Overview of remedial activities at Pridneprovsky Chemical Plant Site, Dneprodzerginsk, Ukraine

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Outline

1. Site location, operation history and contaminated legacies
2. Remediation history, National Remediation Programs and International Technical Assistance Projects
3. Current monitoring program, radiation hazards and remediation challenges/difficulties
4. Results of ENSURE-II (Ukraine-Sweden bilateral technical assistance) project 2011-2013
5. Conclusions: current status of remedial works and outstanding tasks
1.1 Geographical location of the study site

PChP – soviet era uranium ore processing site
Situated in densely populated area close to Dniper River
1.2. Main tailings sites at the Pridneprovsky Chemical Plant

Two sites:

**PChP Industrial Site**
(main site)

**Sukhachevsky Site**
(two large tailings)

Legacy contaminations:
- 7 uranium mill tailings
- 2 uranium ore storage sites
- 28 contaminated buildings
- Contaminated groundwater and surface water
- Contaminated soils and bottom sediments
1.3 Industrial site of the PChP with main radioactively contaminated objects

Waste volumes in tailings:
Dneprovskoe – $5.8 \times 10^6$ m$^3$;
Zapadnoe – $0.35 \times 10^6$ m$^3$;
Central Yar - $0.13 \times 10^6$ m$^3$;
Pivdenno-Shidne - $0.19 \times 10^6$ m$^3$;

1. Building N103;
2. Building N6;
3. Building N112;
4. Tailing Zapadnoe;
5. Tailing Central Yar;
6. Tailing Yugovochtchnoye;
7. Tailing Dniprovskoye;
8. Hot Spots;
9. Ponds (near Tailing Central Yar);
10. PChP North Part
2.1 Remediation history – National Programs

• 1991 - 2000  uranium ore milling and processing at PChP has ceased. Site infrastructure degraded. The PChP has split into a dozen of smaller enterprises No remedial strategy, no proper decommissioning plans... Difficult economical situation...

• 2000 - 2003  SE “Barrier” (Site Operator) was established to carry monitoring and remedial activities at PChP site. First site characterization and monitoring studies started. First State remediation program for the PChP Site was developed Program foresaw relocation of tailings and dismantling of the most contaminated buildings. This strategy assumed very high remedial cost, and has not been implemented

• 2005 - 2008  Systematic and comprehensive site monitoring program established (Ecomonitor LLC). First priority actions defined and initiated (decontamination of some buildings, removal of contaminated pipelines, tailings covers repairing,…)

• 2009 - 2014  Development and launching of the State Program for Remediation of PChP (Second Phase).

Inter-Agency Government Commission created to supervise remedial activities.

Inventory and site characterization studies. Preliminary safety assessment studies. Identification and completing of first priority actions.

National Program for 2015-2020 currently under development
2.2 Key outcomes of National Program of 2009 - 2010 – completion of inventory studies for uranium mill tailings

Layout of characterization boreholes
For Zapadnoe Tailings

U-238 distribution in Zapadnoe Tailings (visualization of gridded kriging data)
2.3 International assistance projects

- **2007-2008** ENSURE-I project (funded by SIDA, managed by SSM, Sweden)
  Assistance in modern safety assessment methodologies, preliminary risk assessment and prioritization of contaminated sites

- **2011-2013** ENSURE-II project (funded by SIDA, managed by SSM, Sweden)
  Main Work Packages
  - Review and development of regulatory documents
  - Development Safety Assessment Methodology
  - Focused monitoring and characterization studies ("Academic project")
  - Development of technical capacity of Site operator ("Barrier" company)
  - Stakeholders Involvement

- **2012** Expert Mission of IAEA for reviewing remedial activities at PChP Site

- **2014-2015** IAEA national TC project
  (Improvement of uranium legacy site management in Ukraine as a basis for preparedness for decommissioning and legacy site remediation)

- **2014-2015** EC INSC Program Project launched
  "Development of the method (strategy, technology) for the remediation activity at the former Uranium facility “Pridneprovskiy Chemical Plant”
3.1 Current monitoring program for the PChP Site
(Carried out Barrier company; assisted by Ecomonitor LLC)

- **Rn-222 concentrations** in the air at tailings, site territory and in the contaminated premises (2 times per year; using track detectors)
- **Rn-222 exhalation rates** from the tailing covers (2 times per year)
- **Air aerosols** monitoring (radionuclides of U decay series and chemical contaminants)
- Sampling **surface waters** (seasonally) and **groundwater** (1 time per year) for radioactive and chemical composition
- **Soil gamma dose rate** surveys (once in 2 – 5 years)
- **Toxic metals** determinations (from 2009 - Pb, Co, Cd, Mn, Cu, Ni, Fe, Zn, As)
- **Basic meteorological** and hydrological parameters
- Radioactivity analyses of selected **biological samples**

Monitoring program allowed identification of the main radiological and eco-toxicological hazards at PChP site
3.2 Difficulties and challenges:
Large number of contaminated buildings and equipment
(not fully characterized yet)

In some locations gamma dose rates reach $10^3 \mu\text{Sv h}^{-1}$, surface beta particle fluxes reach $10^3 \text{Bq cm}^{-2}$, uranium content in dust reaches $10^2 \text{g} / \text{m}^2$
3.3 Priority radiation hazard: Building no.103 (former radiochemical processing workshop)

The highest Gamma dose rates reaches 100-300 µSv/h (reactor column near building 103)

Dismantling of highly contaminated equipment and management of resulting waste is a key problem

Working area (Building 102)
### Specific radionuclides in a dust deposition kBq·m⁻² dry w.

<table>
<thead>
<tr>
<th>Level 1</th>
<th>U-238</th>
<th>Ra-226</th>
<th>Pb-210</th>
<th>Po-210</th>
<th>Th-230</th>
<th>Th-228</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>2,6-6,8</td>
<td>0,4-0,8</td>
<td>0,2-0,6</td>
<td>0,2-0,6</td>
<td>1,3-5,2</td>
<td>0,02-0,04</td>
</tr>
<tr>
<td>min</td>
<td>0,01</td>
<td>0,1</td>
<td>0,02</td>
<td>0,02</td>
<td>0,1</td>
<td>0,002</td>
</tr>
<tr>
<td>max</td>
<td>13,7</td>
<td>1,0-1,2</td>
<td>1,2</td>
<td>1,2</td>
<td>13,2-16,7</td>
<td>0,06</td>
</tr>
</tbody>
</table>

### Specific radionuclide in the spilled materials, Bq·g⁻¹ dry, w

<table>
<thead>
<tr>
<th>Level 1</th>
<th>U-238</th>
<th>Ra-226</th>
<th>Pb-210</th>
<th>Po-210</th>
<th>Th-230</th>
<th>Th-228</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>40-320</td>
<td>6,5-45</td>
<td>3,0-8,5</td>
<td>3,0-8,5</td>
<td>45-80</td>
<td>0,3-0,8</td>
</tr>
<tr>
<td>min</td>
<td>10</td>
<td>0,3</td>
<td>0,3</td>
<td>0,3</td>
<td>20</td>
<td>0,02</td>
</tr>
<tr>
<td>max</td>
<td>3116</td>
<td>168</td>
<td>44</td>
<td>44</td>
<td>436</td>
<td>2-3</td>
</tr>
</tbody>
</table>
3.4. Difficulties and challenges:
Highly heterogeneous soil contamination at Industrial Site

Map of gamma-dose rate distribution at PChP site prepared in the ENSURE-II Project

Gamma-dose rates in hot spots usually correlate with elevated soil content of $^{238}$U, $^{226}$Ra, and of some toxic metals (Mn, Zn, As, Fe, Co, Ni, and Cd)
3.5 Gamma-dose rates distributions (µSv h⁻¹) indicate that the soil covers of tailings Zapadnoe, Central Yar and Base C need to be re-engineered.
3.6 Impact on groundwater and surface water resources

Changes of α-activity of water in Konoplyanka Riv. along the flow path (2010)

U distribution in groundwater in the vicinity of Zapadnoe (2005)
3.7 Some potential remedial options for uranium tailings impoundments

One of key remedial issues is selection of management strategy for uranium mill tailings

**Remedial alternatives:**
- No action / MNA
- Conservation / stabilization in place / MNA
- Relocation to the single large tailing site (Dneprovskoe tailings)
- Tailings relocation to the engineered tailing site (Sukhachevskoe-2 tailings; 14 km distance)
- Tailings relocation to the former granite quarry (Trituzny Pit; wet remediation)
- Tailings material re-treatment (secondary U-extraction prior to remediation)

**Illustrative scheme for remedial options**
4.1 Development of safety assessment methodology for the remediation of uranium legacy sites (ENSURE-I & II)

• The specific task of ENSURE-I & II consisted in development of safety assessment methodology for UPLS (project leader R.Avila)

• Methodology is based on results of IAEA ISAM and EMRAS projects

• Methodology was implemented in a set of Ecolego simulation modules adapted for UPLS (NORMALYSA Tool)

• Screening dose calculations were carried out in ENSURE-I project

• Two Safety Assessment Cases analyzed in detail: (1) Zapadnoe Uranium tailings, and (2) Building no. 103 (ENSURE-II)

• The work is coordinated with IAEA MODARIA Project WG3 “NORM and legacy sites”
4.2 Safety assessment framework for uranium tailings

- Consist of seven interrelated steps
- Based on the IAEA ISAM methodology
- Specific issues considered (FEP lists)
- Improvement of assessment through iteration
4.3 Modeling tool: NORMALYSA simulator

NORMALYSA = NORM And Legacy Sites Assessment software tool is developed by IAEA (project leader R.Avila)

- Based on Ecolego 6
- User friendly
- Make assessments using existing model components (libraries)
- Flexible in conceptual and mathematical model formulation
- Capabilities for probabilistic simulation and sensitivity analyses
Main expose pathways are external gamma radiation and Rn-222 inhalation.

Maximal doses for **Workers** at the PChP site can reach 5-20 mSv a-1 (for conservative exposure scenarios).

In most of cases estimated doses to **Public** residing in surrounding areas are less then 0.01 mSv a-1.
4.5 Prioritization of different contaminated objects at the PChP Site

Identified high potential doses to workers within the site require establishing restriction for access to many locations, and carrying further site clean-up.
4.6 Summary of dose assessment results for Zapadnoe Tailings (ENSURE-II)

- Dose assessment results suggest that in case of Zapadnoe **optimization of remedial measures considering socio-economic circumstances and criteria** is appropriate.

- Excavation and re-disposal of waste will not solve groundwater contamination problem, as future U concentrations are dominated by past releases.

<table>
<thead>
<tr>
<th>Timeframe</th>
<th>Scenario</th>
<th>Exposed Individual</th>
<th>Max.dose, mSv/y</th>
<th>Important Pathways</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current situation</td>
<td>Reference</td>
<td>Member of public</td>
<td>8E-5</td>
<td>Rn dispersion</td>
</tr>
<tr>
<td>Current situation</td>
<td>Reference</td>
<td>Site Worker - Guard</td>
<td>0.59</td>
<td>Rn, external</td>
</tr>
<tr>
<td>Current situation</td>
<td>Reference</td>
<td>Site Worker – Barrier Staff</td>
<td>0.64</td>
<td>Rn, external</td>
</tr>
<tr>
<td>Long-term (&gt;300 y)</td>
<td>Reference</td>
<td>Private Resident</td>
<td>2.64</td>
<td>Vegetable consumption</td>
</tr>
<tr>
<td>Long-term (&gt;300 y)</td>
<td>Reference</td>
<td>On-Site Visitor</td>
<td>0.41</td>
<td>Rn, external</td>
</tr>
<tr>
<td>Long-term (&gt;300 y)</td>
<td>Faster Cover Degradation</td>
<td>Private Resident</td>
<td>3.0</td>
<td>Vegetable consumption</td>
</tr>
<tr>
<td>Long-term (&gt;300 y)</td>
<td>Climate Change</td>
<td>Private Resident</td>
<td>2.9</td>
<td>Vegetable consumption</td>
</tr>
<tr>
<td>Long-term (&gt;300 y)</td>
<td>Intrusion Scenario</td>
<td>Private Resident</td>
<td>19.5</td>
<td>Rn, external (indoors), Vegetable consumption</td>
</tr>
</tbody>
</table>
### 4.7 Dose assessment results for the Building no.103

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Receptor</th>
<th>Calculated Dose (mSv/a)</th>
<th>Main Pathway(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal Conditions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal Scenario 1</td>
<td>“Building 102” worker</td>
<td>1.6</td>
<td>Gamma, Radon</td>
</tr>
<tr>
<td>Normal Scenario 2</td>
<td>Characterization Worker</td>
<td>1.7</td>
<td>Gamma</td>
</tr>
<tr>
<td>Inside “Building 103”</td>
<td>D&amp;D Preparation</td>
<td>1 µSv/h – 1 mSv/h</td>
<td>Gamma</td>
</tr>
<tr>
<td><strong>Abnormal Conditions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal Scenario 1 - Strong Wind</td>
<td>“Building 102” Worker</td>
<td>0.041</td>
<td>Aerosols</td>
</tr>
<tr>
<td>Abnormal Scenario 2 - Tank Spill</td>
<td>PChP Worker (inside and outside)</td>
<td>0.1 to 1</td>
<td>Aerosols</td>
</tr>
<tr>
<td>Abnormal Scenario 3 - Intrusion</td>
<td>PChP Worker</td>
<td>1 - 2</td>
<td>Gamma</td>
</tr>
</tbody>
</table>

- Doses for workers of the adjacent enterprise SE “Smoly” (Building 102) for a number of “normal” and accidental scenarios appear to be relatively low
- Doses of remedial workers can be very high

**The most important project outcome is development of the methodology and toolbox for prospective remedial analyses**
4.8 Development of regulatory documents for remediation of uranium legacy sites

A Set of Generic Regulatory Documents and supporting guidelines developed by team of EC and UA experts in ENSURE-II project (draft version) (A.Buchnea, W.Goldammer, O.Voitsekhovitch, R.Avila)

Part 1. Principles and Criteria
Part 2. Development of Remediation Plans
Part 3. Development a Radiation Protection Program
Part 4. Site Characterization Principles
Part 5. Monitoring and Surveillance Programs Planning
Part 6. Safety Assessment
Part 7. Management of Remediation Wastes
Part 8. Site Management Qualification of Personnel and Training Requirements
Part 9. Application for a License to Remediate

This set of documents is now undergoing review and improvement in the frame of the national IAEA TC project

Development of the “Law on the status of the former uranium facilities Production Association "Pridneprovsky chemical plant“ is planned within the national program (2015)
5 Conclusions: Current status of remediation of the PChP site

- Comprehensive site monitoring program is in place
- Basic site characterization works are mostly completed
- Preliminary risk assessments carried out (assisted by international projects, e.g. ENSURE-I & II)
- Priorities for remediation are identified (imminent risks)
- A number of priority actions are implemented through national program
- Draft regulatory framework documents are developed (… and are currently finalized through national IAEA TC project)
- IAEA national TC project is launched aimed at improvement of site management, site operator capacity building, etc. (2014-2015)
- Development of integrated strategy and feasibility studies for priority objects are in progress, being assisted by EC INSC Project (2014-2015)