DERIVATION OF ACTIVITY LIMITS FOR STORAGE OF RADIOACTIVE WASTES AT "RADON" SITES IN RUSSIA

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ABSTRACT

One important issue in radioactive waste management is derivation of the total activity or amount of radioactive wastes, which could be safely placed in repositories at the site. In 2002 MosNPO"Radon" together with Gosatomnadzor, the Russian Regulatory body, started developing the procedure for derivation of activity limits for long term controlled storage of radioactive wastes at "Radon" sites. The MosNPO"Radon" site near Sergiev Posad (the Site) had been chosen as the object and the test site for consideration in this study. The Site is the biggest in the Russian Federation and its intake is 3000-5000 cubic meters of wastes annually. It has been under operation since 1961.

To derive the activity limits for long term controlled storage in near surface facilities at "Radon" Site the safety assessment approach developed in the framework of the IAEA ISAM Research Coordinated Programme (1997-2001) has been used.

In the paper, the authors present the initial results of the calculations performed for derivation of total activity of low and intermediate level radioactive wastes that may be safely stored/disposed in considered conditions.

INTRODUCTION

The main specific features of the Russian "Radon" facilities are as follows:

- they are usually still under operation and include historical disposal units that are already filled with wastes and closed, operated units, some new repositories under construction or planned to be constructed;
- there are some different types of repositories at one site,
- the facilities are located mostly in quaternary deposits and
- the facilities are located mostly in moderate climatic zones that are usually characterized with large amounts of precipitation and freezing-thawing cycles.

Established in sixties for disposal of radioactive wastes, the "Radon" facilities have no current permission to dispose of wastes, but only to store them for long-term period under active institutional control. These former disposal facilities as well as separate disposal units on the site are officially considered as temporary repositories in compliance with the modern regulations.

The site of MosNPO "Radon" facility is situated in a woodland in the Klinsko-Dmitrovskaya range. It has been operating since 1961 and is around 36 000 m^2 large. There is significant

heterogeneity in thickness, litho-facial properties and hydrological parameters of hosting soils at that site. It is known from hydrogeological studies that the subsoil waters are not present significantly in the top quaternary deposit layer. However, during construction and operation work at the site, local areas of broken soil (excavated, displaced at leveling the site and store construction) have appeared. This broken soil may contain water lenses.

Most of the waste activity is formed with ^{137}Cs (90%) and ^{90}Sr (8%); other radionuclides make about 2% of the total amount of activity.

APPROACH TO DERIVATION OF MAXIMAL WASTE ACTIVITY TO ACCEPT A THE SITE

To derive the maximal waste activity, the first stage calculations of possible migration of radionuclide concentrations in surface and subsurface waters at boundaries of the sanitary protection zone are performed with the basic assumption of provisional initial activity of 1 TBq for each radionuclide. Then the obtained concentration values are compared with maximum permissible concentrations in relation to a certain radionuclide stated in regulatory rules (NRB-99). During the comparison it is possible to determine if the waste activity of 1 TBq is safe or not, should it be reduced to become safe or could be increased. As an endpoint for the comparison the maximum magnitude from all considered scenarios for each radionuclide is to be acceptable regardless of the peak time.

The maximum permissible concentrations from NRB-99 have been taken as safety criteria and the predicted annual effective dose to the public has been controlled to be not higher than the limiting value of 0.1 mSv. Using the maximum permissible concentrations as the endpoints allows restriction of the amount of waste activity in the repository for each radionuclide considered and avoids additional errors and uncertainties that may stem out of the dose calculations at the preliminary stage. After the allowable radionuclide amounts have been determined, check calculations of the annual effective dose for the most pessimistic scenario (or scenarios) should be performed.

The way to decrease the uncertainties in a safety assessment for this study is the application of a reasonably pessimistic description of waste characteristics, engineered barrier states and protective properties of the hosting medium. Such description in case of obtaining positive outcomes of the safety assessment allows avoiding or reducing a number of additional iterations that arise from model specifications and/or data improvement.

To reduce the number of key scenarios for consideration the authors have made some assumptions as follows:

In the study any human behavior at the site is supposed to be reasonable and rational during operation, closure and active institutional control periods;

All engineered barriers perform in regards to their design during operation and some years after closure;

Only solid waste placed at the site for long-term storage or disposal is subject to the study. Liquid waste and spent sealed sources have been exempted from the calculations;

An active institutional control period of 100 years has been adopted.

The calculations of concentrations and effective doses to the public have been performed without time constraints until peak concentrations/doses have been obtained. Global changes of geosphere, biosphere, including changes of climate and human behavior have not been considered.

In the first step, a basic scenario that considered normal evolution of the repository without any disasters and spontaneous events was developed without regard to some possible alternatives. The basic scenario considers only key mechanisms of radionuclide release and migration and key ways of exposure. The alternative scenarios should consider the important features, events and phenomena that are missed in the basic scenario and possibility of inadvertent human activity, such as dwelling at the site, building, construction or farming work.

Generally, the main approach to deriving the activity limits consists of preliminary assessment of impact of the proposed waste amounts on humans and the environment and of subsequently proportionally decreasing of initial proposed amounts as a result of the comparison of the obtained results with regulatory limits (Figure 1).

THE FIRST RESULTS

It was decided to consider all repositories at the site as one source with equal distribution of the radionuclides along the repository volume. The radionuclide concentrations and the annual effective doses for public were calculated at the boundary of the sanitary protection zone.

Results of the first calculations for the initial activity of each isotope in 10^{12} Bq have been obtained. The calculated concentrations in water only for ^{3}H, ^{239}Pu, ^{235}U, ^{231}Pa, ^{227}Ac exceeded 1 Bq/m^3 (see Table I). For all others, including ^{60}Co, ^{90}Sr, ^{137}Cs, ^{226}Ra, it does not exceed that value for initial concentrations up to 10^{21} Bq/m^3.

Consideration of the predicted concentrations of the radionuclides in the ground water and in the soil (Table I) let us make conclusions about the necessity of the restrictive activity controls and perhaps more detailed modeling of radionuclide releases from the waste containing ^{239}Pu and its daughters. At the same time, the concentrations of ^{60}Co, ^{90}Sr, ^{137}Cs, ^{226}Ra are many times less than intervention levels and the maximum permissible concentrations established in NRB-99. So it is possible and safe to locate at the site waste with the radionuclides with activity much more than 10^{12} Bq.

In accordance with the approach (Figure 1) to check the safety of the basic scenario the annual effective doses from intake of the contaminated water have been calculated separately for each radionuclide considered. Results are shown in Figure 2. The calculated doses are much lower than the stated dose limit of 0.1 mSv/y. Most of the contribution in the total dose is from ^{235}U, ^{239}Pu, ^{227}Ac, ^{231}Pa, ^{3}H – the isotopes that have the highest concentrations in the water.

To take into account the additional doses from ingestion and external exposure regarding to the basic scenario the total annual dose from all sources has been calculated. Its maximum is $3{,}8 \cdot 10^{-5}$ Sv/y.

The results of the calculations demonstrate that the proposed amounts of radionuclides are safe, and it is possible to increase them for certain radionuclides.

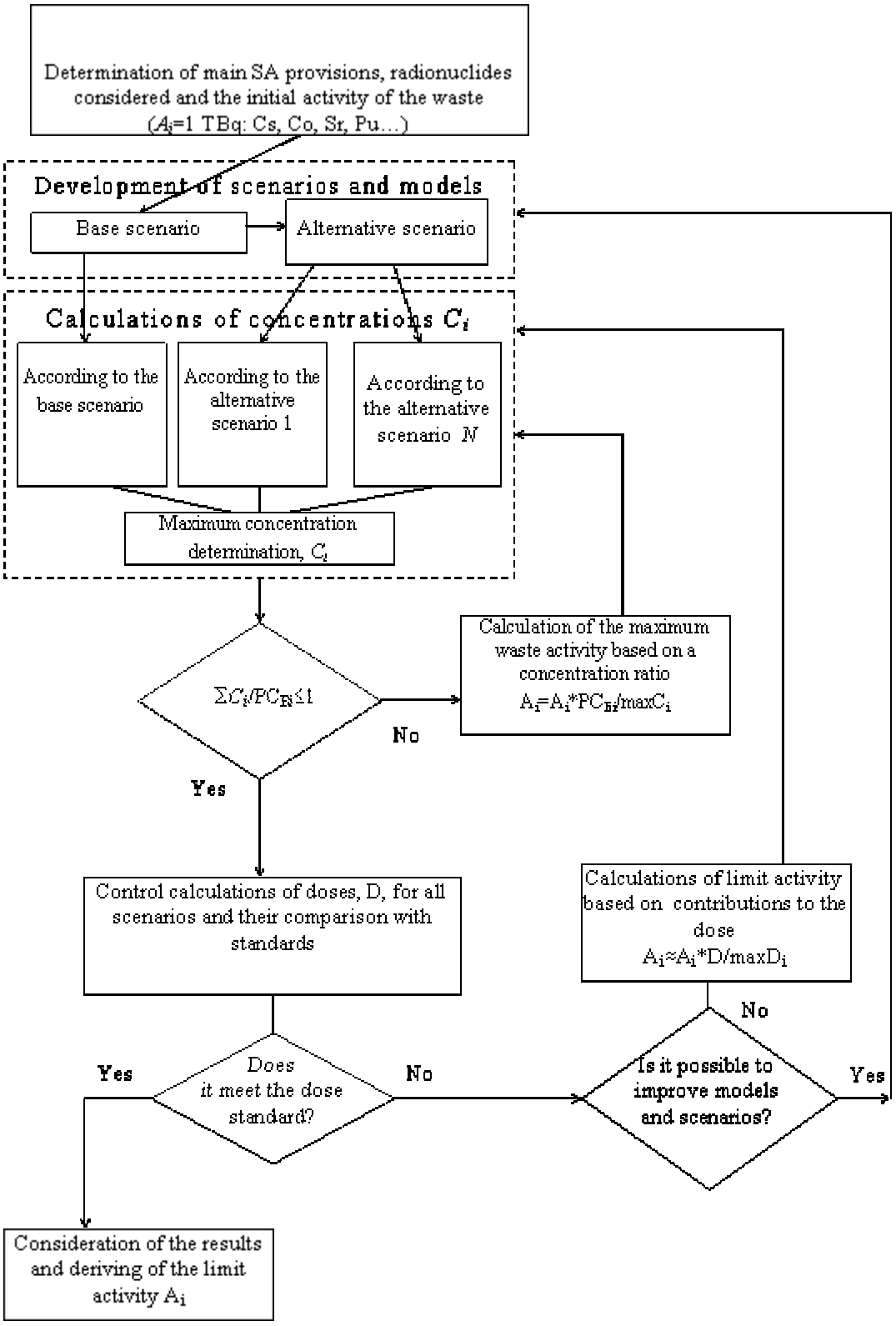

Fig. 1. Scheme of the deriving of the maximum waste activity.

Table I. Maximum predicted concentrations of the radionuclides at the boundaries of the sanitary protection zone at the initial waste activity of 10^{12} Bq.

Radionuclide	State		Peak time, years
	Liquid, Bq/m^3	Solid, Bq/kg	
^{3}H	1.88	-	150
^{239}Pu	2.85	0.31	200000
^{235}U	29.14	1.34	1000000
^{231}Pa	0.18	1.35	1000000
^{227}Ac	0.18	1.35	1000000

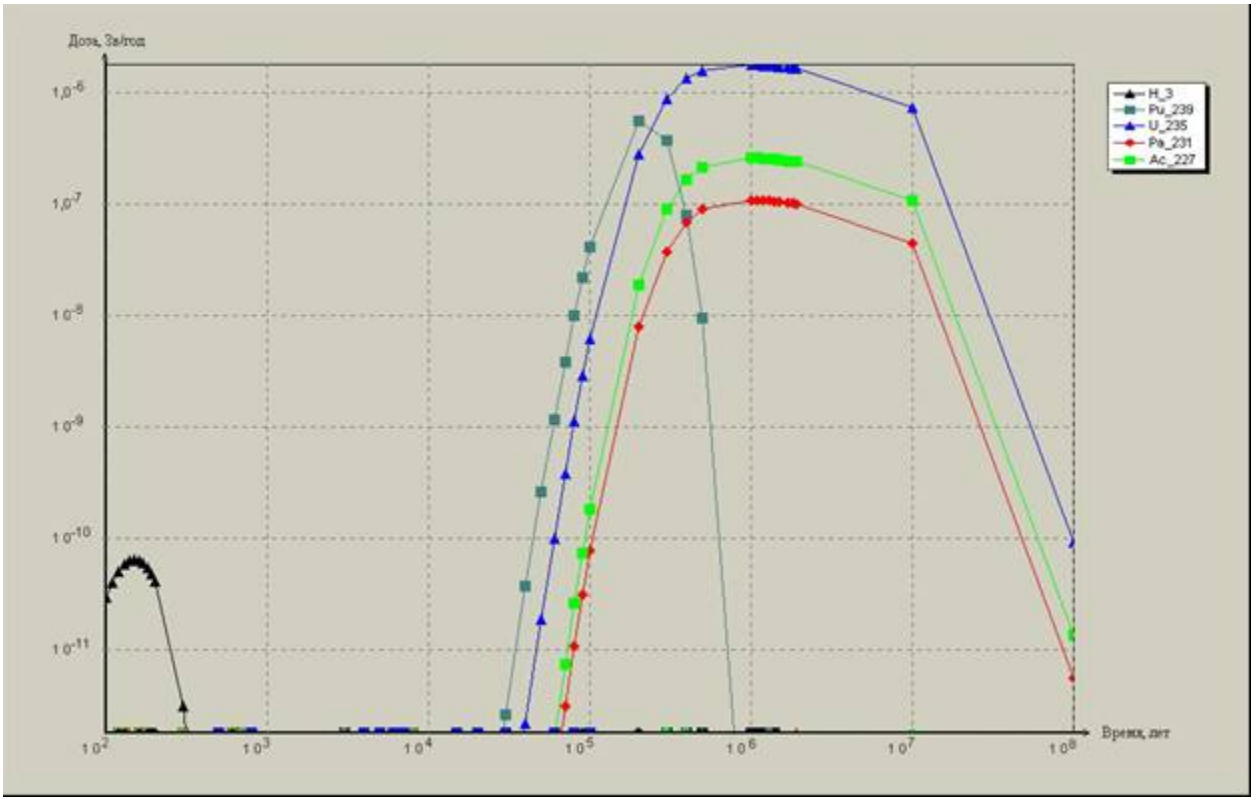

Fig. 2. The predicted annual effective dose from intake of the subsurface water at the initial waste activity of ^{12} Bq.

To determine factors for the calculating the allowable initial activity, the ratio of the control parameters (maximum permissible concentrations) to the endpoints obtained have been derived. Then the initial activity of 10^{12} Bq for each radionuclide was multiplied by the least factor obtained from the ratio and the control calculations of the radionuclide concentrations at the boundaries of the sanitary protection zone have been performed (Table II) as a check. Generally, the obtained concentrations fit to safety criteria: the sum of the relative concentrations of cesium, strontium, cobalt and tritium does not exceed one unit the same as the sum of radium, plutonium

and their daughters. But calculations of the annual individual doses appear to exceed the safety criteria. Thus the amount of activity determined by multiplying with factors is too great for acceptance at the site and shall be reconsidered another way.

Having obtained these results, a decision was made to use the dose safety criteria. For the dose criteria two options have been considered: the first one took into account the current parity of the different radionuclides (as it is in the annual waste streams at the site), the second reckoned the activity of each radionuclide as independent and apart from the others (Table II).

Table II. The calculated maximum waste amount that might be safely placed in the typical repositories at the GUP MosNPO "Radon" Sergiev Posad Site.

Radionuclide	According to the concentrations at the boundaries of the sanitary protection zone for each radionuclide	According to the dose safety criteria	
		Consider the current parity	Consider contributions in the total dose
^{137}Cs	$2{,}03\cdot10^{52}$	$1{,}00\cdot10^{19}$	$2{,}57\cdot10^{23}$
^{60}Co	$5{,}10\cdot10^{48}$	$6{,}51\cdot10^{17}$	$1{,}62\cdot10^{19}$
^{90}Sr	$9{,}86\cdot10^{33}$	$2{,}67\cdot10^{17}$	$8{,}57\cdot10^{17}$
^{226}Ra	$1{,}19\cdot10^{40}$	$2{,}15\cdot10^{17}$	$5{,}37\cdot10^{18}$
^{238}Pu	$6{,}85\cdot10^{16}$	$6{,}85\cdot10^{16}$	$1{,}71\cdot10^{16}$
^{3}H	$4{,}39\cdot10^{17}$	$8{,}57\cdot10^{14}$	$4{,}28\cdot10^{14}$
^{239}Pu	$9{,}11\cdot10^{10}$	$7{,}79\cdot10^{12}$	$1{,}08\cdot10^{12}$

CONCLUSION

Considering the results from the Table II it seems rather safe to place solid waste up to 10^{19} Bq of ^{137}Cs activity in the area of the controlled access zone at the Sergiev Posad Site. To date, the free area of the zone is not more than 15 %. After all repositories are loaded with waste the total ^{137}Cs activity will not exceed the said value. If waste streams do not change their structure, the total activity of the solid waste for the other radionuclides will also not exceed the safe amount.

The comparison of the solid waste activity collected to date with the calculated limits let us make an approximate estimate of the remaining duration of the site operations. In other words, according to the features of the Sergiev Posad site used in the calculations, the maximum waste activity that might be placed at the site is confined by the assumed extent of the controlled access zone. This limitation causes discussion of enlargement of the controlled access zone and, thereafter, increasing waste volumes for disposal at the site at the cost of shortening of the sanitary protection zone.

The controlled access zone expansion together with construction of some additional repositories at the cost of decreasing of the sanitary protection zone radius from 2300 to 2000 m (keeping the same external border) will gain useful area by about 6 times and will prolong the remaining operation period. Additional safety assessment for proposed solution need to be made.

When making the next iteration it is a need to note, that a lot of data and mathematical models used should be substantiated. In addition, it is necessary to consider and analyze other scenarios of alternative evolution of events that are not related to human intrusion. To treat mathematical and software uncertainties it seems to be useful to compare obtained results against another codes e.g. RESRAD calculations. It is supposed to concentrate efforts on the migration models and calculations during the next year and only after that consider detailed biospherical models of the overall system.

The conclusions to date should be considered only as provisional and the issue needs to be more detailed studies.