Steiner, Martin; Urso, Laura; Wichterey, Karin; Willrodt, Christine; Beresford, Nicholas A.; Howard, Brenda; Bradshaw, Clare; Stark, Karolina; Dowdall, Mark; Liland, Astrid; Eyrolle-Boyer, Frédérique; Guillevic, Jérôme; Hinton, Thomas; Gashchak, Sergey; Hutri, Kaisa-Leena; Ikäheimonen, Tarja; Muikku, Maarit; Outola, Iisa; Michalik, Bogusław; Mora, Juan Carlos; Real, Almudena; Robles, Beatriz; Oughton, Deborah; Salbu, Brit; Sweeck, Lieve; Yoschenko, Vasyl. 2014. **Radioecological observatories: breeding grounds for innovative research**. [Extented abstract] In: *3rd International Conference on Radioecology and Environmental Radioactivity, Barcelona, 7-12 Sept 2014*.

Radioecological Observatories – Breeding Grounds for Innovative Research

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INTRODUCTION

Within the EC-funded (FP7) Network of Excellence STAR (Strategy for Allied Radioecology, www.star-radioecology.org) 'Radioecological Observatories' are being established. Radioecological Observatories are radioactively (and chemically) contaminated field sites that will provide a focus for joint, long-term, radioecological research. The innovative aspects include the long-term perspective as well as the joint and coordinated efforts of several participating research groups. The benefit of this progressive approach is to create synergistic research collaborations by sharing expertise, ideas, data and resources. Research at the Radioecological Observatories will primarily focus on radioecological topics outlined in the Strategic Research Agenda (SRA) which presents the major challenges for radioecology over the next 20 years (www.radioecology-exchange.org). Mechanisms to use these sites will be established under the EC-funded project COMET (Coordination and Implementation of a Pan-European Instrument for Radioecology, www.comet-radioecology.org).

SELECTION PROCESS

The European Radioecological Observatory sites were selected using a structured, progressive approach that was transparent, consistent and objective. The aim was to maximize both the efficiency in selecting the optimum site and the degree of acceptance among the STAR partners. A first screening of potential candidate sites was conducted based on the following exclusion criteria: long-term perspective for shared field work and suitability for addressing the radioecological challenges of the SRA. The proposed sites included former uranium mining and milling sites in France and Germany, the Chernobyl Exclusion Zone (CEZ) in Ukraine and Belarus as well as the Upper Silesian Coal Basin (USCB) in Poland. All candidate sites were prioritized based on evaluation criteria which comprised scientific issues, available infrastructure, administrative/legal constraints and financial considerations. Multi-criteria decision analysis (MCDA), group discussions and recommendations provided by external experts were combined to obtain a preference order among the suggested sites. MCDA is an important tool in environmental decision making for formalizing and addressing the problem of competing decision objectives.

Using this approach, the USCB and the CEZ were selected as the Radioecological Observatories. The two sites perform equally well with respect to the list of evaluation criteria and complement each other scientifically. The Polish coal mining area represents a mixed contaminant situation with moderate dose rates to wildlife. The CEZ offers a contamination gradient with high maximum dose rates to wildlife. Significant amounts of non-radioactive pollutants, however, are absent. The enlarged COMET consortium includes organizations that have a long experience in the selected Radioecological Observatories, thus maximizing the efficiency of hypothesis-based field investigations.

CHARACTERISTICS OF THE SELECTED OBSERVATORY SITES

Upper Silesian Coal Basin

The USCB is a post-industrial landscape that has been heavily contaminated by coal mining activities. About fifty underground hard coal mines are still in operation. The daily discharge of mine waters 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 and heavy metals. The Radioecological Observatory in the USCB comprises five different sites:

- Site #1: Upper Vistula river, a natural river which is affected by the continuous discharge of mine brines with high activity levels of radium over a length of about 60 km.
- 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. It is currently excluded from technological processes and filled with freshwater.
- Site #3: Mine settling pond Kaniów (surface area 4.5 ha), an artificial pond that is currently used for clearing mine waters from suspended matter and discharging saline waters into the Vistula river in a controlled way.
- Site #4: Former natural pond Bojszowy (surface area 16 ha) which was used as mine settling pond for more than 20 years. After technical land reclamation, radium-rich bottom sediments were covered with a layer of an inert material.

- Site #5: Country borough Świerklany where a residential area, arable land and wasteland is contaminated by radium over a length of about 2 km along the former stream bed.

All sites are located in the Silesian Upland in southern Poland within 60 km of Katowice. The Silesian Upland is a plateau with heights between 200 and 300 m, divided into distinct ridges by river valleys. It is a highly industrialized region with a high population density and includes a large part of the Upper Silesian coal field. The largest river in the area of the Polish Observatory sites is the Vistula river. The annual average flow rate is 53 $m^3 s^{-1}$ at Kraków, 60 km downstream from the last mine water discharge point.

The climate at the Polish Observatory sites is characteristic of the transition zone between a temperate oceanic and a temperate continental climate. There are typically cold, cloudy, moderately severe winters with frequent precipitation and mild summers with frequent showers and thundershowers.

Radium isotopes and heavy metals originating from mine waters pumped to the surface lead to a mixed contaminant situation. The most important radionuclides are the radium isotopes ^{228}Ra and ^{226}Ra as well as ^{228}Th, ^{222}Rn, ^{210}Pb and ^{210}Po. Usually, the decay chains start with ^{226}Ra and ^{228}Ra, respectively, precipitated from water and deposited in bottom sediments. Radium levels in the sediments of the former mine settling pond Rontok Wielki, for example, amount up to 49,200 Bq kg^{-1} for ^{226}Ra and up to 6,400 Bq kg^{-1} for ^{228}Ra. Highly mineralised formation water is also the source of heavy metal contamination. Heavy metal concentrations in sediments of settling ponds of 10 different coal mines reach 122,000 ppm for Ba, 830 ppm for Pb, 760 ppm for Zn and 270 ppm for Cu. Despite the high mineralization the saline mine waters are often used for technological purposes, resulting in additional contamination with hydrocarbons used as engine oil and lubricants.

The Polish Observatory sites comprise flowing, semi-stagnant and stagnant waters as well as terrestrial ecosystems. Fish are the dominant vertebrate species in the aquatic ecosystems. Nineteen fish species, for example, have been reported in the upper Vistula upstream of Kraków. Vertebrates are absent in the mine settling pond Kaniów. At the former mine settling pond Bojszowy only small rodents and amphibians form resident populations of vertebrate species. The following ICRP reference animals and plants, as defined in ICRP Publication 108, are present in the terrestrial ecosystems: rat, pine tree, bee, frog, earthworm, wild grass and deer.

The weighted absorbed whole-body dose rates to the default reference organisms of the ERICA Tool may exceed the default screening level of 10 $\mu Gy h^{-1}$. At the Kaniów site, for example, potential weighted absorbed dose rates to vertebrates of approximately 30 $\mu Gy h^{-1}$ and above were calculated from the activity concentrations in soil near the pond bank.

Chernobyl Exclusion Zone

The CEZ is one of the most radioactively contaminated sites in the world. Established shortly after the accident in 1986, the CEZ was initially the area within the 30-km radius around the Chernobyl Nuclear Power Plant. Over the last 25 years the borders have expanded. The predominantly rural woodland and marshland area covers an area of approximately 2,600 km^2 in Ukraine and 2,160 km^2 in Belarus.

The area is relatively flat (~ 100-200 m above sea level) plain. The Pripyat River, a main tributary of the Dnieper, runs through the CEZ for about 80 km. Spring flows of the Pripyat River typically have discharges of 800 to 2,200 $m^3 s^{-1}$, with maximum rates exceeding 5,000 $m^3 s^{-1}$.

The climate at Chernobyl is temperate-continental. The growing period starts around mid-April and ends in late October. Snow cover remains for about 80 days, with significant deviations in some years.

The most important radionuclides include long-lived ^{137}Cs, ^{90}Sr, plutonium isotopes, ^{241}Am and uranium isotopes, originally present as particles from submicrons to fragments. A key characteristic of the CEZ is the extremely heterogeneous contamination pattern that offers contamination gradients with high maximum dose rates. The CEZ also provides opportunities to study other longer-lived radionuclides released by the accident including ^{99}Tc, ^{14}C and ^{129}I, which have received relatively little attention in the exclusion zone. Appreciable amounts of non-radioactive pollutants are absent.

The Ukrainian portion contains forests, abandoned farmlands, wetlands, flowing waters, standing waters, deserted villages and urban areas. The Belarusian portion is a land of swamps, marshes and peat-bogs. Here, forest land occupies about one half of the territory. Areas not covered with forest are mostly former reclaimed agricultural lands and meadows.

The CEZ is rich in species. More than 400 species of vertebrate animals, including 67 ichthyoids, 11 amphibians, 7 reptilians, 251 birds and 73 mammals inhabit the vicinity of the CEZ. More than fifty of them belong to a list of protected species according to national Ukrainian and European Red Books. Species falling within the taxonomic families of all terrestrial and freshwater reference animals and plants, as defined in ICRP Publication 108, are present in the CEZ.

Estimated weighted absorbed whole-body dose rates to terrestrial reference organisms as calculated using the ERICA Tool exceed 400 μGy h^{-1} for large mammals (deer) and 1,400 μGy h^{-1} for reptiles. Consequently, the CEZ is expected to provide the opportunity to study long-term effects of ionising radiation on populations of wildlife.

CONCLUSIONS

The complementary characteristics of both European Radioecological Observatories represent an excellent starting point to investigate a broad range of radioecological challenges prioritized in the SRA. Within the Initial Research Activity the COMET consortium focuses on improving the parameterisation of key processes controlling the transfer of radionuclides in terrestrial and aquatic systems, with specific emphasis on dynamic modelling approaches. The Radioecological Observatories will hopefully act as a focal point for scientists from other research groups and disciplines, stimulating them to join the EC Network.

ACKNOWLEDGEMENT

This work has been supported by the European Commission under the 7th Framework Programme through the Network of Excellence STAR (Strategy for Allied Radioecology), grant agreement no. 269672.