PRELIMINARY STUDIES FOR THE DECOMMISSIONING OF THE REACTOR COMPARTMENTS OF THE FORMER PALDISKI MILITARY NUCLEAR SITE AND FOR THE ESTABLISHMENT OF A RADIOACTIVE WASTE REPOSITORY

PROJECT "PRELIMINARY STUDIES FOR THE DECOMMISSIONING OF THE REACTOR COMPARTMENTS OF THE FORMER PALDISKI MILITARY NUCLEAR SITE AND FOR THE ESTABLISHMENT OF A RADIOACTIVE WASTE REPOSITORY"

Results of Task 4

Stasys Motiejūnas

France

November 19, 2015

PRELIMINARY STUDIES FOR THE DECOMMISSIONING OF THE REACTOR COMPARTMENTS OF THE FORMER PALDISKI MILITARY NUCLEAR SITE AND FOR THE ESTABLISHMENT OF A RADIOACTIVE WASTE REPOSITORY

The main objective of the studies:

to select information needed for Environmental Impact Assessment

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Implementation of Task 4:

- Draft of the Task Report (1st version) was developed and delivered to the Customer for review on 6th October
- ALARA reviewed the Draft and presented comments on 19th October
- After evaluation of the comments the updated Task Report (2nd version) was delivered on 3rd November
- ALARA evaluated it and presented comments on 13th November

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Structure and content of the Task Report:

- Legal framework
- Waste inventory: waste sources, available waste treatment and conditioning technologies
- International experience in waste disposal
- Possible disposal options, strategic waste disposal concept
- Areas suitable for waste disposal
- Recommendations
- Conclusions

National policy and legal framework

- Even though Estonia is open to discuss other options, for example a regional disposal, the current national radioactive waste management policy has been built on the principle that the radioactive waste generated in Estonia is managed and disposed of in Estonia
- Estonian radioactive waste disposal facility should be constructed and commissioned by 2040

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National policy and legal framework

- Clearance requirements have direct influence on waste disposal
  - unconditional clearance levels
  - conditional clearance levels

3. WASTE SOURCES, AVAILABLE WASTE TREATMENT AND CONDITIONING TECHNOLOGIES

Preliminary studies for the decommissioning of the reactor compartments of the former Paldiski military nuclear site and for the establishment of a radioactive waste repository

Two waste conditioning methods currently applied in Estonia

- Grouting with concrete in reinforced concrete or metallic containers
- Plastics, textile and other compressible wastes are compressed in 200 L metallic drums

Containers currently used for waste storage

- Concrete containers and metallic containers
  - dimensions 1.2x1.2x1.2 m
- Cylinders for storage of control rods
- ISO full size and half size containers
  - dimensions 6.06x2.44x2.59 m and 6.06x2.44x1.30 m
- Metallic 200 L drums
- Big bags

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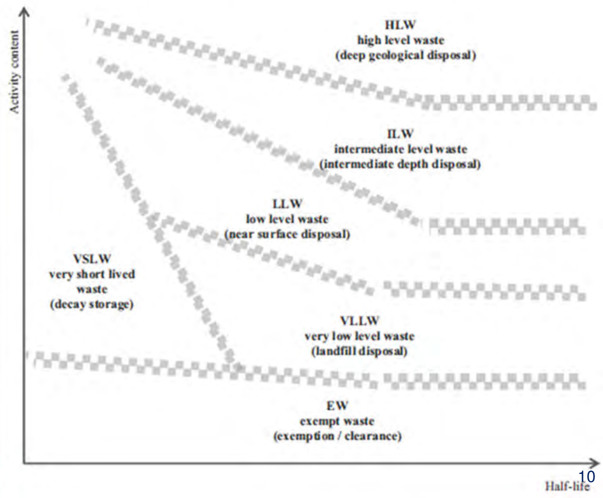
4.1. Classification of disposal facilities and waste type

- In 2009 IAEA introduced new waste classification system based on availability of disposal options /Safety Standards Series No. GSG-1/



4.2. Overview of international experience in waste disposal by type of disposal facilities

- Landfills
- Near Surface Repositories
- Intermediate Depth Repositories
- Geological Repositories
- Boreholes

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Examples analyzed: Landfills

- Sweden
- France, Spain
- Lithuania


Operation of disposal facility in Sweden
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Operation of disposal facility in Sweden
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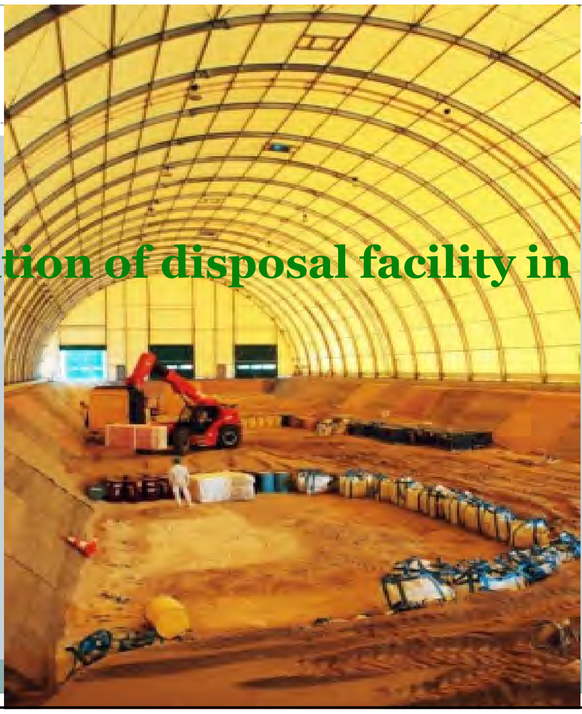

Operation of disposal facility in France

Operation of disposal facility in France

Big components are disposed of

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Examples analyzed: NSRs

- France
- Spain
- Lithuania

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Spanish repository safety concept

Three barriers therefore will form the multi-barrier system:

- The first barrier is the concrete containers with immobilized waste inside
- The second barrier is formed by the disposal vaults (cells) and cap
- The third barrier is the surrounding geological media
  - This would limit the impact to bio sphere of a possible release in the event of an accident or in a hypothetical early degradation of the first two barriers

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Concrete container is a key safety element

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Results of available NSRs experience analysis

- Multi- barrier safety concept is commonly applied in the NSRs
  - a combination of engineered and geological barriers is used to ensure safety
- Waste is emplaced into concrete vaults constructed below or above the surface level represents safe solution for disposal of Short Lived LLW waste
- Wastes containing significant amounts of Long- Lived radionuclides are not to be disposed of in the NSR

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Results of available NSRs experience analysis

- The NSRs are at a risk of human intrusion
  - Risk reducing institution control measures consist of security, surveillance and monitoring activities as well as land use restrictions are usually foreseen for at least 300 years
  - Surveillance, monitoring and physical protection are rather costly
- The surrounding geological media may play an important role in the safety case of the NSR, limiting an impact to bio- sphere in a case of early degradation of the engineered barriers
  - Due to it the repositories are constructed at properly selected sites

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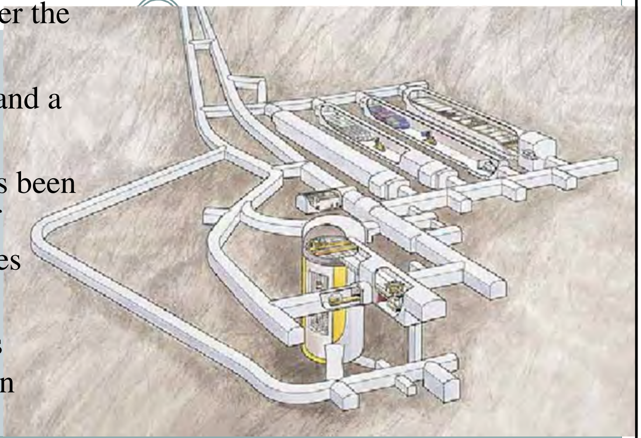
Results of available NSRs experience analysis

- There are two general options of the NSR:
  - “hill-” type constructed above ground water table
  - vaults located in water saturated zone
    - The second is more vulnerable to flooding and bathtubing
- The “hill” type repository consisting of vaults constructed above is better suitable to Estonian environmental conditions (i.g. high ground water level).

Examples analyzed: Intermediate Depth Repository - Swedish SFR

- About 60 meters under the sea bottom
- Consists of tunnels and a silo
- Expansion project has been initiated for disposal of decommissioning wastes
- Disposal of large nonfragmented items is planned in the extension galeries



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Swedish SFR

- The layout of the rock chambers have been adapted to the different types of short- lived LILW
- Silo- shaped cavern 50 meters high with concrete walls, bentonite barrier, and gas venting system houses packages containing the highest activities
- Waste is classified as short-lived,
- however, in the silo the waste also contains very long lived radionuclides

Swedish SFR

- The repository has been excavated in gneissose rock with hydraulic conductivity of 10^{-8} to 10^{-7} m/s
- Locating the repository below the seabed ensures a very low hydraulic gradient and consequently low ground water flow
- The ground water surrounding the repository will be very alkaline and reducing
  - Large amounts of concrete will buffer pH
- Locating the repository below the seabed excludes inadvertent human intrusion

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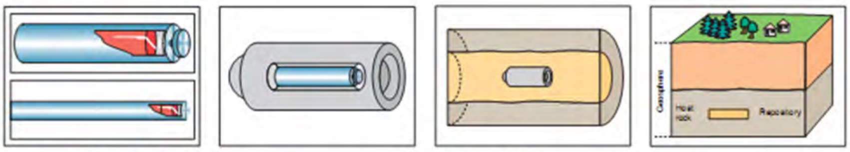
Results of available IDR experience analysis

- The disposal facility built at sufficient depth (more 30 m) is least exposed to a risk of human intrusion
  - Institution control measures, including monitoring, are not required for the IDRs
  - Waste disposed of in IDR can contain significant amounts of Long- Lived radionuclides
- Waste segregation according activity level and longevity is less important if IDR is the only disposal solution selected
- Level of detail in waste characterization is much less important comparing with disposal in the NSR

Examples analyzed: Geological Repository - Swiss Concept



Glass matrix (in steel flask)
- Confinement
  - Containment of radionuclides in glass
- Attenuation of releases
  - Low corrosion rate of glass

or

Spent fuel assemblies
- Confinement
  - Containment of radionuclides in spent fuel pellets and Zircaloy cladding
- Attenuation of releases
  - Low corrosion rates of spent fuel pellets and Zircaloy

Steel canister
- Confinement
  - Prevents inflow of water and release of radionuclides from spent fuel or waste for several thousand years
- Attenuation of releases
  - Corrosion products act as reducing agent (giving low radionuclide solubilities)
  - Corrosion products take up radionuclides

Bentonite backfill
- Confinement
  - Long resaturation time
  - Plasticity (self-sealing following physical disturbance)
- Attenuation of releases
  - Low solute transport rates (diffusion)
  - Retardation of radionuclide transport (sorption)
  - Low radionuclide solubility in pore water

Geological barriers
Host rock
- Confinement
  - Absence of water-conducting features
  - Mechanical stability
- Attenuation of releases
  - Low groundwater flux
  - Retardation of radionuclide transport (sorption and colloid filtration)

Geosphere
- Confinement
  - Physical protection of the engineered barriers (e.g. from glacial erosion)
- Attenuation of releases
  - Retardation of radionuclide transport (sorption)
  - Dispersion

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Swiss Concept

- The host rock formation (Opalinus clay) is approximately 100 m thick
- The plan is to place the repository at depth of approximately 650 m
- The engineered barrier system consists of massive steel canister and a bentonite backfill

Results of available Geological Repository experience analysis

- Geological repositories will be used for highly active Long- Lived wastes, mainly for Spent Nuclear Fuel
- In the current situation this disposal option is not relevant to Estonia
- however, introduction of the Geological Repository may be required in future in relation with construction of a NPP

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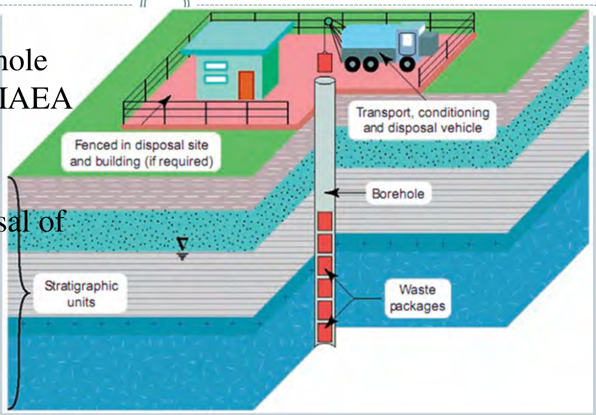
“BOSS” Concept

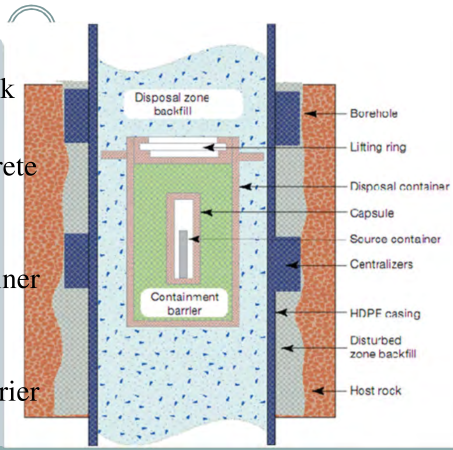
- Small diameter borehole concept developed by IAEA in collaboration with NECSA company
- Developed for disposal of disused sources



“BOSS” Concept

Engineered barrier system:

- The DSS are welded in 3 mm thick stainless steel capsule
- Capsules placed in a hole in concrete insert within a 6 mm thick waste container made from stainless steel
- Leak testing of capsule and container guarantees safe containment of the radionuclides
- Concrete serves as a chemical barrier



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“BOSS” Concept

- Potential human intrusion risk is minimized:
- Waste is disposed of deeper than the 30 m ‘normal residential intrusion zone’
- Probability of intrusion during exploratory drilling minimal:
  - small footprint
  - special inclining steel plate is used

Results of BOSS concept analysis

- Disposal of DSS into small diameter borehole presents simple, safe, secure and cost effective solution
- It is suitable to wide range of geological environments
- Disposal facility siting activities have already been initiated in Ghana, Philippines, Malaysia and Iran
- Applicability of the concept is strongly limited by geometrical dimensions and volume of the sources to be disposed of
- Therefore, in the current situation this disposal option is not relevant to Estonia
- however, introduction of the BOSS Repository may be considered in future as supplementary solution for institutional wastes

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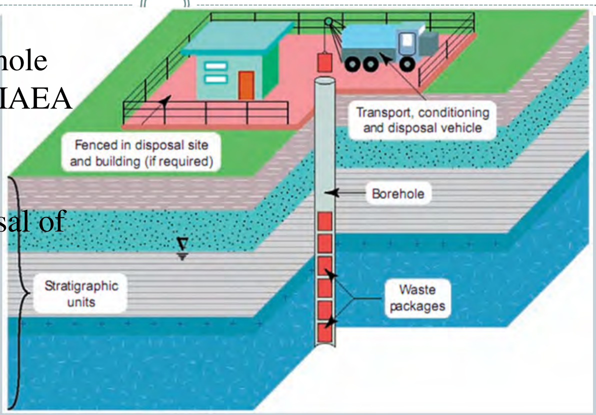

Disposal in existing municipal waste disposal facilities

- In some countries slightly radioactive wastes is disposed of in existing landfills designed for hazardous, municipal or industrial solid wastes
- Combustible waste is incinerated at existing municipal waste combustion plants together with municipal waste
  - Czech Republic, USA
- Following waste clearance concept provided in Annex VII to EU DIRECTIVE 2013/59/EURATOM
- Conditional clearance levels for municipal landfill disposal or incineration can be derived upon comprehensive assessment of doses to members of the public taking into account all pathways of exposure
  - doze criterion of 0.010 mSv/a
- Should be a subject to authorization by the regulatory authority

Disposal in existing municipal waste disposal facilities

- In Estonia the combustible waste could be incinerated together with the municipal waste in waste combustion plant located in Iru village
  - commissioned in 2013 and operated by Eesti Energia
  - process up to 220000 tons a year of mixed municipal waste from around Estonia

Disposal in existing municipal waste disposal facilities

Disadvantages:

- implications regarding public and stakeholders perceptions
- applicable to limited activities and activity concentrations
- needed for sophisticated measurement instrumentation to confirm compliance
- long transportation distance

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Selection of Radioactive waste disposal option

Radioactive waste disposal option and type of facility are selected considering the following factors:

- Political decisions
  - German example: waste to dispose of in geological repositories
- Attitudes of the public and other stakeholders
- Characteristics and volume of waste to be disposed of
  - content of long- lived radionuclides is the most important
- Environmental conditions (climate, geology, hydrology, e.t.c.)
- Cost
- Availability of technical infrastructure and technologies

Selection of Radioactive waste disposal option

- Estonian waste management policy does not make preference to certain disposal concept
- Public opinion regarding waste disposal is not well known as no social survey performed in Estonia
- However, evaluating experience of other countries it is only possible to assume that the public would be better accepting underground disposal solutions and gives preference to geological barriers but not shallow repository concept and engineered barriers

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Selection of Radioactive waste disposal option

- There is rather wide range of radioactive waste in Estonia
  - starting from insignificant activity concentrations and finishing with rather high
- The reactors active zones have been activated by neutron flux and have to be isolated from biosphere for sufficiently long time
- Only underground disposal is suitable for that purpose
- There is no tunnel construction experience and technologies in the country
- Contrarily, shallow repositories are very similar to landfills used for municipal waste disposal. They can be designed and built by experienced local design and building companies. So, repositories built on the soil surface (NSR or Landfill) are preferable from the technical point of view.
- Disposal cost is important factor too. Underground disposal is more expensive than NSR or Landfill

Selection of Radioactive waste disposal option

The climate in Estonia:

- Annual precipitation average is 560 mm, with snowfall around 170 mm.
- low temperatures, low intensity of evapotranspiration
  - In such conditions ground water level is usually high, just few meters below the surface level,
  - snow melting water often stays on the surface
- a risk of the disposal site flooding is significant
- In this situation shallow underground disposal solutions (tranches, pits, boreholes, vaults) are to be excluded
- Geological formations in Estonia are not favorable for construction of tunnels or underground caverns (the rocks are water saturated and often soft)

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Comments/answers

List of proposed candidate sites:

- 1. Paldiski center territory
- 2. Disused quarry nearby Rebala and Jõelähtme villages
- 3. Several areas are still considered (mainly North- Eastern Estonia rich in “blue” clay)

Comments/answers

- A site for t he repository will be selected during EIA process after comprehensive analysis available options
- Safety related issues/questions have to be answered during Safety Analysis of the repository

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Possible disposal options & strategic waste disposal concept

Three most optimal disposal options were identified taking into consideration economic, technical and safety factors:

- Landfill for Very Low Level Waste
- Near Surface Repository
- Intermediate Depth Repository

- Additional option: small diameter borehole for Disused Sealed Sources

Conclusions (1)

- 1. Construction of a repository in Estonia and disposal of radioactive waste is a feasible and the only sustainable solution
- 2. Appropriate waste characterization system should be the key element of a waste management system. It is essential to confirm and verify all available estimations and assumptions on radioactivity of the waste by means of direct measurements. Measurements must started at a very early stage of decommissioning activities
- 3. Interdependence of various waste management steps should be considered within the radioactive waste management strategy. Waste treatment and conditioning techniques have to be selected taking into consideration the selected waste disposal option in order to optimize waste management process

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Conclusions (2)

- 4. Waste conditioning and transportation processes could be significantly simplified if waste disposal site would be selected within the Paldiski navy center or its vicinity
- 5. Wastes containing minor amounts of radionuclides (Very Low Level Waste) can be disposed of in a simple Landfill. Benefits of this option will be most evident if the Landfill is built within Pakri peninsula


THANK YOU VERY MUCH!

Derivation of General Waste Acceptance Criteria for near surface repository of radioactive waste in Estonia

Dr. Evaldas Maceika and Dr. Laurynas Juodis
Center for Physical Sciences and Technology, Lithuania

18 November, France

General requirements for operation of radioactive waste Near Surface Repository (NSR)

- To ensure the safety of both workers and the public (both in the short term and the long term), the operator is required to design a comprehensive waste management system for the safe operation and closure of a near surface disposal facility.
- Part of such a safety system is to establish criteria for accepting waste for disposal at the facility.
- The purpose of the criteria is to limit the consequences of events which could lead to radiation exposures.
- In addition, it is necessary to prevent or limit hazards, which could arise from non-radiological causes.

Waste acceptance criteria (WAC)

Non-radiological criteria

- WAC establishes requirements for chemical, physical and mechanical properties of conditioned waste
- WAC excludes disposal of:
  - free liquids
  - explosives
  - pyrophoric materials
  - chelating agents

Radiological criteria

- Waste acceptance include limits on radionuclide concentrations in waste packages and the total activity in the repository as a whole:

$$\sum_i \frac{C_i}{C_{i\_lim}} \leq 1$$

- According the international practice the disposal the spent sealed sources at the near surface repository cannot be accepted due to compromised safety

Assessment of radionuclide limiting activity concentrations in RW

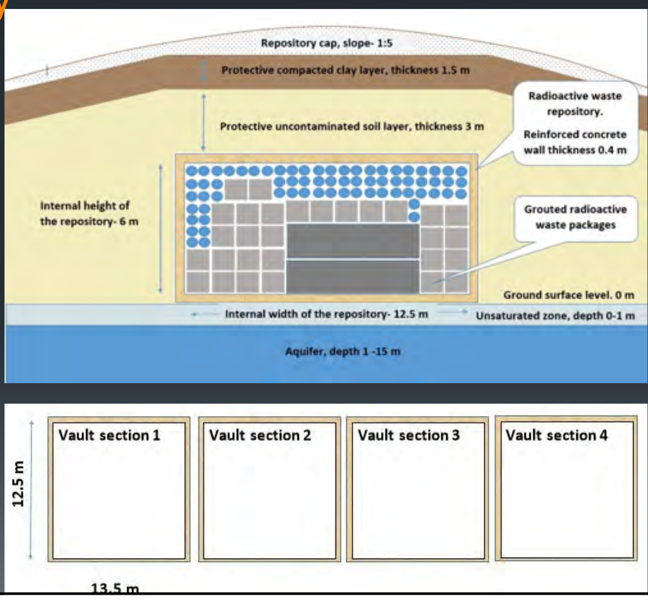
- The general WAC developed by taking into account typical environmental characteristics of Estonia: geological, hydrological, geo- and hydro- chemical, tectonic and seismic, climate and meteorological conditions.
- According to the IAEA recommendations for the WAC development „Derivation of activity limits for the disposal of radioactive waste in near surface disposal facilities, IAEA Tecdoc 1380“ the study provides waste activity limits for relevant radionuclides and considers:
  - repository normal evolution scenario and
  - human intrusion scenarios after repository operational period.
- In particular, the radionuclide off-site migration pathways is modelled taking into account general Estonian conditions, relevant for normal evolution scenario. The radionuclide off-site migration assessment was done by using RESRAD-OFFSITE computer code.

Assessment of radionuclide limiting activity concentrations

- The list of relevant radionuclides to be considered in the derivation of general WAC has been taken on the basis of the recommendations of IAEA Tecdoc 1380.
- It covers all relevant radionuclides for radioactive waste generated in nuclear power plants, as well as coming from industry applications.
- Additionally, taking into account the information about the Paldiski site waste, the Mo-93 isotope was included.

Radionuclide	Half Life (y)	Radionuclide	Half Life (y)
H-3	1.24E+01	Cs-137	3.00E+01
Be-10	1.60E+06	Ce-144	7.79E-01
C-14	5.73E+03	Pm-147	2.62E+00
Na-22	2.60E+00	Sm-151	9.00E+01
Ca-41	1.40E+05	Eu-152	1.33E+01
Mn-54	8.56E-01	Eu-154	8.80E+00
Fe-55	2.70E+00	Tl-204	3.78E+00
Ni-59	7.54E+04	Pb-210	2.23E+01
Ni-63	9.60E+01	Ra-226	1.60E+03
Co-60	5.27E+00	Ac-227	2.18E+01
Zn-65	6.68E-01	Ra-228	5.75E+00
Sr-90	2.91E+01	Th-232	1.40E+10
Zr-93	1.53E+06	U-234	2.45E+05
Nb-94	2.03E+04	U-235	7.04E+08
Tc-99	2.13E+05	U-238	4.47E+09
Ru-106	1.01E+00	Np-237	2.14E+06
Ag-110m	6.84E-01	Pu-238	8.77E+01
Sn-121m	5.50E+01	Pu-239	2.41E+04
Sb-125	2.77E+00	Pu-240	6.54E+03
Sn-126	1.00E+05	Pu-241	1.44E+01
I-129	1.57E+07	Am-241	4.32E+02
Cs-134	2.06E+00	Mo-93	3.50E+03

Projected general design of the vault type near surface repository



Radiological criteria used for assessment of the limiting radionuclide concentrations

- The main criterion underlying the derivation of activity limits for near surface disposal facilities is that the consequential radiation doses to workers and to members of the public from the possible exposure scenarios are compatible with the system of radiological protection criteria:
  - annual dose constrain of **0.3 mSv/year** for residing members of public
  - dose limit of 20 mSv/year for workers
  - dose limit of **1 mSv/year** for consideration of the human intrusion scenarios

Assumptions in WAC assessment

- **Time frames:**

The following time frames of the facility functioning periods were considered during assessment:

- — a repository operational period of 30 years;
- — optionally, institutional control periods of 30, 50, 100 and 300 years; and
- — a time period for post-institutional control calculations that allows the demonstration that the peak dose has been reached for each scenario assessed (within approximately 10000 years).

Summary of assumptions for assessed operational period scenarios

Scenario	Contaminant Release Mechanisms	Contaminant Release Media	Contaminant Transport Media	Contaminant Transport Mechanisms	Human Exposure Mechanisms
SCE1A: Gas release (vault)	Volatilization Degradation Radioactive Decay	Gas	Atmosphere (gas)	Diffusion Dispersion	Inhalation of gas and vapour
SCE2A Off-site residence	Leaching	Leachate	Ground water Soil Crops Animals Atmosphere (dust) Water (irrigation, drinking)	Repository waste; Soil unsaturated water zone; Aquifer; Well water; Sea water; Water abstraction for irrigation and drinking water; Foliar interception; Root uptake; Adsorption; Ingestion of water; pasture and soil by cows; Leaching; Erosion.	Ingestion of water, crops, fish and animal products Inhalation of dust External irradiation from soil
SCE3A: Drop and Crush (vault)	-	-	-	-	External irradiation from waste

Scenario	Contaminant Release Mechanisms	Contaminant Release Media	Contaminant Transport Media	Contaminant Transport Mechanisms	Human Exposure Mechanisms
SCE1B: Bathtubbing	Leaching	Leachate	Overflow leachate Soil Atmosphere (dust) Crops	Overflow of leachate; Suspension; Root uptake; Adsorption.	Ingestion of crops; Inadvertent ingestion of soil; Inhalation of dust; External irradiation from soil.
SCE2B: Off-site residence (the same as SCE2A)	Leaching	Leachate	Ground water Soil Crops Animals Atmosphere (dust) Water (irrigation, drinking)	Repository waste; Soil unsaturated water zone; Aquifer; Well water; Sea water; Water abstraction for irrigation and drinking water; Foliar interception; Root uptake; Adsorption; Ingestion of water; pasture and soil by cows; Leaching; Erosion.	Ingestion of water, crops, fish and animal products; Inhalation of dust; External irradiation from soil.

Scenario	Contaminant Release Mechanisms	Contaminant Release Media	Contaminant Transport Media	Contaminant Transport Mechanisms	Human Exposure Mechanisms
SCE3B: Road construction	Excavation	Dust	Atmosphere (dust)	Suspension	**Inadvertent ingestion of contaminated material and waste; Inhalation of dust; External irradiation from contaminated material and waste.**
SCE4B: Drilling (oil shale excavation)	Excavation	Dust	Atmosphere (dust)	Suspension	**Inadvertent ingestion of contaminated material and waste; Inhalation of dust; External irradiation from contaminated material and waste.**
SCE5B: On-site Residence adult	Excavation Gas generation	Excavated waste Gas	House Gas Soil Atmosphere (dust) Crops	Gas advection Root uptake Adsorption Suspension	**Ingestion of crops; Inadvertent ingestion of soil; Inhalation of dust and gas; External irradiation from soil.**
SCE6B: On-site Residence children play ground	Excavation Gas generation	Excavated waste Gas	House Gas Soil Atmosphere (dust) Crops	Gas advection Root uptake Adsorption Suspension	**Ingestion of crops; Inadvertent ingestion of soil; Inhalation of dust and gas; External irradiation from soil.**

Assumptions in WAC calculations (operational period)

Scenario	Type of scenario	Limiting dose criteria, mSv/year	Exposure Pathways	Fraction of activity, associated with the release (1- total, 0 - nothing)	Assumed duration, spent in the gas plume, hours/year	Assumed duration of external exposure, hours/year
Operational period						
Gas release	Normal	Worker – 20 Popul. – 0.3	Inhalation	H-3 - 0.039 C-14 - 0.2	Work.-1760 Popul.-4383	-
Liquid release (100 m off-site residence; surface water body- 1200 m)	Normal	Popul. – 0.3	External exp.; Inhalation; Ingestion of water, vegetables and fish	Calculated from: precipitation infiltration rate- 3 mm/year; Hydraulic conductivity of waste- $1 \cdot 10^{-9}$ m/s (typical for concrete/clay)	8767	8767
Drop and crush	Accidental	Worker – 20 mSv/y	External exp.; Inhalation	1 waste package – 500 kg.	-	in the cab- 0.0167 h; on the ladder, and on the walkway- 0.0167 h; on the ground level- 0.0333 h

Assumptions in WAC calculations (post-closure period)

Scenario	Type of scenario	Limiting dose criteria, mSv/year	Exposure Pathways	Activity dilution factor (1- not diluted, 0- totally diluted)	Assumed duration, spent outdoors, hours/year	Assumed duration, spent indoors, hours/year
Post closure period						
Bathtubbing	Abnormal	Popul. – 0.3	External exp.; Dust inhalation; Ingestion of soil and veget.	1	2191	6575
Liquid release (100 m off-site residence; surface water body- 1200 m)	Normal	Popul. – 0.3	External exp.; Inhalation; Ingestion of water, vegetables and fish	Calculated from: precipitation infiltration rate- 420 mm/year; Hydraulic conductivity of waste- $1 \cdot 10^{-5}$ m/s (typical for sand/ limestone)	8767	8767
Road construction	Intrusion	Popul.- 1	External exp.; Dust inhalation; Ingestion of soil	0.5	23.7	-
Drilling on site	Intrusion	Popul.- 1	External exp.; Dust inhalation; Ingestion of soil	0.35	160	-
On-site residence adult	Intrusion	Popul.- 1	External exp.; Dust inhalation; Ingestion of soil and veget.	0.35	2192	6575
On-site residence children play ground	Intrusion	10 year old children - 1	External exp.; Dust inhalation; Ingestion of soil and veget.	0.35	2192 +365 h playing above waste	6575

Potentially possible exposure scenarios during the operational period

Scenario code	Scenario name
SCE1A	Gas release
SCE2A	Liquid release (Off-site residence)
SCE3A	Drop and crush
SCE4A	Explosion
SCE5A	Crash of flying object
SCE6A	Criticality incident
SCE7A	Flooding
SCE8A	Bathtubbing
SCE9A	Direct irradiation
SCE10A	Solid release
SCE11A	Fire

Potentially possible exposure scenarios during the post-closure period

Scenario code	Scenario name
SCE1B	Bathtubbing
SCE2B	Off-site residence
SCE3B	Human intrusion- On-site road construction (inhalation and external exposure).
SCE4B	Human intrusion- On-site drilling (Investigation and sampling in the waste; inhalation and external exposure).
SCE5B	Human intrusion- On-site residence adult (water independent)
SCE6B	Human intrusion- On-site residence children play ground (water independent)

Limiting scenarios and activity limits

Radio-nuclide	Operational Period, Bq/kg /Limiting scenario		Post-closure period, Bq/kg / Limiting scenario							
			End of institutional control, years							
			30		50		100		300	
H-3	1.4E+09	Gas	4.4E+05	Off-site	1.4E+06	Off-site	2.6E+06	Bath.	1.4E+09	Off-site
Be-10	N/L	-	1.8E+06	Off-site	1.8E+06	Off-site	1.8E+06	Off-site	1.8E+06	Off-site
C-14	2.2E+08	Gas	3.1E+06	Off-site	3.1E+06	Off-site	3.3E+05	On- site	3.4E+05	On- site
Na-22	4.0E+11	Drop	1.1E+08	Drilling	2.3E+10	Drilling	4.0E+11	Bath.	N/L	-
Ca-41	8.3E+09	Drop	7.9E+07	Off-site	7.9E+07	Off-site	2.0E+05	On-site	2.0E+05	On-site
Mn-54	1.0E+12	Drop	1.0E+12	Drilling	N/L		N/L		N/L	-
Fe-55	1.0E+12	Drop	1.0E+12	Off-site	1.0E+12	Off-site	1.0E+12	On-site	N/L	-
Ni-59	N/L	-	7.7E+06	Off-site	7.7E+06	Off-site	7.7E+06	Off-site	7.7E+06	Off-site
Ni-63	N/L	-	3.3E+09	Drilling	3.8E+09	Drilling	8.7E+06	On-site	3.7E+07	On-site
Co-60	4.0E+11	Drop	1.7E+06	Drilling	2.4E+07	Drilling	9.8E+08	On-site	N/L	-

Setting of the Radiological criteria

IAEA Safety Requirements for waste disposal facilities after closure; SSR-5, 2011

- The dose limit for members of the public for doses from all planned exposure situations is the effective dose of 1 mSv in a year.
- Exposure of representative person who might be exposed in the future as a result of possible **natural degradation** processes affecting the disposal facility does not exceed a dose constraint of 0.3 mSv in a year or a risk constraint of the order of 10^{-5} per year
- If human intrusion were expected to lead to a possible annual dose of more than 20 mSv to those living around the disposal site, then alternative options for waste disposal are to be considered

ICRP recommends:

- Interval from 1 to 10 mSv has been recommended for intrusion

Experience

Dose constrain	Dose limit for **intrusion**
IAEA: 0.3 mSv/a	1 – 20 mSv
France: 0.25 mSv/a 0.001 mSv/a	7.6 mSv
Lithuania: 0.2	5 mSv
Estonia: ?	

Thank you!