Advanced technologies for radioactive waste characterization and Free Release Measurement

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Abstract

Nuclear power generation, medicine and heavy industry are widely using radioactive materials and, as a result, are generating large amounts of radwaste that has to either be stored or free-released to the environment. Free-release procedures require precise detection of radionuclides that can remain in waste. The low activity of such nuclides can be on a level of natural background or even below. That requires the background influence to be removed. ENVINET has developed very low radioactivity materials which can be used to form a low background measuring chamber. The concrete composite based material has several advantages when compare with lead, which is usually used for such purposes.

1. Introduction

The lack of radioactive waste characterization on nuclear sites produces a negative effect upon the safety of storage and economic efficiency of radioactive waste (RW) management.

The routine operation and decommissioning of nuclear facilities creates a great amount of various materials that have to be removed from the site. Parts of these materials can be released into the environment without the necessity of long-term disposal at the repositories. The dismantlers face the problem of choosing an efficient method of measurement of these materials in order to have reliable information on waste characteristics. Errors in waste characterization may result in producing waste packages which do not comply with the waste acceptance criteria for disposal. The large increase in disposal costs has encouraged the development of the effective Free Release Measurement (FRM) procedures to minimize the RW volumes.

In many countries the reporting forms sent from NPPs and RW management facilities to the regulatory authorities very often fail to provide sufficient information for well-grounded conclusions and decisions regarding planning any long-term radioactive waste management programs, and are often useless for analysis of the current waste management system.

The demand for FRM equipment and technologies is increasing due to the growing number of nuclear power facilities being decommissioned. This has revealed the necessity for an effective complex solution for RW management and characterization, including measuring systems and analytical software. The ENVINET a.s. (Czech partner company in ENVINET Pico Envirotec Group, Canada), one of the most successful engineering and supply company to the nuclear industry

in the Czech Republic and in Europe, is directly engaged in developing innovative solutions for RW characterization and free release measurement. Successful FRM solutions enable companies to optimize the radioactive waste storage filling, as well as allowing them to reduce costs and withdraw non-radioactive waste from circulation.

Currently ENVINET specialists are developing a new type of FRM system, called "PAMM" (Potentially Activated Material Monitor) that will provide the most precise measurements at very low activity. The development is based on the company's know-how – shielding of an advanced design. This new heavy metal-free shielding material will allow low activity measurement to be taken. As well, it is environmentally friendly and will significantly decrease the cost compared to the lead shielding method.

2. Innovative type of Free Release Measurement System

2.1 Low radioactive background

Specialists of ENVINET a.s. have over 15 years experience in radioactive waste characterization. The company provides equipment and services in the field of low-intermediate waste characterization to Nuclear Power Plants, industrial companies and research institutions in different countries.

During the last few years ENVINET has developed an exclusive technology of radioactive waste free-release measurements. ENVINET specialists are authorized to provide free-release measurements at both Czech NPP`s, i.e. at NPP Dukovany and NPP Temelin, Czech Republic.

One of the major problems in free-release measurements is a natural background influence. To acquire accurate measurements, the testing sample of radioactive waste has to be insulated from the surrounding environment. This is especially important for some of the European and Asian countries, where the background of natural and man-maid isotopes activity is high.

Usually the measuring chamber of testing equipment is made of lead. Use of lead has a number of disadvantages.

- Lead normally has its own radioactive background. This depends on the metal origin.
- Lead is not environmentally friendly. It is well known that lead is unhealthy for humans.
- The testing chamber made of lead has to be custom constructed for a particular system.
- The price of lead is continually increasing.

Other materials, widely-used for shielding, are sand and concrete.

The sand can be used as a filler of the testing chamber multilayer walls. In that case the complicity of the chamber construction grows significantly.

The construction of the chamber becomes more complicated if it is build of concrete. The concrete has a higher radiation background.

The availability of a low-background material, that would be handy and easy to use, becomes very important for free-release measurements systems.

2.2 The shielding material

Over the last few years, ENVINET has been developing a new material which has specific low-active characteristics. The material is lead-free and heavy-metal-free, based on natural materials with very low content of radionuclides, including their bonding agents, based on cements and organic phase. Therefore, as a concrete composite material, it can be used as a building material in the form of special bricks. The testing chamber, made up of such bricks, will insulate measured samples from natural background activity. Despite being of lower density than lead (material density optimized on 2,4g/cm^3), the price for the equivalent shielding capability is roughly half by comparison. The key advantages are as follows.

- Low and stable price of input components.
- Safe availability of input components.
- Easily manufactured in different shapes and modules.
- No issues when disposing the material.
- It can be used as a construction block for building a shielded testing chamber, or room as a whole,

The new material is made in the form of bricks that can be easy handled. A testing chamber of customized volume and configuration can be constructed from those bricks (Fig.1).

Figure 1 The bricks formed from new shielding material

The background level of the new material is much lower than lead, sand or concrete (Fig.2).

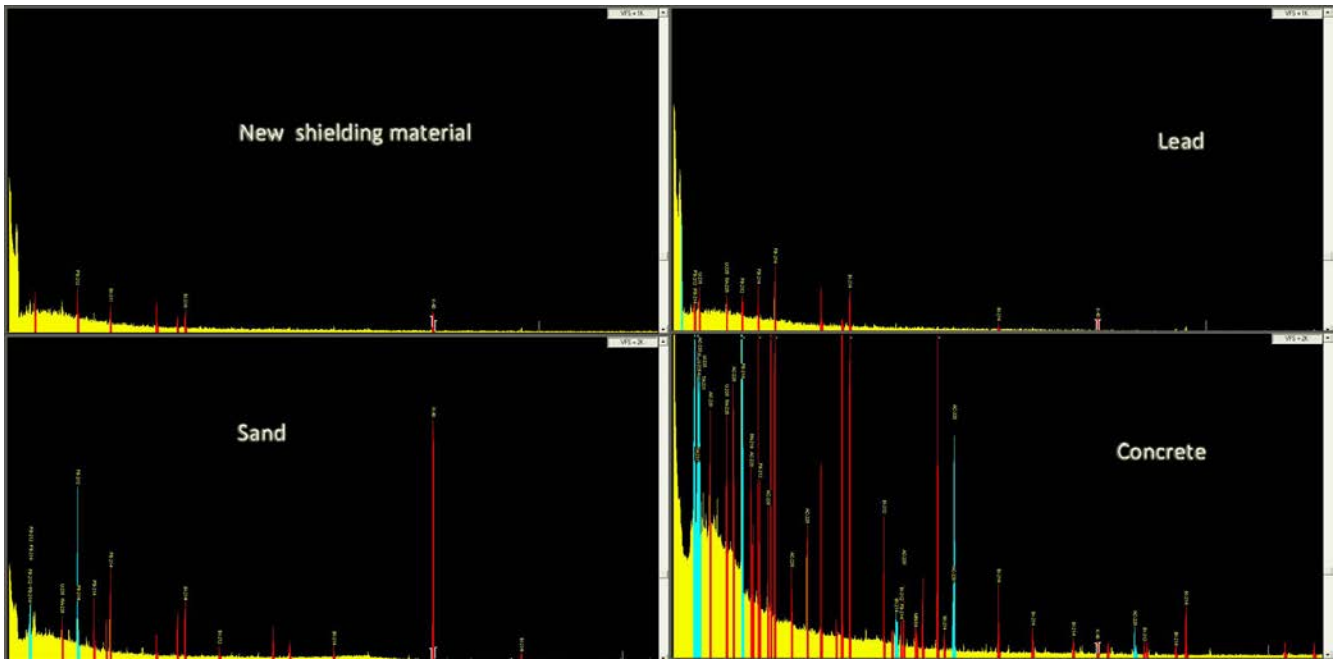

Figure 2 Radiation backgrounds of different materials used for shielding

The low background level of the new material, unified brick shape and its relatively low cost make this material very competitive.

Thanks to this development, ENVINET received an opportunity to design new radioactive waste free-release measurements equipment. The flagship system equipped with new shielding material is PAMM.

2.3 The PAMM System

The PAMM system is the new equipment for measuring the RW prior to its release into the environment.

The first PAMM measuring system is now under realization to be installed in the Nuclear Research Institute Rez (Czech Rep.) during 2012. This system could become a prototype of the unified Europe wide FRM methodology system.

The measuring system consists of the following main components (Fig.3):

- Low-background measuring tunnel;
- 4 HPGe Interchangeable Detector Modules with lead collimators;
- Conveyor for moving the measuring container;
- 4 measuring containers;
- Air-conditioning and filtration unit for the measuring tunnel.

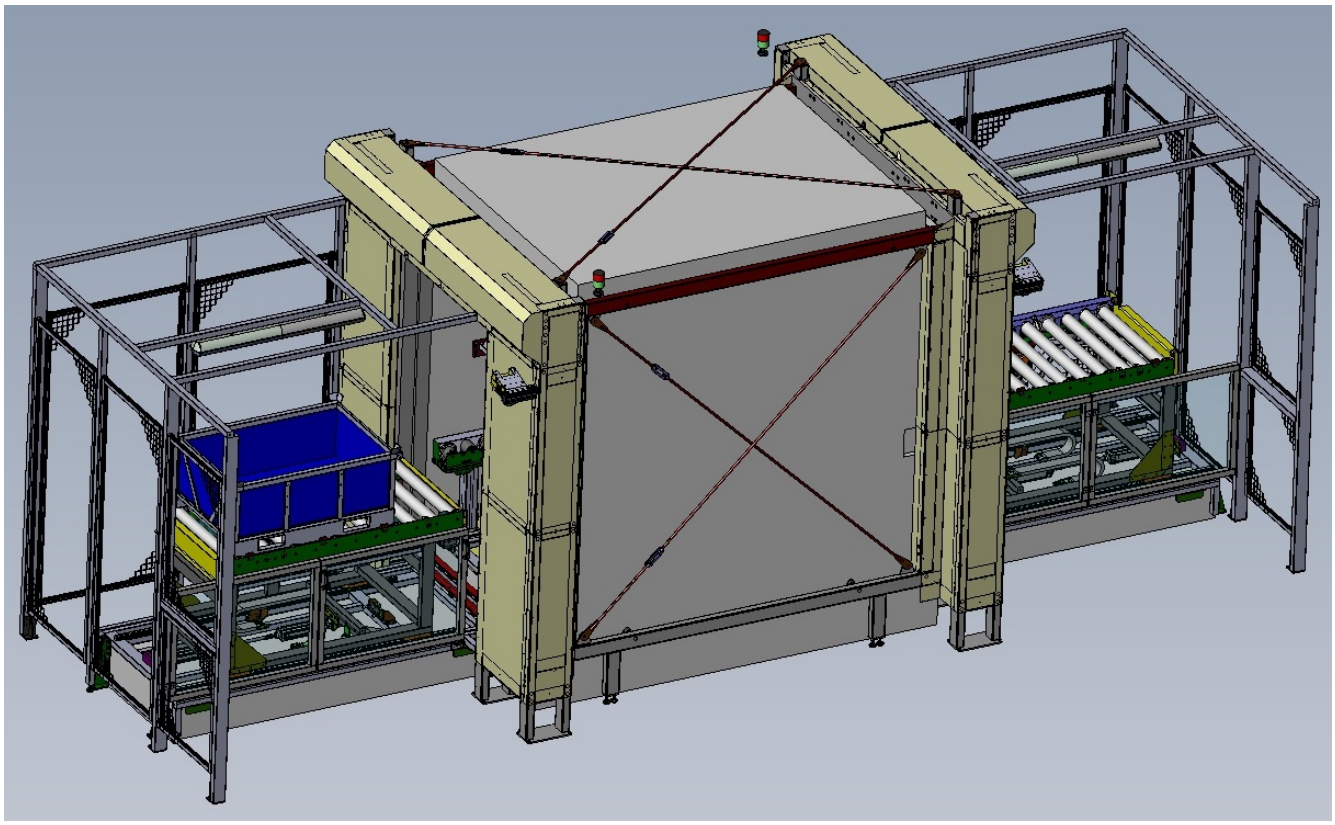

Figure 3 Stationary system PAMM for FRM of radioactive waste

The semiconductor gamma spectrometry is used for the determination of radionuclides in the measured material. The PAMM is a stationary system with two detectors on the top and two on the bottom, installed perpendicular to the longitudinal axis of the measured container. The system uses HPGe detector modules (ORTEC IDM) that have their own detector electrical cooling system. This significantly reduces the space requirements and speeds up the service maintenance.

During the design of PAMM the emphasis was placed on the system‘s modular structure, both in the shielding construction and the measuring parts. The measuring device is placed in the measuring tunnel, assembled from the configuration blocks. Such composition can be rearranged in order to alter the wall thickness and thus to achieve the low detection limits (minimum detectable activity – MDA) during the acceptable measurement time.

The shielding is built using dry masonry of newly developed material, described above, with no connecting mortar. The shielding materials have a very low content of radionuclides and provide very good suppression from the surrounding radiation background. The measuring tunnel is equipped with sliding doors which reduce the penetration of gamma photons in the inner space of the tunnel and maintain the overpressure of filtered and tempered air inside the tunnel.

The suppressed background and advanced semiconductor gamma spectrometry allow the low activity radionuclides to be detected. There is the capability to preset up to 20 windows to be measured simultaneously. The measured values, including the uncertainties, are included in measurement protocols. A "Document of the official measurement" is generated on the basis of such protocol.

The radionuclides that cannot be detected by a particular system setup or hard-to-detect radionuclides (including alpha and beta radionuclides) will be automatically calculated using the correlation coefficients.

As a final result, the user obtains the information on the material and whether there is the possibility that it can be released into the environment.

More precise results of laboratory measurements of alpha and beta nuclides surface activities can be added to the data.

3. Waste characterization and free-release systems

The previous models of FRM systems, build by ENVINET, are currently used for measurements of all the RW originating from both Czech NPPs, and were also supplied for the Free Release Facility project in the Lithuanian Ignalina NPP (Fig.4) which is now under decommissioning. Reliability and effectiveness of the systems have been proven over many years of operation in the European nuclear power industry.

Figure 4 Stationary system for FRM of radioactive waste at Ignalina NPP (Lithuania) and detailed measuring chamber

The previous ENVINET systems, such as MERLIN, were designed for RW measurements after its fragmentation. The new system is designed to measure large quantities of bulky RW metal and non-metal origin (plastics, construction waste, etc.).

4. Complex characterization solutions

A large amount of RW is currently generated by sources other than nuclear power plants. The experience of the Russian RW management organization Radon Moscow can be an example of characterization technology implementation for this category of RW. Radon is responsible for radiation safety of the Central part of Russia which has almost 40 million inhabitants. The ENVINET characterization systems, and implementation of the new measuring procedures, allowed Radon to provide precise measurements and to select the safest and most economically efficient method of waste management.

According to the IAEA recommendations, the waste "shall be characterized with the objective of establishing its physical, chemical and radiation properties, as well as simplification of registration and transfer of radioactive waste from one management stage to another" [1]. In the Russian Federation the key RW characteristics are stated by the waste generator in the certificate ("passport"). There are over 3,500 registered RW generating companies and only about ten non-destructive RW characterization systems in Russia. Therefore, the control of the information accuracy is very complicated. This situation is a direct consequence of lack of RW characterization, which gives rise to numerous problems such as: an absence of free release of waste from the regulatory control; a mixed placement of waste with different degrees of potential danger during processing and storage; a low economic efficiency and incorrect priorities in the system of radioactive waste management [2].

The metrological core of the ENVINET characterization system is the digital multichannel spectrometer DigiDART with electrically cooled HPGe detector. The ENVINET developed software

application allows the system to perform layer-by-layer scanning of the package. The system can be integrated with additional equipment (tuneable collimator, scales, turntables, improved back and side protection of the detectors) and original add-on software. This enhances both the quality of measurement and the user-friendly interface of the whole system.

The automatic operation of the system allows personnel to decrease the time close to the RW. The personnel have only to set the parameters and the system, with a 25 drum conveyer (Fig.5), will perform the measurements [3].

Figure 5 Stationary system for RW characterisation with a conveyer for 25 drums at Radon Moscow (Russia)

The ENVINET complex solution helped to place the characterization process of the SUE SIA Radon Moscow at the highest international level, including measurement procedures, keeping protocols and generating documents required for the data to be reported to the National RW and Radioactive Substances Accounting and Control System of Russia.

5. Conclusion

The instruments and technologies for radioactive waste characterization and management developed by ENVINET a.s. are widely used in different nuclear industry activities, including power generating, research and industrial companies and medicine.

The rising amount of radioactive waste requires more precise discrimination between “active” and “non-active” waste, since the non-active waste can be released into the environment. The modernization and improvement in measurement technologies and equipment is one of the major tasks.

The production of new equipment for free-release measurements of radioactive waste required a new approach in insulation of the waste from the natural background. ENVINET has developed the

new low-active material which can be used in construction of customized low-background measuring chambers.

The new insulation material is used in the design of new free-release measuring equipment.

Nowadays, when the need for characterization as well as the advantages of characterization and FRM measurements became obvious, the innovative measuring equipment can become another step toward qualified and reliable information on waste characteristics, and thus toward effective radioactive waste management.

6. References

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