Low- and Intermediate Level Radioactive Waste Disposal Environmental and Safety Assessment Activities in Slovenia

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Abstract

The protection of the environment is one of the main concerns in the management of radioactive waste, especially in repository planning. In different stages of repository lifetime the environmental assessment has different functions: it can be used as a decision making process and as a planning, communication and management tool. Safety assessment as a procedure for evaluating the performance of a disposal system, and its potential radiological impact on human health and the environment, is also required.
Following the international recommendations and Slovene legislation, a presentation is given of the role and importance of the environmental and safety assessment activities in the early stages following concept development and site selection for a low- and intermediate level radioactive waste (LILW) repository in Slovenia.
As a case study, a short overview is also given of the preliminary safety assessment that has been carried out in the analysis of possibilities for long-lived LILW disposal in Slovenia.

Introduction

Slovenia produces radioactive wastes. They are being produced in industry, medicine and research work, but the greatest producer is the NPP Krško. Since its start-up in 1981, about 2,000 m^3 of low- and intermediate radioactive wastes (LILW) have been accumulated and stored on site. The LILW quantities produced elsewhere, e.g. in medicine, are small but sometimes more complex because of the presence of long-lived radionuclides. Most of these wastes are stored in the interim storage at Brinje.
In 1991 the RAO Agency was established by the Slovenian government to take care of the safe disposal of all radioactive waste categories. One of its tasks is also to develop and implement an appropriate approach to reduce the negative impact of the future radioactive waste repository to conform to the legally allowed level.

In this paper the main focus is on the efforts directed towards protection of the natural and human environment regarding LILW management.

In 1993, Slovenia accepted the main act concerning environmental protection - The Environmental Protection Act. Relevant legislation concerning the safe management of radioactive waste management (i.e. siting, construction, commissioning, commencement of operations, operations, closure and post-closure period of disposal facilities) is being adopted from the former Yugoslav legislation. If these decrees cannot be applied, foreign regulations and international agreements and conventions are being considered.

In accordance with the safe management of radioactive wastes some legal bases on which the work should be done are presented, followed by the obligatory environmental and safety assessments.

Legal and regulatory aspects

Environmental Protection Aspect

In our country, the idea of environmental impact assessement was introduced gradually, starting during the seventies. Although there was no legal requirement, the Ljubljanska Banka as the biggest bank, already at that time required submission of an environmental impact assessment. The aim was to gain loans from the World Bank. For this purpose, within Jožef Stefan Institute, a special group called SEPO (the group for environmental impact evaluation) was established.

In 1993 the Environmental Protection Act was issued. This comprises the basic provisions regulating the protection of the environment as a constituent part of development in the Republic of Slovenia. Consequently, the Environmental Impact Assessment (EIA) and Environmental Impact Statement (EIS) are fairly recent additions to the Slovene legislation concerning environmental protection.

An environmental impact assessment must be carried out for those intended activities which are subject to regulatory approval, and which could significantly influence the effects on the environment. This assessment should be based on the EIS, which is a constituent part of the licencing procedure for the intended activity. The method for the preparation of the comprehensive EIA and the contents of the EIS are prescribed [2]. According to the extent and nature of activity and the environmental characteristics of the site, the Government recognizes categories of environmental strains for which the environmental impact assessment is always mandatory [3]. In the case of LILW management, storing, treatment and disposal facilities are also included.

According to the Community Directive on Environmental Impact Assessment of the European Community (1985), the Slovenian Environmental Protection Act ensures that the public has access to all information about possible environmental effects. The public has the opportunity to present views on the suggested project and on the information provided on the environmental impact of the planned facility.

The Safety Aspect of Radioactive Waste Management

According to the Act on Radiation Protection and the Safe Use of Nuclear Energy [4] including the appropriate regulations, the safe operation of a nuclear facility is assured by submission of the safety analysis report (SAR) including all relevant data, presented in documents which should be attached to all licences (siting, construction, commisioning, commencement of operation, operation of nuclear facilities and closure).

The safety report shall contain information about the planned nuclear facility and its environmental impact, the project design, emergency plan and measures required to eliminate or reduce the occupational and population risks. In addition, the radiological arrangements necessary for the safe disposal of radioactive waste should also be submitted.

The compilation and the contents of the safety report and other documentation, including the written application for the construction, commisioning, commencement of operation and operation licences, are specified by E2 Regulation [5].

As part of the entire licencing procedure, the preparation of EIA and SAR is briefly described below.

Environmental assessment

With regard to radioactive waste disposal activities the environmental assessment has different functions in the lifetime (preoperational, operational, closure and post-closure period) of the LILW repository. This can be used both as a decision making process and as a planning, communication and management tool.
Environmental assessment results in four outcomes that should be of great use for the subsequent phases of radioactive waste management. For the organization responsible for radioactive waste disposal, commitments are given to undertake certain activities. Furthermore, some predictions of the disposal facility behaviour are known. These can be used as guides for reassessment during the subsequent phases of repository planning activities. The baseline data for the specific environment are also established and can be used for comparative purposes during all subsequent phases of disposal activities. Finally, conceptual closure and post-closure plans are proposed. These four outcomes represent a continuous linkage between the planning phase and the development and implementation of the environmental protection program for all subsequent phases of the radioacive waste management.

Safety assessment

The purpose of safety assessment is to predict the behavior of the overall radioactive waste disposal system over its life cycle and to assess the safety of the final disposal facility. In practice, safety assessment provides input to the document that will be needed to obtain regulatory licences and permits for the construction, operation, closure, and post-closure phase of the repository. The results of the safety assessment are intended for use in policy consideration, public information, site characterization, system design improvements and regulatory analysis.
The safety assessment of the repository aims to answer questions about future radiation risks to the population and the environment. It therefore needs to include activities identifying possible future developments of the repository system and its characteristics. International documents recommend that safety assessment should consist of the following elements: broad identification of the future evolution of the selected disposal system (scenario development), development and application of appropriate models, evaluation of potential radiological consequences in an overall assessment, uncertainty and sensitivity assessment, validation and overall review of assessments, comparison of results with criteria and documentation. Radiological and non-radiological hazards should be identified in a formal safety assessment and the protective measures identified to ensure occupational and public safety within the acceptable range of radiological and non-radiological effects.
The behaviour of the technical system of the repository, when considered over a long-term period, is relatively complex. Hence, for the envisaged time scale for LILW, the interpretation of the data produced by safety assessment must be dealt with cautiously before application.

What has already been done in the past ...

By now, the SEPO group has prepared over 800 environmental impact assessments for different types of facilities, e.g. the for metal, chemical, paper, pharmaceutical and agricultural

industries, etc. EIAs for the uranium mine and for nuclear power plant have also been prepared.

In 1989, Bechtel National Inc., USA, conducted preliminary performance assessments for the proposed NPP Krško radwaste repository, i.e. for both the shallow land burial concept [6] and for the tunnel concept [7]. The study assessed the repository performance associated with the receipt, handling, processing, storage, emplacement and long-term waste behavior during pre-closure and post-closure phases. The content of the reports was organized roughly in accordance with the SAR for radiaoctive waste repository.
In this performance assessment a deterministic approach was used. The probability of the occurrence of each identified initiating event was conservatively assumed to be unity. To facilitate the accident scenario development and the modeling, the radwaste repository analysis was divided in accordance with two repository life cycle phases (pre-closure phase - operations and post-closure phase). Each phase was then assessed to identify and screen both internal and external initiating events that could contribute to a significant off-site release of radioactive materials. The internal events were those initiated within the repository as a result of failures during the operation of facility systems and equipment, or as a result of abnormal accidents. The external events consist of both man-made and natural processes. A simplified event tree was developed to identify credible initiating events. Since a prefered site has not yet been selected, safety assessment was performed on a "generic site". This was a generic site which had characteristics that were representative for the locations at that time shortlisted for the NPP Krško. The results (operational accidents, groundwater and intruder impact results) showed that the proposed NPP Krško radwaste repository reference site and disposal technology will fully meet the radiation dose limits imposed both by the regulations and by the ICRP guidelines.

In 1994, IBE Consulting Engineers from Ljubljana, prepared a general basis for the preparation of an environmental impact statement for the LILW repository. The basis served as a starting-point, not only as a preliminary environmental assessment for the LILW siting programme, but also for preparing the legally required EIA method, which was actually adopted in 1996 [2]. According to the main components of the environment (soil, water, flora and fauna) they determined the key principles for finding the acceptability of radioactive waste disposal activities in the environment.

The project "Evaluation of the initial state – hydrology, hydrogeology and hydrobiology" [10] deals with initial state parameters related to either surface or ground waters. Radiological parameters were treated separately; therefore, the project limits itself to other parameters which have to be known and evaluated prior to the construction of the disposal facility. The methodology of individual investigations and the distributions of observations in time is defined. Since initial-state investigations are at the same time the basis for future monitoring, the project also determines the bases for monitoring in the area of the LILW disposal site during operation, closure and post-closure period.

In the same year, a preoperational radioactivity measurements program in the vicinity of LILW repositories was prepared [11]. Generic guidelines were discussed for selecting reasonable preoperational measuring methods appropriate for surveillance of natural as well as global man-made radioactivity. The factors taken into account were: primary objectives of preoperational measurements (reference data, later monitoring optimization, information for the general public), regulatory requirements, site- and time- variability of environmental

radioactivity, quality and comparability of results, type of waste, optimal size, time span, and timing of measurements. The elements for setting up an optimized preoperational measuring programme were listed and explained. The relevant results of radioactivity surveillance, environmental monitoring of NPP, as well as independent natural radioactivity studies performed up to 1995 in Slovenia, were then presented.

Preliminary Safety Assessment of Long-Lived Low- and Intermediate Level Radioactive Waste (long-lived LILW) Disposal in Slovenia

In all the activities that have been carried out until now in the field of LILW the main attention has been paid to the short-lived LILW. In 1996, the Agency RAO initiated an analysis of possibilities for long-lived low- and intermediate level radioactive waste (long-lived LILW) management. According to Slovenian law, long-lived LILW radioactive wastes are those that contain long-lived radionuclides with a specific activity greater than 10^9 Bq/m^3, and a total specific activity that does not exceed the limit for high–level waste.

In Slovenia, a register of long-lived LILW has been compiled. It comprises all sources already stored as radioactive waste, including the sources which are no longer in use and which are to be appropriately disposed of. The sources with long-lived isotopes being used at present, and which will not be returned to the foreign manufacturer upon completed utilization, were also recorded. According to the data from the existing evidence and considering the expected values rough and conservative assessments of long-lived LILW activity, mass and volumes have been carried out. Approximately 6.7 x 10^{15} Bq of total activity (i.e. 330 tons of mass or 250 m^3 of long-lived LILW; most radioactive waste with the following radionuclides: Ra-226, Am-241, Pu-239 and U-238) were assessed.

Particular attention was paid to the different possibilities of the combination *disposal facility type / geological environment* for LILW with or wihout α-emitters. On the basis of the geological experience from other countries, and according to our own specific conditions, the six most probable combinations [12] were identified:

1. Surface type over an open aquifer
2. Surface type on rock with low permeability
3. Underground type in plastic rock with low permeability
4. Underground type in plastic rocks with low permeability (long-lived α-emitters considered)
5. Underground type in hard rock
6. Underground type in hard rock (long-lived α-emitters considered)

In order to evaluate the possibility of long-lived radioactive waste disposal under the geological conditions in Slovenia, approximate quantification of safe disposal criteria by preliminary performance assessment was defined [13]. Combinations 4. and 6. were relevant.

A simple "tube type" model was carried out. An attempt was made to bring the initial geological conditions as close as possible to the expected properties of host rock candidates for the siting and construction of a disposal facility. According to that, only two types of rock occurring in Slovenia are suitable as host rocks for long-lived LILW repository location, i.e. cristalline and clay formations. In the model, marl rock was considered.
Pronounced conservative initial conditions were selected in model building. They reflect the catastrophic scenario (high hydraulic gradient, fast penetration of the contaminant into ground water) beyond a normal evolution scenario. The aim of the preliminary performance

assessment was to calculate the radiological doses to man as a measure of consequence of the disposal practice. The consequences were assessed in terms of the committed dose rate of the most exposed individual of a critical group. The calculations were based only on the concentration level of the radionuclides in drinking-well water, which was contaminated due to the release from the repository. The attenuation of radionuclides in groundwater was mainly accountable to radioactive decay, diffusion, dispersion and sorption processes. The formation of daughter nuclides from decay chains of Am-241, Pu-239, U-238 and Ra-226 was also considered.
Only extremely low individual doses may be expected (in the range of 10^{-8} Sv/a), and these may be expected after about some thousands of years after closing the repository. They are essentially to be accountable to C-14, and later to radionuclides from the Am-241 and U-238 decay chain. The other nuclides decay to insignificant levels before escaping from the host material into the drinking water.
The model showed that the given geological conditions enable safe disposal of long-lived wastes. These could be disposed either together with high-level waste, e.g. spent nuclear fuel, or together with short-lived ILW. The selected type of long-lived LILW disposal should be placed underground in rock with the appropriate isolation properties.

In place of a conclusion - work to be done in the future ...

Environmental and safety assessments play a role in all stages of the life of a waste disposal facility. Their use is of great importance in the early stages following the concept development, and also ***site selection***. The principal role of the environmental and safety assessment lies in the licence application and approval process by the regulators. It includes both radiological and environmental aspects. Environmental and safety assessments may be required at various stages in the licencing procedure. They should be included in applications for construction, operation and close-down licencing, and also when significant changes in the state of the facility are planned. According to the IAEA recommendations it is convenient if the siting process is organized in four stages as follows: concept and planning, area survey, site characterization and site confirmation.

In Slovenia, a new siting process is being prepared. The recommendations for the site suitability assessment are under revision [9]. The activities of the environmental and safety assessment that should be directly involved in the siting process are presented in Table 1:

Table 1:

	CONCEPT AND PLANNING STAGE	AREA SURVEY STAGE	SITE CHARACTERIZATION STAGE	SITE CONFIRMATION STAGE
Safety assessment	Establish generic safety assessment for the intended waste and disposal method	Establish generic safety assessment for various geological conditions	Expand and modify generic safety assessment methods and develop analytical site specific models	Prepare safety assessment for the proposed site
Environmental assessment	Establish criteria and assessment approach	Prepare generic environmental assessment	Prepare environmental assessment for individual sites	Development and implementation of detailed environmental assessment

In Slovenia the involvement of the public in radioactive waste management decision making is considered as a priority. The location of the LILW repository should be found only with the acceptance of the local community.

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