LONG-TERM SAFETY ASSESSMENT OF "RADON" TYPE FACILITY

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ABSTRACT

Up till now multi-barrier systems are accepted as a basic approach for long-term radioactive waste isolation in near-surface and deep repositories. Performance assessment of the natural and hand-made (engineered) barriers on time is one of the main difficulties to evaluate reliability of the waste insulation due to the large number of possible scenarios and uncertainties to be considered. The International Atomic Energy Agency (IAEA) had launched the Coordinated Research Program on Improvement of Safety Assessment Methodologies for Near-Surface Radioactive Waste Disposal Facilities (ISAM) at the end of 1997 with the purpose to provide a critical evaluation of the approaches and tools that are currently used in the long-term safety assessment of near-surface radioactive waste disposal facilities. This paper describes an application of the ISAM methodology to safety assessment of Russian near-surface disposal facilities of low- and intermediate-level radioactive waste ("Radon" facilities)

ISAM PROGRAM: SCIENTIFIC SCOPE AND PROPOSED PROGRAM GOALS

In practice low- and intermediate-level radioactive waste (LILW) are frequently disposed at near-surface repositories, such as vaults, trenches, pits, mounds, boreholes, so on. For any storage/disposal activity it is important to be sure that the activity is safe enough for the public and the Environment. Therefore, it is necessary to perform a safety assessment of the disposal facilities at each stage of their life cycle, which includes site selection, construction works, operation, closure and post-closure periods.

At present there are many methods and approaches to evaluate safety of radioactive hazardous facilities. The methods are used in different ways, for different purposes and conditions and may have a different level of confidence. An initial attempt to develop an improved confidence in safety assessment approaches was the IAEA Co-ordinated Research Program (CRP), which is called the Near-Surface Radioactive Waste Disposal Safety Assessment Reliability Study (NSARS) that was implemented from 1991 to 1995 [1]. NSARS focused on developing confidence in physical process models by conducting comparative studies of approaches for specific test cases that represented typical safety assessment problems. The new program, Implementation of Safety Assessment Methodologies (ISAM), is built on NSARS experience but places special emphasis on the implementation of safety assessment methodologies.

The scope of the program includes the scientific and technical aspects related to long-term safety assessment of near-surface disposal facilities.

The main objectives of the program are [1, 2]:

- to provide a critical evaluation of the approaches and tools that are currently used for the post-closure safety assessment of proposed and existing near-surface radioactive waste disposal facilities;
- to enhance active approaches and tools;
- to provide participants with practical experience in the application of the approaches and tools; and
- to build confidence in the approaches and tools that are used.

In order to achieve these objectives, the associated work program focuses on the examination and improvement of approaches and tools used for:

- Justification and development of scenarios;
- model building and application, including data input; and
- confidence building.

The key focus of ISAM is the methodological aspects of safety assessment with emphasis on practical application of these methodologies, because the practical application is necessary for a thorough understanding of the said methodologies. For this reason one of the main components of the program is development of safety cases in order to test safety assessment methodologies and provide practical experience in their application.

Within the ISAM there are three Working Groups (Scenario Generation and Justification, Modeling and Data, and Confidence Building), an ISAM Virtual Workspace Group and three Safety Case Groups. The Safety Case Groups, which were established to test the methodologies and provide participants with practical safety assessment, are divided accordingly to handle the three kinds of practical situations for safety assessment: large vaults typical of those in Western Europe and North America (Vault), smaller vaults typical for eastern Europe and former Soviet Union ("Radon" Type Facility), and a proposed borehole technology for disposal of spent radiation sources in low-technology conditions (Borehole).

The Eastern European Facility Safety Case (hereinafter "Radon" Type Facility Safety Case) is based on the design and state of "Radon" system enterprises, which were built in the former Soviet Union and some Eastern European countries in the 60-70ties. The subgroup represents ISAM participants from Bulgaria, Hungary, Lithuania, Poland, Russia, Sweden, and USA.

Brief description of the "Radon" systems in Russia is given below in order to present details of the last Safety Case with regard to its application to actual disposal/storage sites.

"RADON" SYSTEM IN RUSSIA

The management of low- and intermediate-level radioactive waste (excluding fuel-and-nuclear) is carried out in Russia by the "Radon" system, that was established in the beginning of 60-th in the Soviet Union and included 35 enterprises. There are now 16 specialized enterprises of this system located in various regions of the Russian Federation. They were designed for transportation, preliminary processing and storage of solid, liquid waste as well as spent sealed sources of ionizing radiation.

"Radon" specializes in radioactive waste management in scientific institutions, industry, agriculture and medical institutions, as well as the aftermath of Chernobyl accident. Waste storage facilities accumulated about 100000 m^3 of LLW/ILW with total activity more than 1 million Ci and spent ionization radiation sources with total activity more than 1.5 million Ci. The biggest part of waste volume (about 85%) consists of solid and solidified waste contaminated with ^{137}Cs. More than 90% of sealed spent ionizing sources use ^{60}Co [3].

All Russian "Radon" facilities were built according to standard design. All wastes are placed into special repositories, which might be concrete vaults or trenches for solid radioactive waste temporary storage, boreholes for spent sealed ionization sources. Liquid wastes are accepted by "Radon" enterprises only for interim storage and following processing.

Solid wastes are usually placed in vaults of different capacity volume and structure. Except few repositories the most solid waste is stored in near-surface rectangular multiple vaults made of monolithic reinforced concrete or cement blocks located at 4.5 m deep under the surface or above the ground. Every section is covered from above with cement plate(s). After section is filled up with waste all hollows between waste packages usually (but not always) are filled with cement. After the whole vault is filled up it is usually covered with asphalt and clay cap of 1.5-2 m thickness.

Eight facilities have 200 m^3 near-surface rectangular vaults of monolithic reinforced concrete covered with concrete plates of 30 cm thickness. They are divided into sections by concrete or wooden partition. Wall and bottom thickness is usually about 30-50 cm. They have outer dump course cover of bitumen or asphaltic felt and as a rule additional brick cover to prevent the waterproof damage. The bottom is usually on the depth of 3.5-5 m. Six facilities have 600 m^3 under surface rectangular vaults of monolithic reinforced concrete and three more facilities have 940 m^3 vaults of similar structure. They are sectioned and have the same waterproofing as 200 m^3 vaults. In some cases we have similar non-monolithic vaults of cement blocks.

Three facilities have similar vaults of 640 m^3, 900 m^3 and more volume but constructed over-ground. On one site we have situation when new over-ground cement block vaults were built on the top of closed under-ground vaults. In two cases solid waste are disposed in conversed under surface liquid waste storage. They are 200 m^3 cylindrical tanks of monolithic reinforced concrete covered inside with all-welded 4 mm stainless steel plate.

Two facilities have old non-typical depositories. In one case there are five exposed trenches of 150 m^3 total volume filled with low-level ^{226}Ra contaminated ground. In other case there are four 200 m^3 concreted trenches without partitioning. Disposal in trenches was performed in sixties. In common the trenches do not have any engineer barriers besides a cap above.

All repositories that are now under operation and some closed repositories have hangars to protect them against precipitation.

Boreholes for spent sealed sources are presented with 6-meter depth wells, drilled in concrete monolith. Inside a well there is a steel container in which the spent sources are loaded through special device. At some sites metal matrix is used for immobilization of the sources in the container.

There are three key points, which differentiate any facility of "Radon" type from those considered in others ISAM Safety Cases [4]:

- While both other cases consider new facilities, which only are planned to build, this case is being developed for an existing facility that has been under operation more than 30 years. This feature also supposes different levels of knowledge about the site, depositories and wastes (taking into account the factor of time) for different cases as well as quality assurance applied for that facility more than 30 years before and modern quality assurance requirements for new facilities;
- Both other cases suppose that all vaults or boreholes located at a considered site are of the same type. "Radon" facility has several different types of repositories at one site such as boreholes, vaults and trenches;
- The last distinction between "Radon" Safety Case and other cases is geographical position in moderate climatic zones that results in freezing-thawing cycles and high precipitation, leading to quick ageing of engineered barriers.

So, these differences caused separation of such facilities due of their specific conditions in a particular safety case. As an example of typical "Radon" facility, Saratov "Radon" site was chosen for testing the ISAM safety assessment methodology.

DESCRIPTION OF THE SITE

The Saratov "Radon" Site is located in the Volga River Region (5 of 16 "Radon" facilities in Russia are located in the Volga Region). The facility considered within "Radon" Safety Case is situated on the right side of the Volga River in 12 km from the regional main town (Figure 1). The nearest village, Doktorovka, is in about 2 km from the site. This Site has been under operation more than 30 years

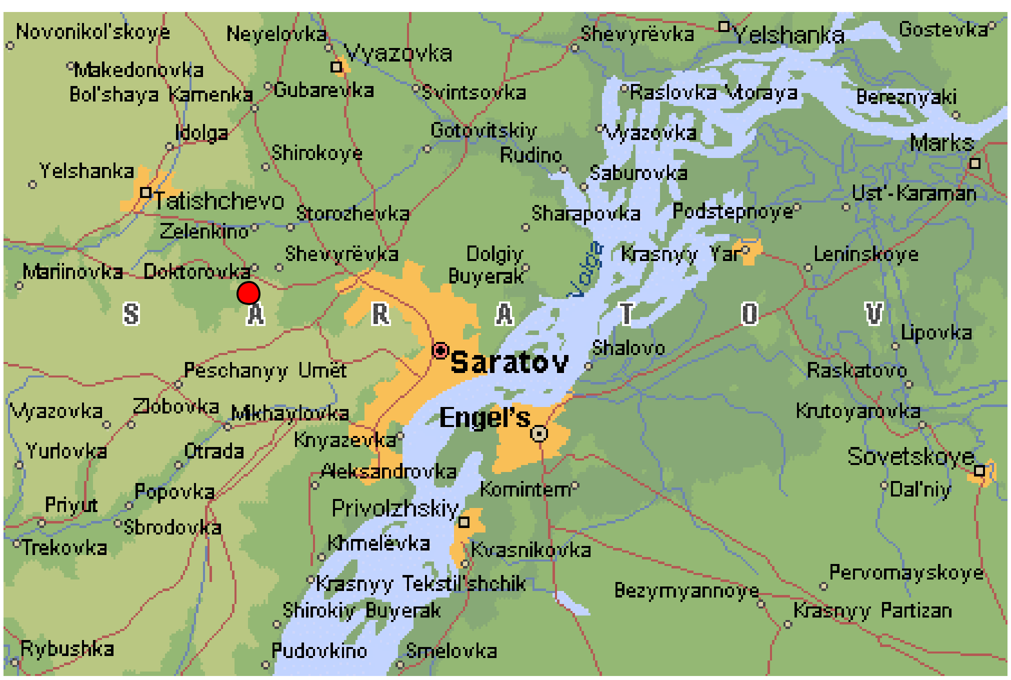

Fig. 1. Geographical map of the region

The regional climate is temperate and continental. The long-term average precipitation is 350 mm per annum but may vary a lot. The nearest surface water body is in 2-2.5 km from the site border and about 80-100 m lower then the site.

The site is situated in the south part of Privolzhsky Heights, in a ravine, bottom of which is formed with Quaternary sandy-clayey deposits. Prospecting drilling at the site has shown the absence of both ground waters and perched waters in the Quaternary sediments within the confines of the site. The ground waters are supposed to be in the deposits somewhere below the site.

The first aquifer occurs in the intercalations of sands and sandstones into Aptian clays. The strata dip to the west and south-west, so their depth increases from 26 m to 130 m and makes 60 m at the site. Thickness of the water bearing sands also increases from 13-14 m at the site up to 20 m and more to the west and the south-west. Hydraulic conductivity is 0.8 m per day. The aquifer is confined with clays. The thickness of the top Aptian clay layer is about 25 m (plus 35 m of Albian clay stratum with sand intercalations without ground water). The bottom Barremian clay layer has 32-60 m in thickness.

In Figure 2 scheme of hy drogeological conditions constructed on a base of available data, is presented.

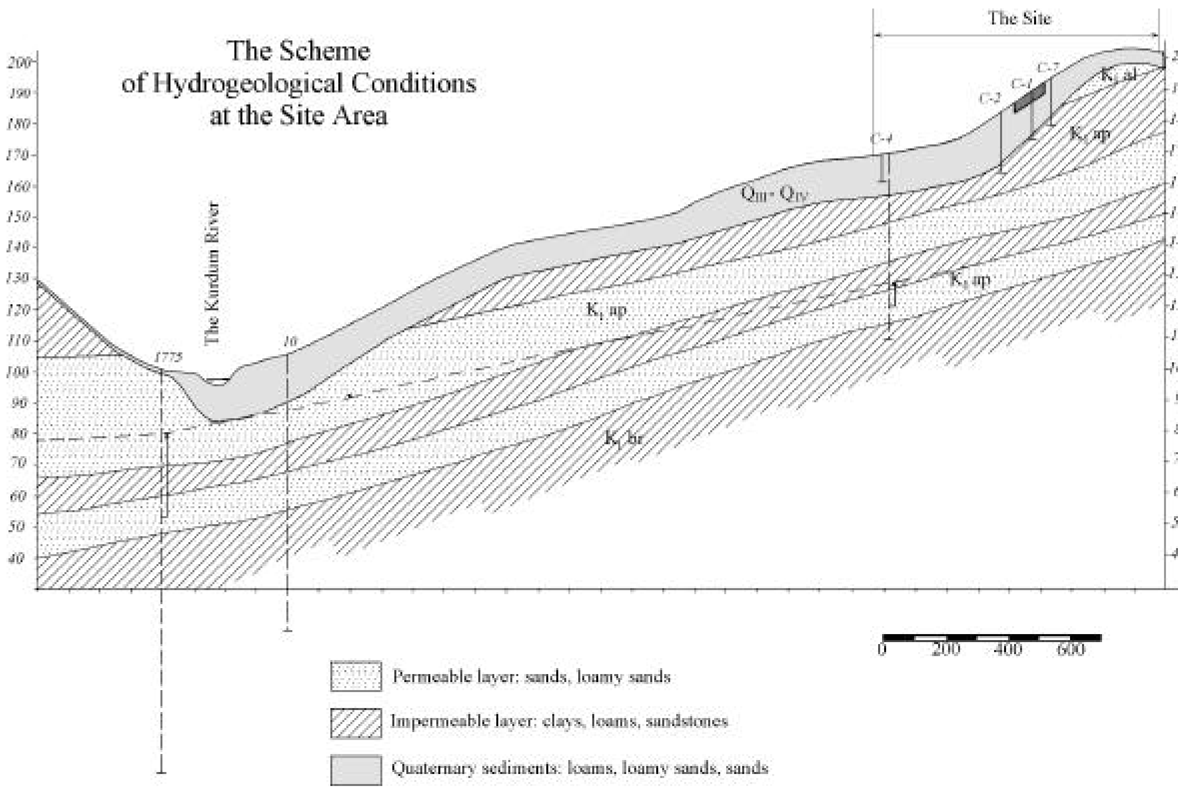

Fig. 2. Scheme of hydrological conditions

FACILITY DESCRIPTION

The Saratov "Radon" facility comprises of 4 concrete vaults (Figure 3) located below ground level for the long-term storage of low and intermediate-activity waste, 5 exposed trenches with low-level RAW and a borehole filled with spent sealed sources. Each repository initially was supposed to be considered and simulated as a separate source term due to the differences in their design, waste origin and inventory.

The most of activity is formed by Po-Be spent sealed radiation sources, ^{232}Th, ^{192}Ir, ^{60}Co, ^{137}Cs. Besides ^{55}Fe, ^{170}Tm, ^{239}Pu, ^{90}Sr, ^{222}Ra, ^{226}Ra are also in presence.

The most part of the waste volume in trenches is ^{226}Ra contaminated ground.

In 1980s the facility accepted up to 0.5 m^3 cemented liquid waste per year. The wastes were cemented into blocks at the client sites.

In some cases there are spent sealed sources kept in their transport containers in solid waste vaults. The sources with long lived radionuclides are also stored in shielded containers in solid waste vaults until the decision on their final disposal.

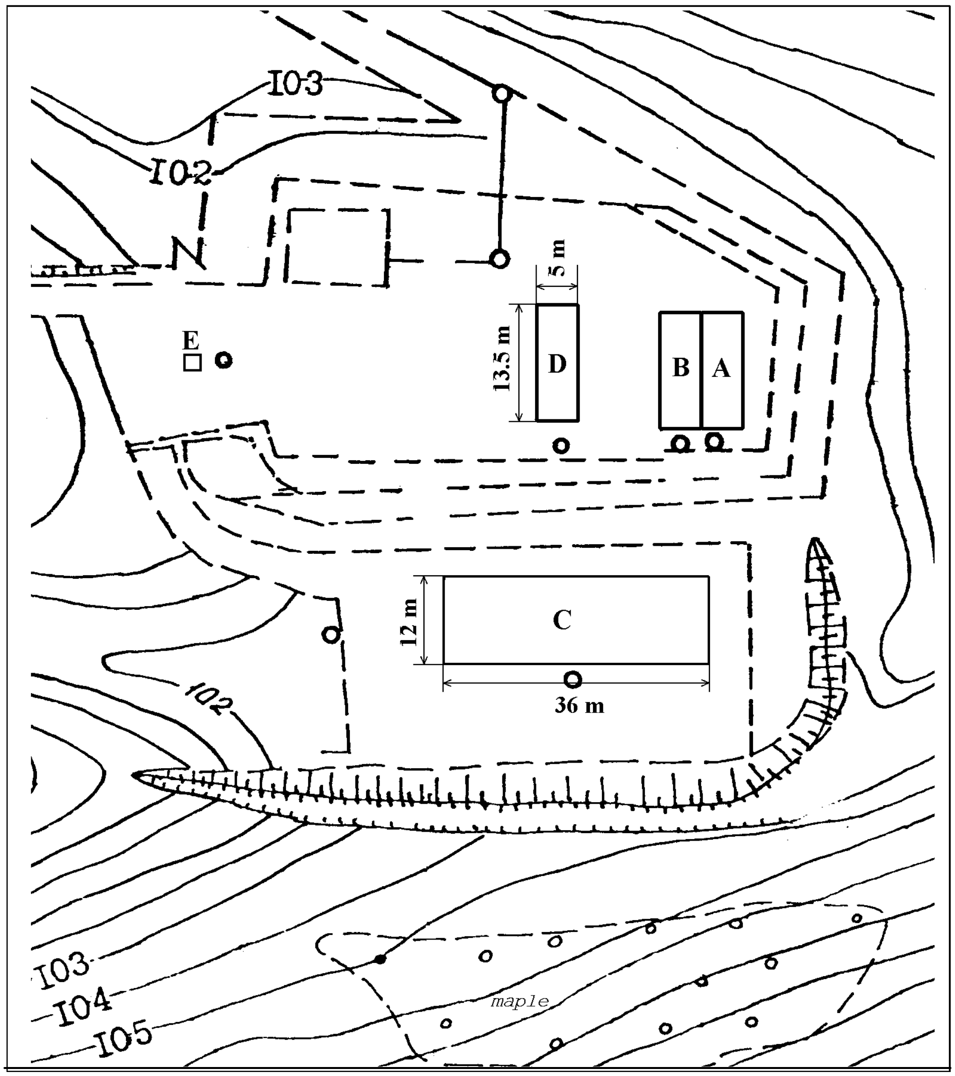

Fig. 3. Layout of Saratov "Radon" Site

APPLICATION OF LONG-TERM SAFETY ASSESSMENT METHODOLOGIES TO THE CERTAIN SITE.

The information given in previous chapters was used for application of ISAM Safety Assessment Methodology.

The key components of the ISAM safety assessment approach are as follows [5]: the specification of the assessment context (Step 1); the description of the disposal system (Step 2); the development and justification of scenarios (Step 3); the formulation and implementation of models (Step 4); and the calculation and analyses of outcomes (Steps 5–8).

Only radiological impacts on human beings were considered in the safety assessment applied. So, chemical or biological toxicity was not assessed. As endpoints annual individual effective dose for critical group was chosen. The dose constraint is 0.1 mSv/yr.

It was accepted that agricultural practice in future would be the same as in Central and Eastern European countries in present. Commercial and industrial activity at the site would be excluded. Social assumptions were made adequate to the current situation: the nearest village is 2 km N-NW and another one is 3 km W from the facility; the nearest city is 12 km from the site; the facility is surrounded by farmlands; ground water from the first aquifer is used for technical water supply in the villages and surface water is used for irrigation, animal watering and all domestic uses.

The range of future behavior and states of a disposal system may be illustrated by a set of scenarios, which can be considered as a hypothetical sequence of processes and events leading to human exposure. Scenarios depend on the environment and disposal system characteristics and on events and processes, which could initiate release of radionuclides from wastes.

Illustrative technique used for Saratov Site consisted of: screening initial FEP's list developed within ISAM program, developing base case scenario, developing alternative scenarios and calculations.

As a base case a Design Scenario had been selected to represent a reasonable future evolution of the disposal system and its surroundings. This future evolution was chosen to be the one that most closely resembled the current situation at the disposal facility.

Conditions chosen for the scenario were as follows. It was assumed that institutional control of the site and the sanitary zone would be maintained for 300 years, after which memory of the existence of the facility would be lost. At that time, individual homes or dachas would be built at the site. Drinking water for individuals near the disposal facility would be assumed to be from a municipal water supply, derived from the first aquifer. It would be assumed that individual homeowners might supplement their food intake from individual gardens. These individual gardens may become contaminated from contact with perched near-surface water. Radionuclides were supposed to transport with atmospheric water, infiltrated through repositories, failed in the end of institutional control period, into hosting soils and with hypothetical perched water in Quaternary deposits to the Kurdjum River.

Results of the annual dose calculations in the first iteration are given in Figure 4.

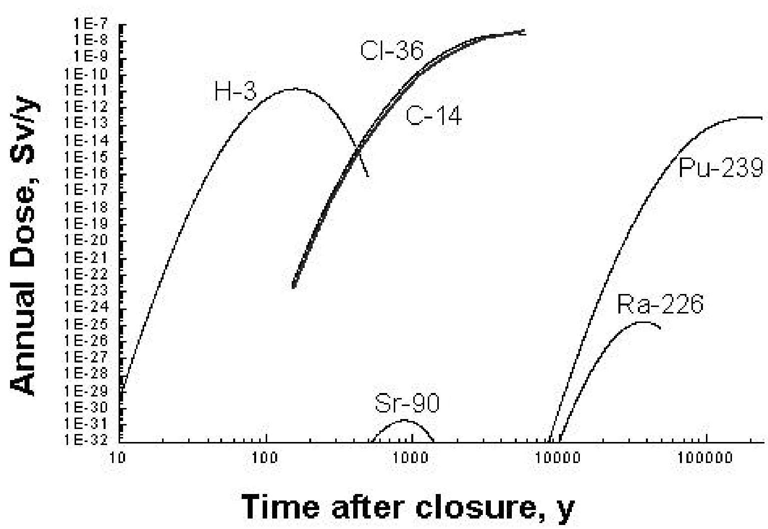

Fig. 4. Calculations of the annual doses

As alternatives a set of 9 additional scenarios was identified for further consideration: Enhanced Degradation Scenario (same as for the Design Scenario but with no credit taken for the engineered barriers); Erosion Scenario; Denudation Scenario; Flooding Scenario; Off-Site Residential Scenario, (as for design scenario but with much closer human residence – about 100 m from repository); Drilling Intrusion Scenario, with intrusion and post-intrusion dose; Road Construction Intrusion Scenario, with intrusion and post-intrusion dose; House Building Intrusion Scenario, with intrusion and post-intrusion dose; Use of Vault as House Foundation Scenario.

The first iteration results has shown that

- migration with perched and surface water should be assessed and/or geological and hydrological data should be clarified;
- hydrogeological conditions at the site should be investigated;
- the inventory should be elaborated and disposal units should be considered separately.

Uncertainties, concerning disposal system evolution, mathematical models and initial information should be considered at next iterations

CONCLUSION

Results of the first application of the ISAM methodology to the Saratov Site revealed that this methodology may be used for "Radon" type facility safety assessment in all stages of facility living cycle (from siting to institutional control cancellation). But in the author's opinion it would be more useful to develop scenarios listing for "Radon" facilities, which may be used at different stages and with different purposes instead of detailed and continuos FEP's screening, that takes too much time. In that case the FEP's screening may be used for control of the scenarios chosen for consideration. Also the uncertainties concerning disposal system evolution, mathematical models and initial information should be taken into account. To dissolve the problems, connected with the uncertainties, additional investigations of the inventory, geological structure, hydrogeological conditions, protective properties of surrounding rocks should be carried out at a "Radon" facility for more reliable safety assessment.

However, the application of the international safety assessment methodologies to "Radon" facility sites in Russia is a matter of great interest, because the sites, as usual, had been constructed in sixties, when regulatory requirements were not so strict as in present. So, the sites should be evaluated from a position of current requirements to exclude any possibility of radionuclide release in the environment that may cause negative consequences for future generations.

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