STAR
STRATEGY FOR ALLIED RADIOECOLOGY

NORM Sites – Promising STAR Candidates for European Observatories for Radioecological Research

Martin Steiner

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Overview

- Concept of Radioecological Observatories
- Network of Excellence STAR
- Selection process of Radioecological Observatories
- Result of the selection process: Coal mining area in Upper Silesia
- Summary

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Radioecological Observatories

— What is a “Radioecological Observatory”?

- A contaminated field site that is **jointly used** for **coordinated long-term** field work by several research groups
- Innovative approach to maximize the efficacy of radioecological field investigations and to promote integration of the organizations involved
- Innovative aspects:
  - Jointly used
  - Coordinated
  - Long-term

Radioecological Observatories

— OECD/NEA clearly expressed the need:

"…environmental data collected over the last half century by the nuclear industry for surveillance purposes has not been utilised in an efficient, co-ordinated manner…. Therefore it is proposed that a useful development would be an international network that allowed researchers to coordinate and understand research in relevant fields. This "observatory" would be grounded on past and ongoing observations in the real environment and allow them to be linked with laboratory and theoretical developments."

Radioecological Observatories

— Highlights of this innovative concept:
  - Strong integrating component
    (for all research groups involved)
  - Efficient approach that will create synergistic effects
    (coordinated efforts, sharing of resources and data etc.)
  - Provides excellent training and education sites

— Within the project **STAR** the concept of Radioecological Observatories is currently being implemented on a European level for the first time.

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Network of Exellence STAR

— STAR (Strategy for Allied Radioecology):
  - EC-funded (FP7) Network of Excellence
  - Nine European organizations

Network of Exellence STAR

— Primary aims of STAR:

- To jointly address scientific and educational challenges related to assessing the impacts of radioactive substances on humans and the environment
- To develop and implement mechanisms to integrate radioecology in Europe
- To develop a long-term vision of radioecological research needed within Europe (**Strategic Research Agenda** in radioecology)

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Selection Process

— STAR selected the Radioecological Observatories in a structured, progressive approach that is transparent, consistent and objective to the greatest possible extent.

— STAR combined multi-criteria decision analysis (MCDA), group discussions and recommendations provided by invited external experts.

— STAR used multi-criteria decision analysis (MCDA)
  - To formalise and address the problem of competing decision objectives.
  - To determine a preference ordering among a number of suggested candidate sites.

— Ranking of candidate sites depends on how well they perform according to a list of criteria.

Major Steps of the Selection Process

1. Development of a list of selection criteria, including their classification as being mandatory (**exclusion criteria**) or not (**evaluation criteria**)
2. Selection of an appropriate method for MCDA
   - **Weighted linear average method**
   - Criteria weights calculated by applying a rank-based method (**rank-order centroid method**)
3. Preselection of the candidate sites based on the exclusion criteria
4. Application of the agreed method for MCDA
   - The overall score (multi-attribute value) of each candidate site indicates the degree to which the site complies with the list of criteria and produces a defensible ranking.

Selection Criteria

— Exclusion criteria:
  - Specific requirements for STAR

— Evaluation criteria (in total 18 criteria):
  - **Scientific issues**
  - Infrastructure aspects
  - Administrative/legal constraints
  - Financial considerations

Selection Criteria – Examples

- Example 1: Mixed contaminant site with a variety of radiation types and radionuclides, heavy metals and (persistent) organic contaminants
- Example 2: Chronic exposure situation for wildlife at low dose rates (ideally contamination gradient exceeding 10 µGy h^{-1} for vertebrates)
- NORM sites are promising candidates to meet **both** criteria:
  - Mixed contaminant exposure situation (NORM + non-radioactive co-contaminants)
  - Elevated dose rates for non-human biota
- Chernobyl exclusion zone: Contamination gradient with high maximum dose rates for non-human biota but no relevant amounts of non-radioactive pollutants

Weighted Linear Average Method

— Multi-attribute value (MAV):

$$MAV = \sum_{j=1}^{N} Z_j \cdot w_j$$

Z_j: absolute score of the option under criterion j
w_j: (normalised) weight for criterion j
N: number of criteria

— The higher the MAV, the better the performance of an option with respect to the criteria list.

Weighting Criteria

— Rank N criteria according to their importance, with criterion 1 being the most relevant one and criterion N the least relevant one.

— Rank-order centroid (ROC) weights:

$$w_j = \frac{1}{N} \cdot \sum_{n=j}^{N} \frac{1}{n}, \qquad j = 1, \ldots, N$$

w_j: weight for criterion j
N: number of criteria

Weighting Criteria

— Example: 3 criteria (N = 3)

$$w_1 = \frac{1}{3} \cdot \left(1 + \frac{1}{2} + \frac{1}{3}\right) = 0.611$$

$$w_2 = \frac{1}{3} \cdot \left(\quad \frac{1}{2} + \frac{1}{3}\right) = 0.278$$

$$w_3 = \frac{1}{3} \cdot \left(\qquad \frac{1}{3}\right) = 0.111$$

Weighting Criteria

— Selection criteria for Radioecological Observatories: 18 criteria (N = 18)

w_1 = 0.194
w_2 = 0.139
w_3 = 0.111
w_4 = 0.092
w_5 = 0.078
w_6 = 0.067
w_7 = 0.058
w_8 = 0.050
w_9 = 0.043
w_{10} = 0.037
w_{11} = 0.031
w_{12} = 0.026
w_{13} = 0.022
w_{14} = 0.017
w_{15} = 0.014
w_{16} = 0.010
w_{17} = 0.006
w_{18} = 0.003

— Weights drop rapidly with increasing rank:
  - Sum of top third: 0.682
  - Sum of lowest third: 0.072

— Against human intuition

— Scientific justification

Scoring the Candidate Sites

— Score a candidate site against the evaluation criteria using a scale from 0 to 5, where 0 denotes a complete lack of compliance and 5 indicates perfect compliance.

- Absolute scale:
  Not susceptible to the reversal of option ranks (potential technical problem with relative scales)
- Coarse scale:
  Reflects the confidence with which a decision maker is realistically able to rate the compliance of an option with a criterion

Practical Application – Recipe for Ranking the Candidate sites

— Ranking involves the following sequence:

- Generate criteria weights for the evaluation criteria.
- Preselect the candidate sites based on the exclusion criteria.
- Score the remaining candidate sites against the evaluation criteria.
- Calculate the multi-attribute value (MAV) for each candidate site, i.e. its overall performance.
- Rank the candidate sites according to their MAVs. The candidate site with the highest MAV performs best.

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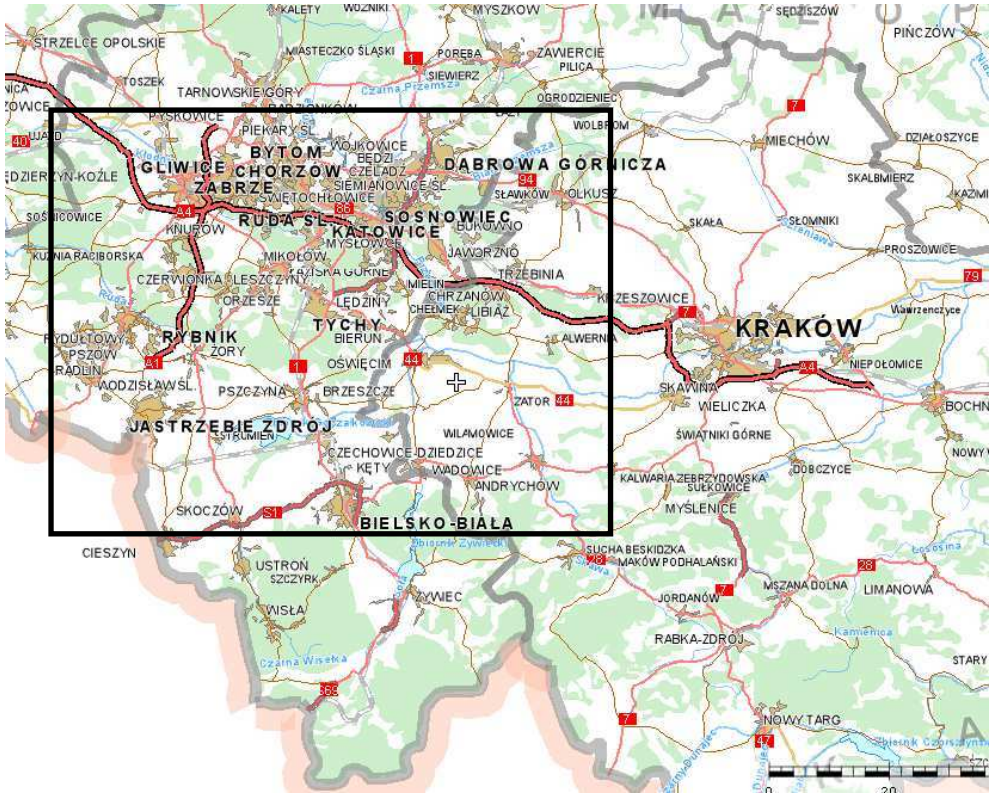
Coal Mining Area in Upper Silesia

— Key information (kindly provided by Boguslav Michalik, Central Mining Institute, Poland):

- The Upper Silesian Coal Basin is a post-industrial landscape that has been and still is heavily affected by coal production.
- Fifty underground hard coal mines are still in operation.
- The daily discharge of mine water into surface reservoirs exceeds 600,000 m^3.
- Currently, there are 25 settling ponds in use which contain in total 5,000,000 m^3 of sediment with enhanced levels of radium isotopes.

Coal Mining Area in Upper Silesia



All Upper Silesian sites for becoming Radioecological Observatories are located in the Silesian Voivodeship at distances of 60 km or less from Katowice (50°16'15.22" N; 19°1'35.47' E):

Coal Mining Area in Upper Silesia

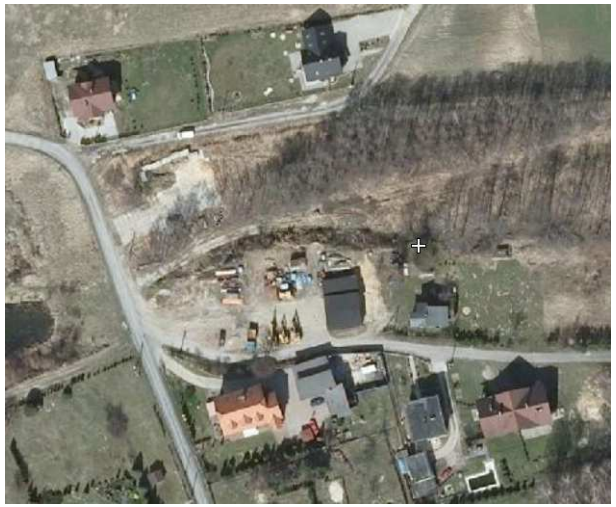
— Site #1:
Upper Vistula basin, a natural river affected by discharges of mine brines with high levels of radium.

— Site #2:
Former mine settling pond Rontok Wielki (surface area 32 ha), a natural pond that was adapted in the past as settling and retention pond for mine waters but is currently excluded from technological processes and filled with fresh water.

Coal Mining Area in Upper Silesia

— Site #3:
Mine settling pond Kaniów (surface area 4.5 ha), a semi-artificial pond that is currently used for clearing mine water from suspended matter and discharging saline waters into inland water in a controlled way.

— Site #4:
Former mine settling pond Bojszowy (surface area 16 ha). After technical land reclamation bottom sediments were covered with a layer of an inert material.



— Site #5:
County borough Świerklany, a residential area, arable land and wasteland contaminated due to the discharge of mine brines.

Radioactive Pollutants

— Radium isotopes dominate.

— Example: Former mine settling pond Rontok Wielki

- Radium levels of sediment:
  - up to 49,200 Bq kg^{-1} ^{226}Ra
  - up to 6,400 Bq kg^{-1} ^{228}Ra
- Dose rates for non-human biota:
  - up to 22 µGy h^{-1} for vertebrates living on the soil surface
  - up to 67 µGy h^{-1} for burrowing vertebrates
  - up to 69 µGy h^{-1} for the root system of plants
  - up to 36 µGy h^{-1} for the aerial parts of plants
- Screening value for generic ecosystems: 10 µGy h^{-1}

Non-radioactive Pollutants

— **Heavy metals** represent the dominant non-radioactive pollutants.

— Example: Heavy metals in sediment
  - Ba: up to 122,000 ppm
  - Pb: up to 830 ppm
  - Zn: up to 760 ppm
  - Cu: up to 270 ppm

— Additional contamination with **hydrocarbons** (engine oil, lubricants), since brines are often used as process water

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Summary

— Radioecological Observatories are an innovative approach to maximize the efficacy of radioecological field investigations and to promote integration of the organizations involved.

— STAR selected the Radioecological Observatories in a structured, progressive approach that is transparent, consistent and objective to the greatest possible extent.

— The selected coal mining area in Upper Silesia offers two advantages:
  - Mixed contaminant exposure situation
  - Elevated dose rates for non-human biota

STAR on the Internet

— Access STAR via the **Radioecology Exchange**:
https://wiki.ceh.ac.uk/display/star/The+Radioecology+Exchange

Thank you very much!