ANALYSIS OF RADIOACTIVE EFFLUENTS PIPELINES FOR CONTAMINATION/ACTIVATION

IOAN IORGA[1, 2], DANIELA GURAU[1], OCTAVIAN SIMA[2]

[1]Horia Hulubei National Institute for Nuclear Physics and Engineering, P.O.B. MG-6, 077125, Bucharest-Magurele, Romania
[2]Faculty of Physics, University of Bucharest, P.O.B. MG-11, 077125, Bucharest-Magurele, Romania,
Email: johnny@nipne.ro; daniela.gurau@ymail.com; octaviansima@yahoo.com

Received July 23, 2014

Laboratory analysis were performed for radiological characterization of the underground pipes connecting the 30 m^3 buffer tank of liquid effluents belonging to the Nuclear Reactor VVR-S to the 300 m^3 tanks from the IFIN-HH Radioactive Waste Treatment Station.
Measurements for the assessment of the contaminants inside of the pipelines were done using high resolution gamma-ray spectrometry, with the detector placed inside of the pipe. Due to the specific measurement geometry, experimental efficiency calibration was not possible; therefore the peak efficiency curve was obtained by Monte Carlo simulation using GESPECOR software.

Key words: radioactive effluents, efficiency curve, Monte Carlo simulation.

1. INTRODUCTION

Horia Hubulei National Institute of Physics and Nuclear Engineering (IFIN-HH) Magurele, Romania, owns a VVR-S nuclear research reactor that was built between 1955–1957, operated until 1997 and was permanently shut-down in 2002. During his life time, it was functional for a period of 113467 h, including 2000 h at 3.0–3.5 MW power. The total power output up to 1997 was 9.59 GWd. In 2002 the reactor was permanently shut down. The decommissioning of the reactor has started in 2010 and is planned to be finalized in 2020.

The reactor was fitted with a 30 m^3 radioactive effluents leakages pond connected by an underground pipe with two 300 m^3 radioactive effluents storage ponds belonging to the IFIN-HH Radioactive Waste Treatment Plant (STDR).

During decommissioning activities these underground structures needed to be removed from the ground and subjected to radiological characterization.

From operational history we assess that the radioactive effluents were discharged to 30 m^3 pond from the primary circuit. Take in to consideration that the VVR-S nuclear research reactor from Magurele was shut down 17 years ago, only radionuclides with half live higher than one year have a significant contribution to the radionuclide inventory.

2. RADIOLOGICAL CHARACTERIZATION

2.1. PIPES DESCRIPTION

Three types of pipes were decommissioned:

- a stainless steel pipe used for radioactive effluents transport, with an outer diameter of 108 mm and a wall thickness of 5 mm, buried in the ground at depths between 2.75 m and 7 m;
- a carbon steel pipe, used for the ventilation of the 300 m^3 ponds, with an outer diameter of 62 mm and a wall thickness of 5 mm, buried in the ground at depths between 1.5 m and 2.5 m;
- a carbon steel pipe, used for the ventilation of the exhausted filter storage with an outer diameter of 108 mm and a wall thickness of 5 mm, buried in the ground at depths between 1.5 m and 2.5 m.

2.2. MEASUREMENTS

In situ measurements and laboratory analyses were used for radiological characterization of the pipes. Three kinds of *in situ* measurement were performed: dose rate measurements, radioactive contamination measurements and gamma spectrometry. The sampling and laboratory analysis help to obtain information about contamination and activated materials. The involved measurement techniques allow detection of many radionuclides emitting alpha/beta/gamma radiation.

Our goal is to determine the activation/contamination of the pipes and the possible migration of the radionuclides implied in the pipes wall.

Preliminary measurements using a NaI(Tl) detector were carried out to evaluate the level of radioactivity. The detector was collimated and placed along the pipes, from place to place, perpendicular with these (Fig. 1). The approach developed by Radu *et al.* [1] using efficiency measured with point sources combined with theoretical procedures was applied for obtaining the peak efficiency for disk sources measured with NaI(Tl) detector. An absorber equivalent with the matrix and thickness of the pipes was considered.

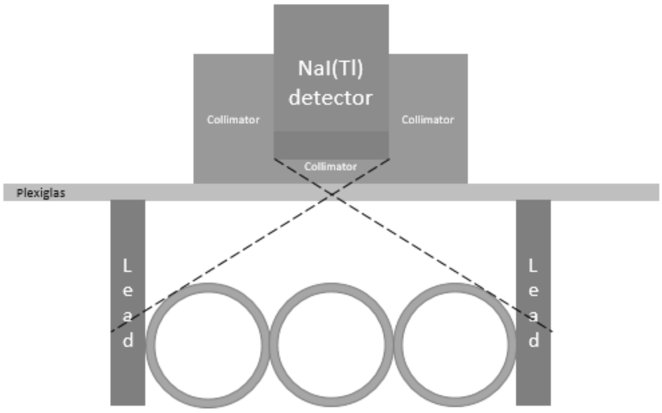

Fig. 1 – NaI(Tl) detector above the pipes.

For a more specific assessment of the contaminants inside of the pipelines, high resolution gamma-ray spectrometry, with the detector placed in the same geometry, are required.

3. EFFICIENCY CALIBRATION BY MONTE CARLO

Due to the specific measurement geometry, experimental efficiency calibration is not possible in this case; therefore the peak efficiency curve should be obtained by computation. In this work we applied the Monte Carlo simulation code GESPECOR.

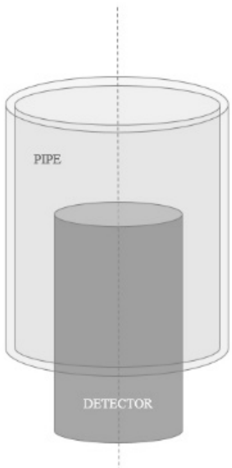

Fig. 2 – HPGe detector inside of pipe.

In the measurement of the pipes, various cases concerning contamination and/or activation should be considered. It is possible that only the inner side of the pipe walls are contaminated due to the contact with the radioactive effluents. Or a thicker deposit of contaminated sludges can be formed on the inner part of the pipe. In the case of pipes from the core of the reactor, neutron activation produces a non-uniform distribution of radioactive nuclides across the walls of the pipe.

For a correct assessment of the activity by gamma-ray spectrometry it is necessary to have information on the activity distribution and on the full energy peak efficiency dependence on this distribution.

In this work a detailed study of the dependence of the efficiency of the detector in the particular geometry (detector inside the pipe) was carried out by Monte Carlo simulation using the GESPECOR software [2]. GESPECOR was previously applied in studies related to nuclear reactors or waste containers, *e.g.* for efficiency calibration for the measurement of a fuel rod from the HELEN Subcritical Assembly [3], for simulation of radioactive waste drums [4-9], etc.

In order to obtain useful results for various cases of activity distributions, the efficiency was evaluated for the following cases:

- a uniform distribution of activity between R_i and R_o; R_i and R_o are the inner and outer radius of the pipeline.
- activity distribution restricted to a thin cylindrical shell of radius R, with R bigger or equal to R_i and smaller or equal to R_o.

In the simulation we considered the following nuclides: ^{137}Cs with E=661.66 keV, ^{60}Co with E_1=1173.23 keV and E_2=1332.49 keV and ^{152}Eu with E_1=122.78 keV, E_2=344.28 keV and E_3=1408.01 keV.

In Fig. 3 the dependence of the efficiency on the radius R of the shell containing the activity is represented for the energies of interest. The decrease of the efficiency with R is due to the decrease of the detection solid angle and to the increase in attenuation of the photons in the walls of the pipe when R increases.

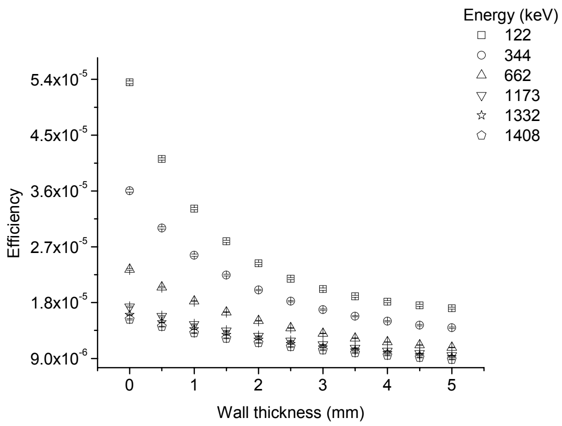

Fig. 3 – Peak efficiency curve results.

From Fig. 3 the efficiency dependence $\varepsilon(R)$ on R can be obtained. Then if the relative dependence of the activity $A(R)$ inside the walls of the pipe is known, the specific efficiency for the actual distribution of the activity can be obtained by a convolution of the functions $A(R)$ and $\varepsilon(R)$. After obtaining the appropriate efficiency, the absolute value of the activity can be evaluated.

4. CONCLUSIONS

The assessment of the activity of effluent pipes by gamma-spectrometry may be done in a measurement geometry with the detector placed inside the pipe. Experimental efficiency calibration in this geometry is difficult, if not impossible. In this work the efficiency was evaluated by Monte Carlo simulation, both in the case when the activity is uniformly distributed across the wall of the pipe and in the case when the activity is restricted to a thin cylindrical shell within the wall. The results obtained can be used for the efficiency calibration for any particular distribution of the activity.

Acknowledgements. The present study is useful for the project EMERSYS (Toward an integrated, joint cross-border detection system and harmonised rapid responses procedures to chemical, biological, radiological and nuclear emergencies), MIS-ETC code 774 (European Regional Development Funds, Romanian Ministry of Regional Development and Public Administration).

REFERENCES

1. D. Radu, D. Stanga, O. Sima, *A method of efficiency calibration for disk sources in gamma-ray spectrometry*, Rom. Rep. Phys., **61**, 203–213 (2009).
2 O. Sima, D. Arnold, C. Dovlete, *GESPECOR: A versatile tool in gamma-ray spectrometry*, *J. Radioanal. Nucl. Chem.,* **248**, 359–364 (2001).
3. O. Sima, L. Dinescu, *Efficiency calibration and gamma-ray spectrometry measurement of a HELEN fuel rod*, Rom. J. Phys., **46**, 165–174 (2001).
4. O. Sima, I. L. Cazan, L. Dinescu, D. Arnold, *Efficiency calibration of high volume samples using the GESPECOR software*, Appl. Radiat. Isot., **61(2–3)**, 123–127 (2004).
5. M. Haralambie, L. Dinescu, O. Sima, P. Stoica, *Study concerning the efficiency calibration of a drum waste assay system*, Rom. J. Phys., **51**, 77–87 (2006).
6. M. Toma, O. Sima, C. Olteanu, *Experimental and simulated studies for the calibration of a radioactive waste assay system*, Nucl. Instr. And Meth. In Phys. Res. A, **580(1)**, 391–395 (2007).
7. M. Toma, O. Sima, C. Cristache, F. Dragolici, L. Done, *Efficiency calibration studies for gamma spectrometric systems: the influence of different parameters*, Rom. J. Phys., **53**, 795–800 (2008).
8. M. Toma, C. Olteanu, L. Done, F. Dragolici, O. Sima, *On the efficiency calibration for different systems used for the assay of radioactive waste containers*, Rom. Rep. Phys., **62**, 821–826 (2010).
9. D. Stanga, D. Radu, O. Sima, *A new model calculation of the peak efficiency for HPGe detectors used in assay of radioactive waste drums*, Appl. Radiat. Isot., **68**, 1418–1422 (2010).