Development of a Method for Characterization and Segregation of Metallic Waste after Decommissioning

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Abstract

During decommissioning adequate radiological characterization is important for the optimization of metallic waste management.
The characterization could be carried out by means of 1) neutron activation calculations based on reactor design and neutron flux; 2) dose rate measurements; 3) in-situ gamma spectrometry; 4) sampling for determination of the scaling factors in activated and contaminated components. In-situ characterization is carried out during dismantling to classify and package the generated waste. This is usually achieved by using portable devices to measure dose rates or total counts. Then, the packages are monitored for activity assessment and determination of the management route.
The radiological characterization of contaminated components is essential for the decision-making process during decommissioning. The selection of cutting and decontamination techniques should be based on accurate activity determination. It is important to decide in which cases the decontamination will be efficient as well as to select the appropriate decontamination techniques based on whether the waste is slightly activated or contaminated or both.
A Semi-empirical technique for optimization of determination of contamination and activation of components and metallic waste is under development based on a combination of gamma spectrometry measurements and MCNPX Monte Carlo simulations. The technique aims to a reduction of the uncertainties related to the density and activity distribution. The specific activities inside and on the surface of the materials could be determined by using the measurement results of the proposed non-destructive technique.

The causes of uncertainty in the non-destructive gamma spectrometry measurements and the way to cope with them

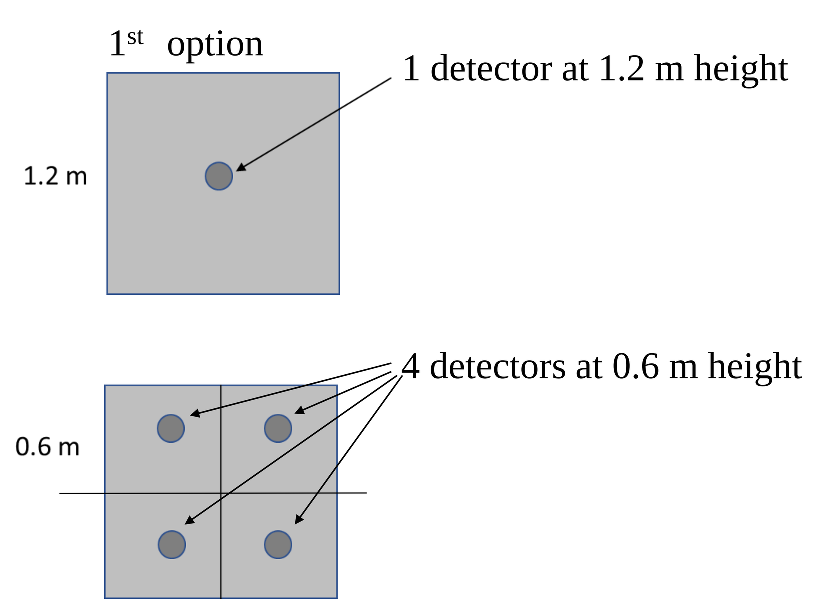
causes of uncertainty	way
a. Density in-homogeneity	Segregation based on the geometries of the metallic segments
b. Activity in-homogeneity (1): different measurement efficiencies for different distances of the source from the detector	Reduction of the range of the distances/ the detector away from the source
c. Activity in-homogeneity (2): different measurement efficiencies for different angles of the source to the detector	Reduction of the solid angle of detection/ moving the detector away from the source
d. Activity in-homogeneity (3): different attenuation of radiation	Reduction of the source thickness
e. Statistic of the measurement	Sufficient measurement efficiency and acceptable measuring time to achieve MDA ≤ 10 times lower than the clearance criterion

The steps of this work

- Selection of the measurement layout and preliminary parameters of the measurement: segregation of the metallic segments based on their geometries; small amount of metallic waste/ thin source; sufficient amount of metallic waste to be measured/ about 100 kg;
- Estimation of the efficiencies for several geometries of the metallic segments (i.e. pipes, metallic slab, convex surfaces, screws and bolts, flanges etc). The efficiencies should allow sufficient statistic for 1-2 min measuring time;
- Determination of bias because of activity inhomogeneity, for several geometries of the segments;
- Study of the simplified geometries and carry out sensitivity analysis against the parameters that influence the efficiency of the measurement;
- Drawing of the layout for the non-destructive gamma spectrometry measurement, suggestion of the procedures

Measurement set up to reduce the uncertainties

The segments are put on a square shallow box. The detector/ detectors are above the box



Items geometry	total weight on one tray kg
metallic items of small dimensions, homogeneous density of 4 g/cm^3, layer of 5 cm thickness	290
12 steel pipes of 10 cm diameter, 0.2 cm thickness, 120 cm length	70
6 steel pipes of 20 cm diameter, 0.3 cm thickness, 120 cm length	104
4 steel pipes of 30 cm diameter, 0.4 cm thickness, 120 cm length	140

MCNPX simulations was carried out for source-detector configuration and the models will be validated by using volume sources and possibly ISOCS

Challenge to Solve/ Objective

Challenge

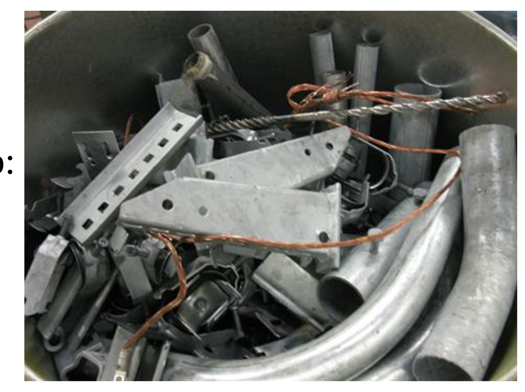
After decommissioning of a NPP, a large amount of activated or/ and contaminated metallic waste is produced (ILW, LLW, VLLW, EW). Therefore, the adequate radiological characterization is important for optimizing the management of metallic waste and for increasing the volume of scrap metal for release.

Table 1: Estimated nuclear power plant scrap metal mass –clearance [1]

Region		Iron and Steel (10³ tons)	Annual Average Releases for the Period of 2010 – 2043 (10³ tons)
North America	Surface contaminated/ removable	902	58.4
	Suspect radioactive	1025	
Europe	Surface contaminated/ removable	1128	85.5
	Suspect radioactive	1693	

[1] Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W. & Wilson, S.E. (1998): Analysis of disposition alternatives for radioactively contaminated scrap metal. Journal of the Franklin Institute 335 (6), 1089–1103)

Objective



Reduction of the measurement uncertainty before decontamination
at the stage after dismantling and cutting of components into segments to help:

- to decide if decontamination is worth
- to select the appropriate decontamination techniques
- to select the clearance procedure

The aims of the proposed non-destructive γ-spectrometry set up

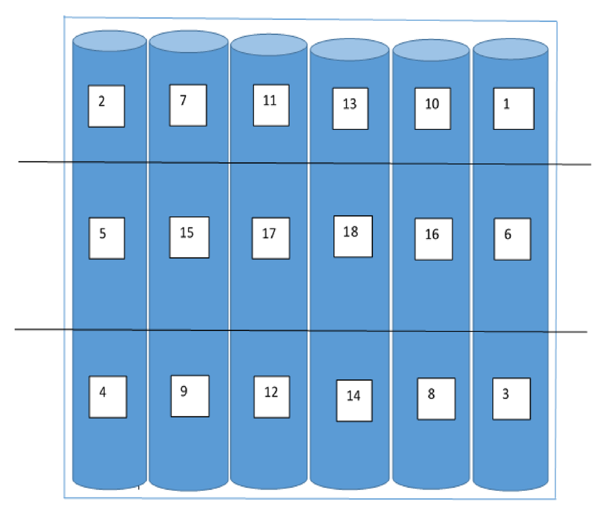
- Significant reduction of the measurement uncertainty (the target is to achieve less than 30 % uncertainty)
- Adequate sensitivity for key radionuclides for acceptable measuring time (Co-60 & Cs-137 but could be also others)

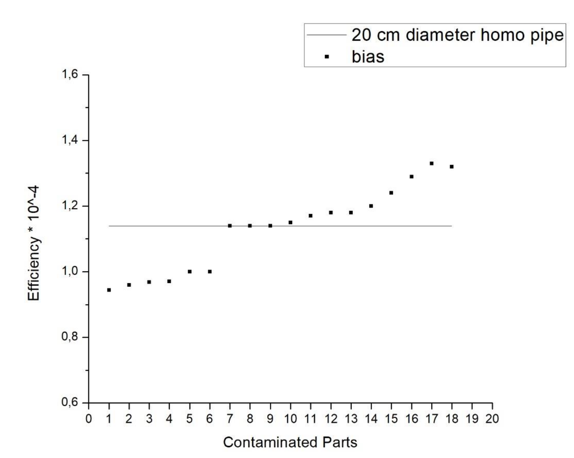
Results

Determination of measurement Bias

Internally contaminated pipes in shallow box – case of one detector

- Pipes diameter 20 cm, thickness 0.3 cm, and distance detector center – base shallow box 120 cm



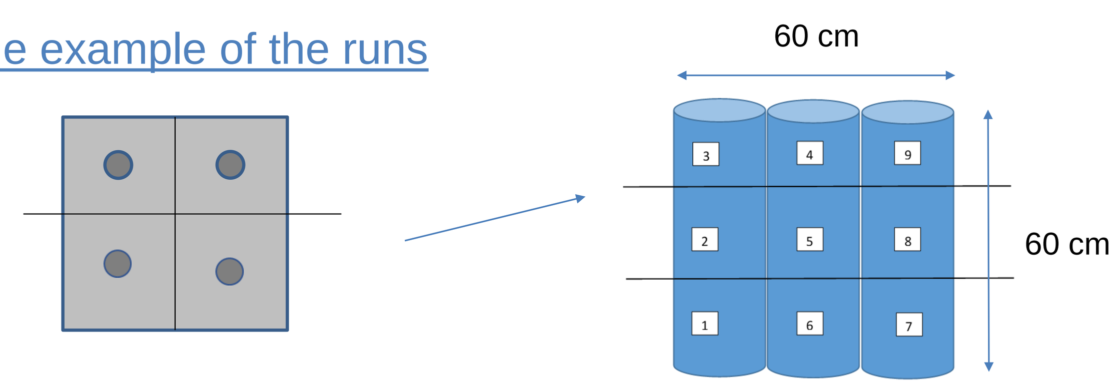


Efficiency 1.14 * 10^{-4}
bias +16 % -18 %

Internally contaminated pipes in the shallow box – case of four detectors

- Pipes diameter 20 cm, thickness 0.3 cm, and distance detector center – base shallow box 60 cm

one example of the runs



Four 3X3 NaI detectors at 60 cm height

Part	MCNPX efficiency for 662 keV (10^{-4}) Relative Error< 6‰	BIAS (%)
1	5.26	-8
3	5.28	-8
7	5.28	-8
9	5.23	-9
2	5.98	+4
4	5.89	+3
6	5.93	+3
8	5.95	+4
5	6.85	+19

Diameter (m)	Efficiency	Bias
0.1	4.80 * 10^{-4}	+16% -14%
0.2	5.74 * 10^{-4}	+19% -9%
0.3	7.10 * 10^{-4}	+14% -5%

Conclusions/ Future work

Conclusions
- Significant reduction of the measurement uncertainty and sufficient sensitivity for acceptable measuring time
- The measurement efficiency decreases when the detector-source distance increases, while the accuracy is getting better

Future Work
- Investigation of more items geometries (i.e. convex pipes, convex surfaces etc.)
- Use of simplified geometries
- Sensitivity analysis against the parameters which affect the measurement efficiency will be carried out, when necessary