

**Principles on Radiological Characterization of the Unit 1 at Ignalina NPP  
for Decommissioning Purposes – 8096**

P. Poskas, R. Zujus, G. Drumstas,  
R. Poskas, V. Simonis  
Lithuanian Energy Institute  
3 Breslaujos Str., LT-44403 Kaunas, Lithuania

**ABSTRACT**

There is only one nuclear power plant in Lithuania – Ignalina NPP (INPP). The INPP operated two similar units with installed capacity of 1500 MW(each). They were commissioned in 12/1983 and 08/1987, and the original design lifetime was projected out to 2010 and 2015 respectively. But the first Unit of Ignalina NPP was shutdown December 31, 2004, and second Unit will be closed down before 2010 taking into consideration substantial long-term financial assistance from the EU, G7 and other states as well as international institutions.

Implementation of dismantling activities requires detailed knowledge of the radiological situation at the Unit 1. General Programme of Radiological Survey for Ignalina NPP Unit 1 based on NUREG-1575 was prepared in 2005-2006 by Consortium led by Lithuanian Energy Institute and approved by Regulatory Bodies. It includes such main steps as historical site assessment, scoping, characterization, remedial actions/decontamination support surveys and final status surveys.

General Programme of Radiological Survey defines content and principles of the surveys, and preliminary survey considerations, including identification of the contaminants, establishment of the free release levels, principles on areas classification depending on contamination potential, identification of the final survey units, criteria for selection survey instrumentation, techniques and methods etc. So, in the paper information on these principles and the content of the different stages in General Programme of Radiological Survey is presented.

**INTRODUCTION**

There is only one nuclear power plant in Lithuania – Ignalina NPP. Two similar units with installed capacity of 1500 MW (each) were commissioned 12/1983 and 08/1987 respectively. The original design lifetime was projected out to 2010-2015. But the first Unit of Ignalina NPP was shutdown December 31, 2004, and second Unit will be shutdown before 2010 taking into consideration substantial long-term financial assistance from the EU, G7 and other states as well as international institutions.

In 2001 the Government of Lithuania in relation with Unit 1 decommissioning approved the Ignalina NPP Unit 1 Decommissioning Program until year 2005. According to this Program implementation of new technologies for treatment and conditioning of radioactive waste, construction of the interim dry storage facility for spent nuclear fuel and preparation of the licensing documents for decommissioning of the Unit 1 and some other projects were planned. New Decommissioning Programme for the year 2005-2009 was approved in 2005, and it reflects the tasks that are already under implementation but also the new ones such as preparation for the dismantling of the equipment and some dismantling activities. The progress in preparation for decommissioning of Unit 1 at Ignalina NPP, waste management strategy and lessons learnt were presented in [1-4].

General Programme of Radiological Survey for the Unit 1 of Ignalina NPP was prepared in 2005-2006 and approved by Regulatory Bodies. It includes such main steps as historical site assessment, scoping, characterization, remedial actions/decontamination support surveys and final status surveys. Activities on decommissioning radiological characterization are based on known nuclide vectors. The General Programme of Radiological Survey was developed by Consortium led by Lithuanian Energy Institute, and is based on NUREG-1575. This paper describes the main principles of the General Programme of Radiological Survey for the Unit 1 of Ignalina NPP.

**UNDERLYING PRINCIPLES OF GENERAL PROGRAMME OF RADIOLOGICAL SURVEY**

General Programme of Radiological Survey design is based on the main principles presented in papers [5, 6, 7].

The main goal of General Programme of Radiological Survey is to define the main activities and present basic survey principles, paying attention to optimisation of sampling scope and reliability of the measurement results. Selection of survey instrumentation and techniques basics will be presented preparing separate Programmes for survey phases.

The main radiological survey phases include:

- Historical site assessment;
- Scoping surveys;
- Characterization surveys;
- Remedial actions/decontamination support surveys;
- Final status surveys.

It is necessary to indicate, that the higher mentioned survey phases, not always will be performed. Some surveys may be integrated into one depending on the previous survey results. E.g., if historical site assessment provides sufficient data to prepare characterization surveys programme, the scoping surveys may be omitted. Or, if scoping surveys provides sufficient data to prepare final status surveys programme, then the characterization surveys may be omitted.

Remedial actions/decontamination support surveys activities for solid materials are performed only when free release procedure gives advantage against disposal procedure (reduction of radioactive waste amount, reuse of material, financial benefit). Remedial action/decontamination support surveys activities for site areas and building structures are usually always performed, because the majority of these survey units released from the radiation control. Remedial actions/decontamination support surveys are performed to assure, that contamination reduction of final status survey object is sufficient.

The General Programme of Radiological Survey provides methodology for all radiological survey phases:

- Historical site assessment enables performing initial dividing of survey units into impacted and non-impacted and initial classifying of impacted survey units;
- Scoping survey enables correction of survey units classification and provides information for characterization survey programmes preparation;
- Characterization survey provides information to correction of survey units classification and for remedial action/decontamination support survey programmes preparation;
- Characterization survey and remedial actions/decontamination support survey provide main information for dismantling planning of installations (thorough dose rate measurements, key radionuclides  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$  activity measurements), as well as information for preparing of final status survey programmes;
- Final status survey confirms that final status survey units meet the free release criteria.

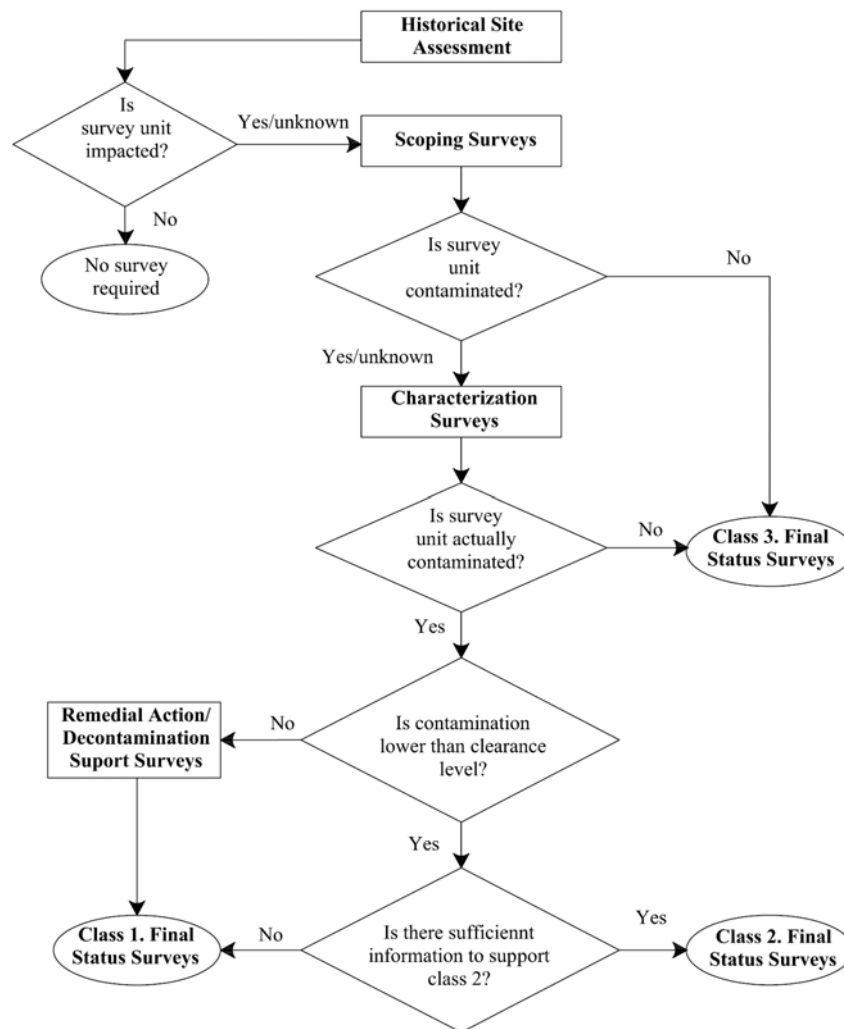
When performing radiological characterization of Ignalina NPP it is planned to perform and prepare such documents:

- General Programme of Radiological Survey (approved by State nuclear energy safety inspectorate (VATESI) and Ministry of Environment);
- Historical Ignalina NPP site contamination assessment report;
- Scoping survey: Scoping survey programme and Scoping survey report;
- Characterization survey: Characterization survey programme and Characterization survey report.
- Remedial action/decontamination support survey: Remedial actions/decontamination support survey programme and Remedial actions/decontamination support survey report.
- Final status survey: Final status survey programme (approved by VATESI and Ministry of Environment) and Final status survey report (approved by VATESI and Ministry of Environment).

Then radiological surveys will be performed at blocks/buildings according to the sequence of their planned dismantling based on radiological survey programmes.

Historical Ignalina NPP site contamination assessment, scoping surveys, characterization surveys and remedial action/decontamination support surveys are defined as preliminary radiological surveys. The objective of these preliminary radiological surveys is to collect radiological data, necessary to perform dismantling projects, and provide information necessary to prepare final status surveys programme. Final status surveys are performed only for survey units, which are intended to release from radiation control. Therefore final status surveys programmes have to be approved by VATESI and Ministry of Environment.

Fig. 1 presents a scheme of land, building structures and large-size equipment surfaces radiological survey. As it is shown on the scheme, the survey starts with the analysis of collected data on the plant, which would help to split the whole territory and equipment into potentially impacted and non-impacted survey units. Impacted survey units are initially classified according to potential for contamination. Non-impacted survey units do not require surveys.



**Fig. 1. Radiological survey of land, building structures and large-size equipment**

In case of potentially impacted survey units, scoping survey is performed enabling corrections of survey units' classification. The survey units impacted but not contaminated or contaminated below the free release level are classified as class 3 survey units, if they are subjects to free release. For the rest survey units, radiological characterization survey and then correction of classification is performed. Remedial action/decontamination procedures are performed for those survey units, which exceed free release levels significantly, if it is reasonable. The last procedure is the final status survey, which has to confirm that final status survey units meet the free release criteria.

The algorithm of solid material radiological survey is similar to the algorithm of land, building structures and large-size equipment surveys (Fig. 1), however there are some principle differences:

- The first difference as against the preceding algorithm (Fig. 1) is the release control performed by applying Ignalina NPP procedure TB-32 for class 3 survey units;
- Next difference is judgment whether efforts on free release activities are reasonable. This question is answered by consideration of efforts, which are needed for free release activities, and possible benefits. Materials (system equipment, different auxiliaries, furniture, etc.) may be disposed as radioactive waste, and only a small part of them will be available for unconditional or restricted re-use;
- Another difference is the fact that final survey of materials with the purpose to release them from further radiological control is also to be carried out using free release measurements facility (FRMF), while surfaces of areas, building structures and large-size equipment will be scanned or surveyed with the help of discrete measurements. Optimization of number of discrete measurements (samples) and determination of its sufficiency are verified by statistical tests.

It is important to keep in mind that characterization process in practice is iterative. During each further survey, the data of preceding surveys have to be specified. Though, after remedial actions/decontamination final status survey units will retain the class defined before remedial actions/decontamination.

Radioactive contamination of survey units will be explored using various methods, to achieve the foreseen survey objectives. To achieve this goal, survey units will be measured using at least two different methods. A list of measurement methods used during various radiological survey phases is presented in Table I.

Table I. Measurement methods used during various radiological survey phases

<b>The main radiological survey phases</b>	<b>Planned measurements</b>
Historical site assessment	Not planned
Scoping surveys	Dose rate, Surface beta contamination
Characterization surveys	Dose rate, Gamma activity of key radionuclides $^{60}\text{Co}$ and $^{137}\text{Cs}$ (gamma spectrometry), Surface scanning to define the areas of elevated activity
Remedial action/decontamination support surveys	Dose rate, Laboratory measurements of samples, Surface scanning
Final status surveys	Dose rate, Surface scanning, Gamma activity of key radionuclides $^{60}\text{Co}$ and $^{137}\text{Cs}$ (gamma spectrometry), Surface beta contamination, Laboratory measurements of samples

A list of measurement methods used at various radiological survey phases may be updated depending on some circumstances arising when performing surveys.

The highest requirements for data quality are at final status surveys because it is related to release from radiation control. To meet these requirements integrated survey strategy is applied by using five different methods of measurements.

### **HISTORICAL SITE ASSESSMENT**

The radiation survey starts from the Historical Site Assessment (HSA) and is later followed by other surveys that lead to the final status survey. The HSA is an investigation to collect existing information describing a site's complete history from the start of site activities to the present time. The necessity for detailed information and amount of effort to conduct an HSA depend on the type of site, associated historical events, regulatory framework, and availability of documented information.

The main tasks of HSA are:

- To identify potential, likely or known sources of radioactive material and radioactive contamination based on existing or derived information;
- To identify sites that need further action as opposed to those posing no threat to human health;
- To provide information necessary to scoping and characterization surveys (to define measurement methods and instrumentation for scoping survey, radiological data, unusual events, sampling points, etc.);
- To split of the survey units to impacted and non-impacted, and provide preliminary classification of impacted survey units.

There are three classes of impacted survey units:

Class 1 survey units are the units with the highest potential for contamination, and meet the following criteria:

- Impacted,
- Potential for delivering a dose above the release criterion,
- Potential for small areas of elevated activity,
- Insufficient evidence to support reclassification as Class 2 or Class 3.

Class 2 survey units are the units that meet the following criteria:

- Impacted,
- Low potential for delivering a dose above the release criterion,
- Little or no potential for small areas of elevated activity.

Class 3 survey units are the units that meet the following criteria:

- Impacted,
- Little or no potential for delivering a dose above the release criterion,
- Little or no potential for small areas of elevated activity.

Detailed information on HSA at Unit 1 of Ignalina NPP is presented in [8].

### **SCOPING SURVEYS**

If the data collected during the HSA or knowledge of technological process indicate that a site or area is impacted, a scoping survey could be performed. The objective of this survey is to provide more information about the sites with potential residual contamination. Specific objectives may:

- To provide input to the characterization survey design,
- To support the classification of all or part of the site as a Class 3 area for planning the final status survey,
- To obtain an estimate of the variability in the residual radioactivity concentration for the site,
- To identify non-impacted areas that may be appropriate for reference areas and estimating the variability in radionuclide concentrations when the radionuclide of interest is present in background.

If the HSA indicates that contamination is likely, a scoping survey could be performed to provide initial estimates of the level of effort for remediation and information for planning a more detailed survey, such as a characterization survey. Not all radiological parameters need to be assessed when planning for additional characterization because total surface activity or limited sample collection may be sufficient to meet the objectives of the scoping survey.

Planning a scoping survey involves reviewing the HSA. This process considers available information concerning locations of spills or other releases of radioactive material. Reviewing the radioactive materials license or similar documentation provides information on the identity, locations, and general quantities of radioactive material used at the site. This information helps to determine which areas are likely to contain residual radioactivity and, thus, areas where scoping survey activities will be concentrated.

For scoping surveys that are designed to provide input for characterization surveys, measurements and sampling may not be as comprehensive or performed to the same level of sensitivity necessary for final status surveys. If residual radioactivity is not identified during judgment sampling, it may be appropriate to classify the area as Class 3 and perform a final status survey for Class 3 areas. However, collecting additional information during subsequent surveys (e.g., characterization surveys) may be necessary to make a final determination as to area classification. Dose rates for equipment and in the compartments, as well as, surface beta activity for equipment measurements will be performed at scoping survey. These activities are conducted based on HSA data and professional judgment. Background activity and radiation levels for the area should be determined including direct radiation levels on building surfaces and radionuclide concentrations in media. Survey locations should be referenced to grid coordinates, if appropriate, or fixed site features. It may be considered appropriate to establish a reference coordinate system in the event that contamination is detected above the free release levels (CLs). Scoping survey activities provide an initial assessment of the locations and general extent of residual radioactivity.

Also measurement registration sheets, final report forms, survey units' drawings with sampling locations has to be presented in the report.

### **CHARACTERIZATION SURVEYS**

Radiological characterization surveys programmes are prepared based on historical and scoping surveys data. The main objectives of characterization survey include:

- Determining of the nature and extent of radiological contamination,
- Evaluation of remediation alternatives (unrestricted use, restricted use, disposal in various types of repositories, etc.),
- Input to pathway analysis/dose or risk assessment models for determining site-specific CLs (Bq/kg, Bq/m<sup>2</sup>),
- Evaluating remediation technologies,
- Input to final status survey design.

Results of the characterization survey include:

- The identification and distribution of contamination in the survey units (buildings, structures, solid materials and other site facilities),
- Necessary coefficient of deactivation for unrestricted use,
- The concentration and distribution of contaminants in surface and subsurface soils.

Characterization survey information will be used:

- For updating of preliminary classification of survey units,
- For remedial action/decontamination support survey programmes preparation,
- For dismantling planning of installations (dose rate measurements, key radionuclides <sup>60</sup>Co, <sup>137</sup>Cs activity measurements),
- For preparing of final status survey programmes for the survey units to be free released.

The characterization should include sufficient information on the physical characteristics of the site. The design of the site characterization survey is based on the data quality assessment for the information to be collected, and is planned using the HSA and scoping survey results.

The characterization surveys should clearly identify those survey units that have been affected and have not been affected by the site activities. When planning for the potential use of characterization survey data as part of the final status survey, the characterization data must be of sufficient quality and quantity for that use. There are several processes that are likely to occur in conjunction with characterization. These include considering and evaluating remediation alternatives, and calculating site-specific CLs. The survey should also provide information on variations in the contaminant distribution in the survey unit. The contaminant variation in each survey unit contributes to determining the number of data points based on the statistical tests used during the final status survey. Additionally, characterization data may be used to justify reclassification for some survey units (e.g., from Class 1 to Class 2). Characterization surveys include measurements of dose rate, gamma activity of key radionuclides  $^{60}\text{Co}$  or  $^{137}\text{Cs}$  (gamma spectrometry), surface scanning to define the areas of elevated activity. Characterization surveys activities often involve the detailed assessment of survey units. Results of preliminary surveys are used for identification of the contaminated objects. Selection of survey instrumentation and analytical techniques are typically based on knowledge of the appropriate CLs.

### **REMEDIAL ACTION/DECONTAMINATION SUPPORT SURVEYS**

Remedial action/decontamination support surveys are conducted to:

- Support remediation activities,
- Determine when a site or survey unit is ready for the final status survey,
- Provide updated estimates of site-specific parameters to use for planning the final status survey.

A remedial action/decontamination support surveys serve to monitor the effectiveness of decontamination efforts that are intended to reduce residual radioactivity to acceptable levels. This type of survey guides the cleanup in a real-time mode. The remedial action/decontamination support survey typically relies on a simple radiological parameter, such as direct radiation near the surface, as an indicator of effectiveness. Such surveys are intended for expediency and cost effectiveness, and does not provide thorough or accurate data describing the radiological status of the site. This survey does not provide information that can be used to demonstrate compliance with the CLs and is an interim step in the compliance demonstration process. Survey units that are determined to satisfy the CLs on the basis of the remedial action/decontamination support survey will then be surveyed in detail by the final status survey. Alternatively, the remedial action/decontamination support survey can be designed to meet the objectives of a final status survey.

A remedial action/decontamination procedure may change activity ratios between radionuclides on the surface of remediate survey unit. It is reasonable to confirm nuclide vectors for these survey units, or to define new nuclide vectors to be used at final status survey stage. The objective of the remedial action/decontamination support survey is to detect the presence of residual activity at or below the CLs criteria. Though the presence of small areas of elevated radioactivity may satisfy the CLs, higher efficiency may be got if remedial actions/decontamination will be applied to these areas. Information identifying areas of elevated activity that existed prior to remediation may be useful for planning final status surveys. After remediation/decontamination procedure final status survey units are not reclassified.

### **FINAL STATUS SURVEYS**

A final status surveys are performed to demonstrate that residual radioactivity in each final status survey unit satisfies the predetermined criteria for release for unrestricted use or, where appropriate, for use with designated limitations. For each final status survey unit a separate decision will be made whether the unit attains the site-specific reference-based cleanup standard for the designated pollution parameter. Therefore this survey is more complex than preceding surveys.

Final status survey process begins with development data quality requirements. On the basis of these objectives and the known or anticipated radiological conditions at the site, the numbers and locations of measurement and sampling

points used to demonstrate compliance with the CLs are then determined. Finally, survey techniques appropriate to develop adequate data are selected and implemented.

Planning for the final status survey should include early discussions with VATESI and Ministry of Environment. A confirmatory survey may be performed by the responsible regulatory agency (Ministry of Environment).

The General Programme of Radiological Survey presents recommendations on:

- Application of Decommissioning Criteria;
- Determining Numbers of Data Points for Statistical Tests – Contaminant Present in Background;
- Determining Numbers of Data Points for Statistical Tests – Contaminant Not Present in Background;
- Determining Data Points for Small Areas of Elevated Activity;
- Determining Survey Locations;
- Developing an Integrated Survey Strategy;
- Material free release;
- Evaluating Survey Results.

### **PRELIMINARY SURVEY CONSIDERATIONS**

The General Programme of Radiological Survey also gives recommendations on such basic questions:

- Decommissioning criteria;
- Identification of contaminants and establishing free release levels;
- Classifying areas by contamination potential;
- Selecting of background reference areas;
- Selecting of background reference materials;
- Identifying final survey units;
- Criterion for Selecting Survey Instrumentation, Techniques and Methods.

### **SUMMARY**

General Programme of Radiological Survey for Unit 1 of Ignalina NPP presents basic survey principles, paying attention to optimisation of sampling scope and reliability of the measurement results. It also presents methodological principles for selection of survey instrumentation and techniques for preparing radiological survey Programmes for scoping surveys, characterization surveys, remedial action/decontamination support surveys and final status surveys. The methodology and recommendations presented in this General Programme were already applied for preparation of the Characterization Surveys Programmes for different buildings at the Ignalina NPP UNIT 1.

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