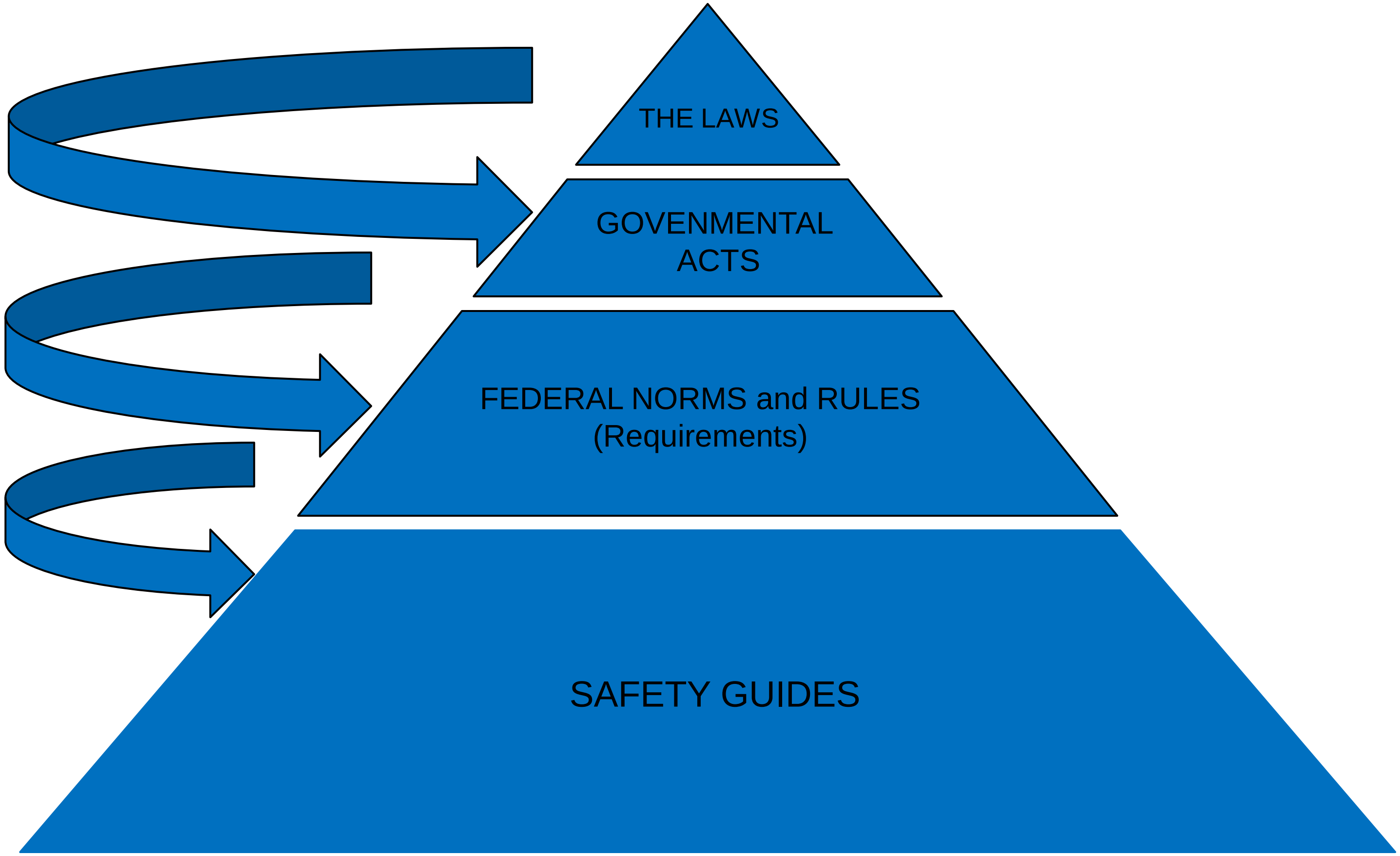
Andrey Guskov

Safety assessment of near surface disposal facilities in Russia

Agenda

- Regulatory aspects
- Historical aspects
- Assessment aspects

Regulatory Pyramid



Federal Law
On Radioactive Waste Management: content

- Unified State System for radioactive waste management
  - *incl.* development of radioactive waste disposal facilities
- Radioactive waste management and disposal provisions
- Classification of radioactive waste (introduced by the Government)
- Obligation for radioactive waste final disposal
- National Operator for Radioactive Waste Management
- Financial provisions of radioactive waste management
- Radioactive waste export and import

Federal Law
On Radioactive Waste Management: overview

- Basic terms definition
- RAW classification
  - special RAW and retrievable (disposable) RAW
  - classes of Retrievable RAW (based on disposal option)
- For Special (nonretrievable) RAW:
  - emplacement site and
  - site for conservation

Federal Norms and Rules on RAW Disposal

- NP-058-04 “Safety of Radioactive Waste Management. General Provisions”
- NP-019-2000 “Collection, treatment, storage and conditioning of Liquid RAW. Safety Requirements”
- NP-020-2000 “Collection, treatment, storage and conditioning of Solid RAW. Safety Requirements”
- NP-021-2000 “Gaseous RAW Management. Safety Requirements”
- NP-055-04 “Disposal of radioactive wastes. Principles, criteria and general safety requirements”
- NP-069-06 “Near-surface disposal of radioactive waste. Safety requirements”

Federal Norms and Rules on RAW Disposal

Safety Fundamentals
SF-1

Safety of Radioactive Waste Management. General Provisions
NP-058-04

Predisposal RAW management. General Safety Requirements
GSR, part 5

Disposal of Radioactive Waste. Special Safety Requirement
SSR-5

Collection, treatment, storage and conditioning of Solid RAW. Safety Requirements.
NP-020-2000

Collection, treatment, storage and conditioning of Liquid RAW. Safety Requirements.
NP-019-2000

Gaseous RAW Management. Safety Requirements.
NP-021-2000

Disposal of radioactive wastes. Principles, criteria and general safety requirements.
NP-055-04

Near-surface disposal. Safety Requirements
WS-R-1

RAW WAC for Disposal
NP

Near-surface disposal of radioactive waste. Safety requirements.
NP-069-06

Safety Guides on RAW Disposal

- RB-058-10 “Regulation on the structure and content of the safety case report for near-surface radioactive waste disposal facilities”

- RB-011-2000 “Safety assessment of near-surface repositories for radioactive waste”

Governmental Decree 1069

Criteria for classifying radioactive waste to special and retrievable RAW

Special RAW	Retrievable RAW
RAW, including: *•RAW generated:* *• in result of implementation of the state program of armaments and state defense order* *• In result of the use of nuclear weapon for peaceful purposes* *• In result of nuclear and (or) radiation accident in nuclear facility* *•Liquid RAW, accumulated in surface water-storage facilities, totaling more than 25000 m³, commissioned before the entry into force of the Federal Law "On the treatment of waste ...", as well as the sediments of the storage reservoirs meet the following criteria:*	*RAW hasn't been classifies as special RAW*

1
- *The collective effective dose for the entire period of the potential danger*
- *The risk of potential exposure*

Moving away > *On site disposal*

2
Moving away:
- *The cost of moving away, processing, conditioning, transportation to disposal facility and disposal of radioactive waste*

\>

On site disposal:
- *The size of the possible harm to the environment*
- *The cost of disposal of radioactive waste, including conversion Site of sRAW to RAW disposal facility, its operation and closing, its safety over the period of the potential danger*

3 *RAW storage and its sanitary protection zone located outside the boundaries of settlements, protected areas, coastal protection strips and water protection zones of water bodies, and other security protection zones*

Governmental Decree 1069

Criteria for classifying retrievable RAW

Class 1	*Class 2*	*Class 3*	*Class 4*	*Class 5*
Solid RAW: *•materials* *•equipment* *•products* *•solidified liquid RAW*	***Solid RAW :*** *•materials* *•equipment* *•products* *•ground* *•solidified liquid RAW* *•DSRS of 1 и 2 categories*	***Solid RAW:*** *•materials* *•equipment* *•products* *•ground* *•solidified liquid RAW* *•DSRS of category 3*	***Solid RAW:*** *•materials* *•equipment* *•products* *•биологические объекты* *•ground* *•solidified liquid RAW* *•DSRS of category 3*	***Liquid RAW:*** *organic and inorganic liquids, pulps, muds*
HLW: $>10^{11}$ *Bq/g - T* $>10^{7}$ *Bq/g - β (except for T)* $>10^{6}$ *Bq/g - α (except for t/u)* $>10^{5}$ *Bq/g - t/u*	***HLW:*** $>10^{11}$ *Bq/g - T* $>10^{7}$ *Bq/g - β (except for T)* $>10^{6}$ *Bq/g - α (except for t/u)* $>10^{5}$ *Bq/g – t/uy* ***Long-lived ILW:*** $10^{8}÷10^{11}$ *Bq/g - T* $10^{4}÷10^{7}$ *Bq/g - β (except for T)* $10^{3}÷10^{6}$ *Bq/g - α (except for t/u)* $10^{2}÷10^{5}$ *Bq/g – t/u*	***ILW:*** $10^{8}÷10^{11}$ *Bq/g - T* $10^{4}÷10^{7}$ *Bq/g - β (except for T)* $10^{3}÷10^{6}$ *Bq/g - α(except for t/u)* $10^{2}÷10^{5}$ *Bq/g – t/uy* ***Long-lived LLW:*** $10^{7}÷10^{8}$ *Bq/g - T* $10^{3}÷10^{4}$ *Bq/g - β (except for T)* $10^{2}÷10^{3}$ *Bq/g - α (except for t/u)* $10^{1}÷10^{2}$ *Bq/g – t/u*	***LLW:*** $10^{7}÷10^{8}$ *Bq/g - T* $10^{3}÷10^{4}$ *Bq/g - β (except for T)* $10^{2}÷10^{3}$ *Bq/g - α (except for t/u)* $10^{1}÷10^{2}$ *Bq/g – t/u* ***VLLW:*** $<10^{7}$ *Bq/g - T* $<10^{3}$ *Bq/g - β (except for T)* $<10^{2}$ *Bq/g - α (except for t/u)* $<10^{1}$ *Bq/g – t/u*	***ILW:*** $10^{4}÷10^{8}$ *Bq/g - T* $10^{3}÷10^{7}$ *Bq/g - β (except for T)* $10^{2}÷10^{6}$ *Bq/g - α (except for t/u)* $10^{1}÷10^{5}$ *Bq/g – t/u* ***LLW:*** $<10^{4}$ *Bq/g - T* $<10^{3}$ *Bq/g - β (except for T)* $<10^{2}$ *Bq/g - α (except for t/u)* $<10^{1}$ *Bq/g – t/u*
Disposal in deep disposal facility after storage before decay to increase heat generation	*Disposal in deep disposal facility*	*Disposal in near-surface disposal facility (till 100 m depth)*	*Disposal in near-surface disposal facility at ground level*	*Disposal in existing deep well injection disposal facilities*

Class 6	*RAW, resulting from the extraction and processing of uranium ores and mineral and organic materials with a high content of natural radionuclides*	*Disposal in near-surface disposal facility*

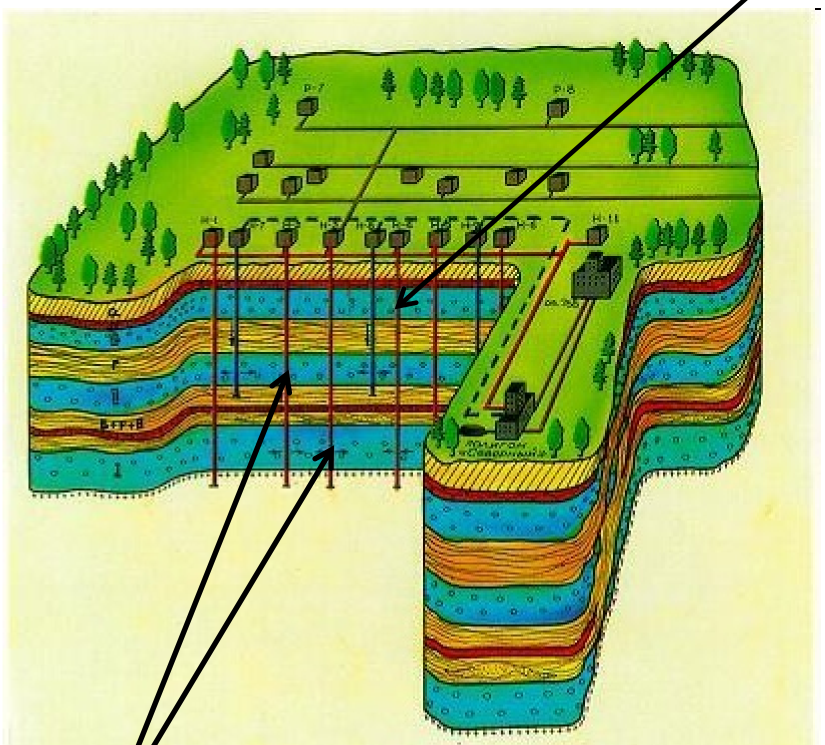
Waste Disposal in The Russian Federation

- Disposal Facilities in Operation
- Legacy Disposal Facilities
- Planned Disposal Facilities

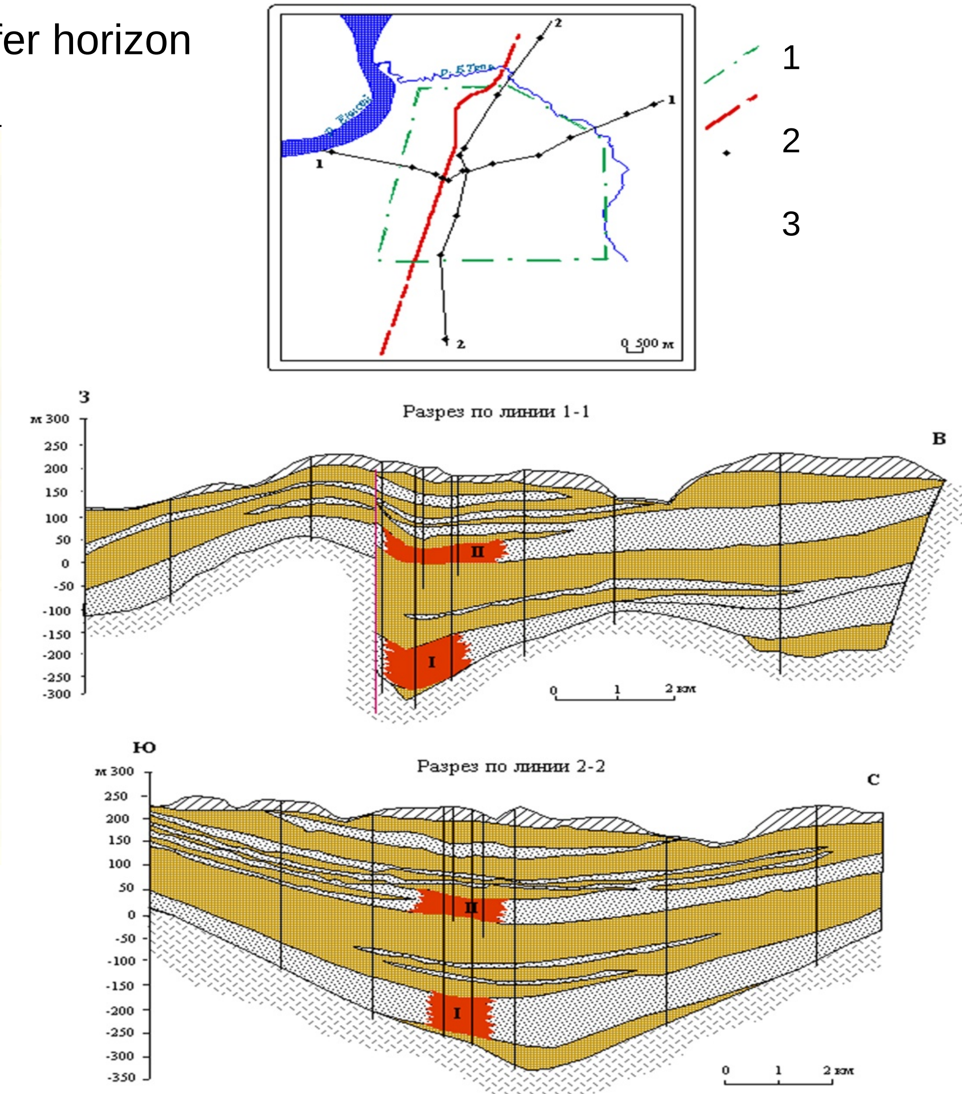
Waste Disposal in The Russian Federation

- Deep Well Injection

Buffer horizon

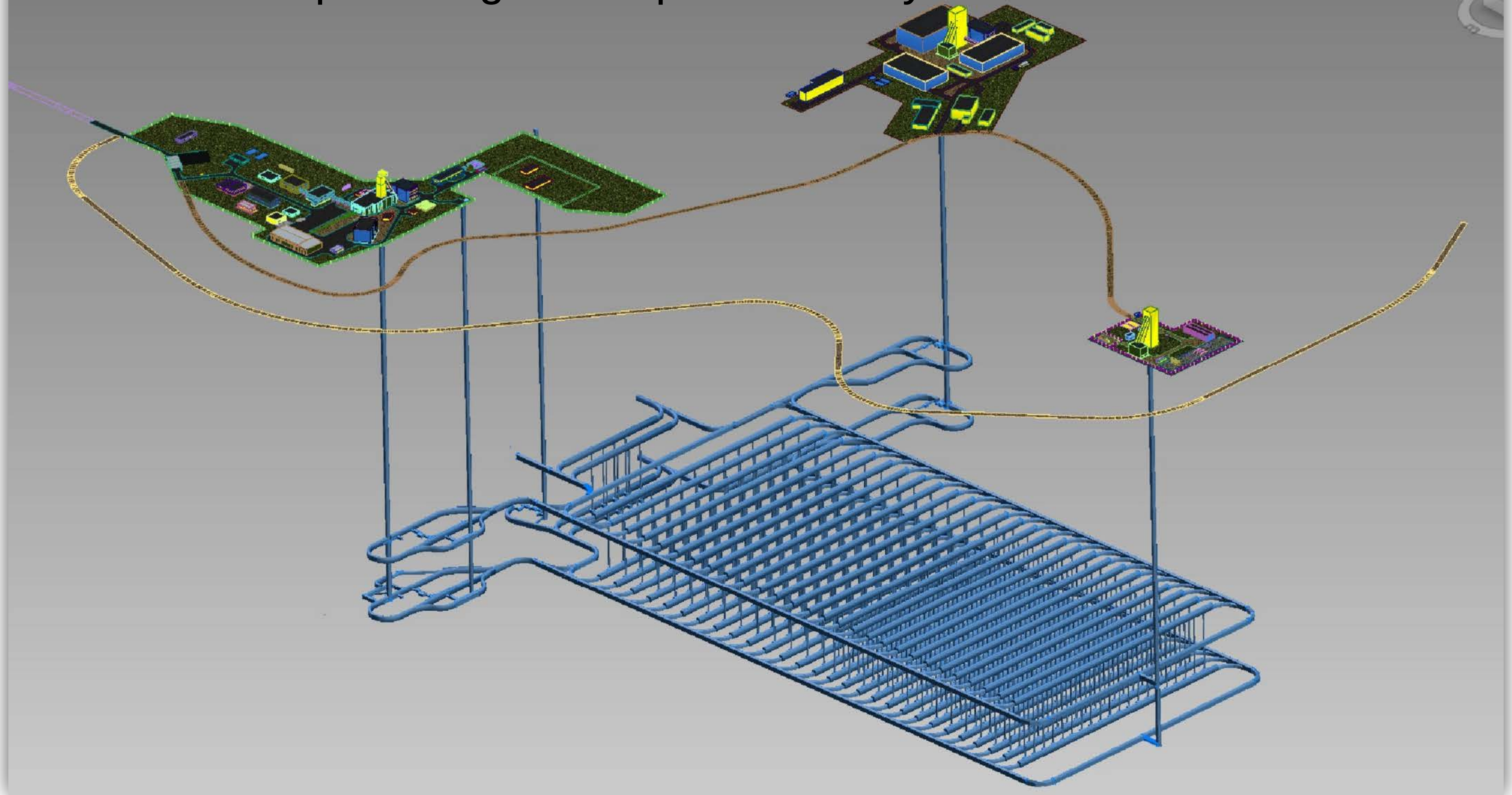


Injection horizons



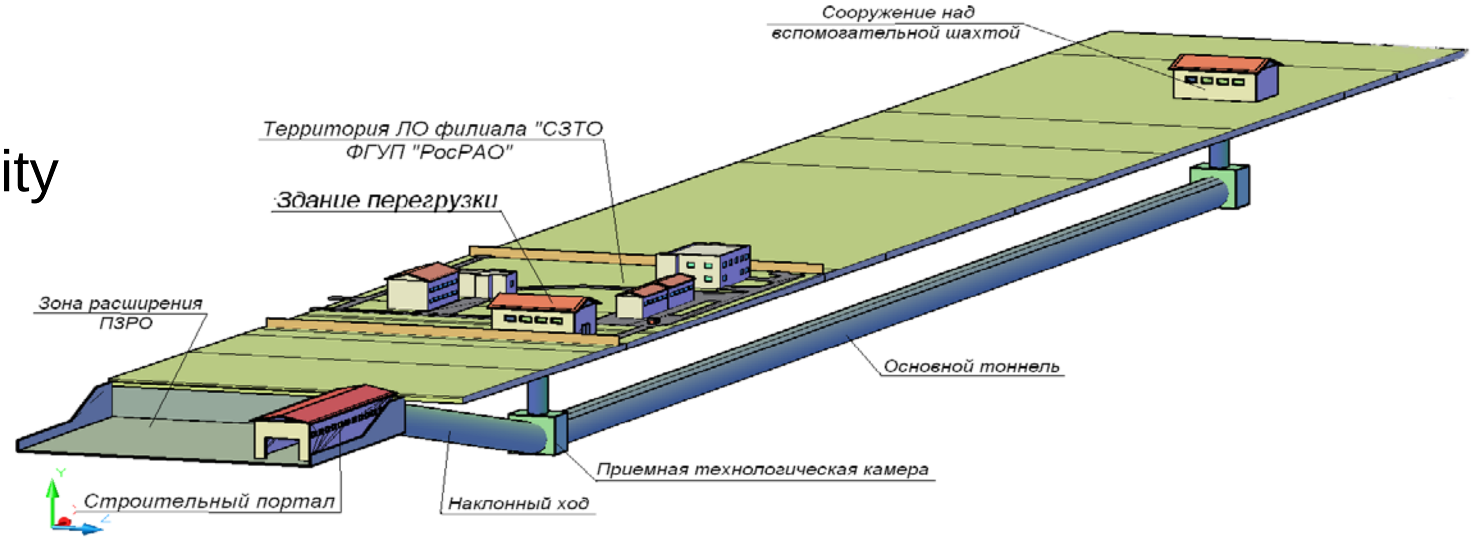
Waste Disposal in The Russian Federation

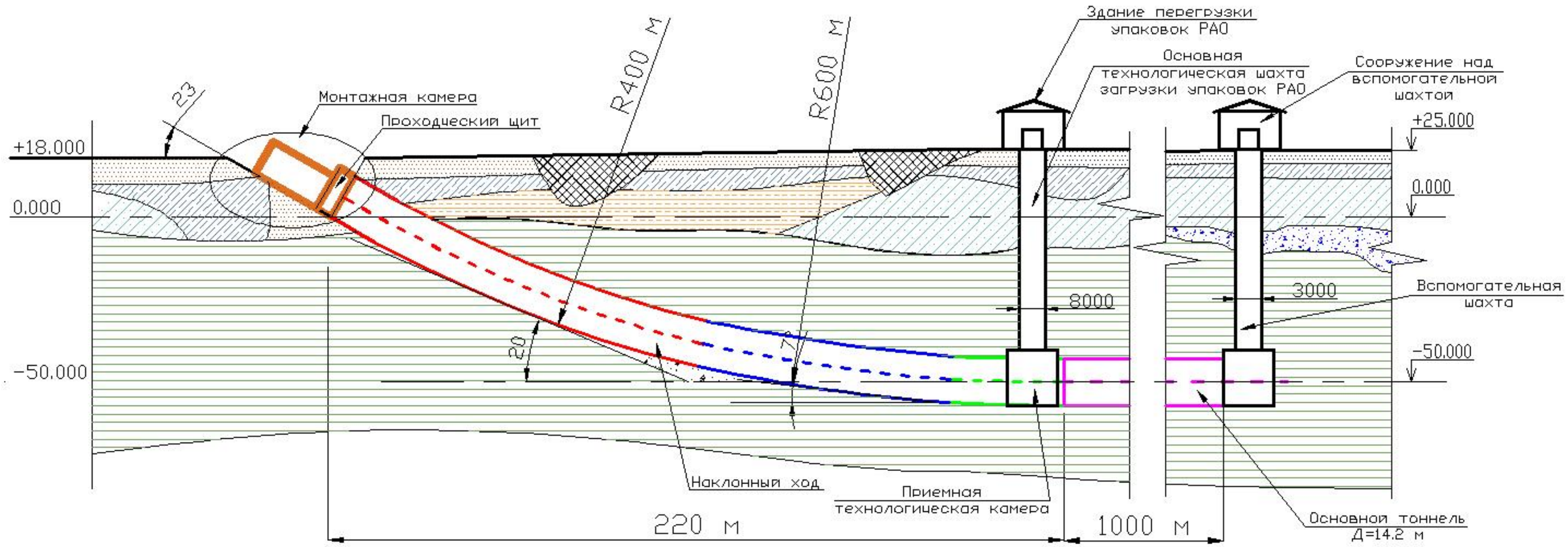
- Planned Deep Geological Disposal Facility



Waste Disposal in The Russian Federation

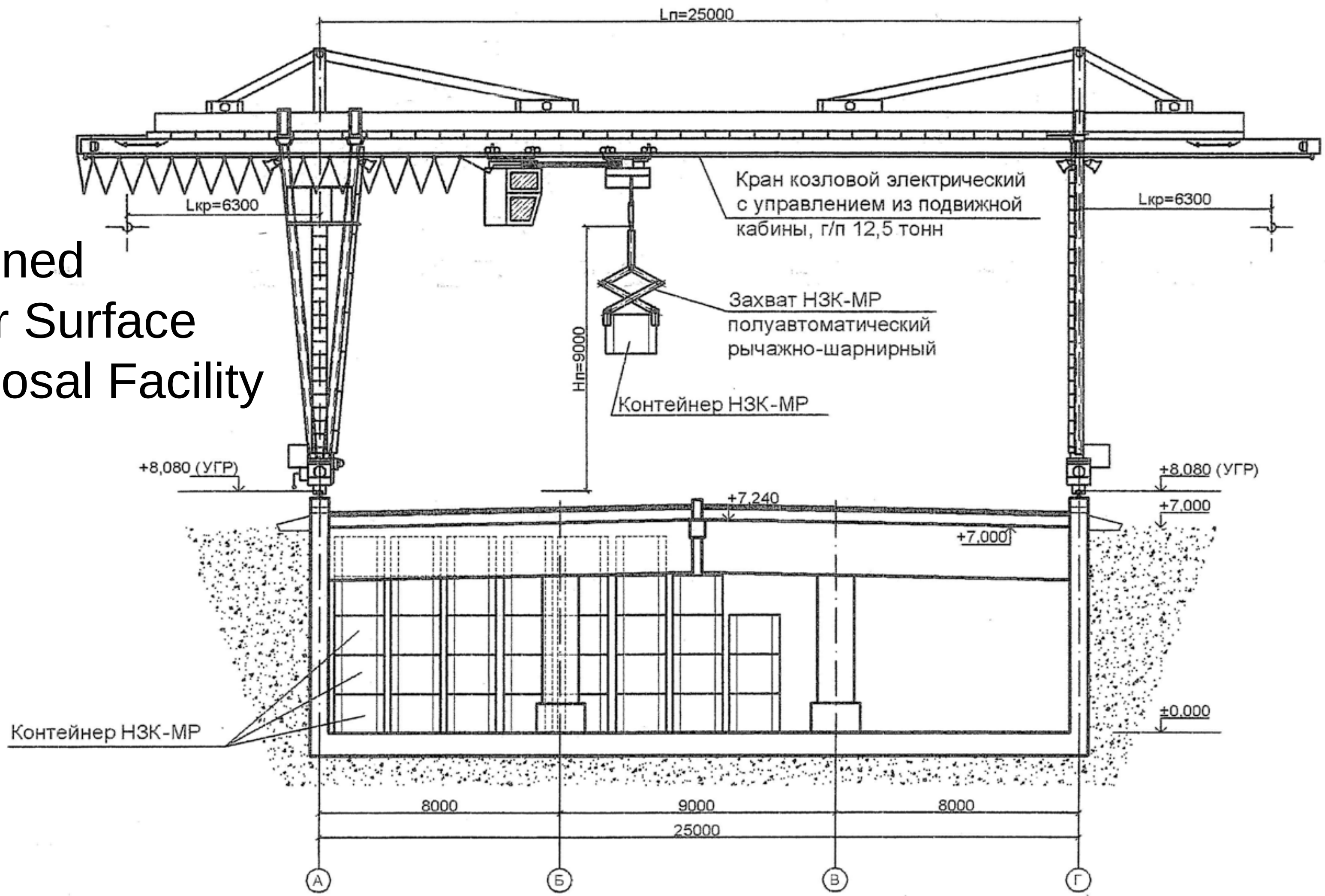
- Planned
  Near Surface
  Disposal Facility





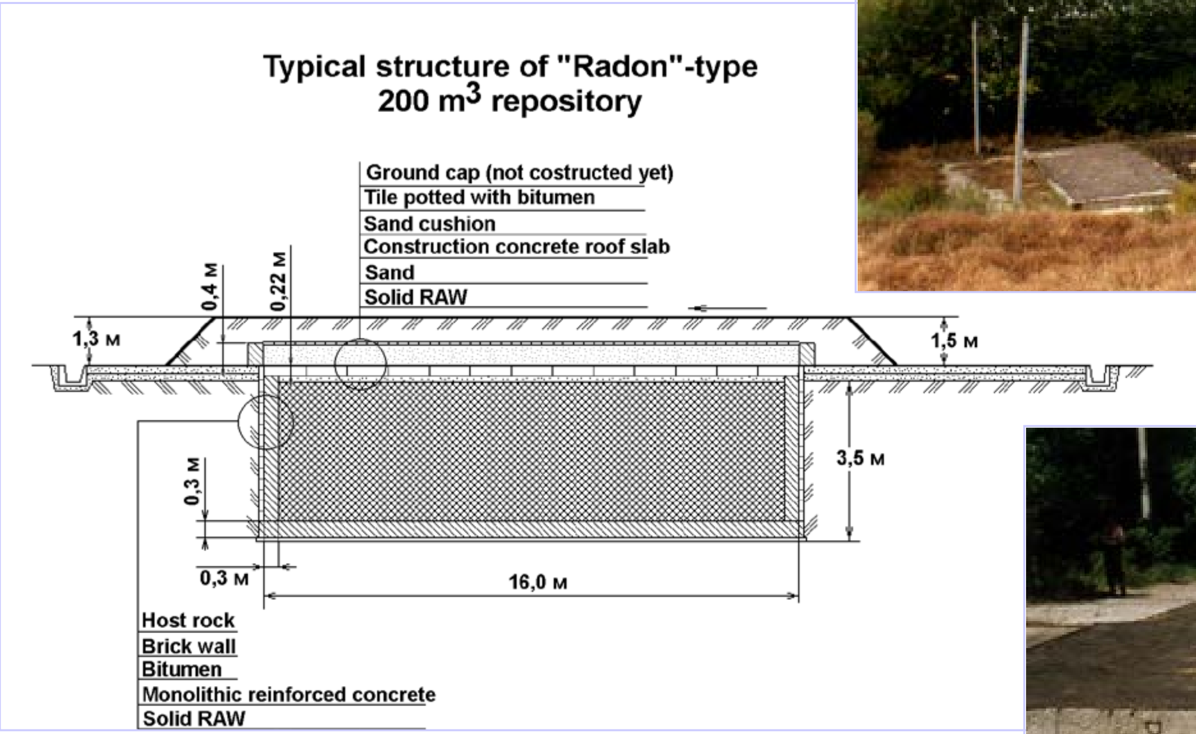
Waste Disposal in The Russian Federation

- Planned
  Near Surface
  Disposal Facility



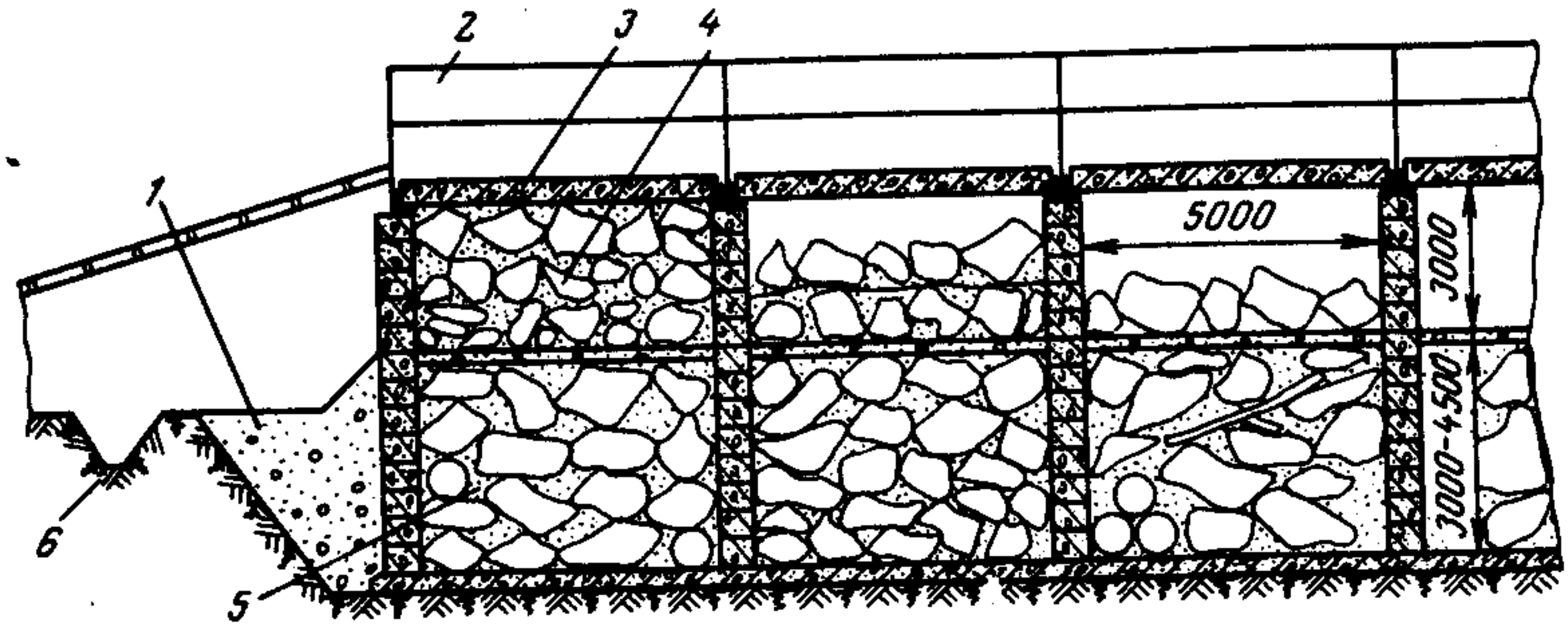
Waste Disposal in The Russian Federation

- Legacy Disposal Facilities 1960-1980s



Waste Disposal in The Russian Federation

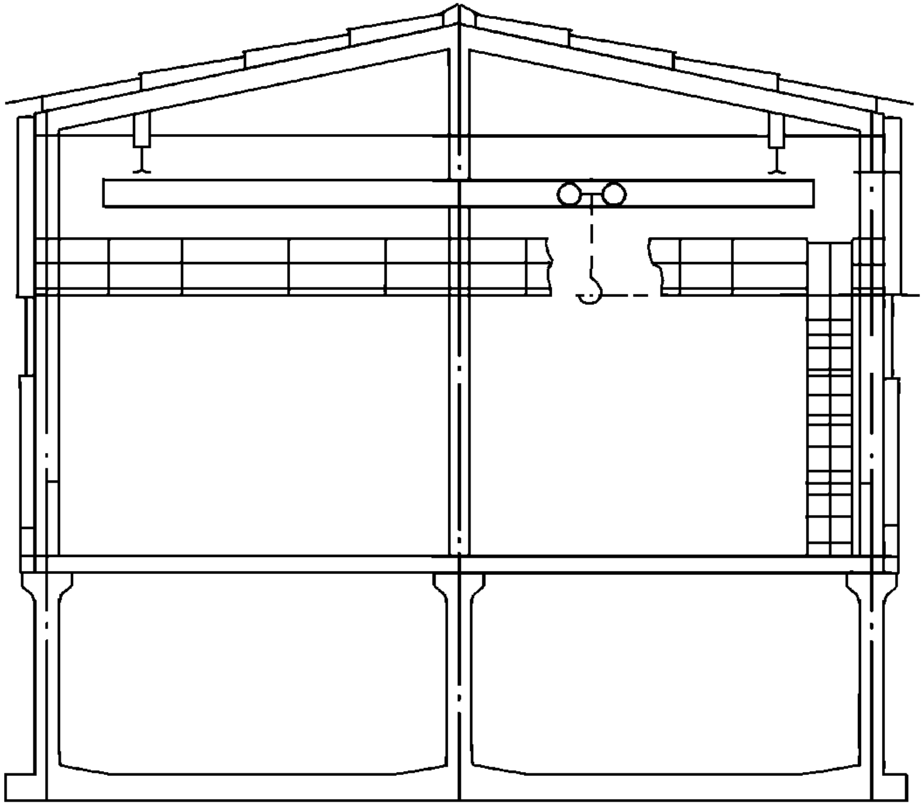
- Double Deck Facility for Solid LILW *(1970-1980s)*



1 – clay; 2 – enclosure; 3 – covering plate; *4* – waste; 5 – cement backfill; 6 – drainage

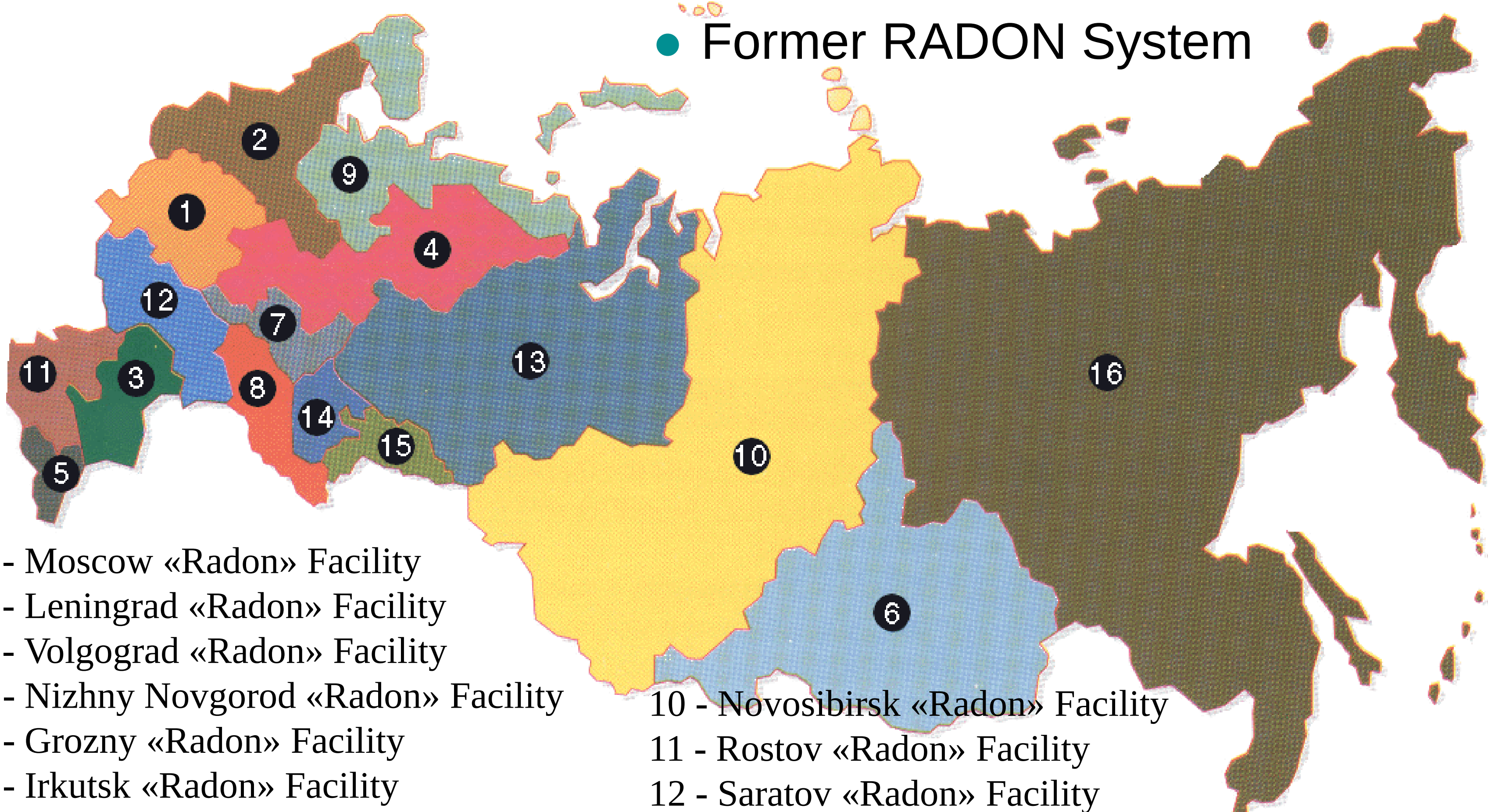
Waste Disposal in The Russian Federation

- Legacy Disposal Facilities (1980s)



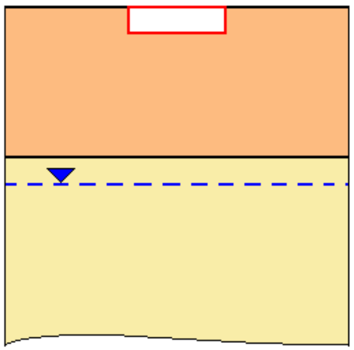
Waste Disposal in The Russian Federation

- Former RADON System

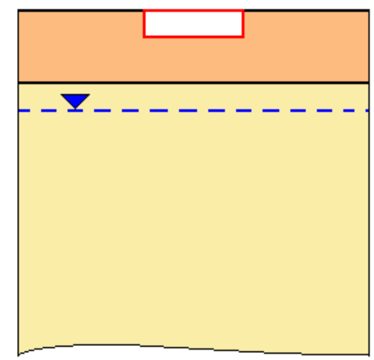


1 - Moscow «Radon» Facility
2 - Leningrad «Radon» Facility
3 - Volgograd «Radon» Facility
4 - Nizhny Novgorod «Radon» Facility
5 - Grozny «Radon» Facility
6 - Irkutsk «Radon» Facility
7 - Kazan «Radon» Facility
8 - Samara «Radon» Facility
9 - Murmansk «Radon» Facility
10 - Novosibirsk «Radon» Facility
11 - Rostov «Radon» Facility
12 - Saratov «Radon» Facility
13 - Sverdlovsk «Radon» Facility
14 - Bashkirskiy «Radon» Facility
15 - Chelyabinsk «Radon» Facility
16 - Khabarovsk «Radon» Facility

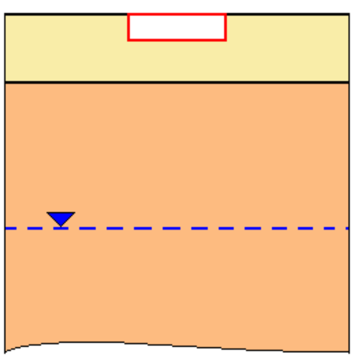
Geological-and-Hydro-Geological Types



Top 15-57m of of low permeable rocks (loam and clay)
The first aquifer at 30-72m depths
Sites: Volgograd, Samara and Moscow.

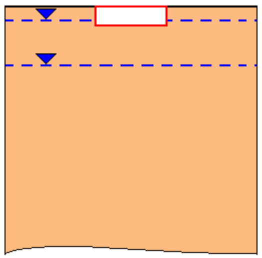


Top 7-14 up to 18-40m of clayey rocks
The first aquifer at 9-20m depths
Sites: Bashkir, Novosibirsk, Rostov, Habarovsk and Chelyabinsk facilities



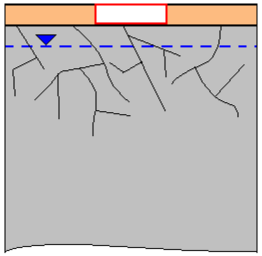
Top 4-18m of permeable rocks with filtration coefficient more than 0.7 m/day
The first aquifer at 50m depth.
Sites: Saratov and Irkutsk

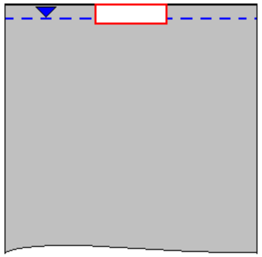
Geological-and-Hydro-Geological Types



Irregular temporary groundwater in the depths of 0.1 – 3.0m
Low permeable rocks (loam, boulder clay, heavy loamy sand)
Aquifer at 13 – 30m depths
Sites: Kazan, Leningrad and Nizhny Novgorod

Top 0.8-7m of low permeable rocks (loam and clay),
with original volcanogenic rocks below
Crevice underground water without pressure at 5-10m depth
Sverdlovsk site





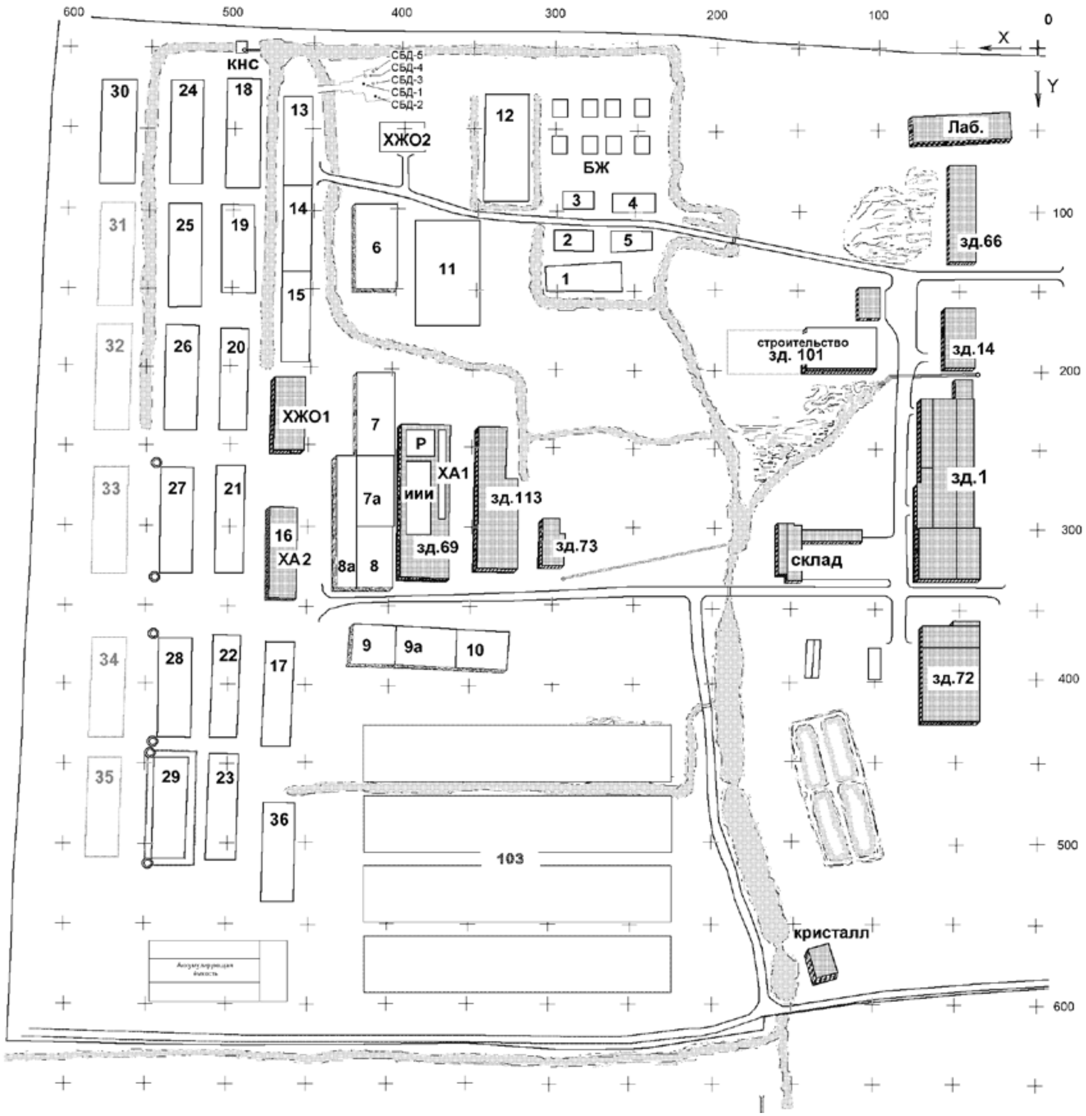
Original metamorphic rocks
Crevise underground water at 1-5m depths
Murmansk facility site

RADON Facility Structure

- Near-surface "Radon"-type facilities were designed as a part of special regional enterprises. The first projects of these facilities were designed at the end of the 1950-th (TP-509) and then were upgraded (TP-6069, TP-4891, TP-416-9-9).
- Typical structure of RADON Facility is based on differentiation of the territory into two areas:
  - Restricted Area (Zone of possible contamination)
  - Clear Zone
  - Sanitary-Protective Zone (500-1000 m radius)
  - Survey Zone (Moscow only)

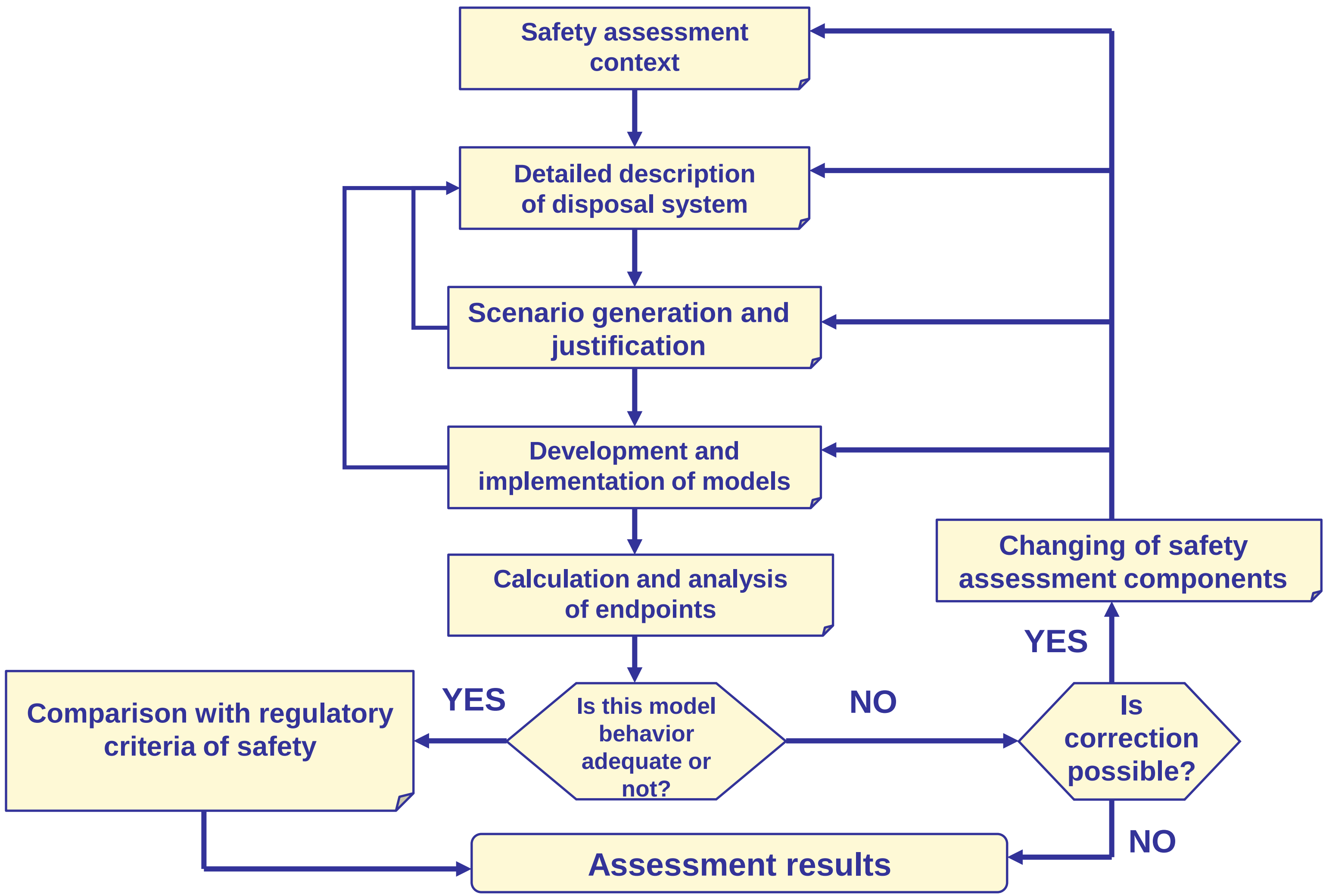
FSUE “Radon” Site

FSUE “Radon” Site



- Zone of possible contamination

Safety Assessment



Safety Assessment

- Assessment context
  - Purpose: Need in waste retrieval
  - Criteria: Dose for public
  - Facility: partly degraded near surface facility with wide range of radionuclides
  - Philosophy: Conservative
  - Conditions: As at present time, farming
  - Calculation period: Dose peak
  - Audience: Operator

Safety Assessment

- Scenarios
  - Normal evolution
- Models:
  - Key processes:
    - EBS degradation
    - Convective-and-dispersive, diffusion, surface runoff
    - Decay and daughters
- Software
  - Ecolego

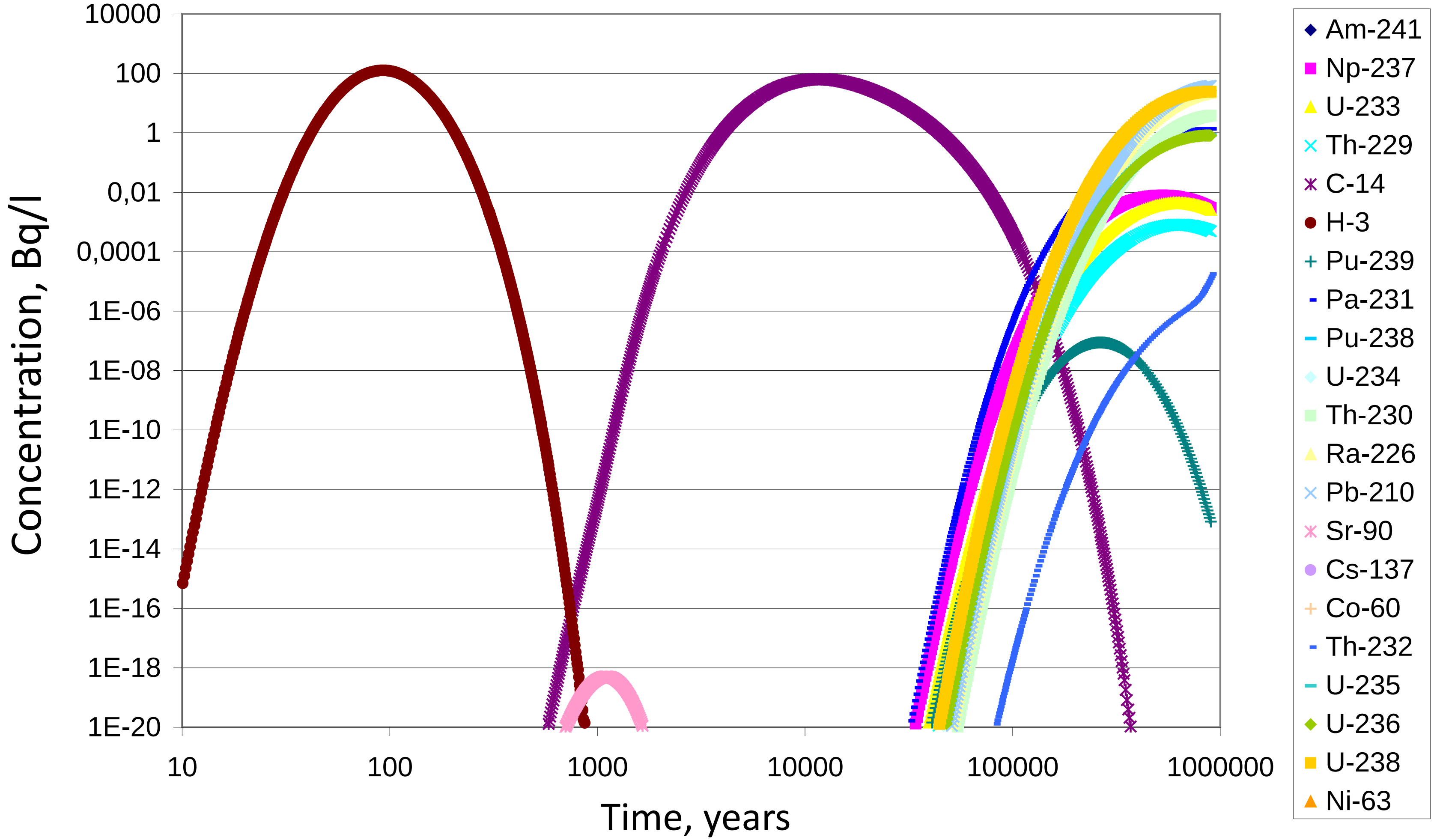
Safety Assessment Results

Facility	*Distance, km*	*Maximal concentration of radionuclides in groundwater in ILDW / Time in years*			
		α-emmiters	*^{3}H*	*^{14}C*	*^{90}Sr*
Kazan	0,6	$640/2,9\cdot10^{5}$	89/11	-	0.3/267
Saratov	2	$74/6,2\cdot10^{4}$	71/5	0.2/2,6·103	-
Nizhniy Novgorod	5	$1863/4,7\cdot10^{4}$	-	-	27/201
Samara	2	$31/1,5\cdot10^{5}$	79/10	-	0.8/250
Blagoveshensk	2	$20/1,3\cdot10^{3}$	-	-	-
Irkutsk	3	$2205/4\cdot10^{4}$	-	-	1665/141
Novosibirsk	1,5	$0.2/4,9\cdot10^{5}$	-	-	-
Khabarovsk	3,8	$1063/5,2\cdot10^{4}$	263/7	18/819	-
Volgograd	5	$655/9\cdot10^{5}$	-	1.0/1,3·104	-
Rostov	1,5	$4375/9\cdot10^{5}$	-	-	-
Sverdlovsk	2	$643/2\cdot10^{5}$	24/26	2/4,2·103	-
Chelyabinsk	5	$5510/3,1\cdot10^{5}$	-	-	-
Leningrad	2,5	$700/4,5\cdot10^{4}$	6/4	-	12/47
Murmansk	10	$97/1,3\cdot10^{3}$	0.9/2	-	147/43
FSUE «Radon»	4	$1121/1,4\cdot10^{5}$	4/42	5/3,4·103	-

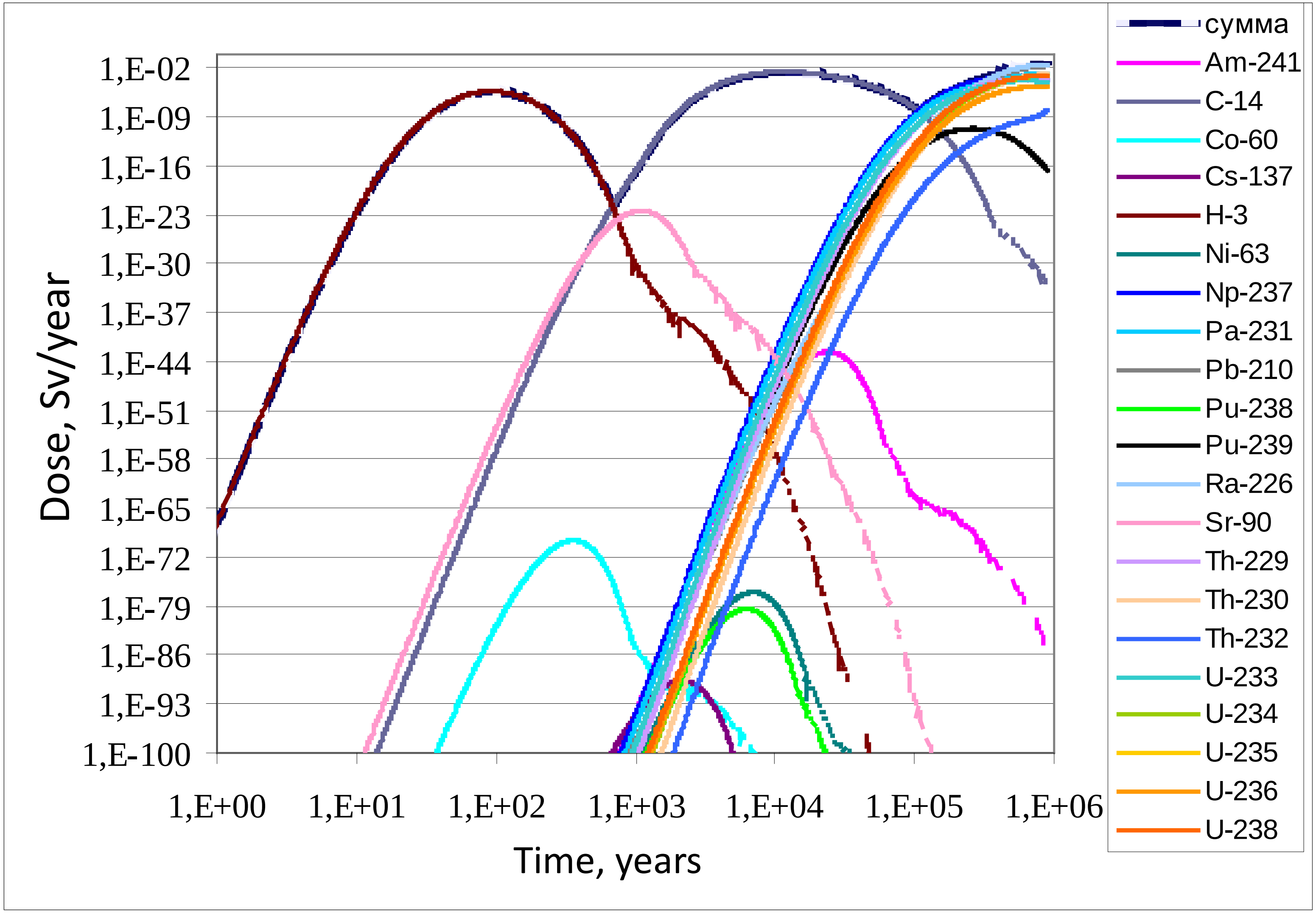
Safety Assessment Results

- In decades the concentration of tritium in groundwater in the nearest settlement can go beyond the safe level even at considerable distances from the repository
- After several thousand years the ground water contamination will be formed by long-lived α-emitting radionuclides (and their decay products), the most significant of which are ^{238}U, ^{235}U, ^{232}Th and their daughter radionuclides ^{231}Pa, ^{226}Ra and ^{210}Pb.
- The maximum contamination of aquifers in nearby settlements can be reached in a few tens of thousands up to hundreds of thousands of years and can several times exceed the "*Intervention Level for Drinking Water*"

Safety Assessment Results



Safety Assessment Results



Safety Assessment Results

1) In the short-term perspective (decades) the radiation safety is determined by the isolating properties of engineered barriers of operated and closed facilities that can contain tritium. The higher effective doses for the public (more than 1 mSv/year) due to the migration of tritium are calculated for the following branches of the FSUE "RosRAO" (in descending order of the danger): Khabarovsk , Kazan , Samara , Saratov , Sverdlovsk , Leningrad. For these branches the priority is to ensure that the operating organization follows the requirements of the paragraph 5.3.5 of NRB-99/2009 regarding mandatory monitoring of the specific activity of tritium in groundwater at the site and the buffer zone. Systematic monitoring of the tritium content in the samples taken from monitoring wells, would allow to identify signs of elevated concentrations of radionuclides in time and to take measures to restore the integrity of the engineered barriers.

Safety Assessment Results

2) In the medium term perspective (from tens to hundreds of years) the safety of facility is determined by engineered and natural barriers to limit the spread of the radionuclide ^{90}Sr. The higher effective doses for the public (more than 1 mSv/year) due to the migration of strontium calculated for the following branches of the FSUE “RosRAO" (in descending order of danger): Irkutsk , Murmansk , Nizhny Novgorod , Leningrad. This must be taken into account the operating organization in the implementation of conservation (closure) projects for that facilities. The priority in providing safety should be given to ensurance in adequate isolating properties of existing (and optionally additional) engineered barriers to prevent the spread of ^{90}Sr out of the repository, as well as the portional or complete retrieval of the most hazardous waste, which can not be reliably isolated in citu.

Safety Assessment Results

3) In the long term perspective, the possibility to transfer the radioactive waste long-term storage facilities into the category of disposal facilities is determined by the accumulated activity of ^{14}C and long-lived alpha-emitting nuclides. The greatest danger such nuclides present for the following facilities (in descending order of danger): Chelyabinsk branch of FSUE "RosRAO", Rostov , Irkutsk , Nizhny Novgorod Branch, Federal State Unitary Enterprise "Radon" , Khabarovsk branch of FSUE " RosRAO ", Leningrad , Volgograd , Sverdlovsk , Kazan , Murmansk , Saratov , Samara and Blagoveshshensk branches. The potential danger of waste containing alpha-emitting nuclides will persist for hundreds of thousands of years. The long period of the potential danger of such waste does not allow for their safe isolation from the environment in the near-surface disposal facilities. The priority in ensuring the long-term safety for these facilities is to enable the retrieval of the most dangerous part of the waste for subsequent disposal in deep geological disposal facilities.

Findings

- The results can be considered as the very conservative estimate of public radiation exposure in case of an administrative transfer of operating facilities into the final disposal facilities without substantial upgrading of safety barriers and other necessary measures to compensate for the deficiencies of safety. The results can also be used to determine priorities in decision making regarding the order of decommissioning of considered facilities

- The final decision on the fate of each object should take into account the specifics of the object and results of clarifying calculations for comparison of the radiation risks associated with the waste retrieval and disposal on-site, made on the basis of the results of the initial registration and inventory of accumulated waste (radionuclide composition, specific and total activity, physical form, placement, retrievability)

Conclusion

- The systematic approach used in this work should be used in terms of safety for decision making on the historical RAW classification into “special” and “retrievable” waste
- It’s necessary to improve further the safety assessment methodology by developing techniques for its separate steps and recommendations for application and use of safety assessment results in solving practical problems
- In order to improve the reliability to the safety case results it’s necessary to develop full-scale mathematical models of existing disposal facilities completely taking into account the monitoring results and important features, events and processes of natural and man-made origin