Terms of Reference for Radioecology WG

Title and acronym:

Human Food Chain

Topical area

The Working Group activities aim to improve radioecological models used in (decision support systems) DSS in Europe, including the inclusion of agricultural practice/production and dietary habit data for different regions. This should lead to improved recommendations of remedial actions and their consequences. In part some of the activities of the WG were initiated, but largely not carried forward, in earlier EC projects (e.g. SAVE, STRATEGY). The WG will learn from the Fukushima and Chernobyl accidents.

The revised ICRP Recommendations state that model predictions should be able to assess the first year dose to humans from all exposure pathways. One important pathway over this time is through the human food chain. The Terrestrial Food Chain and Dose Module (FDMT) as used in Europe within both the ARGOS and RODOS DSS to predict doses from ingestion. One of the deficiencies in FDMT as currently implemented, is the fact that most default parameters (based on German values) may not be appropriate for other regions in Europe.

The focus of the working group over the first 5 years will be the consideration of post-accidental situations in both the short and longer-term. As such the WG will try to learn from studies in Japan following the Fukushima accident (i.e. were there unexpected pathways, how well did models parameterised for European systems work, what parameters/information were lacking in trying to respond to contaminated foodstuffs) and also put these into context with lessons learnt in Europe following the Chernobyl accident.

Were relevant radionuclides associated with, for instance, waste disposal will also be considered. The WG will consider all terrestrial (focussing on agricultural) and freshwater foodstuffs. The WG will not consider NORM radionuclides, nor food products from forest or marine ecosystems as these areas all have dedicated WGs.

Our objectives will be achieved through a combination of experimental/field studies and modelling (sensitivity analyses, testing and improvement). Key strength of the ALLIANCE in being able to achieve this are our wide-ranging expertise, facilities, databases and experience. A number of research topics will be initiated through PhD studentship and our work plan will consequently also contribute to future capacity building. Where appropriate we will align our activities with those of the IAEAs MODARIA follow-on programme to maximise resources, relevance and impact.

Some of the activities discussed below are already on-going/planned in individual member institutes (other key activities are not on-going nor has funding been identified to achieve them), a challenge for the ALLIANCE will be to co-ordinate research activities in a focussed manner and to broaden participation in key research areas.

Leadership

Nick Beresford (NERC-CEH, UK)

Starting date and estimated duration of the WG to accomplish its plan

Starting date: September 1, 2015

Duration of the WG: 5 years

Intended activities (task, approach, steps to accomplish, expected outcomes)

Task 1 Mechanistic and dynamic transfer studies

Process based models of Cs in soil-plant systems have been developed previously (e.g. Tarsitano et al. *J. Environ. Radioact*., 102, 262-9 (which presents an update of the 'Absalom' model)). Using available data on soil properties such models can make spatially explicit predictions of transfer and should be a key tool in post-accident planning. However, studies in Japan following the Fukushima accident are suggesting the underlying models developed in Europe are not optimised to make predictions for all soil types. The further development and testing of such models for Cs, and other radionuclides which may be important following an accident (e.g. ^{90}Sr), should provide a much improved predictive capability, both of radionuclide transfer and also the effects of remediation measures (especially those such as K or Ca fertilisation). Key in the development of process-based models is not to over-parameterise them but to identify, through experimentation and model testing, the key process which need to be parameterised.

A research focus in the next 5 years will be on gaining an understanding of radionuclides (predominantly Cs and Sr) dynamic behaviour in soils (including interaction with water (pore water, vertical leaching to groundwater, horizontal erosion and runoff)), plant uptake (soil-solution-root interface including root exudates and the influence of soil micro-organisms) and deposition (dry/wet deposit, aerosols, plant interception). The overall aim is to identify and characterise key parameters/processes which explain the current high degree of variability in radiological parameters (e.g. K_d, CR). This will reduce uncertainty in parameters used to dynamically describe the transfer of radionuclides between the soil, the soil solution and the roots system of plants and ultimately predicted dose rates to human consumers. This will enable us to propose and develop alternative models that take into account dynamic processes (e.g. chemical speciation, organic matter degradation, sorption/desorption, root uptake and bioavailability). The experimental research will utilize two complementary approaches (a biology-based approach and a chemically-based approach) combining laboratory studies with field experiments including in Europe and areas of Japan and Ukraine impacted by the Fukushima and Chernobyl accidents respectively. We will try to establish why the European models have not worked well in Japan and also utilize this knowledge to improve predictions for European systems.

In addition to the above soil-plant focused studies we will also attempt to identify the K transporters involved in Cs absorption/translocation within plants. We hope to consequently determine the influence of the chemical composition of soil solution (competition with ions, e.g. potassium) on radiocaesium uptake and translocation in plants.

In recent years processes of interception, retention and translocation of radionuclides in plants has been largely unstudied and our models rely upon relatively old parameter values. The Fukushima accident raised question on these issues (e.g. what was the process of contamination of fruit in the

first year after the accident). We will conduct experiments, via a PhD project, to investigate these processes for Cs and I (and also Se and Th).

Other studies will utilise members' expertise and on-going programmes to investigate:

- the long-term dynamics of ^{99}Tc, Pu and Am transfer from different soils to crops (studies in the CEZ;
- the long-term behaviour ^{137}Cs and ^{90}Sr in human food chains including investigation of peat soils used as pastures (such pastures continue to be a 'problem' in fSU countries impacted by Chernobyl) and sampling in a number of countries to investigate the derivation of regionally appropriate transfer parameters (such studies could also provide validation data for any process based models developed);
- the application of ionomics/stoichiometry/phylogeny to determine if data for well studied elements can be used to make predictions of radionuclides to a wide range of food and forage crops
- the applicability of catchment modelling to predict radionuclides in drinking waters (pilot study in Norway).

In addition to radionuclides likely to be released by nuclear accidents we will also consider some key radionuclides associated with radioactive waste: I, Se, U and Cl. Activities will include:

- testing of processed based models (Pérez-Sánchez &Thorne) of ^{79}Se and ^{238}U-series in soil-plant systems.

Expected outcome**:** *Improved knowledge of key process determining radionuclide transfer leading to the development of process-based models which should be more widely applicable than existing approaches.*

Task 2 Development of regional parameters

Radioecological modelling is an integral part of advanced European DSS (such as ARGOS and RODOS) for nuclear emergencies. The transfer of radionuclides in food-chain depends on regional characteristics, for instance, agricultural practices and human consumption habits. However, such factors are usually ignored in the current DSS (many being based on southern German data). To allow adaptation of the DSS to local conditions, so called 'radioecological regions' need to be defined and model parameters derived for these. Task 2 of this road map seeks to do this; the activity will in part be started through work package 3 of the COMET project and the EURATOM HARMONE project (due to begin autumn 2015). Required data will be collated from national sources as well as European and FAO statistical data sources. All European areas from Fennoscandia to the Mediterranean will be considered; ALLIANCE members involved in this task have a good geographical spread to enable its success.

Specific soil properties also significantly impact on the transfer of radionuclides, in particular for radiocaesium. In general, highly organic peaty soils with low levels of caesium-fixing clay minerals (e.g. illite), low potassium levels and high concentration of ammonium tend to have higher transfer of caesium to plants than many other types of soil. Studies under Task 1 will develop models taking into account such soil properties and the outputs of this work will be considered here for inclusion in DSS as regionally applicable transfer parameters. Some studies specifically to determine regional specific transfers will also be conducted (see Task 1).

Expected outcome**:** *Improved prediction of the radionuclide transfer through the human food chain to humans on a regional basis and an enhanced ability to plan and predict the effect of remediation measures.*

Task 3 Remediation measures

A key activity of this task should be to evaluate the remediation measures used following the Fukushima accident and compare lessons learnt with those from the Chernobyl accident to better inform post-accident planning and identify future research needs.

The process based models developed above should be able to predict the impact of soil based countermeasures such as K^+ application or liming. However, such predictions would require experimental validation.

A potential remediation measure previously suggested but rejected from inclusion in handbooks (such as those developed by the EURANOS project) was the exploitation of inter-varietal variation in radionuclide uptake to replace a variety of a given crop with an alternative variety with a lower radionuclide uptake. This was rejected previously because of a lack of evidence that the approach was feasible. However, recently a meta-analyses of the available data has shown that this approach may be practicable as considerable variation in Cs and Sr uptake exists between varieties of the same crop (Penrose et al. *J. Environ. Radioact*., **139** (2015) 103-117). We will investigate the inter-varietal variation in crop and forage plants to determine if it is possible to select "safe plants".

We will also screen a collection of soil bacteria for their ability to accumulate Sr and/or Cs, and proteins will be engineered to optimize their affinity and selectivity for Sr and/or Cs with the longer term goal of investigating these strains for bioremediation.

Expected outcome**:** *An improved remediation measures 'toolbox' for Europe.*

Task 4 Improvement of models and Bayesian statistics

The data obtained in previous Tasks, will feed into the improvement of DSS. It is hoped that through participation in programmes such as the IAEAs replacement to the MODARIA programme we will be able to test (and improve) the DSS developed and also widely communicate our activities to increase their impact.

Bayesian statistics

In recent years, the use of probabilistic modelling has generated a substantial interest in deriving more robust parameter values for modelling purposes. In particular, Bayesian methods offer modellers and decision-makers options when faced with a lack of knowledge and data.

The Bayesian Theorem provides a method for modification of probability in the light of new evidence. It allows for both prior knowledge (e.g. generic data) and site-or study specific empirical data to be used. In a food dose assessment model, the use of Bayesian networks could aid the separation of uncertainty and variability in model parameters. Linked to this, the second task will explore how Bayesian statistics can improve the parameterisation of models. Bayesian statistics will be used to estimate probability distributions of transfer parameters and it will also address how we can pool site-specific and generic data. This work has been initiated under the COMET project.

Expected outcome**:** *Improved parameterisation of models*

Expected problems, gaps/lack of knowledge, etc. that might prevent the accomplishment of the research

Lack of funding, where this is not already in place, and an unwillingness to co-ordinate research activities are likely problems which will need to be overcome if this WG is to be successful.

Partners with a brief description of their assigned role

Partner	Specific interest or contribution
BfS	Provide information on national agricultural practices and dietary habits.
CEA	Mechanistic analysis of radionuclides bioavailability, transfer and/or accumulation in plants, and soil bacteria and algae. Speciation of the radionuclides both in soils and in vivo. Acquire the experimental data necessary for parameterisation of the key processes controlling the transfer of radionuclides. Identification of the transporters involved in the uptake and translocation of radionuclides (Cs) in plants. Determine radionuclide interaction with protein targets leading to accumulation or sequestration, optimization of chelating proteins or peptides (Sr, Cs) for biodetection or remediation.
NERC-CEH	Evaluation of post Fukushima situation including countermeasures. Contribute data from animal studies to IRSN modelling activities. Assessment of varietal variation on forage grass & crop plant uptake (on-going PhD studentship). Testing of SAVE-'Absalom' (or as revised the 'Tarsitano') model (requires funding). Potentially develop alternative models for transfer (under TREE project – progress depends on outcomes of initial plant studies). Could contribute to the provision of regional parameter values as have previously co-ordinated EURATOM projects on this topic (currently no funding for this activity).
CIEMAT	Task 1 Mechanistic and dynamic transfer studies • Understanding and improve alternative dynamic model in soil-plant systems taking into account process of interaction with water (pore water, vertical leaching to groundwater, horizontal erosion and runoff), plant uptake (soil-solution-root interface including root exudates and the influence of soil micro-organisms) and deposition (dry/wet deposit, aerosols, plant interception). • Application of dynamic model to specific radionuclides (Se, U, I, Cl) taking into account the soil properties related to Spanish climate class and regional transfer parameters. • Consider spatial and temporal variability of parameter in process based model as support to identify, through model testing, the key process which need to be parameterised. The activities will include: the development of a semi-mechanistic model for I and Cl; testing of processed based models of 79Se and 238U-series in soil-plant systems. Task 2 Development of regional parameters • Review, update and define regional parameters and characteristics (climate and other regional settings), mainly for the called Mediterranean radiecological regions, but also in another regions in the Iberian peninsula, that will be improved with the knowledge and descriptions of the most representative climate (Cr, Cs, Bs, Bh) and ecosystem (ex. Atlantic, Mediterranean, Steppe) in Spain.
GIG	Minor contribution to the WG – Sr and Cs transfer to agricultural products. Assessment of committed dose taking into account regional customisation of agricultural practices, food production and dietary habit data for different European regions (including specific minorities) – this will be conducted in collaboration with work under the NORM TG.

HMGU	Define regional parameters for human food chain models. Transfer of radionuclides to soil, freshwater and plants by snow and snow melt.
IRSN	Laboratory experiments are ongoing to identify the factors influencing bioavailability for plants and their subsequent translocation fluxes (using Arabidopsis and ryegrass as a plant models). The objective is to determine the role of the chemical composition of the soil and soil solution, bacterial activities, root architecture, organic acid root exudates (e.g. citrates, phytosiderophores), and identification and characterization of membrane transporters responsible for the absorption/translocation of specific elements. In the field, an experimental layout is dedicated to study the transfer of tritium in a grassland ecosystem (fluxes between air, rain water, grass and soil). Field studies also concern freshwater systems, e.g. in Fukushima prefecture (Japan), and terrestrial systems, e.g. in Chernobyl. Compile and analyses data/databases regarding a large range of processes addressing the human food chain (e.g. sorption/desorption in soils and freshwater, root transfer, foliar pathway, transfer to terrestrial and freshwater animal products). Original approaches in data analysis cover: dynamic models, Bayesian statistics, improved categorisation of soils/plant (e.g. based on phylogeny), etc.. Develop SYMBIOSE, an Integrated Environmental Modelling software to include uncertainty/sensitivity analyses and various spatial scales from simple and generic to a complex and site specific landscape-level. Some of this will be achieved through linked PhD studentships.
IST	Mediterranean regional customisation of parameter values to provide predictions on food contamination and consequent doses to humans. Long-term dynamics of soil-to-plant transfers for long-lived radionuclides. Behaviour of caesium during composting of contaminated plant (Alfalfa) biomass. Laboratory small-scale experiment with plants contaminated a) by aerosol deposit, and b) through root uptake. The bioavailability of Cs from detritus will be examined by sequential extraction method in order to distinguish fractions: i) exchangeable, ii) fulvic acid, iii) humic acid, iv) other organic matters
NRPA	Derive parameter values (e.g. transfer, agricultural practices and dietary habits) appropriate for Nordic ecosystems for use in FDMT in ARGOS. Investigate the application of Bayesian methods to derive more robust parameter values in cooperation with IRSN. Continue studies of long-term consequences of the Chernobyl fallout in Norway, including remedial actions. This includes mechanistic analysis of radionuclide (^{137}Cs) bioavailability, transfer and/or accumulation in plants and lichens, and model development. Acquire the experimental data necessary for parameterisation of the key processes controlling the transfer of radionuclides to grazing ruminants (some of this require additional funding) Pilot study on modelling concentrations of radionuclides in surface drinking water after nuclear fallout.
NUBiP	Long-term dynamics of ^{99}Tc transfer factors to agricultural and forest products from different soils under field conditions in CEZ. Long-term dynamic of ^{137}Cs availability in wet peat (soils with extremely high transfers). Long-term dynamics of ^{90}Sr transfer factors to forest products under field conditions in CEZ Region-specific parameters for modelling and countermeasures.

SCK·CEN	Concentrate on mechanistic/process based mobility and bioavailability assessment/prediction and application of countermeasures. Experiments to study the effect of soil-plant remediation measures for specific soil types. We can provide regional data on land use, soil types, dietary habits, hydrology for application in DSS. Set up experiments to derive interception, retention, translocation data for food crops (PhD. studentship 2016-2020). Improve understanding and modelling of soil-to-plant transfer of radiocaesium in Japanese soils (PhD. studentship 2013-2017).
STUK	Development of the terrestrial food chain and dose module (FDMT) used in the decision supporting systems ARGOS and RODOS to predict ingestion doses as well as long term doses from other pathways. Definition and introduction of regional parameter values and habit data into the RODOS. STUK will couple radiation measurements with JRODOS/FDMT to provide them as an input for calculations. The measurements include gamma dose-rate monitoring network results, LaBr3 spectrometer network results, and mobile measurements.
UoP	We are currently working on long term availability of radiocaesium and radiostrontium in ecosystems including freshwater systems. A particular focus is modelling temporal changes in radiocaesium/strontium availability and mobility using long term historical data sets. A further interest is determination of appropriate model complexity using Monte Carlo analysis of sensitivity/uncertainty coupled with analytical methods to determine appropriate dynamic (temporal) resolution of model processes.

Work plan

Planned research activities and time scale: tasks, responsibilities, participants, use of observatory sites, use of large scale facilities, milestones, deliverables, resources committed by partners (estimated man months, in-house funds), requested funds and targeted calls (EC Call, other calls)

Partner	Task	Means	Resources
BfS	Task 2	BfS funds; departmental research projects initiated and supervised by BfS and funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety	5 mm (BfS resources)
CEA		Program Investissement d'avenir (PIA) DEMETERRES, Toxicology program PhD funded by CEA in the framework of the CEA/SCK.CEN project to inventory species living in spent nuclear fuel pools	
NERC-CEH		TREE project; CEH funds	3-4 mm
CIEMAT		CROMERICA, JRODOS, EURANOS manual, BIOPROTA developments	
GIG			
HMGU			
IRSN			

IST	Tasks 1+2		
NRPA	Task 2+4 Task 1 Task 1 – drinking water	COMET NRPA in-kind CERAD projects NRPA in-kind	3 mm 1 mm 3-4 mm 1 mm
NUBiP	Long-term dynamics of TF's of ^{99}Tc and ^{137}Cs	NUBiP	4 mm
SCK·CEN		Regional data (EC HARMONE) Cs behaviour in Japanese soils (PhD funded by Flemish government and SCK•CEN) Interception, retention, translocation project (PhD)-	0.25 mm 48 mm (ends April 2017) 2016-2020 (48 mm)
STUK		JRODOS/STUK	
UoP			

Major elements of the communication plan (workshops, publications, guidance documents…)

Partner	Activity
BfS	Reports, workshops, conferences, contributions to national and international databases
CEA	Referred publications, workshops and conferences, participation to data bases
NERC-CEH	Referred papers, workshops & conferences, liaison with IAEA programmes (currently chair two MODARIA WG's, contributing to SRAS-19 update, contributor to draft 'Comprehensive Fukushima Report'), social media.
CIEMAT	Referred papers, workshops and conferences and liaison with IAEA programmes a Referred papers, workshops, conferences and courses. Liaison with IAEA programmes and ICRP C5. Spanish Platform on Radiation Protection.
GIG	
HMGU	
IRSN	Referred papers, workshops & conferences and liaison with IAEA programmes
IST	Referred papers, workshops & conferences
NRPA	Peer review papers, reports, workshops & conferences, blogging
NUBiP	Referred papers, workshops & conferences
SCK·CEN	Referred papers, workshops & conferences and liaison with IAEA programmes
STUK	Workshops and conferences
UoP	

Links with other activities identified at the national and the international levels

Partner	Link
BfS	BfS projects, national departmental research projects
CEA	DEMETERRES (Development of bio/eco remediation technologies of effluents and soils in support of a post-accident remediation strategy) – coordinated by CEA, co-funded by ANR (French National Research Agency) RSNR call (2013-2018 – 9 m.m/year).
NERC-CEH	TREE project; UK funded PhD.; IAEA programmes; COMET WP3.
CIEMAT	COMET WP3; ICRP C5; UNSCEAR, IAEA (MODARIA); BIOPROTA; PREPARE; JRODOS user group; I+D Committee of the NERIS platform; PEPRI (Spanish Platform on Radiation Protection).
GIG	
HMGU	
IRSN	DEMETERRES (Development of bio/eco remediation technologies of effluents and soils in support of a post-accident remediation strategy) – collaboration with CEA, co-funded by ANR (french National Research Agency) RSNR call (2013-2018 – 9 m.m/year, 1 PhD co-funded) AMORAD project (funded by French gov, same call); COMET/WP3 IAEA programmes (MODARIA) Submitted project HARMONE (OPERRA call) GGP-Environnement (e.g. Modeling of the mid-long term fate of contamination in terrestrial ecosystems. Alternative approaches to Kd) - co-funded by EDF (2014-2016, 12 m.m./year) ACTISOL (influence of siderochelates and phytoionophores on the environmental availability of radionuclides in soils) - collaboration with CNRS, co-funded by NEEDS call (2015-2016, 3 m.m/year) IRSN funded PhD.
IST	C2TN activities
NRPA	CERAD, NRPA activities.
NUBiP	National projects, Ukraine funded PhD.
SCK·CEN	Link with EC HARMONE, FRAME IAEA programmes SCK·CEN funded PhDs
STUK	Part of regular JRODOS update project
UoP	