Application of Ecolego in assessments of risks from contaminated lands

Rodolfo Avila, Facilia
Outline

• Short presentation of Ecolego
• Examples of applications in NORM problems
• Overview of relevant IAEA TECDOC currently under development
Ecolego in a Nutshell

The development was supported by:

NRPA – Norwegian Radiation Protection Authority.

SSM – Swedish Radiation Safety Authority.
Ecolego - Simulation Modelling and Risk Assessment Software

Flexible software tool for creating dynamic models and performing deterministic or probabilistic simulations. Ecolego can be used for conducting risk assessments of complex dynamic systems evolving over time with any number of species. Ecolego has specialized databases and other add-ons designed for the field of radiological risk assessment.

Models are represented with the help of interaction matrices instead of the traditional flow diagrams.
User interface

Ecolego has a modern user interface, where the latest techniques for customization and user-friendliness have been applied. A wide array of windows is available to support the many different tasks in modeling.
Hierarchical models
Database of radionuclides and parameters
Simulations

Ecolego can handle everything from simple systems, to huge, stiff problems.

**Monte Carlo simulations**
With an impressive list of probability density functions (PDFs), together with Monte Carlo and Latin Hypercube sampling and parameter correlation settings, Ecolego has everything needed for advanced probabilistic analysis.

**Sensitivity analysis**
Rank correlation coefficients are available for tornado plots or correlation tables. These can be used to find the parameters in a model that influence results the most.

**Post-processing**
Simulation outputs can be re-evaluated using post-processing functions, without re-running simulations.
Ecolego Player

Ecolego Player is a free tool for running models created with Ecolego.

It allows for people not having Ecolego to perform simulations of any models created with Ecolego, including changing the parameter values etc.

The only restriction is that the structure of the model cannot be changed.
Summary

- Ecolego can be used for development of specialized models which. These can be used to set up Assessment Models applicable to specific situations.

- Once the models have been implemented in Ecolego, these can be distributed with the help of the Ecolego player.

- Model sets based on Ecolego have been developed in other projects:

  SAFRAN (IAEA project) - Safety Assessment Framework for Radioactive Waste Management and Decommissioning.

  2-FUN (EC project): Integrated model for assessment of risk from radionuclides and chemicals
Assessment of current doses from uranium tailings
Summary

Presentation of results derived from two main studies:

- **Swedish Radiation Protection Authority:** Assessment of Risks to Human Health and the Environment from Uranium Tailings in Ukraine - Phase 1 report. Facilia ENSURE Report: TR/SIUS/01.

- **IAEA:** Appendix: “Assessment of doses from exposures to elevated levels of natural radionuclides in areas close to uranium tailings in Tajikistan and Uzbekistan” of the IAEA Report: Safe Management of Residues from Former Mining and Milling Activities in Central Asia. *Regional Technical Cooperation Project RER/9/086.*
Investigated sites

Ukraine: Dniprodzerzhinsk
Tajikistan: Taboshar and Degmay
Uzbekistan: Charkesar

Contamination not spatially homogeneous with large variation of radionuclide levels in different areas within a given site.
Dniprodzerzhinsk Site, Ukraine

42 M tonnes

3,2 x 10^{15} Bq

258 000 inhabitants
Two sites in Tajikistan

Taboshar tailing site

Degmay tailings near Khudjand and Chkalovsk

7.6 M tonnes 12 000 inhabitants 20 M tonnes 16 000 GBq

salt covers with $^{238}\text{U}$ 10-20 Bq g$^{-1}$ 164 000 & 22 000 inhabitants
Mines and disposal areas near Charkesgar village, Uzbekistan

482 000 m³  $3 \times 10^{13}$ Bq  2,500 inhabitants
European data extracted from TREN report “Situation concerning uranium mine and mill tailings in an enlarged EU” (2006)
Methodology

Hazard identification

- Hazard 1
- Hazard 2
- Hazard 3 etc

Exposure pathways

- Quantify hazards

Identify exposed groups

Assess current dose rates to exposed groups

Use of models, dose rates/unit time, etc

Scenarios

Quantify risk
Identification of hazards

Monitoring:

• Gamma dose rates outside and inside of buildings

• Radionuclide concentrations
  – aerosols, soils and tailing materials
  – in water and food products (not at the Ukrainian site)

• Radon concentrations outside and inside buildings
## Identified hazards

<table>
<thead>
<tr>
<th>Location</th>
<th>Hazards</th>
</tr>
</thead>
</table>
| **Dniprodzerzhinsk** | • Workers on the site get the highest radiation doses  
• Elevated radionuclide and radiation levels:  
  a) inside and outside polluted buildings  
  b) Hot Spots in the forest  
  c) in the different tailing sites |
| **Taboshar**   | • Elevated radionuclide and radiation levels:  
  a) indoors and outdoors at settlement  
  b) at tailings, locals go and animals graze  
  c) at pits, locals visit and swim  
  d) in waters contaminated by tailings or/and pits |
| **Degmay**     | • External exposure to gamma radiation and radon  
• Elevated radionuclide and radiation levels:  
  a) in the Degmay settlement  
  b) at the uranium tailings  
  c) in ground waters (water from local wells) |
| **Charkesar**  | • Tailing materials used for house construction  
• Elevated radionuclide and radiation levels:  
  a) areas close to and away from the industrial site  
  b) at the industrial site  
  c) in water bodies, e.g. springs, mine waters, rivers |
Derivation of doses

To provide a basis for necessary exposure assessments at these sites, we used the methodology (and models) highlighted by the German Federal Ministry for the Environment (BMU), Nature Conservation and Reactor Safety (1999):

“Berechnungsgrundlagen zur Ermittlung der Strahlenexposition infolge bergbaubedingter Umweltradioaktivität (Berechnungsgrundlagen - Bergbau)”

[Assessment principles for estimation of radiation exposures resulting from mining-related radioactivity in the environment (Assessment principles for mining)]
Exposure pathways

- soil contamination for reference persons inside and outside buildings
- aerosols inside and outside buildings
- in, and exposure to, locally grown foodstuff (not yet included in the Ukraine project)
- exposure through the direct ingestion of soil
- inhalation of $^{222}\text{Rn}$ and its short lived progeny
Chosen radionuclides

1. $^{238}\text{U} \rightarrow ^{234}\text{U} \rightarrow ^{230}\text{Th} \rightarrow ^{226}\text{Ra} \rightarrow ^{210}\text{Po} \rightarrow ^{210}\text{Pb}$

2. $^{235}\text{U} \rightarrow ^{231}\text{Pa} \rightarrow ^{227}\text{Ac}$

3. $^{232}\text{Th} \rightarrow ^{228}\text{Ra} \rightarrow ^{228}\text{Th}$

This may lead to slight underestimation of these doses
Screening models placed in Ecolego
Comparison of doses between the four sites
Comparison of doses between all site categories
Example: current doses at Taboshar

Scenarios:

<table>
<thead>
<tr>
<th>Group</th>
<th>Exposure (hr/y) to different hazards</th>
<th>Fraction of annual consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outdoor at tailing</td>
<td>Outdoor at waste rock piles</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
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<td>3</td>
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<tr>
<td>4</td>
<td>1460</td>
<td>730</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1380</td>
</tr>
</tbody>
</table>
Dniprodzerzhinsk

Derived dose rates based on experimental data

- Ponds (near Tailing Central Yar)
- Tailing Central Yar
- Tailing Dniprovo skoye
- Tailing Zapadnoe
- Tailing Yugovostochnoye
- Hot Spots
- PChP North Part
- Inside polluted Building
- Outside polluted Building

- 20 mSv/y for Category A Worker
- 5 mSv/y for Category B Worker, i.e., staff from the Barrier Enterprise
- 1 mSv/y for public
Migration from the tailings

Conceptual model of radionuclide migration from the “D” tailings

Model compartments with initial contamination ($t_0 = 2000$)

Tailings impoundment

advection, $V$

dispersion, $D$

aquifer in alluvial deposits

Dnieper River

Infiltration

$H_t$

$h_a$

$L_t$

$La$
Prognoses for different remediation alternatives

Cumulative U flux from "D" tailings to Dnieper River for different scenarios

- Base case
- Conservative
- Soil screen
- Waste removal
Summary

A consistent approach to deriving doses to exposed groups of people to uranium tailing contaminants has been applied to four locations in Ukraine and Central Asia.

Dose rates can be calculated by identifying hazards and quantifying them based on exposure pathways.

This approach forms the basis for quantifying the risk of exposure to given groups of the population.

Test Cases based on these studies could be developed in the frame of the EMRAS WG 2
Mathematical Models for Assessing Remediation of Radioactively Contaminated Sites

IAEA TECDOC – under development

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• ASSESSMENT OF REMEDIATION SOLUTIONS
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Main transport pathways

- Atmospheric dispersion
- Source: Release, Deposition, Leaching
- Land Surface: Release, Deposition, Surface runoff, Irrigation
- Vadose: Leaching, Recharge
- Well: Abstraction
- Surface Water: Discharge
- Groundwater
- Contaminated Area
- Groundwater transport
- Receptor Location
# Processes influencing the radionuclide transport

<table>
<thead>
<tr>
<th>ATMOSP</th>
<th>Rainfall</th>
<th>Dry deposition</th>
<th>Gas uptake</th>
<th>Rainfall</th>
<th>Dry deposition</th>
<th>Gas uptake</th>
<th>Rainfall</th>
<th>Dry deposition</th>
<th>Gas uptake</th>
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<tbody>
<tr>
<td>Resuspension</td>
<td>Source</td>
<td>Percolation</td>
<td>Advection</td>
<td>Diffusion</td>
<td>Dispersion</td>
<td>Colloid transp.</td>
<td>Erosion</td>
<td>Surface runoff</td>
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</tbody>
</table>
Processes in the source, the vadose, the groundwater and the surface land compartments

<table>
<thead>
<tr>
<th>INPUT</th>
<th>AQUEOUS</th>
<th>Adsorption / Surface complexation Ion exchange</th>
<th>Precipitation</th>
<th>Volatilization Heterogeneous reaction Diffusion Decay (Rn, Tn)</th>
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<tbody>
<tr>
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<td>Desorption Ion exchange</td>
<td>SOLID</td>
<td>Co-precipitation</td>
<td>Decay (Rn, Tn)</td>
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<td>Dissolution</td>
<td>Co-precipitation</td>
<td>SUSPENDED</td>
<td>Decay (Rn, Tn)</td>
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<td>Condensation Diffusion Decay (Rn, Tn)</td>
<td>Decay (Rn, Tn)</td>
<td>Decay (Rn, Tn)</td>
<td>GASEOUS</td>
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<tr>
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<td></td>
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<td>MICROBES</td>
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<tr>
<td>OUTPUT</td>
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</tbody>
</table>
Summary

• The models described in the TECDOC could be used in this WG for selected study cases,

• The models could be implemented in a toolbox that could be made freely available to member states