Annals of Nuclear Energy 94 (2016) 93–101

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

Technical note

Updating of the public dose assessment approach for decommissioning related releases from the Ignalina NPP

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ARTICLE INFO

Article history:
Received 26 January 2016
Received in revised form 23 February 2016
Accepted 25 February 2016

Keywords:
Ignalina NPP
RBMK-1500
Decommissioning
Radioactive release
Dose assessment
Release-to-dose calculation factor

ABSTRACT

The methodology used at the Ignalina NPP for the assessment of the public exposure from radioactive releases to the environment is based on the use of so called "release-to-dose calculation factors" (RDFs). Application of RDFs is straightforward and in practice is used both to assess impacts from measured releases and to assess impacts from planned activities. The set of radionuclides and RDF values corresponding to them for operational releases were approved by the regulatory authorities.

The decommissioning-related radiological characterization of the plant components and wastes revealed that the available set of RDFs is not sufficient for the decommissioning needs. To overcome this, a simplified approach has been proposed for the estimation of the missing RDF values. However, estimations using the simplified approach might be very inaccurate and not necessary conservative.

This paper addresses the current practice of the dose assessment for releases from the Ignalina NPP and the necessity of extension of the available set of RDFs. New RDF values for the calculation of radiological impacts due to airborne releases from the power units and waterborne releases into Lake Drūkšiai are proposed for the decommissioning-relevant radionuclides. The significance of individual radionuclides in releases to the environment during decommissioning is discussed.

1. Introduction

The only nuclear power plant in the Republic of Lithuania – Ignalina NPP – is situated in the north-east of the country, on the banks of Lake Drūkšiai. The power plant operated two RBMK-1500 water-cooled graphite-moderated channel-type power reactors. Following the country accepted obligations to the European Union and the National Energy Strategy (Parliament, 2002), the first reactor was shutdown at the end of 2004, after 21 years of operation. The second reactor was shutdown at the end of 2009, after 23 years of operation. The Government of Lithuania approved the decision to implement an immediate dismantling strategy for the decommissioning of Ignalina NPP Unit 1 (Government, 2002). The same dismantling strategy is applied for the decommissioning of Unit 2 and the remaining plant components. Preparation for decommissioning and the decommissioning itself have been the main activities at the Ignalina NPP since 2010.

Operation and decommissioning of a nuclear power plant lead to release of radionuclides to the environment. Radioactive releases must be planned and controlled in accordance with the regulatory prescribed conditions and limits. Proper assessment of release-associated impacts (e.g. doses to the population) is important from the environmental and the public health protection point of view.

The methodology used at the Ignalina NPP for the assessment of public exposure is based on the use of so called "release-to-dose calculation factors" (RDFs). RDF is the ratio of the annual effective dose to a critical group member of the population to the unit activity of a particular radionuclide released from the Ignalina NPP into the environment. Application of RDFs is straightforward and convenient. In practice, it is used for both to assess impacts from measured releases and to assess impacts from the planned releases from decommissioning and waste management activities. The set of radionuclides and values of RDFs corresponding to them for the operational releases were approved by the regulatory authorities.

The decommissioning-related radiological characterization of plant components and wastes revealed that the current set of RDFs is not sufficient for decommissioning needs. To overcome this, a simplified approach has been proposed for the estimation of the missing RDF values. The approach is based on the assumption that

Abbreviations: EIA, environment impact assessment; NPP, nuclear power plant; RDF, release-to-dose calculation factor.

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http://dx.doi.org/10.1016/j.anucene.2016.02.028
0306-4549/

contributions of the radionuclides in question to the total dose should be minor and, therefore, precise estimation is not needed. However, estimations using the simplified approach might be very inaccurate and not necessary conservative. Thus, it was considered that the available set of RDFs should be revised and updated to meet the decommissioning needs.

2. Background

The main sources of radionuclide release into the atmosphere during operation of the Ignalina NPP and after the shutdown of the power reactors are ventilation systems servicing the power units and the existing solid and liquid radioactive waste management facilities. Where feasible, current decommissioning activities use the existing ventilation systems and, therefore, the defined radionuclide release routes have not been changed. In addition to the existing ones, new release locations will be established due to operation of the new facilities constructed to support the decommissioning (Poskas et al., 2012). The new solid radioactive waste treatment facility will house waste sorting, size reduction, compaction and incineration technologies. The new spent nuclear fuel interim storage facility will have a hot cell where bundles of spent nuclear fuel can be inspected and repacked. The low and intermediate-level short-lived radioactive waste near-surface disposal facility will have a technological building for the final conditioning of waste packages of certain types. All these and other new facilities will have their own ventilation systems from which radionuclides could be released into the atmosphere. The new facilities will be built inside and outside the existing Ignalina NPP industrial site. In addition, performance of some dismantling works may require installation of local ventilation systems with direct releases into the environment. In comparison with normal operation, the Ignalina NPP decommissioning phase can be characterized as having more airborne activity release locations, which also are distributed over a wider area.

The technical and industrial storm water drainage channels inside the Ignalina NPP sanitary protection zone are used for release of radioactive effluents from the existing nuclear facilities into the aquatic environment. From these channels, radionuclides in surface water flows are discharged into Lake Drūkšiai. The power plant equipment cooling water is released directly into Lake Drūkšiai. The newly built nuclear installations will not fundamentally change the existing radionuclide migration routes. Radionuclides will be released into the surface water channels, from where they will reach Lake Drūkšiai. A schematic layout of the main existing and newly planned locations of radionuclide release into the environment from the Ignalina NPP is shown in Fig. 1.

Radioactive releases into the environment are planned and controlled in accordance with the regulatory prescribed conditions and limits. During operation of the Ignalina NPP, exposure of the population from radioactive releases has steadily decreased. Annual effective doses since 1999, assessed with application of RDFs (State, 2011), have not exceeded 5 μSv, Fig. 2. After the shutdown of the first and the second reactors, the impact from radioactive releases has dropped below 0.1 μSv (in the years 2010–2014). The radionuclides ^{14}C, ^{60}Co, ^{90}Sr and ^{137}Cs determine the dose from releases into the atmosphere. The radionuclides ^{3}H, ^{60}Co and ^{137}Cs determine the dose from releases into Lake Drūkšiai.

However, a few aspects should be kept in mind. Due to delays in construction of the new solid radioactive waste management and storage facilities, treatment and conditioning of solid radioactive waste basically has not been started yet. Due to delays in construction of the new spent nuclear fuel interim storage facility, the majority of spent nuclear fuel is still kept in the power units. Decommissioning works so far include dismantling of mostly uncontaminated or lightly contaminated equipment components. With progress in decommissioning and management of radioactive waste, the nature of radioactive releases into the environment may change.

Radiological impacts on the population from radioactive releases are assessed during the planning of decommissioning works (Ragaišis et al., 2014) and afterwards, when performing analyses of measured releases. Usually, the radiological impact is evaluated using regulatory approved RDFs (State, 2011). This methodology has been developed for the assessment of the Ignalina NPP impact under normal operational conditions and has been used in practice for more than a decade.

Use of RDFs is straightforward and the annual effective dose E (Sv) to a member of the population is calculated as follows:

$$E = \sum_i \sum_j Q_{i,j}^A \times F_j^A \times K_i + \sum_j Q_j^W \times F_j^W,$$

where: $Q_{i,j}^A$ is the annual release of radionuclide j into the atmosphere from the source i (Bq), F_j^A is the RDF for radionuclide j release into the atmosphere (Sv/Bq), K_i is the release height factor for the source i (dimensionless), Q_j^W is the annual release of radionuclide j into the aquatic environment (Bq) and F_j^W is the RDF for radionuclide j release into the aquatic environment (Sv/Bq).

Mathematical models for the calculation of RDFs were developed taking into account specific aspects of the local environment (Nedveckaite et al., 2000) with the following main assumptions regarding the operation of the Ignalina NPP:

- The release of radionuclides into the environment is continuous. Daily release does not exceed 1% of annual release and monthly release does not exceed 25% of annual release.
- The Ignalina NPP has been operating and the radionuclides have been continuously released for 40 years, i.e. radionuclide accumulation in the environment for 40 years is taken into account.
- Meteorological observations from the nearby located Dūkštas meteorological station for the years 1987–1991 were used for quantification of atmospheric dispersion.
- Exposure only of adult members of the critical group of the population is considered. Twice higher than the national average (and for fish products – 10 times) food product consumption rates were set for critical group members.

RDFs were defined for 53 radionuclides that potentially could be released into the atmosphere and 60 radionuclides that potentially could be released into the aquatic environment (State, 2011). Values of RDFs vary from 7×10^{-24} to 1×10^{-15} Sv/Bq for releases into the atmosphere and from 2×10^{-20} to 7×10^{-15} Sv/Bq for releases into the aquatic environment.

Studies of the radionuclide inventory in the operational radioactive waste (Remeikis et al., 2009), and radiological characterization of the equipment and components performed in the frame of preparation for the decommissioning revealed that the existing set of RDFs is not sufficient for the assessment of the impact from the decommissioning activities. Separate investigations also indicate that there are some radionuclides not covered by the current set of RDFs (e.g. ^{55}Fe, ^{63}Ni), for example in the activated reactor materials such as graphite (Smaizys et al., 2005; Narkunas et al., 2009) as well as in the environment of the Ignalina NPP (Gudelis et al., 2010). A list of radionuclides without RDF values is summarized in Table 1. Radionuclides to be considered in a particular release depend on the decommissioning activity and the type of managed waste. Possibly, this list could be extended with other radionuclides. For example, some publications (Remeikis et al., 2012; Jermolaev et al., 2014) discuss