The main objective of the studies:

to select information needed for Environmental Impact Assessment
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

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

November 19, 2015
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.

Clearance requirements have direct influence on waste disposal:
- unconditional clearance levels
- conditional clearance levels
3. WASTE SOURCES, AVAILABLE WASTE TREATMENT AND CONDITIONING TECHNOLOGIES

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

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

Examples analyzed: Landfills

- Sweden
- France, Spain
- Lithuania
Operation of disposal facility in France

Big components are disposed of
Examples analyzed: NSRs

- France
- Spain
- Lithuania

Operation of disposal facility in Spain
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 biosphere of a possible release in the event of an accident or in a hypothetical early degradation of the first two barriers
Containers are not applied in other concepts (in Japan)

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 a 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
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

November 19, 2015

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.e. 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 galleries

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

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

- 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

“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

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

“BOSS” Concept

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

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

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)

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 the 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

November 19, 2015

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

November 19, 2015
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 start 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.

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.

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Half Life (y)</th>
<th>Radionuclide</th>
<th>Half Life (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-3</td>
<td>1.24E+01</td>
<td>Cs-137</td>
<td>3.00E+01</td>
</tr>
<tr>
<td>Be-10</td>
<td>1.60E+06</td>
<td>Ca-44</td>
<td>7.79E+01</td>
</tr>
<tr>
<td>C-13</td>
<td>5.73E+03</td>
<td>Pr-147</td>
<td>2.62E+00</td>
</tr>
<tr>
<td>Na-22</td>
<td>2.60E+00</td>
<td>Sm-151</td>
<td>9.00E+01</td>
</tr>
<tr>
<td>Ca-41</td>
<td>1.40E+05</td>
<td>Eu-152</td>
<td>1.33E+01</td>
</tr>
<tr>
<td>Mn-54</td>
<td>8.56E-01</td>
<td>Eu-154</td>
<td>8.80E+00</td>
</tr>
<tr>
<td>Fe-55</td>
<td>2.70E+00</td>
<td>Ti-204</td>
<td>3.78E+00</td>
</tr>
<tr>
<td>Nb-93</td>
<td>7.54E+04</td>
<td>Pb-210</td>
<td>2.33E+01</td>
</tr>
<tr>
<td>W-93</td>
<td>9.60E+01</td>
<td>Pa-216</td>
<td>1.60E+03</td>
</tr>
<tr>
<td>Co-60</td>
<td>5.27E+00</td>
<td>Ac-227</td>
<td>2.18E+01</td>
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<tr>
<td>Zn-65</td>
<td>6.68E-01</td>
<td>Pu-228</td>
<td>5.75E+00</td>
</tr>
<tr>
<td>Sr-89</td>
<td>2.91E+00</td>
<td>Th-232</td>
<td>1.40E+10</td>
</tr>
<tr>
<td>Zr-93</td>
<td>1.53E+06</td>
<td>U-234</td>
<td>2.45E+05</td>
</tr>
<tr>
<td>Sr-90</td>
<td>2.03E+04</td>
<td>U-235</td>
<td>7.34E+08</td>
</tr>
<tr>
<td>Zr-96</td>
<td>2.13E+05</td>
<td>U-238</td>
<td>4.47E+09</td>
</tr>
<tr>
<td>W-169</td>
<td>1.01E+00</td>
<td>Np-237</td>
<td>2.14E+06</td>
</tr>
<tr>
<td>Ag-100m</td>
<td>6.84E+01</td>
<td>Pu-238</td>
<td>8.37E+01</td>
</tr>
<tr>
<td>Sn-115m</td>
<td>5.50E+01</td>
<td>Pu-239</td>
<td>2.41E+04</td>
</tr>
<tr>
<td>Sn-117m</td>
<td>2.77E+00</td>
<td>Pu-240</td>
<td>6.54E+03</td>
</tr>
<tr>
<td>Sm-149</td>
<td>1.00E+05</td>
<td>Pu-241</td>
<td>1.44E+01</td>
</tr>
<tr>
<td>Pd-124</td>
<td>1.07E+01</td>
<td>Am-241</td>
<td>4.52E+02</td>
</tr>
<tr>
<td>Cs-134</td>
<td>2.06E+00</td>
<td>Mo-93</td>
<td>3.50E+03</td>
</tr>
</tbody>
</table>

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

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

### Additional scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Contaminant Release Mechanisms</th>
<th>Contaminant Release Media</th>
<th>Contaminant Transport Media</th>
<th>Contaminant Transport Mechanisms</th>
<th>Human Exposure Mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCE1B: Bathtubbing</td>
<td>Leaching</td>
<td>Leachate</td>
<td>Overflow leachate, Soil, Atmosphere (dust), Crops</td>
<td>Overflow of leachate; Suspension; Root uptake; Adsorption.</td>
<td>Ingestion of crops; Inadvertent ingestion of soil; Inhalation of dust; External irradiation from soil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCE2B: Off-site residence (the same as SCE2A)</td>
<td>Leaching</td>
<td>Leachate</td>
<td>Ground water, Soil, Crops, Animals, Atmosphere (dust), Water (irrigation, drinking)</td>
<td>Repository waste; Soil unsaturated water zone; Aquifer; Well water; Sea water; Water abstraction for irrigation and drinking water; Foliage interception; Root uptake; Adsorption; Ingestion of water; pasture and soil by cows; Leaching; Erosion.</td>
<td>Ingestion of water, crops, fish and animal products; Inhalation of dust; External irradiation from soil</td>
</tr>
<tr>
<td>Scenario</td>
<td>Contaminant Release Mechanisms</td>
<td>Contaminant Release Media</td>
<td>Contaminant Transport Media</td>
<td>Contaminant Transport Mechanisms</td>
<td>Human Exposure Mechanisms</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------------------------------</td>
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<td>----------------------------</td>
<td>---------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SCE3B: Road construction</td>
<td>Excavation</td>
<td>Dust</td>
<td>Atmosphere (dust)</td>
<td>Suspension</td>
<td>Inadvertent ingestion of contaminated material and waste; Inhalation of dust; External irradiation from contaminated material and waste.</td>
</tr>
<tr>
<td>SCE4B: Drilling (oil shale excavation)</td>
<td>Excavation</td>
<td>Dust</td>
<td>Atmosphere (dust)</td>
<td>Suspension</td>
<td>Inadvertent ingestion of contaminated material and waste; Inhalation of dust; External irradiation from contaminated material and waste.</td>
</tr>
<tr>
<td>SCE5B: On-site Residence adult</td>
<td>Excavation Gas generation</td>
<td>Excavated waste Gas</td>
<td>House Gas</td>
<td>Gas advection</td>
<td>Ingestion of crops; Inadvertent ingestion of soil; Inhalation of dust and gas; External irradiation from soil.</td>
</tr>
<tr>
<td>SCE6B: On-site Residence children play ground</td>
<td>Excavation Gas generation</td>
<td>Excavated waste Gas</td>
<td>House Gas</td>
<td>Gas advection</td>
<td>Ingestion of crops; Inadvertent ingestion of soil; Inhalation of dust and gas; External irradiation from soil.</td>
</tr>
</tbody>
</table>

### Assumptions in WAC calculations (operational period)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Type of scenario</th>
<th>Limiting dose criteria, mSv/year</th>
<th>Exposure Pathways</th>
<th>Fraction of activity, associated with the release (1 - total, 0 - nothing)</th>
<th>Assumed duration, spent in the gas plume, hours/year</th>
<th>Assumed duration of external exposure, hours/year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gas release</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>Worker – 20 Popul. – 0.3</td>
<td>Inhalation</td>
<td>H-3 - 0.039</td>
<td>Work.-1760 Popul.-4363</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid release (100 m off-site residence; surface water body: 1200 m)</td>
<td>Normal</td>
<td>Popul. – 0.3</td>
<td>External exp.; Inhalation; Ingestion of water, vegetables and fish</td>
<td>Calculated from: precipitation infiltration rate: 3 mm/year; Hydraulic conductivity of waste: 1·10⁻² m/s (typical for concrete/clay)</td>
<td>8767</td>
<td>8767</td>
</tr>
<tr>
<td>Drop and crush</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accidental</td>
<td>Worker – 20 mSv/y</td>
<td>External exp.; Inhalation</td>
<td>1 waste package – 500 kg.</td>
<td>-</td>
<td></td>
<td>in the cab: 0.0167 h; on the ladder, and on the walkway: 0.0167 h; on the ground level: 0.0333 h</td>
</tr>
</tbody>
</table>

| 23.12.2015 |
## Assumptions in WAC calculations (post-closure period)

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

## Potentially possible exposure scenarios during the operational period

<table>
<thead>
<tr>
<th>Scenario code</th>
<th>Scenario name</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCE1A</td>
<td>Gas release</td>
</tr>
<tr>
<td>SCE2A</td>
<td>Liquid release (Off-site residence)</td>
</tr>
<tr>
<td>SCE3A</td>
<td>Drop and crush</td>
</tr>
<tr>
<td>SCE4A</td>
<td>Explosion</td>
</tr>
<tr>
<td>SCE5A</td>
<td>Crash of flying object</td>
</tr>
<tr>
<td>SCE6A</td>
<td>Criticality incident</td>
</tr>
<tr>
<td>SCE7A</td>
<td>Flooding</td>
</tr>
<tr>
<td>SCE8A</td>
<td>Bathtubbing</td>
</tr>
<tr>
<td>SCE9A</td>
<td>Direct irradiation</td>
</tr>
<tr>
<td>SCE10A</td>
<td>Solid release</td>
</tr>
<tr>
<td>SCE11A</td>
<td>Fire</td>
</tr>
</tbody>
</table>
Potentially possible exposure scenarios during the post-closure period

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

Limiting scenarios and activity limits

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Operational Period, g/kg</th>
<th>Limiting Period, g/kg</th>
<th>Limiting scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Post-closure period, g/kg</td>
<td>End of institutional control, years</td>
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</tr>
<tr>
<td></td>
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<td>30</td>
<td>50</td>
</tr>
<tr>
<td>H3</td>
<td>1.4E+0</td>
<td>9</td>
<td>Off-site</td>
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<tr>
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<td>5</td>
<td>Off-site</td>
</tr>
<tr>
<td>Be-10</td>
<td>N/L</td>
<td>1</td>
<td>Off-site</td>
</tr>
<tr>
<td>C-14</td>
<td>2.6E+0</td>
<td>6</td>
<td>Off-site</td>
</tr>
<tr>
<td></td>
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<td>6</td>
<td>Off-site</td>
</tr>
<tr>
<td>N-22</td>
<td>4.0E+1</td>
<td>1</td>
<td>Off-site</td>
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<tr>
<td>Ca-41</td>
<td>8.3E+0</td>
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<td>Drilling</td>
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<td>Off-site</td>
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<tr>
<td>Mn-54</td>
<td>1.2E+1</td>
<td>2</td>
<td>Off-site</td>
</tr>
<tr>
<td>Co-60</td>
<td>4.0E+1</td>
<td>1</td>
<td>Off-site</td>
</tr>
</tbody>
</table>
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**
  - IAEA: 0.3 mSv/a
  - France: 0.25 mSv/a
  - Lithuania: 0.2
  - Estonia: ?
  - Dose limit for intrusion:
    - 1 – 20 mSv
    - 7.6 mSv
    - 5 mSv
Thank you!