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Software and hardware package for justification of safety of nuclear legacy facilities

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Abstract

Determination of future fate for nuclear legacy facilities is becoming an extremely important near-term issue. This includes decommissioning options to be identified based on detailed justifications of respective designs. No general practice has been developed in Russia to address such issues, while the initial steps to this end have been made as part of the federal target program "Ensuring Nuclear and Radiation Safety for 2008 and Up to the Year 2015". Problems arising in justification of decommissioning options for such facilities, in terms of radiation protection and safety assessments both for the public and personnel, differ greatly from tasks involved in design of new nuclear installations. The explanation is a critical shortage of information on both nuclear legacy facilities as such and on the RW they contain. Extra complexities stem from regulatory requirements to facilities of this type having changed greatly since the time these facilities were built. This puts priority on development of approaches to justification of nuclear, radiation and environmental safety. A software and hardware package, OBOYAN, has been developed to solve a great variety of tasks to be addressed as part of this problem based on a combination of software and hardware tools enabling analysis and justification of the NLS safety in their current state and in a long term. The package's key components are computational modules used to model radiation fields, radionuclide migration and distribution of contamination in water and air, as well as to estimate human doses and risks. The purpose of the study is to describe the structure and the functional capabilities of the package and to provide examples of the package application.

Keywords: Nuclear legacy; Mathematical modeling; Radioactive waste; Safety justification; Engineered barriers; Host environment; Radiation transport; Radionuclide migration.

Introduction

Nuclear facilities require analysis of nuclear, radiation and environmental safety throughout their lifecycles, and the safety analysis results form the basis for the development of documentation required to have any particular activities licensed. Such analysis is normally based on design data, engineering and radiological survey (ERS) findings for respective facilities and predictive modeling of important processes involved in their evolution.

Special difficulties arise in a safety analysis for nuclear- and radiation-hazardous facilities (NRHF) classified as nuclear legacy facilities (NLF) [1–3], the number of which in Russia is about 2000 [4]. There is a whole range of factors to explain this. One of these factors is a critical difference in approaches to justification of safety as compared to facilities under design or construction. It is possible to select the suitable site, materials, etc. for new projects, while the situation is quite different for nuclear legacy facilities due to a great number of uncertainties and their locations which, as a rule, fail to meet modern requirements. Another factor is that most of these facilities were built in the early years of nuclear power with less stringent (as compared to the present time) regulatory requirements to ensuring safety. Most of them were shut down back in the previous century and the systems of

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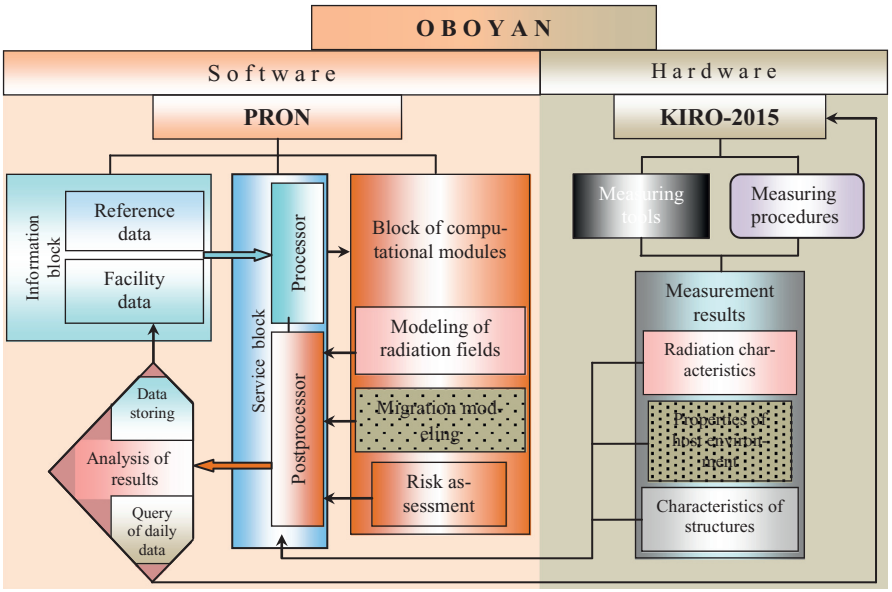

Fig. 1. Diagram of the OBOYAN package.

safety barriers for protection against the spreading of radioactive materials into the environment are nearing the end of their service life. As a rule, no documented history of the facility operation exists in whole or in part, the current state of the safety barriers is unknown, and some of the information required for the facility state description cannot be recovered due to long-term facility operation, while the available information occasionally fails to reflect the reality to the full extent as the result of accidents, accident response activities and upgrades to systems, components and some of the structures.

In recent decades, a "deferred decision" approach has been the practice for the vast majority of such facilities. In the near term therefore, a top priority task will be to determine the future fate of these facilities or rather to select the option for the closing stage of their lifecycle, including prioritization and practicability assessment of decommissioning options and detailed justification of the decommissioning project.

A software and hardware package, OBOYAN (Obosnovaniye bezoposnosti obyektov yadernogo naslediya; in English: Justification of safety of nuclear legacy facilities), has been developed at NSI to address many of the tasks described as part of the presented problem [5]. The package complies with modern international practice and supports safety analysis and justification for nuclear legacy facilities in their current state and in a long term allowing so well-reasoned selection of the approach to managerial decision-making concerning the priority status and deadlines for the measures to ensure safety.

General description of the software and hardware package

A study involving a nuclear, radiation and environmental safety analysis suggests the use of modern tools for the computational modeling of important physicochemical processes in the most likely NRHF evolution scenarios with objective and sufficient information being available on the facilities in question.

This requires an integrated approach to assess the radiological risks to humans based on the complete set of influencing factors evaluated with regard for the results of both computational and experimental studies. After the problem is defined and the available information on the facility of interest is collected and assessed for being sufficient and accurate, the list of the ERS tasks is generated the purpose of which is to acquire missing information on the radiation source, the current state of engineered safety barriers and the properties of the host environment. Personnel and/or public doses and their respective radiological risks are estimated for the facility evolution options under consideration.

Such approach forms the basis for the requirements to the functional content of the OBOYAN package which is structured based on the principles of providing the greatest possible compatibility of different systems and the possibilities for its independent use both as the complete package and as individual modules or their combinations. The software and hardware development procedures took into account the OBOYAN peculiarities in compliance with the principle of forming a single information environment to ensure the consistency of operation of individual subsystems and special-purpose modules.

The OBOYAN package consists of two basic components (Fig. 1). One of the components is the software information package PRON (Programmny kompleks obosnovaniya bezopasnosti obyektov naslediaya; in English: Software package for justification of safety of legacy facilities) comprising three blocks: an information block, a computation block and a service block. The other one is KIRO-2015, a software and hardware package used for measurements and practical studies for the purpose of obtaining the complete set of initial