Evolution of Approaches to Calculation Justification of Long-Term Safety of Radioactive Waste Disposal Facilities in the Russian Federation (ID : 55)

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1. Introduction

At all stages of the life cycle of radioactive waste disposal facilities (RWDF), a long-term safety assessment is required, based on calculations of the migration of radionuclides into the environment. As part of the justification for the RWDF long-term safety, the operating organization develops, using computer programs, calculation models that describe the processes of migration of radionuclides from the RWDF, while making assumptions and simplifications regarding the evolution of the radioactive waste (RW) disposal system and boundary conditions.

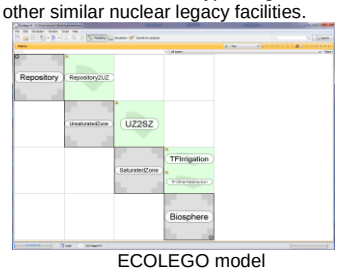
When evaluating the RWDF long-term safety justification, the input data, assumptions and simplifications of the conceptual and calculation model adopted by the operating organization must be carefully and comprehensively analyzed for correctness, reliability and adequacy.

The most effective way to evaluate the RWDF long-term safety justification is to verify the RWDF model by comparing the results obtained by the operating organization with the results obtained from an independent model.

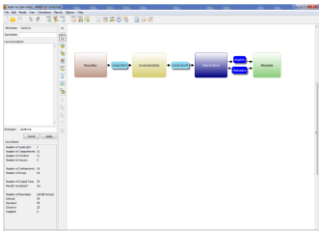
2. The use of a conservative approach in justification of the RWDF long-term safety

In 2004, the IAEA published the results of the international project ISAM (Safety Assessment Methodologies for Near Surface Disposal Facilities (NSDF)) [1], which was devoted to current approaches to safety assessment and the calculation tools used. In the ISAM project as a perspective approach to the NSDF long-term safety assessment the use of the compartmental modeling was considered.

Using compartmental modeling SEC NRS has carried out long-term safety assessments of Radon-type long-term storage facilities for radioactive waste, tailings and other similar nuclear legacy facilities.



ECOLEGO model



AMBER model

The experience of using compartmental modeling pointed to its fundamental drawback, which is associated with obtaining excessively conservative results due to a significant simplification of the RWDF engineered barrier system (EBS) and the geological environment. In particular, when using compartmental modeling it is impossible to consider some features of engineered barrier, topographical relief, the presence of flooding factors, geological heterogeneities such as tectonic disturbances, regional hydrogeological conditions, real paths of radionuclides migration.

It should be noted that the use of compartmental modeling was justified when conducting express safety assessments of nuclear legacy facilities, characterized by a limited set of initial data.

3. Further development of requirements for the justification of the RWDF long-term safety

The adoption in 2011 of the Federal Law “On the management of radioactive waste and on amendments to certain legislative acts of the Russian Federation” dated July 11, 2011 No. 190-FZ [2] required ensuring of safe and cost-effective RW. In order to comply with the requirements of the law [2], in the federal rules and regulations in the field of the use of atomic energy were established requirements for the scope and quality of RWDF safety justifications, including the assessment of the long-term safety of RWDF, based on results of which the EBS, the radionuclide composition of RW and the permissible RW total activity in the RWDF are justified.

In this regard, it became necessary to use a realistic approach to assessing the long-term safety of RWDFs.

4. Modern domestic computer codes designed for the calculation justification of the RWDS long-term safety

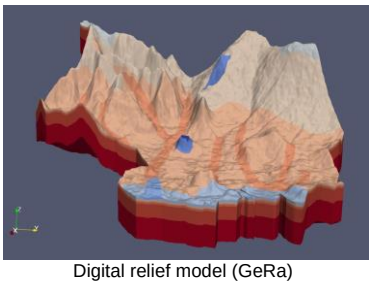
A realistic approach implies the use in the calculation model as the initial data and calculation parameters of the characteristics of the RWDF, the conditions of the site and the area of its location, the boundary conditions, confirmed by field data and experimental studies. The implementation of this approach has become possible with the development of modern computer codes that make it possible to develop three-dimensional geofiltration geomigration models based on the finite volume method (FVM) and oriented to the use of unstructured computational mesh. Such models can significantly improve the reliability and accuracy of the results of RWDF long-term safety assessment. Currently, in Russia, for RWDF long-term safety assessment the domestic computer codes GeRa and NIMFA are used, which have passed verification and validation in the Rostechnadzor system.

5. The use of realistic computational models for an independent evaluation of the RWDS long-term safety justification

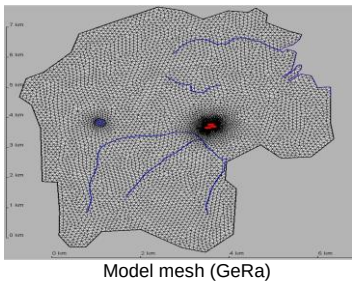
Since 2021, SEC NRS on behalf of Rostechnadzor has been working on the development of RWDF computational models in order to obtain independent predictive estimates of the RWDF long-term safety. The development of models is carried out using the domestic computer code GeRa, while a realistic approach is applied whenever possible.

According to the IAEA document [1], the development of RWDF computational models includes the following stages: analysis of initial information, development of a near field model (RW and EBS), a field model (geosphere) and a biosphere model.

The far field model includes the development of a digital relief model of the RWDF site and region, geological, geofiltration and geomigration models. To develop a realistic model of the RWDF far field, a large amount of field data characterizing the geological and hydrogeological characteristics of bearing rocks is required.

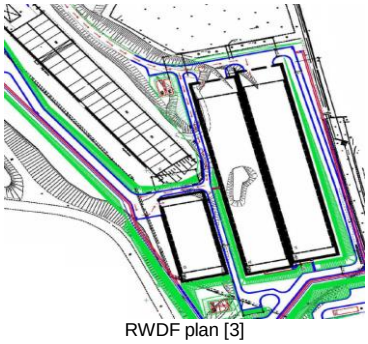


Digital relief model (GeRa)

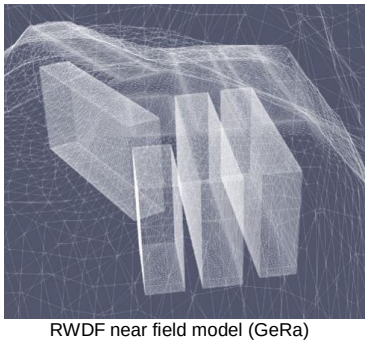


Model mesh (GeRa)

The use of unstructured mesh in the GeRa computer code makes it possible to implement the RWDF near field with high accuracy in setting the elements of the RWDF EBS. At the same time, it is possible to evaluate the contribution of each safety barrier to ensuring the RWDF long-term safety.



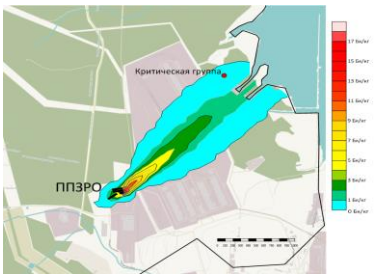
RWDF plan [3]



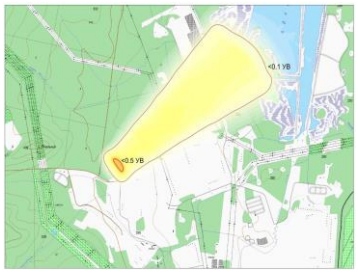
RWDF near field model (GeRa)

An important feature of the independent calculation model is the integration of the RWDF near field into the geosphere model. This makes it possible to avoid errors that may occur when pairing models of the RWDF near and far fields developed in different computer codes.

The results of the predictive calculations performed using the independent RWDF model are compared with the results obtained by the operating organization.



Independent model results



Results of operating organization [3]

In case of minor deviations in the results of predictive calculations, it can be concluded that the RWDF provides for long-term safety.

6. Conclusions

The evolution of requirements for justification of the RWDFs long-term safety, including the requirements for justification of the long-term EBS performance, has led to the need to change from using a conservative approach to RWDFs long-term safety assessment to a realistic one. The necessary conditions for using a realistic approach are the availability of a sufficient amount of field and experimental data, as well as modern computer codes.

7. References

1. INTERNATIONAL ATOMIC ENERGY AGENCY. Safety Assessment Methodologies for Near Surface Disposal Facilities. Results of a co-ordinated research project. IAEA, Vienna (2004).

2. Federal Law of July 11, 2011 No. 190-FZ "On the management of radioactive waste and on amendments to certain legislative acts of the Russian Federation" (*in Russian*).

3. Official internet page of FSUE NORWM: https://www.norao.ru/upload/medialibrary/МОЛ%20Том%201_итог_.pdf.