into a form which cannot cause any large exposure even if the waste package is handled without special precautions [1,5].

Depending on the safety margin between calculated results and dose rate criteria, there may be cases where verification is required. Calculations using computer codes may be cross-checked by the shielding assessor independently, especially if the safety margin is small. Using survey data, hand-calculations etc. may serve as an appropriate verification, and can provide additional confidence in calculated results [4]. The shielding assessor should take a graded approach when deciding on the appropriate verification method.

The MicroShield analysis calculates and reports the external radiation, primarily gamma and dose rate for the approved waste container for disposal. The Egyptian nuclear and radiological regulatory authority has begun to move away from such extreme conservatism in cases such as using the regulatory maximum as the external dose rate for disposal container in developing transportation of waste container to disposal facilities.

## Conditioning Procedure for Disused Radioactive Sealed Sources

In Egypt, in accordance with IAEA guidance; conditioning of spent radiation sources in Type A packages was used. The conditioning option is based on the immobilization of the source within a Type A package as defined in IAEA transport regulations [7]. The source/sources in its cask and is placed in the center of a 200 L drum lined with cement mortar (Fig.1-4). This conditioning procedure is suitable for any type of source, assuming its size fits to be accommodated in the center of a 200 L drum. Conditioning in this way prevents unauthorized removal of the source because of the weight, bulk and robust nature of the package. It also provides a barrier against loss of containment of radioactive material. The adoption of this method will depend upon a number of factors including: the number of spent sealed sources, the half life and activity of the sources, the toxicity of the radionuclides in the sources, and the final disposal scheme for the sources.

Fig. (1) Prefabricated casks contain the dismantled Co-60 or Cs-137 sources [1].

Fig.(2) 200 L drum for the prefabricated cask contain the dismantled C0-60 or Cs-137 sources[1].

Fig. (3) Conditioned drums ready for transportation and storage [1].

Fig.(4) 200L drum contains the prefabricated Cask contains the dismantled $Co^{60}$ or $Cs^{137}$ sources

Four conditioned drums were selected in this study with data shown in table 1 and three methods used for verify and calculate the external exposure dose rate, namely, MicroShield computer code, RadProCalc software and direct measurement.

**Table 1. Data of the conditioned drums ready for transportation and storage [1, 2].**

| Drum no. | Source | No. of sources | Total activity (Ci) |
|---|---|---|---|
| 1 | Cs-137 | 117 | 4.625 |
| 2 | Cs-137 | 58 | 4.86 |
| 3 | Cs-137 | 56 | 5 |
| 4 | Co-60 | 1 | 1 |

### Microshield computer Code

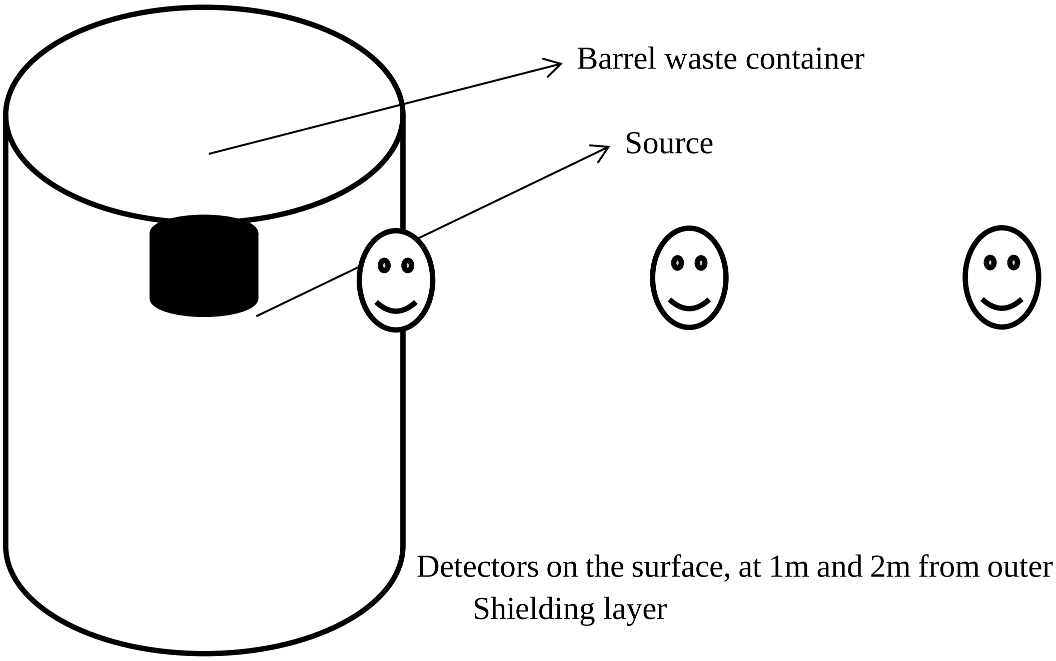
MicroShield is a comprehensive photon/gamma ray shielding and dose assessment program that is widely used for designing shields, estimating source strength from radiation measurements, minimizing exposure to people, and teaching shielding principles. MicroShield is useful to health physicists, waste managers, design engineers, and radiological engineers and only requires a basic knowledge of radiation and shielding principles. MicroShield is provided with a library of photon/gamma ray distributions for 497 radionuclides. MicroShield also provides the user with the capability to specify a unique photon/gamma ray distribution for up to 25 energies [4].

### Model Parameters

This analysis was performed using information gleaned from more than one document. Characteristics of waste container in this study were obtained from published paper titled "Management of disused radioactive sealed sources in Egypt" [5].
The second source of information utilized in this study was from published papers titled "Classification of the inventory of spent sealed sources at Inshas storage facility" [4], " Conditioning procedure for spent Cs-137 sealed sources in Egypt" [6], "Conditioning and repackaging of spent radioactive Cs-137 & Co-60 sealed sources in Egypt" [1].
The computer code MicroShield 6.01 software was used to three - dimensionally model the container loaded with specific source material in order to estimate dose rate on the surface and at 1m and 2m from the outer a shielding layer at the axial midpoint of the container (200L drum).

### Geometry

For each waste container (200 L drum) the geometry of cylinder volume with side shields was employed for the analysis. In MicroShield computer code, a container will be oriented such that the axial length of the cylinder is in the positive Y-axis direction, with the center of the cylinder's bottom placed at the origin. The appropriate layers of side shielding with their respective thickness surround the cylinder in MicroShield in the radial, Z-axis.
The dimension of the lead shield is X = 10 cm, Y = 25 cm, Z= 10 cm [2]




**Detectors**
The models were built with detectors placed on the surface of the container and at, 1m, 2m away from the outermost gamma shielding layer (200 L drum shield). These detectors were also centered axially since maximum dose was expected to be achieved at the axial midpoint active length of the container. The dose in the air gap between the detectors and the waste container were calculated by MicroShield computer code depending on the input container dimension.

**Waste container materials**
The material compositions of the drum were specified under the materials tab in MicroShield. The densities provided by the internal library of MicroShield were used for air, iron, and the waste. A density of 10.96 g/cm$^3$ was a manual input for the source material as the density of the waste. The MicroShield iron density value was used as the density of ferritic stainless steel. A custom material characterizing the density of stainless steel was used for the container comprised of stainless steel. This external material file was set up according to its atomic structure. The transition gap and air gap were specified as being composed of air such that the MicroShield internal library values were again used. The neutron shielding layer was neglected in this analysis because it is assumed that the neutron dose contribution would be

minimal. The methods of conditioning are based on Type A packages as defined in IAEA transport regulations [7].

**Source**

The source material (disused sealed sources) with container (200 L drum) was loaded for modeling as a specific source. This source material is the waste material.

**Build-up**

Build-up is defined as the scattering interactions that contribute to the overall dose. Dose build- up factors depend on photon energy, the mean free path traveled by a photon in the material of consideration, geometry of the source, and geometry of the attenuating medium [8]. Build-up must be considered in this study as it will contribute to the external dose rate of the container (200 L drum). The build-up calculated by MicroShield 6.01 taking the above-mentioned components into consideration was used in this study. The build-up values can be seen under the build-up tab in MicroShield.

**RadProCalc Software [9]**

The external dose rate on the surface of the drum and, at 1m, 2m has been calculated using RadProCal software. Rad Pro Calculator performs many nuclear calculations that are useful to the health physicist, radiological researcher, radiochemist, radiation safety officer, health physics technician (HP) and nuclear medicine professional. It calculates, among other things, radiation safety unit conversions (SI and US customary) and gamma emitter dose rate and activity. Other calculations include:

Gamma shielding equations (with or without buildup)

Beta emitter dose rate and activity

Dose-rates for x-ray machines and devices

Grams of plutonium (Pu) and uranium (U) from activity (specific activity)

Decay and half life equations

Bremsstrahlung x-ray calculations for beta interactions

Uranium enrichment from U-234 and U-238 lab data for environmental levels of uranium (also works well for uranium fuel enrichment and U enrichment in nuclear waste)

Inverse Square Law calculations for electromagnetic energies

Minimum detectable concentration and contamination (MDC aka MDA) for counters and scan instruments (includes LLD and critical level calculations)

ALARA calculations for dose and job planning.

**Direct measurements**

Direct measurements using Automess 6150 AD5 survey meter with measuring range 0.1mR/h – 100R/h (1µSv/h – 1000mSv/h) and energy range (45keV – 3 MeV) has been performed to measure the exposure dose rate on the surface of 200 L drum and at 1m and 2m from the surface.

## RESULTS

Four conditioned drum has been used in this study containing Cs-137 and Co-60. Three drums (no.1,2,3) contains Cs-137 source while drum no. 4 contain Co-60 source and the total activities for each drum is shown in table 1. MicroShield computer code, RadProCalc software and direct measurement has been performed to calculate and vitrify the external exposure dose rate on the surface of the drum and at 1,2 meter from the surface of the drum. The obtained data are listed in tables 2, 3 and 4. From these tables it is clear that the total activity and the distance play an important role in the calculation of external dose rate. In case of using MicroShield computer code, Drum no.3 with 5Ci has 0.643 and 0.028 mSv/h with and without build-up, respectively, while in case of using RadProCalc the dose rate was 0.811 and 0.030 mSv/h with and without build-up, respectively . Direct measurement for drum no. 3 using AD5 survey meter display the dose rate was 0.71mSv/h.

By comparing the results obtained from the three methods, we can find that slight difference between MicroShield computer code and AD5 survey meter, while a clear difference in case of using RadProCalc software. Thus, we recommend using Microshield computer code to verify the exposure dose rate on the surface of the conditioned drum before transportation and storage process.

**Table 2. Radiation exposure dose rate at the surface of the conditioned drum**

| Drum no. | External Dose rate (mSv/h) | | | | |
|---|---|---|---|---|---|
| | MicroShield Code | | RadProCal sowftware | | AD5 measurements |
| | Without Buid-up | With Buid-up | Without Buid-up | With Buid-up | |
| 1 | 0.019 | 0.643 | 0.024 | 0.731 | 0.62 |
| 2 | 0.021 | 0.682 | 0.029 | 0.797 | 0.66 |
| 3 | 0.028 | 0.701 | 0.030 | 0.811 | 0.71 |
| 4 | 0.011 | 0.510 | 0.013 | 0.690 | 0.50 |

**Table 3. Radiation exposure dose rate at 1 m from the surface of the conditioned drum**

| Drum no. | External Dose rate (mSv/h) | | | | |
|---|---|---|---|---|---|
| | MicroShield Code | | RadProCal sowftware | | AD5 measurements |
| | Without Buid-up | With Buid-up | Without Buid-up | With Buid-up | |
| 1 | 0.015 | 0.583 | 0.017 | 0.781 | 0.22 |
| 2 | 0.018 | 0.591 | 0.019 | 0.817 | 0.23 |
| 3 | 0.019 | 0.611 | 0.020 | 0.843 | 0.25 |
| 4 | 0.009 | 0.490 | 0.007 | 0.580 | 0.02 |

**Table 4. Radiation exposure dose rate at 2m from the surface of the conditioned drum**

| Drum no. | External Dose rate (mSv/h) | | | | |
|---|---|---|---|---|---|
| | MicroShield Code | | RadProCal sowftware | | AD5 measurements |
| | Without Buid-up | With Buid-up | Without Buid-up | With Buid-up | |
| 1 | 0.013 | 0.446 | 0.014 | 0.451 | 0.16 |
| 2 | 0.014 | 0.463 | 0.015 | 0.489 | 0.17 |
| 3 | 0.017 | 0.485 | 0.019 | 0.491 | 0.21 |
| 4 | 0.003 | 0.201 | 0.004 | 0.131 | 0.01 |

## CONCLUSION

The inspector may wish to check and makes shore that all data and information listed on the waste package label are correct. Calculations using computer codes may be cross-checked by the shielding assessor independently, especially if the safety margin is small. MicroShield computer code, RadProCalc and direct measurements can be used to measure the exposure dose rate for the conditioned waste drum before transportation and storage process. By comparing the results obtained from the three methods we recommend using Microshield computer code to verify the dose rate for the conditioned waste drum.

## References

[1] M.A. Hasan, Y.T. Selim, T. EL-Zakla, Conditioning and repackaging of spent radioactive Cs-137 & Co-60 sealed sources in Egypt, WM 2013 Conference, Phoenix, Arizona USA February 2013.

[2] Y.T Mohamed, M.A. Hasan and Y.F Lasheen, Conditioning procedure for spent Cs-137 sealed sources in Egypt, WM'06 Conference, Tucson, Arizona USA February 2006.

[3] Mahmoud A. Hasan, Yasser T. Mohamed and Yasser F. Lasheen" Conditioning of Co-60 spent sealed sources" Radioprotection Vol 41 no.3, pages 345-355, 2006

[4] S. Cohen Review of DOE Planned Change Request for Shielded Containers for Remote-Handled Transuranic Waste, Contract Number EP-D-10-042 Work Assignment No. 1-02, S. Cohen & Associates 1608 Spring Hill Road Suite 400, Vienna, Virginia 22182, December 2010.

[5] Y.T Mohamed, M.A. Hasan and Y.F Lasheen, Management of Disused Radioactive Sealed Sources in Egypt, WM 2013 Conference, Phoenix, Arizona USA February 2013.

[6] K. El-Adhim, M.A.Geleel, N.S. Mahmoud, Classification of the Inventory of Spent Sealed Sources at Inshas Storage Facility, WM'06 Conference, Tucson, Arizona USA February 2006.

[7] International Atomic Energy Agency, Management of Spent High Activity Sources (SHARS), IAEA-TECDOC-1301, Vienna (2002).

[8] Tsoulfanidis Nicholas, Measurement and Detection of Radiation, Second Edition, Washington D.C., Taylor and Francis, 1995.
[9] Rad Pro Calculator version 3.26 software development by Ray McGinnis, May 24 2009.