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**

**Tallinn**

December 14, 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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# Structure and content of the produced 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**
- Summary



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# 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

# Waste sources in Estonia

- 1.Waste stored in Paldiski storage facility, including
  - waste from Paldiski site
  - waste retrieved from Tammiku storage facility
  - institutional waste
- 2. Waste to be produced during decommissioning Paldiski nuclear submarine training centre)
- 3. Future NPP waste
- 4. AS Molycorp Silmet radioactive waste (out of scope of the current project)
- 5. Future institutional waste



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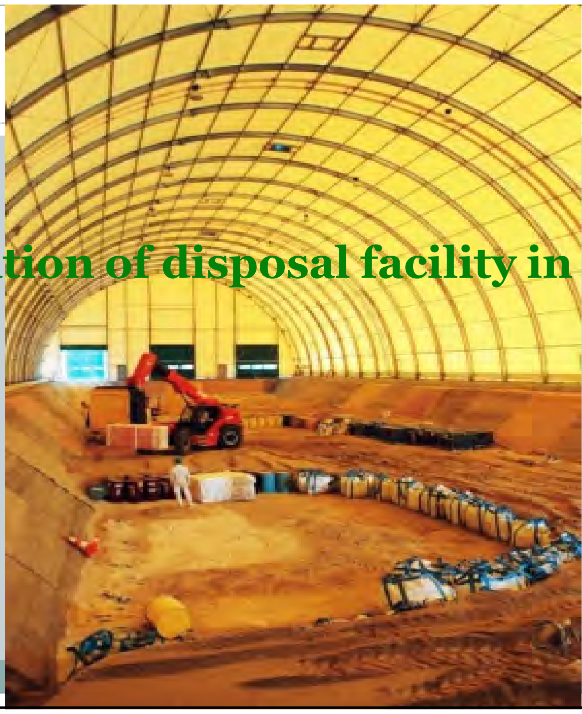
# International experience in waste disposal: types of disposal facilities

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

# Examples analyzed: Landfills

- Sweden
- France, Spain
- Lithuania





# Operation of disposal facility in France

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# Examples analyzed: NSRs

- France
- Spain
- Lithuania

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# Operation of disposal facility in Spain

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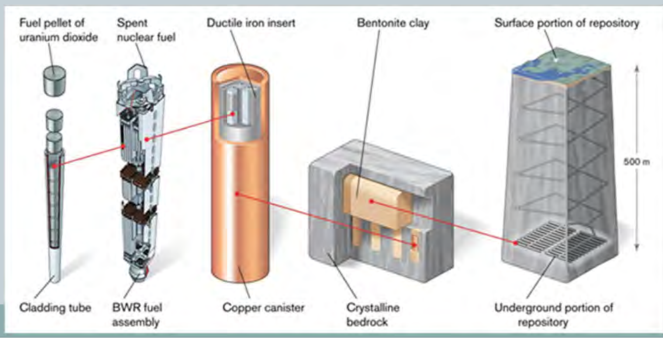
## Examples analyzed: Geological Repositories

- Swiss
- Sweden, Finland

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## General Waste Acceptance Criteria for Near Surface Repository

- Radioactivity of most active reactor components exceeds radionuclide activity limits derived for near surface disposal of radioactive waste, mainly due to risk of inadvertent human intrusion into the disposal facility
- Therefore, the most active reactor components and available long lived waste have to be disposed of at **minimal depth of 30 meters to minimize the intrusion risk**

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# Selection of disposal methods suitable for Estonia

- Intermediate Depth Repository
  - deeper than 30 m
- Near Surface Repository
  - concrete vaults built on the ground
- Landfill
  - built on the ground

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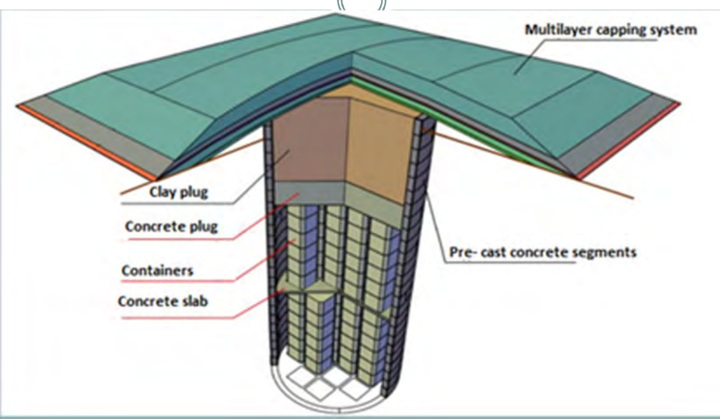
# Intermediate Depth Repository

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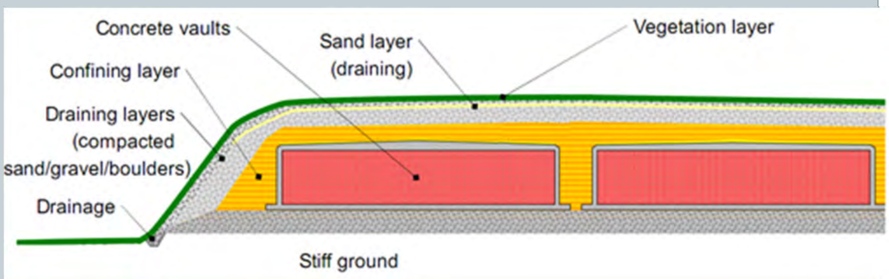
# Near Surface Repository

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# Landfill

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# Analyzed disposal options

1. Intermediate Depth Repository
2. Combination of Near Surface Repository and Intermediate Depth Repository
3. Combination of Landfill and Intermediate Depth Repository

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# Optimal disposal strategy proposed considering various factors:

- Political
- Environmental
- Technical
- Social
- Economical (cost)

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## Optimal disposal solution

- Advantages and disadvantages of the disposal options evaluated together with Estonian experts and representatives of stakeholders
- Conclusion:
  - Combination of Near Surface Repository and Intermediate Depth Repository is the preferred strategy



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## Repository siting

- Intermediate Depth Repository:
  - Cambrian- Lontova clay in Northeastern Estonia
- Near surface repository:
  - Moraine hills in Northern part of Estonia

# Repository siting (2)

- The main candidate sites proposed to be investigated in detail during EIA process:
  1. Paldiski navy center
  2. Rutja site in North East of Estonia
  3. Rebala site east from Tallinn

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# CONCLUSIONS (1)

- Construction of a repository in Estonia and disposal of radioactive waste is a feasible solution and the only sustainable option
- Radioactivity of most active reactor components exceeds radionuclide activity limits derived for near surface disposal of radioactive waste, mainly due to risk of inadvertent human intrusion into the disposal facility. Therefore, the most active reactor components and available long lived waste have to be disposed of at minimal depth of 30 meters to minimize the intrusion risk

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# CONCLUSIONS (2)

- Combination of underground disposal modules with disposal vaults built on the ground is the most appropriate disposal solution. Conceptually different disposal modules can be built on the same site, but can also be located at two separate sites better satisfying different requirements for the site, i.e., if selection of a single site suitable for the both disposal options is not successful
- Territory adjoining Paldiski navy center is regarded as a potential site for construction of waste disposal facility. Waste conditioning and transportation can be substantially simplified were the waste disposal take place in the vicinity of the center
- The other identified potential disposal sites are Rutja and Rebala. They are the main candidate sites to be investigated in detail during EIA process

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

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Tallinn

December 14, 2015

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

- Purpose:
- To ensure the safety of both workers and the public (both in the short term and the long term)
  - 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

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

Radiological criteria

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

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

# Assessment of radionuclide limiting activity concentrations in RW

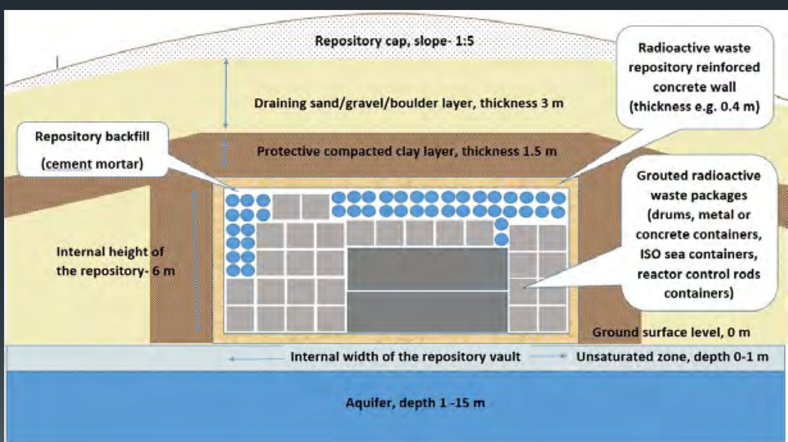
- The general WAC developed by taking into account typical environmental characteristics of Estonia: geological, hydrological, climatic
- Waste activity limits derived according to the IAEA recommendations for:
  - **scenario of normal repository evolution and**
  - **human intrusion after repository operational period**
- In particular, the radionuclide migration following repository degradation is modelled taking into account general Estonian conditions
- The radionuclide off-site migration assessment was done by using RESRAD OFF-SITE 3.1 computer code

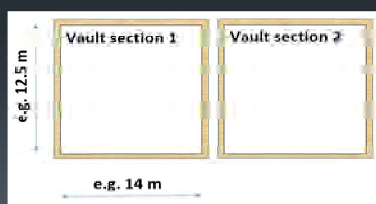
## List of relevant radionuclides

- Covers all relevant radionuclides for radioactive waste generated in NPP, as well as coming from industry applications
- Additionally, Kr-85 and Mo-93 isotopes were included taking into account information about the Paldiski site

| Radionuclide | Half Life (y) | | Radionuclide | Half Life (y) | | Radionuclide | Half Life (y) |
|---|---|---|---|---|---|---|---|
| H-3 | 12.4 | | Nb-94 | 20300 | | Tl-204 | 3.78 |
| Be-10 | 1600000 | | Tc-99 | 213000 | | Pb-210 | 22.3 |
| C-14 | 5730 | | Ru-106 | 1.01 | | Ra-226 | 1600 |
| Na-22 | 2.6 | | Ag-110m | 0.684 | | Ac-227 | 21.8 |
| Ca-41 | 140000 | | Sn-121m | 55 | | Ra-228 | 5.75 |
| Mn-54 | 0.856 | | Sb-125 | 2.77 | | Th-232 | 14000000000 |
| Fe-55 | 2.7 | | Sn-126 | 100000 | | U-234 | 245000 |
| Ni-59 | 75400 | | I-129 | 15700000 | | U-235 | 704000000 |
| Ni-63 | 96 | | Cs-134 | 2.06 | | U-238 | 4470000000 |
| Co-60 | 5.27 | | Cs-137 | 30 | | Np-237 | 2140000 |
| Zn-65 | 0.668 | | Ce-144 | 0.779 | | Pu-238 | 87.7 |
| Kr-85 | 10.72 | | Pm-147 | 2.62 | | Pu-239 | 24100 |
| Sr-90 | 29.1 | | Sm-151 | 90 | | Pu-240 | 6540 |
| Mo-93 | 3500 | | Eu-152 | 13.3 | | Pu-241 | 14.4 |
| Zr-93 | 1530000 | | Eu-154 | 8.8 | | Am-241 | 432 |

## Generalised structure of considered 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
- — 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 10 000 years)

# Potentially possible exposure scenarios

| Operational period scenarios |
|---|
| Gas release |
| Liquid release |
| Drop and crush |
| Explosion |
| Crash of flying object |
| Criticality incident |
| Flooding |
| Bathtubbing |
| Direct irradiation |
| Solid release |
| Fire |

| Post-operational period scenarios |
|---|
| Bathtubbing |
| Off-site residence |
| Human intrusion- On-site road construction (inhalation and external exposure). |
| Human intrusion- On-site drilling (Investigation and sampling in the waste; inhalation and external exposure). |
| Human intrusion- On-site residence adult (water independent) |
| Human intrusion- On-site residence children play ground (water independent) |

# Considered human exposure pathways

- External exposure
- Dust and gas inhalation
- Ingestion of water, vegetables and fish
- Ingestion of soil

## Assumptions for 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<br>Popul. – 0.3 | Inhalation | H-3 - 0.039<br>C-14 - 0.2<br>Kr-85 - 1 | Work.-1760<br>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;<br>Hydraulic conductivity of waste- $1 \cdot 10^{-9}$ m/s (typical for concrete/clay);<br>Four types of waste packages:<br>• metal containers;<br>• concrete container;<br>• 200 L drums;<br>• Reactor control rods containers. | 8767 | 8767 |
| **Drop and crush** | Accidental | Worker – 20 mSv/y | External exp.; Inhalation | 1 waste package – 500 kg. | - | |

## Assumptions for 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.;<br>Dust inhalation;<br>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.;<br>Inhalation;<br>Ingestion of water, vegetables and fish | Calculated from: precipitation rate- 700 mm/year;<br>Hydraulic conductivity of waste- $1 \cdot 10^{-5}$ m/s (typical for sand or limestone) | 8767 | 8767 |
| **Road construction** | Intrusion | Popul.- 1 | External exp.;<br>Dust inhalation;<br>Ingestion of soil | 0.5 | 23.7 | - |
| **Drilling on site** | Intrusion | Popul.- 1 | External exp.;<br>Dust inhalation;<br>Ingestion of soil | 0.35 | 160 | - |
| **On-site residence adult** | Intrusion | Popul.- 1 | External exp.;<br>Dust inhalation;<br>Ingestion of soil and veget. | 0.35 | 2192 | 6575 |
| **On-site residence children play** | Intrusion | 10 year old children - 1 | External exp.;<br>Dust inhalation;<br>Ingestion of soil and | 0.35 | 2192<br>+365 h playing above waste | 6575 |

# Activity limits and limiting scenarios for some radionuclides

| | Operational Period, Bq/kg /Limiting scenario | | Post-closure period, Bq/kg / Limiting scenario | | | |
|---|---|---|---|---|---|---|
| | | | End of institutional control, years | | | |
| | | | 100 | | 300 | |
| H-3 | 1.4E+09 | Gas | 2.6E+06 | Bath. | 1.4E+09 | Off-site |
| C-14 | 2.2E+08 | Gas | 3.4E+05 | On- site | 3.4E+05 | On- site |
| Ni-59 | N/L | - | 1.0E+07 | On-site | 1.0E+07 | On-site |
| Ni-63 | N/L | - | 8.7E+06 | On-site | 3.7E+07 | On-site |
| Co-60 | 4.0E+11 | Drop | 9.8E+08 | On-site | N/L | - |
| Nb-94 | 5.0E+11 | Drop | 3.0E+03 | On-site | 3.0E+03 | On-site |

# Thank you!