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Infrastructure: databases, sample banks, methods and facilities for radioecological research

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Executive Summary

The overarching goal of STAR Work Package 2 "Integration and Infrastructure" is to facilitate the long term sustainable integration of European radioecological research, with an appropriate governance structure. To ensure effective collaboration and integration, an inventory of infrastructure covering radioanalytical equipment and methods, bioinformatic equipment and methods, sample archives, models, expertise and facilities for radioecological research has been created (using an on-line wiki pages). The infrastructure survey shows that STAR partners and the associated Alliance have a high-quality infrastructure, extended expertise and competence for radioecological research in Europe.

STAR partners have expertise in wide-ranging areas of radioecology, encompassing the atmospheric dispersion, dosimetry, ecology, ecotoxicology, environmental radiation protection, environmental surveillance, foodstuffs, terrestrial, freshwater and marine radioecology, modelling, radiobiology and radionuclide analytics, emergency preparedness, education and training. Within STAR partners have more than 170 experts are covering these areas.

A wide-ranging expertise is available within STAR partners for radioanalytical methods. Many of the methods are accredited emphasising the remarkably high quality of the partner laboratories. There are also many different holistic bioinformatic equipment and platforms for molecular and biochemical analysisto study (radiation) effects endpoints in Europe.

The STAR NoE is highly resourced. The large inventory of specialized facilities and research equipment highlights the ability of the STAR network to perform high-quality radioecological research. The facilities comprise different kinds of laboratories, such as rooms for: pre-treatment of samples, specially constructed experimental systems for radioecological and biological studies and measurement, specialized equipment for radioactivity measurements, radiochemical and biological treatment of samples and organisms.

The STAR NoE also holds a large variety of samples from the terrestrial and aquatic environment, and samples from a variety of air samplers collected by a various methods. These samples can be analysed systematically in future to address help address scientific questions in a cost effective manner (e.g. to improve parameter values within WP3 or help meet research requirements outlined in the STAR Strategic Research Agenda see www.star-radioecology.org). The partners have collected samples during environmental surveillance programmes, within research projects and as a service for customers. Some of the archived samples were collected as early as the 1910s, but most are more recent. Some institutes do not have sample archives of their own, but their samples have been archived elsewhere.

Amongst the STAR partners, expertise covers at least 40 different models for radioecological purposes. These covers many challenging fields in area of radioecology like radionuclides atmospheric dispersion, deposition and transport of radioactivity in the aquatic and terrestrial environment. The models are used for calculations of the dose rates, activity concentrations and assessment of risk from ionising radiation. Some of the models are also used for calculating stability diagrams, the equilibrium states, for transport of multiple components, mixed equilibrium and kinetic biogeochemical reactions, as well as various groundwater flow systems, which are designed to simulate aquifer systems. The focus of the models is on human and biota impact assessment. STAR partners are often both users and developers of the models.

The SWOT analysis of the STAR infrastructure survey indicated many strengths and opportunities. Most of the strengths are related to integration, knowing and understanding the perspectives of each partner, a wide range of equipment, methods, analytical capacities, and expertise available for common research. This information could also be used for coordination and integration in response to emergencies. In the future, the potential of the infrastructure database is for training and to explore the potential for collaboration between STAR/ALLIANCE and other research organisations, international organizations (e.g. IAEA) and other platforms (NERIS, HERCA, MELODY). The infrastructure database also requires further development, in particular the need for maintenance and updating. The data in the infrastructure wiki pages must be real time.

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1 Objectives and Scope

The overarching goal of the STAR Work Package 2 "Integration and Infrastructure" is to facilitate the long term sustainable integration of European radioecological research, with an appropriate governance structure. This will ensure an efficient and effective integration of resources and capacities at a European level, and lead to the establishment of a true European Research Area in the field of radioecology. The network partners bring together not only radioecology but also leading expertise in biology, ecotoxicology, ecology, radiobiology and modelling. Their wide breadth of expertise will facilitate the acknowledged requirement for greater integration of these research areas, enabling the development of improved conceptual and numerical models for increased protection of the environment and humans. The STAR NoE will initiate integration processes and establish mechanisms to ensure long term sustainability under the Radioecology ALLIANCE (http://www.er-alliance.org/).

To achieve this role, several specific objectives/tasks are being pursued within WP2:

1. Produce a long term Strategic Research Agenda (task 2.1)
2. Produce an inventory of infrastructure including databases and sample archives (task 2.2)
3. Create a virtual laboratory (task 2.3)
4. Produce a plan of long term integration (2.4)
5. Create a European Observatory Site for radioecological research (task 2.5)

This Deliverable deals with the second objective, to produce an inventory of infrastructure including databases and sample archives. The task will help ensure effective collaboration and integration between the partners, with the possibility to enlarge to other radioecology institutes in Europe and worldwide.

The main goals of the task 2.2 were:

1. Survey the radioanalytical methods, laboratory procedures, field methods and general protocols used by the STAR partners and identify best practices to create guidance for laboratories.
2. Create a catalogue of databases held by the STAR partners.
3. Create a catalogue of sample archives held by the STAR partners. The partners have various sample archives accumulated through research and monitoring schemes.
4. Assess inventory of current and planned infrastructure for their appropriateness to meet the radioecological research needs of STAR and later the ALLIANCE.
5. Develop a strategy to best meet these needs with the existing and planned new facilities in an integrated way by joint use of infrastructure and development of new infrastructure.

2 Introduction

Design of the infrastructure survey was started at the Infrastructure workshop in March 2011 in Saint Maximin la Sainte Baume, France. The goal of the workshop was to define which issues should be considered when carrying out the survey. The participants were divided into four groups, and each discussed one of the following topics: 1) facilities, equipment and methods 2) models, 3) databases, sample archives, 4) bioinformatic tools. Each group discussed the purpose of the questionnaire and how expertise and publications should be considered in the questionnaire.

The **facilities, methods and equipments** group discussed the extent of information needed.. They concluded that the compilation of information needed to be comprehensive, for example the equipment would include also instruments used for other physical or chemical parameters that are relevant for studies concerning radioactivity. The **bioinformatic tools group** considered biological methods for assessing biological effects. The **models** group noted that the list of model types (radioecological, risk assessment, human doses, other) should focus on the endpoint of the model (concentration in media, dose, risk quotient, other). The next level should then divide the dose and risk quotient into human and non-human. The survey must be divided into model ”users” and ”developers”. The ”users” section should be concise, and confined to the name of the model, level of skill and field of application. In the **databases and sample archives group**, the members decided to make the process simple, such as by asking each partner to write one page free description about the sample archives. The **expertise** group discussed the importance of all participants knowing what the other partners can do. Therefore, it is important to have web pages describing the members' competencies, such as each partner preparing a one page description of their expertise related to the radioecology. The group also needs to know the availability of grey literature by each participant, and the availability of other databases. Grey literature is an important resource and constitutes a pooled knowledge bank. However, it was not decided how to survey this resource (although a request has been made for each partner to make on-line publication lists available via the Radioecology Exchange) and EURATOM project outputs are being collated by WP7.

The important points for consideration in the design of the infrastructure were agreed to be:

1. Within the STAR Network, to facilitate integration and to share an inventory of knowledge.
2. To avoid overlapping efforts and thus increase efficiency.
3. To exploit synergistic interfaces.
4. To serve as a resource for education and knowledge transfer.
5. To advance increasing the participation and collaboration in the ALLIANCE.
6. To maintain the dynamic inventory which serves as a structure for further integration.
7. The inventory serves to higlight gaps and weaknesses and directs the future efforts and the functions related to the Strategic Research Agenda.

The infrastructure database was constructed in a wiki form. CIEMAT and NERC made the template pages on the description of the questionnaire, e.g. click box/open text box, functionality etc. and then STUK and UMB tested the template pages using existing data. After the testing period, the other STAR partners started to fill in their own data. The main page of the infrastructure database is presented in figure 1.

Figure 1. The main page of the STAR infrastructure database.

The SWOT analysis for the infrastructure survey was performed after receiving all data from the partners. The SWOT analysis was used to assess strengths, weaknesses, potentials, and threats of the infrastructure catalogue.

3 Use of the infrastructure survey

The intended use of the infrastructure survey was to identify what assets we already have and where we have to improve for integration among the ALLIANCE – STAR partners, i.e. to identify the current lack of know-how among the STAR/ALLIANCE partners. Equally, we also have to compare expertise with other countries and to list models and expertise availability. The infrastructure catalogue was considered to be a useful tool for partners to search for skills the other partners might have, particularly those skills not normally associated with radiation measurements. And if integration is to take place among the STAR/ALLIANCE members, the database will help to locate possible overlap, as well as needs.

The connections of infrastructure to the ALLIANCE were discussed by the partners and it was concluded that the infrastructure database is:

- a step towards integration, and integration is a goal of the ALLIANCE
- useful for potential new ALLIANCE partners in both directions (new partners will know our capabilities and we can identify which capabilities are missing within the STAR/ALLIANCE)
- a useful tool for training and mobility (i.e. by identifying where one partner can send staff to be trained by another partner)
- a useful tool for research collaboration
- a useful tool for emergency preparedness

The potential end-users of the infrastructure database were considered and identified as follows:

- Experts
- STAR partners
- Partners in ALLIANCE
- Platforms like NERIS, HERCA, MELODY, IGTP
- International organisations, e.g. IAEA
- The European Commission
- Authorities (Local, Regional, National)
- Media
- Students: high school, university (parts of the infrastructure), PhD (complete infrastructure).

The content and use of the infrastructure will be further evaluated and improved in the task 2.4. In the evaluation process, needs arising from SRA will be taken into account as well as integration of European radioecological research.

4 Summary of the infrastructure

Detailed data from each organisation is presented in the Appendix of this deliverable and on the wiki pages (https://wiki.ceh.ac.uk/display/smi/Home).

4.1 *Facilities and equipment*

The laboratories of the STAR partners operate in several European countries (Belgium, France, Finland, Germany, Norway, UK, Spain and Sweden). The mission of each laboratory is defined in the strategy of the relevant institute. The expertise, facilities and equipment used in the institute has been built up to support the institute's strategy. These facilities are used in research, environmental monitoring, emergency preparedness and to provide services for customers.

The facility and equipment part of the survey covered a wide range to achieve the research goals of STAR/Alliance. Laboratory facilities and equipment are an important part of radioecological research and represents basic elements of our combined infrastructure. All STAR-partners have together an impressive array of highly specialized laboratory equipment, essential to perform high-quality radioecological research. Modern analysis techniques cover a multidisciplinary area going from radionuclide measurement techniques such as gamma spectrometers, alpha detectors, proportional counters and liquid scintillation spectrometers over classical chromatographic and spectrometric techniques for ion and stable element detection to highly specialized biological measurement techniques.

Within the area of radionuclide measurement techniques, the availability of high purity germanium detectors makes it possible to accurately perform reliable environmental and whole-body measurements. Many important radionuclides emit gamma-rays with suitable energies allowing quantitative determination of the radionuclides by high resolution gamma spectrometry. High-quality alpha detectors make it possible to analyse alpha active isotopes, like polonium, plutonium, americium, etc. at extremely low activity levels. Liquid scintillation counters, mostly used for the detection of alpha and beta-emitting radionuclides, are useful tools for routine low level environmental measurements, security screening and accidental preparedness applications.

Also classical chromatographic (e.g. ion chromatography, high performance liquid chromatography) and spectrometric (e.g. atomic absorption spectrometry, atomic emission spectrometry, mass spectrometry) techniques find their application within radioecological research by quantitatively and qualitatively determining ions and stable elements in several environmental and biological matrices. When for example determining the nutritional or elemental composition of growth media, environmental water samples, plant material, etc. these techniques are indispensable.

To perform high quality research, studying the effects of radionuclides and radiation on different levels such as genetic, molecular, cellular, individual and populational for model organism such as *C. elegans*, *D. magna*, *L. minor*, *A. thaliana*, Salmon, etc., specialized equipment is available. For example to study radiation-induced effects on genetic level a complete genomic platform including a DNA chip spotter, analyzer and scanner, a hybridization station, a slide booster, etc. is available. Endpoints on molecular level can be analyzed using (real-time) PCR systems, fluori- and photometers, Western blotting equipment, electrophoresis systems, proteomics equipment, etc. Also to measure other endpoints, STAR members are well equipped with flow cytometers, various types of microscopes, a chlorophyll fluorescence measurement system, etc.

In addition to the above described equipment, other specialized facilities such as mobile laboratories, air-sampling and monitoring systems, radon track-edge laboratories, automated ambient dose rate measurements, radon calibration rooms, different kind of exposure facilities etc. are also available within the STAR partners.

These large inventories of specialized facilities and research equipment, are summarized in tables 1 and 2, highlights the ability of the STAR network to perform high-quality radioecological research.

Table 1. Summary of the facilities relevant to radioecology in the partner institutes.

Institute	Facility in the partner
BfS	Calibration of radon-222 and short-lived progenies measuring devices, whole body counting, automated ambient dose rate measurements, in-situ measurements (mobile laboratory), gamma dose rate probe inter-calibration and air sampling (monitoring immission and emissions).
CIEMAT	Chemical characterizations, in-situ measurements (mobile laboratory), supercomputation, facility to measure radioactivity on different environment compartments and to perform internal and external dosimetry of humans.
IRSN	Studying radionuclides availability, transfer and migration, transfer experiments on organisms and internal radiation experiments on organisms.
NERC	Facilities for studying availability, transfer and migration, chemical characterization, sample processing and transfer on organisms.
NRPA	Radiochemistry laboratories alpha/beta, whole body counting, low-background gamma counting laboratory, isotopic laboratory type C, radon track-edge laboratory, radon calibration room, low-background whole body counting laboratory and mobile laboratory (including whole body counter).
SCK-CEN	Anthropogammametry, alpha measurements and spectrometry, beta measurements, gamma measurements, chemical and radiochemical analyses, laboratory for high and medium activity, deep geological disposal, environmental measurements, internal radiation on organisms, external radiation on organisms, cell culture and animal models, plant culture, availability, transfer and migration.
STUK	External radiation experiments, in-situ measurements (mobile laboratory), whole body counting, alpha particle irradiation, automated airborne radionuclide sampler, radon track-edge laboratory and radon calibration room
SU	Studying radionuclides availability, transfer and migration, internal radiation experiments on organisms and external radiation experiments on organisms.
UMB	Radiochemistry laboratories alpha/beta, gamma counting laboratory,transfer experiments on organisms, external radiation experiments on organisms and in-situ measurements (mobile laboratory).

All together, the STAR partners have:

- Over 150 gamma spectrometers. These can be used for detection of gamma emitting radionuclides in all kinds of samples. Most of the institutes have high resolution spectrometers for gamma spectrometry.
- Over 270 alpha detectors. These are used for detection of low level alpha active elements after radiochemical separation.
- Nearly 50 liquid scintillation spectrometers and 30 proportional counter systems, which are used mainly for detection of alpha and beta active elements directly or after radiochemical separation.
- Over 10 spectrometers for stable elements and isotopic measurements e.g. noble gas, AAS, TIMS, AES and conventional ICP-MS equipments.
- Four tritium and carbon analysers.
- Over 50 equipments for biological, molecular and chromosome analysis, such as applied biosystem equipment, a full system for analysis of affymetrix chips, TEMEDX, SIMS, ASS, autoradiography, flow cytometry, immunohistochemistry, fluorimetry etc..
- 5 human whole-body *in-vivo* measurement systems

Table 2. Summary of the equipment used in STAR partners for radioecological and biological research.

Institute	Equipment used in the partner
BfS	29 high-resolution gamma spectrometers, 14 alpha measurement devices, 9 liquid scintillation spectrometers, 12 proportional counter systems, 5 in-vivo measurements, one radiation biology equipment and 2 atomic absorption spectrometers.
CIEMAT	11 high-resolution gamma spectrometers, one high-resolution low energy gamma spectrometry, 24 alpha measurement devices, 3 liquid scintillation spectrometers, 3 proportional counter systems and 8 solid scintillation counters.
IRSN	5 High resolution gamma spectrometers (in-situ), 20 high resolution gamma spectrometers (standard), 17 high resolution gamma spectrometries (low level), 4 high resolution gamma spectrometers (ultra low level), 122 alpha measurement devices, 20 liquid scintillation spectrometers, 10 proportional counter systems, two tritium and carbon analysers, one He3 Mass Spectrometer (Tritium analyser), one C14 AMS, six ICP-MS, one particle and non-destructive analysis, one transmission electron microscope, one flow cytometer.
NERC	9 high-resolution gamma spectrometers, 8 alpha measurement devices, one liquid scintillation spectrometer, one autogamma, one tritium and carbon analyser, and an accredited environmental chemistry laboratory including ICP-MS and ICP-OES.
NRPA	15 High-resolution gamma spectrometers, 14 alpha measurement devices, 2 liquid scintillation spectrometers, 2 proportional counter systems, 3 In-vivo measurements, 1 mobile laboratory, 5 air sampling and monitoring systems.
SCK-CEN	53 alpha measurement devices, 10 beta measurement devices, one gamma measurement device, 13 gamma-ray spectrometers, 5 spectrometers, 6 neutron activation analysers, various types of dosimeters, one specific plant analysing device, 8 types of equipment needed for the genomic platform, 17 types of

	equipment within molecular biology (such as genomic platform, RT-PCR, flowcytometers), 7 types of equipment within cell biology and biochemistry, several microgravity simulation devices, 4 chromatographic devices and different types of microscopes, SEM, TEM.
STUK	14 high-resolution gamma spectrometers, 40 alpha measurement devices, 6 liquid scintillation spectrometers, 3 proportional counter systems, one equipment for particle and non-destructive analysis, 40 NaI(Tl) gamma spectrometries, one tritium and carbon analyser, one PCR Detection System, one proteomics facility, one microscope network for chromosome analysis, one radiation biology equipment, one microwave burning-in oven, one atomic absorption spectrometry.
SU	Two liquid scintillation spectrometers.
UMB	4 high-resolution gamma spectrometers, one NaI detector, 6 alpha measurement devices, 2 liquid scintillation spectrometers, one mobile laboratory, one equipment for particle and non-destructive analysis.

4.2 Methods

The laboratory survey indicates that a wide-ranging expertise in the area of radionuclide determination methods can be found within the STAR partners. Expertise covers analysis methods for natural radionuclides like U-238 and Th-232 series radionuclides, artificial radionuclides like Pu, Am, Sr, Tc, as well as methods for nutrient and ion concentration determinations. All together STAR partners have also a strong expertise in case of emergency preparedness (extensive know-how in advanced gamma spectrometric analysis and rapid radiochemical analysis methods), which supports integration between STAR partners. Most of the analysis methods are either evaluated or accredited by an external evaluator, which shows the remarkably high quality of the laboratories.

Radiochemistry involves the application of the basic facts of inorganic, organic, physical and analytical chemistry. Conventional analytical techniques generally operate at the ppm or higher levels, but the most sensitive techniques are capable of measuring concentrations at the part per trillion levels, which makes radiochemistry a very unique technique. One of the unique features of radiochemical analysis is that high yields are not necessarily needed and non-isotopic carriers are used in the analysis. In radiochemistry the emphasis is put more on radioactive purity.

The wide-ranging expertise in radionuclide methods is important because knowledge of radionuclide migration in the environment, use of models and risk assessment is largely based on results of quantitative and accurate radioactivity measurements. In the future, the need for knowledge of effects caused by exposure to low doses especially for living organisms is increasing as well as the use of verified models. These issues have specific requirements for infrastructure and quality management in laboratories.

A summary of the analysis methods used for radionuclide and other isotope analyses is given in tables 3 and 4. Table 5 summarizes the expertise in the area of environmental sampling which is accredited at SCK-CEN, CIEMAT, NERC and STUK.

Table 3. Summary of the radiochemical analysis methods used in various partners.

Analysis method	BfS	CIEMAT	IRSN	NERC	NRPA	SCK-CEN	SU	STUK	UMB
Advanced gamma spectrometric analysis	x	x	x	x	x	x		x	x
Strontium analysis Sr-90, Sr-89	x	x	x			x		x	x
Plutonium analysis Pu-238, Pu-239+240	x	x	x	x		x		x	x
Americium analysis Am-241	x	x		x	x	x		x	
Tritium analysis H-3	x	x	x			x		x	x
Uranium analysis U-234, U-235, U-238	x	x	x		x	x		x	x
Thorium analysis Th-228, Th-230, Th-232	x	x	x		x	x		x	
Polonium analysis Po-210	x	x	x		x	x		x	x
Lead analysis Pb-210	x	x	x		x	x		x	x
Gross alpha and beta analysis	x	x	x		x	x		x	x
Radium analysis Ra-226, Ra-228	x				x	x		x	
Radon analysis Rn-222, Rn-220	x				x			x	
Carbon 14 analysis	x	x	x			x	x	x	x
Technetium analysis Tc-99	x			x	x	x		x	x
Iodine analysis I-131	x	x				x			

Table 4. Summary of other analysis methods used in various partners.

Analysis method	BfS	CIEMAT	IRSN	NERC	NRPA	SCK-CEN	SU	STUK	UMB
Nutrient analysis						x	x		
General beta analysis	x					x			
Neutron Activation analysis						x			x
Element concentration	x					x			x
Ion concentration analysis	x					x			
Advanced stable isotope analysis	x					x	x		x

Table 5. Summary of expertise in environmental sampling for radiological studies.

Institute	Expertise in area of environmental sampling	Accredited
BfS	Terrestrial, Aquatic, Air and deposition, Bioassay	No
CIEMAT	Terrestrial, Aquatic, Air and deposition, Bioassay	Yes
IRSN	Terrestrial, Aquatic, Air and deposition, Bioassay	No
NERC	Terrestrial, Aquatic	Yes
NRPA	Air and deposition	No
SCK-CEN	Terrestrial, Aquatic, Air and deposition, Bioassay	Yes
STUK	Terrestrial, Aquatic, Air and deposition, Bioassay	Yes
SU	Terrestrial, Aquatic, Bioassay	No
UMB	Terrestrial, Aquatic, Air and deposition, Bioassay	No

4.3 Bioinformatic equipment and methods

To fulfil specific objectives within two of the key research themes within STAR "radiation protection in a mixed contaminant context" and "ecologically relevant low dose effects", specialized bioinformatics equipment and methods are indispensable.

Bioinformatics applies computer science and information technology in the field of biology and medicine. Common activities in bioinformatics include mapping and analysing DNA and protein sequences, aligning different DNA and protein sequences to compare them and creating and viewing 3-D models of protein structures. Bioinformatic tools are created aiming to develop methods for the analysis and integration of omics (genomics, transcriptomics, proteomics, and metabolomics).

To assess the impact of mixed contaminant conditions on radiation induced effects and improve the understanding of underlying molecular mechanisms and processes and identification of the molecular target site of the contaminants, focused molecular analyses will be performed. To understand how radiosensitivity at the molecular and individual levels mechanistically links to impacts on individuals and populations and to understand how dose-characteristics influence the biological efficiency of radiological damage by identifying the metabolic pathways that produce individual trait disturbances, a combination of a more holistic approach using omics tools with a specific endpoint/biomarker approach will be used within STAR.

Within the questionnaire, bioinformatics equipment has been classified into two classes: "holistic-equipment" and "methods for specific endpoints". Holistic equipment is classified into “omics types” and "observations at the (sub)-individual level". Under the methods for specific endpoints are the level of biological organisation and the type of end points that are possible to study within STAR partners. A summary of the bioinformatics equipment and methods used are listed in table 6.

From the summary in table 6 it is clear that a major platform is available within STAR partners to perform high quality mechanistic research on multiple levels of biological organisation (genetic, molecular, cellular, tissue/organ, individual, population). Specific endpoints such as oxidative stress related responses (ROS, enzymes, metabolites, etc.), genotoxic, cytotoxic and neurotoxic endpoints (flow cytometry, gamma-H2AX, DNAPK, etc.), immune responses, energetic, metabolism and physiological parameters (respiration, mitochondrial activity, photosynthesis, etc.), etc., can be measured by the STAR partners for various aquatic (such as unicellular algae, invertebrates, fish, aquatic plants, etc.) and terrestrial (nematodes, plants, etc.) biological models.

The platform also offers the possibility to combine several omics tools such as transcriptomics, proteomics, metabolomics, etc. with associated bioinformatics tools to investigate radiotoxicity response mechanisms in a holistic manner. Specialized equipment for microscopy ((epi)fluorescence microscope, transmission electronic microscope, etc.), cell measurements (flow cytometer, etc.), in situ element microlocation (TEMEDX, SIMS, autoradiography, etc.) and separative speciation (HPLC coupled to ICP-MS, etc.) makes it possible to combine previously described mechanistic responses with responses on (sub)-individual level.

As each STAR partner contributes to the platform with its own specific expertise (as is clear from the appendix and summary in table 6), a high level of integration by training and exchange of bioinformatics equipment and methods is ensured.

Table 6. Summary of bioinformatic equipment and methods used by STAR partners.

Institute	Holistic-equipment		Methods for specific endpoints	
	Omics types	Observations at the (sub)-individual level	Level of biological organisation	Type of end points
BfS	-	Microscopy	Cellular	-
CIEMAT	-	-	-	-
IRSN	Associated bioinformatics	Microscopy, Cell measurements, In-situ element microlocation, separative speciation	-	Oxidative stress, Genotoxicity, Cytotoxicity, Metal detox, Immune response, Endocrine disruption, Reproductive endpoints, Neurotoxicity, Energetics/metabolism/physiological parameters, Growth and development, Behavioural effects, exposure
NERC	Transcriptomics, Metabolomics, Genetic diversity Associated bioinformatics	-	-	Immune response, reproductive endpoints, reproductive endpoints, behavioural effects
NRPA	-	-	-	-
SCK-CEN	Transcriptomics, Microarrays Genetic diversity Associated bioinformatics	Microscopy, Cell measurements, In-situ element microlocation, separative speciation	Molecular, Cellular, Tissue/organ, Individual	Oxidative stress, Genotoxicity, Cytotoxicity, Metal detox, Immune response, Endocrine disruption, Reproductive endpoints, Neurotoxicity, Energetics/metabolism/physiological parameters, Growth and development, Behavioral effects, Exposure.
STUK	Proteomics, Genetic diversity, Associated bioinformatics	Microscopy, Cell measurements	Molecular, Cellular Tissue/organ	-
SU	Proteomics Microarrays Genetic diversity	Microscopy, Cell measurements	-	-
UMB	Proteomics, Microarrays, Transcriptomics, Bioinformatics	Microscopy, Cell measurements, In-situ element microlocation, separative speciation	Molecular, Cellular Tissue/organ	Oxidative stress, Genotoxicity, Cytotoxicity, Metal detox, Immune response, Reproductive endpoints, Metabolism/physiological parameters, Growth and development, Behavioural effects, exposure

4.4 *Sample archives*

The STAR NoE also holds a large variety of samples from terrestrial and aquatic environment, and samples from a variety of air samplers collected by various methods. Sample archives contain unique samples e.g. samples at the beginning of 1900, samples before and after the Tschernobyl accident and samples where many long-term time series has been analysed. These are very valuable for radioecological studies in the future e.g for missing information. These samples can also be analysed systematically in the future to help address scientific questions in a cost effective manner (e.g. to improve parameter values within WP3 or to help meet research requirements outlined in the STAR Strategic Research Agenda see www.star-radioecology.org).

STAR partners have collected sample archives from analysed samples during environmental surveillance, in research projects and as a service for customers. Some of the archived samples have been collected starting as early as in the 1910s, whereas some are more recent. Some institutes do not have sample archives of their own, but the samples have been archived in other places or by another institute.

Table 7 summarizes the main sample classes of the archived samples, more detailed information from samples can be found on the infrastructure pages.

Table 7. Summary of the sample archives at various partners.

Institute	Sample classes of archived samples	Collected
BfS	Terrestrial, aquatic, human and air samples, industrial and food products	From 1913
CIEMAT	Terrestrial, aquatic, human and air samples, industrial and food products	From 1960
IRSN	Aquatic and air samples	From 1960
NRPA	The samples stored at the NRPA are not organised in any sort of sample archive or database. Therefore, it is not possible to get an overview of all the samples they have in storage, but it includes a wide variety of samples.	-
NERC	Terrestrial samples from radioeclogical studies (other archives maintained by CEH for other areas of research)	From mid-1980
SCK-CEN	Terrestrial samples (soils)	-
STUK	Terrestrial, aquatic and air samples, industrial and food products.	From 1963
SU	Stockholm University does not have any sample archives. However, the Swedish Museum of Natural History has an environmental sample bank of 270000 samples, mainly from fish, birds and mammals, collected from 1964 onwards. These are the basis for much of the museum's research on environmental contaminants and for monitoring of environmental contaminants in Sweden.	From 1964
UMB	Terrestrial, aquatic, human and air samples, industrial and food products.	From 1950

4.5 Models

Among STAR partners there is expertise in using at least 40 different models (table 8). These cover many challenging fields in the area of radioecology like radionuclides atmospheric dispersion, deposition and transport of radioactivity in the aquatic and terrestrial environment. Models are used for calculations of the dose rates, activity concentrations, assessment of risk from ionising radiation and the coupled radiation transport of photons, electrons and positrons. Some of the sophisticated models are also used for calculating stability diagrams, the equilibrium states, transport of multiple components, mixed equilibrium and kinetic biogeochemical reactions, as well as various groundwater flow systems, which are designed to simulate aquifer systems.

These conceptual models try to qualitatively simplify the complex phenomena occurring in the environment using mathematical models, which try to quantify different endpoints as accurately as possible. Models include interaction matrices which organize the different features, events and processes occurring from the presence of a radionuclide in the biosphere to the interaction with different organisms, including humans. Mathematical models aim to quantify simple qualitative models to give outputs such as concentrations, doses or risks which can be used for several purposes, one of which is protection of the environment.

Wide knowledge using different models is essential since models yield important information for decision makers e.g. in nuclear emergency situations. Models are necessary tools for dispersion of radioactivity, assessment and mitigation of radiological consequences due to radioactive contamination of large areas. For example, in case of a nuclear accident, the Real-time On-line Decision Support system for off-site emergency management (RODOS) provides consistent and comprehensive information on the present and future radiological situation, the extent and the benefits and drawbacks of emergency actions and countermeasures, and methodological support for taking decisions on emergency response strategies. The system is designed for enabling a seamless transition between local/regional/national/European/global scales, early and later phases of an accident and all types of emergency actions and countermeasures. To that purpose, models and databases can be customized to different site and plant characteristics and to the geographical, climatic and environmental variations. Other models provide basic tools for data acquisition, data management, data analysis, data visualisation and the preparation of reports.

Table 8. Summary of the models used and/or developed by STAR partners.

Institute	Models used in institute	User / developer
BfS	HYDRUS-1D, PENELOPE, RODOS, PARK ERICA, ARTM-DARTM, LASAIR	User and developer for Rodos, Park, Artm-Dartm and Lasair. User for ERICA, Hydrus-1D and Penelope.
CIEMAT	CROM, AMBER, RESRAD, JRODOS, ERICA-TOOL, HOTSPOT, MCNP	User and developer for CROM and ERICA. User for the other.
IRSN	ERICA, EDEN, Symbiose, DEBTox, Leslie Matrices	User and developer for ERICA, EDEN and Symbiose. User for DEBTox and Leslie.
NRPA	ERICA, ARGOS, Fasterlite, Arctic-marine	User and developer for ERICA. Developer for

		Fasterlite and Arctic-marine.
NERC	ERICA,PC-CREAM, RESRAD-BIOTA, EA R&D128, WHAM7	User and developer for ERICA and WHAM7. User for the others.
SCK-CEN	Biosphere, BRENDA, ERICA, Geochemical workbench, HP1, Hydrus (1D, 2D-3D), Mike11, Modflow, MT3DMS, Noodplan Kempen, Doel, Tihange, Partek Genomics Suite, Porflow, RODOS, SWAT, WestiGauss	User and developer for Biosphere, BRENDA, Geochemical workbench, HP1, Noodplan Kempen, RODOS, SWAT, WestiGauss. User for ERICA, Hydrus, Mike11, Modflow, MT3DMS, Partek Genomics Suite, Porflow.
STUK	JRodos, KETALE, ERICA, HOTSPOT	User and developer for KETALE. User for JRodos and ERICA and HOTSPOT.
SU	TADPOLE, ERICA tool, RESRAD-Biota, Coastal ecosystem models	User and developer for TADPOLE and Coastal ecosystem models. User for RESRAD-Biota and ERICA.
UMB	ERICA tool, Atmospheric transport simulation	User of ERICA tool and ATS

4.6 Expertise

For effective cooperation, it is important that all participants know what competencies the others have. This information is, however, difficult to achieve by a conventional questionnaire. Therefore, it was agreed that the best way to compile the information was to populate a web page describing the competencies of the members. The partners made a survey of their resources and expertise in areas that include atmospheric dispersion, dosimetry, ecology, ecotoxicology, education and training, emergency preparedness, environmental radiation protection, environmental surveillance, foodstuffs, freshwater radioecology, marine radioecology, modelling, radiobiology, radionuclide analytics, radon risk assessment and terrestrial radioecology.

The survey of expertise indicated that all STAR partners together have over 170 experts covering these areas (table 9). The numbers of experts presented in table 9 are not comparable since people have completed the survey in different ways, some focussing on those relevant involved in STAR and some listed all experts in the area of radioecology.

Table 9. Summary of the expertise at various partners in Europe. In some partners, the number of experts given indicates only the heads of laboratories or heads of laboratory sections. Therefore, the total number of experts is larger than presented here.

Institute	Expertise in the institute	Number of experts
BfS	Education and training, environmental protection, environmental surveillance, foodstuffs; radionuclide analytics, radon, emergency preparedness, quality assurance, terrestrial radioecology, dosimetry, atmospheric dispersion, modelling, freshwater radioecology, radiobiology, risk assessment	46
CIEMAT	Atmospheric dispersion, dosimetry, emergency preparedness, modelling, risk assessment, ecology, environmental radiation protection, foodstuffs, radon, education and training, radionuclide analytics, radiobiology, environmental surveillance	8
IRSN	Atmospheric dispersion, modelling, dosimetry, risk assessment, marine radioecology, terrestrial radioecology, ecotoxicology, risk assessment, emergency preparedness, freshwater radioecology, radiobiology, radionuclide analytics, risk assessment, radon	37
NERC	Education and training, emergency preparedness, environmental radiation protection, foodstuffs, modelling risk assessment, terrestrial radioecology, radon, radionuclide analytics, ecotoxicology	7
NRPA	Radionuclide analytics, environmental surveillance, marine radioecology, terrestrial radioecology, radon	8
SCK-CEN	Atmospheric dispersion, dosimetry, radon, modelling, emergency preparedness, marine radioecology, radionuclide analytics, terrestrial radioecology, radiobiology, environmental surveillance, risk assessment, freshwater radioecology, environmental radiation protection, ecotoxicology, education and training	17 (heads)
STUK	Atmospheric dispersion, dosimetry, radon, modelling, emergency preparedness, marine radioecology, radionuclide analytics, terrestrial radioecology, radiobiology, environmental surveillance, foodstuffs, risk assessment, freshwater radioecology, environmental radiation protection	32
SU	Ecology, ecotoxicology, education and training, freshwater radioecology, marine radioecology, modelling, risk assessment	5
UMB	Atmospheric dispersion, ecology, ecotoxicology, education and training, environmental surveillance, foodstuffs, freshwater radioecology, marine radioecology, risk assessment, emergency preparedness, environmental radiation protection, radionuclide analytics, terrestrial radioecology, radiobiology	6

4.7 Data holding

The data holding pages are a 'self-contained' site to enable the collation of data holdings that the individual STAR partners want to make available via the Radioecology Exchange or to the STAR consortium. Given initial difficulties of some STAR partners in determining if they could make data available a deadline of 31st August 2012 has been set for an initial completion of this task. The entries will then be reviewed together with WP7 to decide on how to best proceed. However, there is already a link to most metadata entries on the Spatial Gateway – an on-line data and/or metadata catalogue which is compliant with the INSPIRE Directive. Not all partners have elected to make metadata available via this route. In table 10, a summary of the data holdings currently provided by the partners are presented. The data holdings will be added to and resultant output on the Radioecology Exchange maintained throughout the STAR project.

Table 10. Summary of the data holdings at various institutes.

Institute	Dataset
BfS	Fungi monitoring data
CIEMAT	-
IRSN	Milk monitoring data, permanent observatories of environmental radioactivity data, rivers monitoring data, teleray data, waste water monitoring data
NERC	Fukushima monitoring data, natural radionuclide concentrations in England and Wales, Exposure of burrowing mammals to Rn-222, Dataset for ICRP RAPs collected from a forest ecosystem, Post Chernobyl surveys.
NRPA	Milk monitoring in grazing animals, mushroom monitoring data
SCK-CEN	Environmental monitoring data
STUK	Air monitoring, Baltic Sea monitoring, cereals, deposition monitoring, foodstuffs monitoring, freshwater fish, Fukushima monitoring, groundwater monitoring, milk monitoring, moose, mushroom, reindeer, river water monitoring, timber
SU	Aquatic ecosystem element dataset
UMB	-

5 SWOT analysis of infrastructure

SWOT analysis is a valuable tool assessing strengths, weaknesses, opportunities and threats. SWOT analysis is a very simple process that can offer powerful insights into the potential and critical issues affecting, in this case, our infrastructure. A SWOT analysis for infrastructure was carried out during the workshop held in Madrid in spring 2012. The results of this SWOT analysis are presented in table 11.

5.1 Questions in SWOT analysis

Strengths include the positive attributes of the infrastructure for the European Radioecology Alliance, including knowledge, expertise, update to date, contacts etc.. Strengths capture the positive aspects in infrastructure that add value or offer a competitive advantage.

Questions that were considered:

- Where have we succeeded during the construction of the infrastructure?
- What resources do we have?
- What advantages does the infrastructure provide?

Weaknesses
Note the weaknesses within the infrastructure which might include lack of expertise, limited resources, lack of access to skills or technology etc. These are factors that are under our control, but for a variety of reasons, need to be improved to effectively exploit the infrastructure.

Questions which were considered:

- Which areas need to be improved?
- What actions should be avoided?
- How does real-time data and updating work in the infrastructure? Who operates and how?
- Usability of the infrastructure - is the information easily found? (queries)

Opportunities
Opportunities assess the external factors that represent the reason for the STAR infrastructure. Opportunities may arise from the number of new users of the infrastructure and new organizations in the Alliance and are external to our current work. If we have identified “opportunities” which are internal in the organization and within your control, they may actually be strengths.

Questions that were considered:

- What useful opportunities exist in the infrastructure you hope to benefit from? Useful opportunities related to our field can emerge from aspects such as technological developments and markets and developments in radioecology.
- What interest is there in infrastructure?

A useful approach when looking at opportunities is to look at our strengths and ask ourselves whether these open up any (new) opportunities.

Threats
Threats include factors that could replace our infrastructure. A threat can be a challenge created by a development that may lead to deteriorating use of infrastructure. It is also valuable to classify threats according to their “seriousness” and “probability of occurrence.”

Questions that were considered:

- What factors are potential threats to infrastructure? Are their competitors?
- What situations might threaten the use of infrastructure?
- Does changing technology threaten the infrastructure?

5.2 Summary of the SWOT analysis

The SWOT analysis of the infrastructure database indicated that it has a lot of strengths and opportunities. Most of the strengths involve integration, knowing each partner; details of our expertise, wide range of equipments, methods, analytical capacities, and expertise available for high quality radioecological research. This information can also be used for coordination and integration in response to emergencies, especially if equipment breaks down in that there is then more likelihood of backup from other partners. The infrastructure catalogue is now on-line (for STAR partners), it is easy to update and has handy search functions. It is readily available to any current STAR member and covers more than radioecology, extending to ecotoxicology, ecology and toxicology.

In the future, the potential of the infrastructure database is to show stakeholders our capabilities, use information in training and standardisation of methods (where appropriate) between the institutes, and collaborations with other partners, other platforms (e.g. NERIS, HERCA, MELODI) and international organisations (e.g. IAEA).

The infrastructure database also needs maintenance and updating. The data in the infrastructure database must be real time if they are to be of value in the future. One of the current weaknesses is the variable quality and quantity of the data and the approach to the entry of information. The inputs into the infrastructure databases are also linked to the structure and ‘politics’ of each STAR partner. The other weakness is that the infrastructure catalogue is now open for STAR partners but only small teams are currently involved in the project.

The threats are linked to the use of the infrastructure database. What will happen if the database is not updated or used? Also conflicts with national policy about availability of data and internal politics of different organisation are possible.

Table 11. The SWOT analysis of STAR infrastructure database.

Strengths	Weaknesses
- On-line - Details our expertise, knowing each partner - Readily available to any current STAR member - Easy to update - Easy to see on one website, no need to go to individual partner websites - Covers more than radioecology, such as ecotoxicology, ecology, toxicology - Could be used to meet INSPIRE directive to make publiccally funded data - Coordination and integration towards emergency situations - Coordination and integration towards remediation situations - Wide range of equipment, methods, analytical capacities, and expertise available for radioecological research - It facilitates stakeholders by showing our capabilities. - Helps identify best practices between the institutes if appropriate - Useful in training	- Variable quality, quantity and approach to entry of information - Linked to structure and politics of each STAR partner - For some ALLIANCE partners, the infrastructure is only the structure of the small teams currently involved in the STAR project. A more comprehensive list could be included - Who will maintain/operate/administer it? - What will be the motivation to keep it up to date? - Communication with partners should go via a central lab or key person, many people within each organisation are not aware of STAR or the infrastructure database - Some aspects of the infrastructure database are currently weaker than others - Not easy to use at all points (searching the data, infrastructure map)
Opportunities	**Threats**
- Identifies backup if your equipment breaks down. This could be expressed in proposals for funding agencies to give confidence that the work will get done - Stronger contribution to international organisations (e.g. IAEA) - Opportunities are constrained by how restricted the document is (i.e. to STAR partners). - Data may be useful for purposes not originally intended - Possibility to find partners for future collaborations - Training - Mobility - Defines good practices - Identify infrastructure gaps	- Will not be updated - Will not be used - Conflict with the national/institutional policy about availability of data - Hosted by one organisation - Institutes do not want to give their data for public - If partner input is unbalanced, represents a threat to integration - Internal politics of organisation

6 Appendix: Data of the infrastructure