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TERRITORIES Workshop on: Assessing risks from radioactive legacy sites and how to better present uncertain information

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Abstract

A total of four workshops were held within the context of EJP-CONCERT Sub-task 9.3.4 (TERRITORIES WP4) entitled "*Strategic and integrated communication, education and training*". Of these four workshops, three were organized under EJP-CONCERT Sub-subtask 9.3.4.3 (TERRITORIES Task 4.3) entitled "*Development and implementation of E&T activities for appropriate audiences*". This document describes the outcomes of the last TERRITORIES Task 4.3 workshop, which was held on 19-20 March 2019 in Oxford, United Kingdom on the topic of "**Assessing risks from radioactive legacy sites and how to better present uncertain information".**

The objective of the workshop was to discuss the risk assessment process as applied to radioactively contaminated legacy sites as well as to planned exposure situations, and how to present the assessment findings and associated uncertainties to stakeholders. During the workshop, general aspects of uncertainties in risk assessments of radioactively contaminated legacy sites were discussed. Furthermore, the case of the risk assessment process applied to a real site at Sellafield, UK was present. The following audiences were encouraged to attend and apply for TERRITORIES travel scholarships to participate in the workshop: students (final year, MSc, PhD) and early career scientists in the field of radiation protection and nuclear sciences, particularly radioecology and environmental impact assessment.

The TERRITORIES workshop on **Assessing risks from radioactive legacy sites and how to better present uncertain information** had 100 participants from 15 different countries, 50% of whom were not members of the TERRITORIES project. There was a significant representation of students and early career scientists at the workshop (32% of the total participants and 87% of these students and early career scientists were not involved in the TERRITORIES project). The participants were highly active in the discussions held during the workshop. Special mention must be made to the speakers, the sessions and round tables chairs, the panellists of the round tables and the early career scientists who participated in the Early Stage Researchers Session. All of them have contributed to the success of the workshop and, directly or indirectly, to this deliverable.

List of acronyms

ALLIANCE	European platform on radioecology research (http://www.er-alliance.eu/)
BfS	German Federal Office for Radiation Protection
CENS	Center for Ecological-Noosphere Studies, Armenia
CEPN	Centre d'étude sur l'évaluation de la protection dans le domaine nucléaire
CIEMAT	Spanish Centre for Energy, Environment and Technology
COMARE	Committee on Medical Aspects of Radiation in the Environment
CONFIDENCE	COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs European research project funded in the framework of the EJP-CONCERT [grant agreement No 662287]
DSA	Norwegian Radiation and Nuclear Safety Authority
EA	Environmental Agency, UK
E&T	Education and Training
EJP-CONCERT	European Joint Programme for the Integration of Radiation Protection Research under Horizon 2020 (http://www.concert-h2020.eu/en)
ENA	European NORM Association
ERA	Environmental Risk Assessment
FANC	Federal Agency for Nuclear Control
GEP	Pluralistic Expertise Group of France
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IRSN	French Institute for Radiation Protection and Nuclear Safety
JAEA	Japan Atomic Energy Agency
NGO	Non-Governmental Organization
NORM	Naturally Occurring Radioactive Materials
PHE	Public Health England
SCK•CEN	Belgian Nuclear Research Centre
SEPA	Scottish Environmental Protection Agency
TERRITORIES	To Enhance unceRtainties Reduction and stakeholders Involvement TOwards integrated and graded Risk management of humans and wildlife In long-lasting radiological Exposure Situations. European research project funded in the framework of the EJP-CONCERT [grant agreement No 662287] (http://territories.eu/; https://territoriesweb.wordpress.com/)
TSC	TERRITORIES Steering Committee
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UK	United Kingdom
USA	United States of America
UT	University of Tartu, Estonia
WP	Work Package

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1. INTRODUCTION AND OBJECTIVES

TERRITORIES (To Enhance unceRtainties Reduction and stakeholders Involvement TOwards integrated and graded Risk management of humans and wildlife In long-lasting radiological Exposure Situations), is part of the EJP-CONCERT project. TERRITORIES has three main objectives:

- To meet the requirements that emerged after the recent Fukushima experience and the publication of International and European Basic Safety Standards.
- To reduce uncertainties to a level that can be considered fit-for-purpose (graded approach).
- To bridge NORM vs post-accident (after transition phase) exposure situations, monitoring *vs* modelling, human *vs* wildlife population, experts *vs* decision-makers *vs* the general public in management (integrated approach).

One of the aims of EJP-CONCERT Sub-task 9.3.4 (TERRITORIES WP4) on strategic and integrated communication, education and training, led by UT (Estonia), is to "i*dentify and communicate to appropriate audiences the existing capabilities, key uncertainties, needs and knowledge gaps in radiological risk assessment and management for humans and wildlife in long-lasting radiological exposure situations*".

The Sub-subtask 9.3.4.3 (TERRITORIES Task 4.3), led by CIEMAT (Spain), coordinates the development and implementation of education and training activities for appropriate audiences, including stakeholders, professionals and students. Within Sub-subtask 9.3.4.3, three workshops were planned to be organized, to encourage the discussion on key issues on risk assessment in long-lasting exposure situations, including socio-ethical aspects, between researchers and stakeholders. The first workshop on "**Communication of uncertainties of radiological risk assessments to stakeholders**" was organised on the 16 November 2017, in Oslo, Norway. The objective of the workshop was to discuss the implications and relevance of uncertainties in radiological risk assessments for different stakeholders, and to work out how these uncertainties can be better communicated. Discussions were organized to collect feedback from regulators, industry, scientists and the general public on this subject. In this workshop, the focus was on the uncertainties related to radiological risk assessments in long-lasting exposure situations (both NORM and post-accidental exposure situations). Ethical and social uncertainties were not explicitly addressed in this workshop. The results were published in a previous deliverable (CONCERT-TERRITORIES D9.75, 2017).

The second TERRITORIES workshop took place at CIEMAT (Madrid, Spain) during 13-14 June 2018, on the topic "**Multidisciplinary forum to discuss the scientific basis for reducing uncertainties and improving risk assessment**". The workshop aimed to get feedback from experts in different scientific disciplines, on the application of the two guidance documents that are being developed in TERRITORIES: to design environmental monitoring for dose assessment and support to remediation; and to select the appropriate level of complexity in models. The workshop focused on methodologies to reduce uncertainties related to sampling and monitoring strategies as well as the quantitative handling of the various types of uncertainties that play a major role in radioecological modelling, including conceptual model uncertainty and scenario uncertainty. The results of the workshop, including the lessons learned, were published in a previous deliverable (CONCERT-TERRITORIES D9.74, 2018).

The last workshop planned under EJP-CONCERT Sub-subtask 9.3.4.3 (TERRITORIES Task 4.3), took place at The Queen's College (Oxford, UK) during 19-20 March 2019, on the topic "**Assessing risks from**

radioactive legacy sites and how to better present uncertain information". The objective of the workshop was to discuss the risk assessment process as applied to radioactively contaminated legacy sites, as well as to planned exposure situations, how to present the assessment findings and associated uncertainties to stakeholders. The workshop discussed general aspects of uncertainties in risk assessments of radioactively contaminated legacy sites and planned exposure situations. Additionally, it was presented how the risk assessment process has been applied to a real site at Sellafield, UK. The following audiences were encouraged to attend and apply for TERRITORIES travel scholarships to participate in the workshop: students (final year, MSc, PhD) and early career scientists in the field of radiation protection and nuclear sciences, particularly radioecology and environmental impact assessment.

This deliverable D9.76 presents a summary of the talks, discussions and feedback given by the workshop speakers and participants, the session of early stage researchers, as well as the discussions held during the two round tables. Conclusions are presented to summarize the final results of the workshop.

2. WORKSHOP ORGANIZATION

To coordinate the organization of the workshop, a Programme Committee was established, consisting of the TERRITORIES participants: Kelly Jones, Wayne Oatway and Tiberio Cabianca (PHE), Almudena Real and Juan Carlos Mora (CIEMAT), Marie Simon-Cornu (IRSN), Alan Tkaczyk (UT) and Pascal Croüail (CEPN).

It was decided to organise the workshop on 19-20 March 2019, just before the TERRITORIES Annual Meeting (21-22 March 2019), at The Queen's College, Oxford, UK.

The Programme Committee held five video conferences (16 July 2018, 21 August 2018, 14 September 2018, 30 November 2018 and 31 January 2019) and exchanged numerous emails to prepare the programme of the workshop. Once the draft programme (with the titles of the lectures and the potential speakers) was agreed, the proposed speakers were contacted, asking if they were willing to participate in the workshop.

The detailed programme of the workshop on "Assessing risks from radioactive legacy sites and how to better present uncertain information" is presented in Annex 1 (Section 6.1). The workshop was structured in two sessions (Introductory Session and Case Studies Session), two Round Tables (Define What is Meant by "Uncertainties" in the Context of Decision-Making; and From Science to Policy) and a special session devoted to early stage researchers (students and early career scientists).

For the round tables, some questions were prepared in advance by the Programme Committee and distributed both to the chairs and the panellists of the round tables (Section 6.2. Annex 2).

One aim of the workshop was to attract as many students and early career scientists as possible. The possibility to apply for travel scholarships was advertised on the TERRITORIES webpage and TERRITORIES blog, and applications from students and early career scientists were particularly encouraged. Additionally, TERRITORIES partners were encouraged to disseminate information about the travel scholarships through their professional networks. PHE contacted several Universities in the United Kingdom (Birmingham, Central Lancashire, Exeter, Liverpool, Manchester, Sheffield, Stirling, Warwick), to attract as many students and early career scientists as possible to the workshop.

For the **dissemination** of the workshop to a variety of potential audiences and stakeholders, the event was announced using different tools. The programme was disseminated through the TERRITORIES Webpage (https://territories.eu/) and Blog (https://territoriesweb.wordpress.com/). The information about the workshop was also distributed by e-mail to all the members of the European projects TERRITORIES, EJP-CONCERT and CONFIDENCE, as well as to the members of the European Radioecology Alliance (ALLIANCE). Additionally, TERRITORIES project partners were requested to disseminate information about the workshop to their professional networks.

The TERRITORIES workshop on **Assessing risks from radioactive legacy sites and how to better present uncertain information** had 100 participants from 15 different countries (Armenia, Austria, Belgium, Estonia, Finland, France, Germany, Japan, Lithuania, Nigeria, Norway, Poland, Spain, UK and USA) (Section 6.3. Annex 3). Of these participants, 50% were not members of the TERRITORIES project, which speaks highly of the dissemination of the workshop advertisement, and the high quality of program and guest speakers arranged and invited by the Workshop Programme Committee. The attraction of students and early career scientists was exceedingly successful, representing 32% of the total participants. Of these students and early career scientists, most of them (28/32) were not involved in the TERRITORIES project). Five members of the TERRITORIES Steering Committee also attended the workshop.

Figure 1. Participants of the TERRITORIES workshop on **Assessing risks from radioactive legacy sites and how to better present uncertain information**, 19-20 March 2019, The Queen's College (Oxford, UK). Photograph: Copyright Mariana Costa (PHE) with special thanks to the Provost and Fellows of The Queen's College.

TERRITORIES awarded 25 grants for the attendance of students to the Workshop: 18 grants to students from UK Universities (Birmingham, Liverpool, Manchester, Sheffield and Stirling); 1 grant to a student from the Federal University of Technology Akure (Nigeria), 1 grant to a student from the Center for Ecological-Noosphere Studies (CENS, Armenia), and 4 grants to TERRITORIES early career scientists (CIEMAT, IRSN, SCK•CEN, UT).

A customized web-based survey was distributed to all the participants, to obtain feedback on scientific-technical aspects, as well as on organizational aspects of the workshop. The survey and feedback received are presented in Annex 4 (Section 6.4).

3. SUMMARY OF THE PRESENTATIONS AND DISCUSSIONS HELD DURING THE WORKSHOP ON "ASSESSING RISKS FROM RADIOACTIVE LEGACY SITES AND HOW TO BETTER PRESENT UNCERTAIN INFORMATION"

All the presentations done during the workshop are available in the TERRITORIES webpage (https://territories.eu/dissemination#oxford-2019).

3.1. Summary of the presentations of the Introductory Session

The introductory session was chaired by Marie Simon-Cornu (IRSN, France) and Tiberio Cabianca (PHE, United Kingdom).

Before the introductory talks, **Dr. Simon Bouffler**, interim Deputy Director for Research and Head of Biological Effects Department at the Centre for Radiation, Chemical and Environmental Hazards of Public Health England (PHE, United Kingdom), and coordinator of EJP-CONCERT WP5 on Stakeholder involvement, welcomed the participants to Oxford and briefly presented the EJP-CONCERT project.

Dr. Marie Simon-Cornu (IRSN, France), coordinator of the TERRITORIES project, presented the objectives, structure, tasks, expected results and characteristics of the consortium involved in TERRITORIES. She also presented the scope of the workshop, highlighting the aim to provide a greater understanding of the dose assessment process for humans and biota and its uncertainties, as well as to clarify how regulators deal with uncertainties and how public uncertainties fit into the picture.

The presentations made during the introductory session are summarized below.

- ***Protecting the public against radiations: Assessing the dose.*** Juan Carlos Mora (CIEMAT, Spain).

The main objective of the system developed for protecting the people against the hazards raised by ionising radiations is to avoid the appearance of deterministic effects (i.e. to keep doses below the thresholds for these effects) and to reduce to the maximum extent possible the probability of appearance of stochastic effects. This objective is achieved by applying three fundamental principles: Justification, Optimization and Limitation of Doses.

The dose limits are defined taking into account the relationship between effects and dose, applying the Linear Non-Threshold model (LNT). LNT model correlates an aggregate of the increase in the probability of appearance of stochastic effects (mainly different types of cancer and heritable effects), with a quantity that can be experimentally determined. In the case of humans a non-directly measurable quantity, but quantifiable in terms of several experimental quantities, was developed, the name of that quantity being effective dose. In practice, a limit of the effective dose for the public is defined by considering an acceptable protection. Currently 1 mSv/y is recommended by the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) and universally accepted), and an effective dose constraint is defined for a controlled situation or installation (a fraction of that limit, recommended to be below 1/3 of the limit).

Effective dose is related with the energy deposited in the tissues (Joules per kg), weighted by the influence of a given type of radiation with the increase of the probability of developing stochastic effects (w_R, radiation weighting factor), and the radio-sensitivity of the tissue where the energy is being deposited (w_T, tissue weighting factor), both determined mainly by epidemiological studies. The unit of this quantity is the Sievert, and the limit is defined as per year (Sv/y). This quantity should be calculated for given conditions for a hypothetical person.

That hypothetical person compiles several characteristics which are extrapolated to the rest of the humans. For instance, the epidemiological studies are always performed in restricted groups of humans (e.g. data from the Hiroshima and Nagasaki survivals cohorts are restricted to an Asiatic group, majority of which were women, and either old or children males. However, we use the data for every other human. To reflect that fact "the reference person" was created, with well-defined characteristics, and but who does not exist in reality. For many years the reference person was defined as a 20-30 years old Caucasian, 1.70 m height, 70 kg weight, with strictly given weights for each organ, and hermaphrodite. On the other hand, as the habits and consumption rates of different food also depend on the group of humans, together with the reference person "the representative person" was defined. That representative person, as defined by the ICRP, is representative of the individual, within a given sufficiently homogeneous group of exposed people, receiving the maximum effective dose.

For a given situation where effective dose should be evaluated, let us say a contaminated terrain, a representative person is defined by considering different exposure scenarios, usually by law or by iterative approaches. For that representative person, external and internal exposures, from different pathways considered in the given problem, are calculated. Examples of those exposure pathways are the external exposure due to the contamination of a soil, or the internal exposure due to the ingestion of radionuclides transferred to the food cropped from the soil. By modelling (using particle transport models and bio-kinetic models), dose conversion factors for external and for internal exposures are pre-calculated for the reference person, and often compiled in the law. By statistical studies, habits and consumption rates are determined for the group of people considered to define the representative person, with these values sometimes being given in the national law. By measurements, or by modelling (depending on the availability of measurements and if retrospective or prospective assessments are needed), concentrations of every radioisotope on each material affecting the pathways, are determined.

Finally, a combination of the measurements, modelled results, pre-calculated dose conversion factors and statistically determined habits or consumption rates, summed for every exposure pathway and radionuclide, provides an estimation of the effective dose received by the representative person. If that value (properly determined) is below the dose limit (1 mSv/a) an adequate protection of any person who could be affected by the radiations raised in that same situation, is assured.

A scientific discussion of the uncertainties included in every step mentioned in this text can be found in the UNSCEAR 2012 report, but in practice, most of them are neglected.

- ***What about the environment? Impact on non-human biota.*** Karine Beaugelin-Seiller (IRSN, France).

One key objective in any scientific field is to learn lessons from past studies in order to improve future work. This talk illustrates this concept by presenting our experience of conducting an Environmental Risk Assessment (ERA) on some French former uranium mining sites. A second goal of the workshop is to discuss how better present the assessment findings and associated uncertainties to stakeholders.

We will share with the audience our feedback from our participation in a pluralist group including authorities, operators, NGOs, technical experts and scientists.

From 2005 to 2011, the GEP mines (group of pluralistic expertise on the former uranium sites in the center of France) conducted an exhaustive and rigorous investigation of actual impacts of these legacy sites. The underlying question, at the origin of the group genesis, was to know if the management of these sites complied with their regulatory obligations with regard to protection of both people and the environment. Beginning with a technical analyse of the present situation to clarify the best options for their management and monitoring, the group provided recommendations on option development to reduce the current impacts and to foresee those in the long term according to the preparation of a long term plan. To fulfil the mandate of the GEP, a sub-group of about 25 people representative of all stakeholders focused on the question of the environmental impact, considering both human health and ecological aspects. At the time of the study, dealing with the radiological impact on wildlife in a somewhat regulatory context was something new, with international developments in radiation protection of the environment just starting out.

The talk presents the principles of the ERA as applied to the French former uranium mining sites, looking to take into account impacts from both radiological and chemical nature on an aquatic ecosystem. Results from the successive tiers that were necessary to achieve our goals are described; making clear which refinement was applied from one tier to another. By the way, limitations and uncertainties in the applied approach are discussed. To conclude, recommendations are made about the requirements to robustly implement such ERA method, the additional data necessary to complement the direct information on toxic levels in the environment, as well as some perspectives in terms of research and development we identified at this time.

- ***What do we mean by uncertainty when assessing the dose?*** Martin Steiner, Laura Urso (BfS, Germany).

Doses and dose rates are the key measures of potential health consequences of ionizing radiation to the whole human body (effective dose) or to specific organs (organ doses). They are required for regulatory purposes, e.g. for demonstrating compliance with legal dose limits for members of the public in licensing procedures, as well as for research purposes, e.g. for relating radiation-induced health effects with epidemiological observations. Doses and dose rates are also the basis for decision making and communication of risks and benefits of any human action (risk-benefit analysis).

There is an increasing demand for evaluating and communicating the uncertainty in dose assessments. An uncertainty analysis provides information on the robustness and limitations of a dose assessment, which increases the confidence of politicians, decision makers, stakeholders and the society in the assessment results.

Apart from ambient dose rates, which can directly be measured, doses are calculated from a source term, either releases of activity into the environment or measured activity levels of environmental media. As a first step, activity levels in food, drinking water, air and the environment are calculated using radioecological models. In a second step, the dose to humans is calculated from information on the human behaviour (inhalation rates, consumption rates, locations and periods of stay) and dose (rate) coefficients. Therefore, uncertainty in the calculated doses arises from uncertainties in the source term, uncertainties related to the radioecological models used, uncertainties in the human behaviour and, at least in principle, uncertainties in dose coefficients and dose rate coefficients.

Modelling uncertainties, i.e. all contributions to uncertainty that propagate to the model output, play a key role in dose assessments. The types of uncertainty that dominate the total uncertainty budget of a radioecological model include:

- Parameter uncertainty that arises from a limited knowledge of the values for the model parameters (point estimates and/or probability density functions) and the correlations of the model parameters,
- Conceptual model uncertainty (structural uncertainty) that arises from a simplified, incomplete or even wrong translation of the real world into a conceptual model and its mathematical representation, and
- Input uncertainty (uncertainty in the source term) that results from a lack of representativeness of the sampling procedure, uncertainties in the lab measurements and/or incomplete information on the activities released into the environment.

At present, the focus of uncertainty analyses is on parameter uncertainty. Correlations between model parameters are often ignored, and the tails of probability density functions are often not properly taken into account, even if high percentiles of the doses are to be estimated. Other important contributions to the total uncertainty of radioecological models, e.g. the conceptual model uncertainty, are rarely considered.

In summary, it is recommended to define an acceptable level of total uncertainty, depending on the specific purpose of the dose assessment. Taking all potential contributions to uncertainty into account and prioritising them allows for a practical approach, in which major contributions are dealt with in detail and minor contributions in a simplified way. Last but not least, communication of uncertainties helps to make the dose assessment more transparent, creates confidence in the assessment results and increases acceptance.

- ***Regulator's concerns – what do we want to see and how confident do we need to be?*** Paul Dale (SEPA, United Kingdom).

The presentation described the types of radioactive legacy sites in Scotland, the Scottish Legislation and the purpose of Scottish Environmental Protection Agency's (SEPA) Walkover Survey Guidance.

The SEPA has encountered several legacy sites contaminated with radioactivity, including: civilian clock and watch manufacturers; former military sites (airfields, aircraft repair yards, radar stations); oil and gas pipe laydown yards and former power station. The most common radionuclide found in these sites is Ra-226 (and decay products). Ra-226 is the most common radionuclide at historic military sites and civilian watchmakers, it was used to provide luminescence to dials, clock and watch faces, and was also used in transmit-receive tubes in radar stations.

The Legislation for existing radioactive contamination in Scotland includes: (i) The Radioactive Contaminated Land (Scotland) Regulations 2007 (and amendments) – Known as Part IIA; and (ii) the Town and Country Planning Act 1990 & The Town and Country Planning (Scotland) Act 1997.

In 2017, SEPA published the "Guidance on monitoring for heterogeneous Radium-226 sources resulting from historic luminescing or waste disposal sites", to aid local authorities and contractors in undertaking what SEPA considers to be current best practice for radiological walkover surveys concerning gamma-emitting radionuclides, specifically Ra- 226 (and daughters), under Part IIA and also under the planning regime in Scotland. The guidance follows the COMARE recommendation.

Regarding dealing with uncertainty, the guidance sets out: (i) Criteria for Part IIA and Planning; (ii) what SEPA considers to be best practice to achieve the COMARE recommendation from their 15th Report of to detect 20 kBq of radium to a depth of 100 mm with a 95% probability of detection for Part IIA; (iii) for planning it outlines what SEPA consider to be best practice to optimise the basic survey requirements for Part IIA in order to detect the lower criteria stipulated for a change of use.

The guidance includes legislative criteria, providing dose and dose rate values for different situations (heterogeneous or homogeneous contamination) as well as planning criteria (dose constraints). For remediation it outlines SEPA's position, in relation to *Environmental Authorisations (Scotland) Regulations 2018,* with respect to radioactive contamination in situ, for excavated soil with radioactive contamination and for segregation and characterisation of waste

The document also describes what SEPA considers best practice for walkover surveys in relation to the methodology to be used (i.e. instrumentation, limit of detection, walking speed, transect spacing, height of detector) and the verification (i.e. data Analysis (GPS), natural background, calibration, monitoring results). It also includes the aspects that need to be considered for a change in use of the legacy site after remediation actions.

The SEPA Guidance is available online in https://www.sepa.org.uk/media/286898/sepa-guidance-for-walkover-surveys-on-rcl.pdf.

- ***How do we control natural radiation – NORM? The Belgian experience.*** Geert Biermans (FANC, Belgium).

Phosphate industry has been present in the Campine Region since the early 20th century. Industrial production of phosphates for cattle food with the hydrochloric acid process has led to liquid discharges into two small rivers: the Winterbeek, a river in the Demer Basin and the Grote Laak, a river in the Nete Basin.

Until 1995, considerable amounts of heavy metals and salts, among which ^{226}Ra, were released daily through liquid discharge into the rivers, contaminating the riverbed sediments and, through dredging and flooding, the riverbanks and the marshlands which occur along the length of both rivers. The radiological contamination caused by ^{226}Ra, with dose rates up to 10 times the normal background levels and concentrations up to several Bq/g, accompanies high levels of chemical contamination by cadmium and arsenic above the remediation levels defined by policy. Extensive efforts have been made in the last three decades, by both federal and regional authorities to identify the extent of the combined contamination vector.

While the source of contamination is now gone, several questions still remain: how does the radium present in the river systems behave? How can the contamination of riverbed and riverbanks be remediated taking into account, among many other factors, the radiological and ecotoxicological risks?

In Belgium, chemical contamination and its remediation is regulated by the regional authorities (OVAM), while the regulation of radiation protection resides at the federal level (FANC). This potentially leads to a discrepancy between regulatory and remediation goals for chemical and radioactive components. In addition, other stakeholders such as the regional environmental agency (VMM) also have to be involved in the discussion.

The approach for mixed contamination was therefore based upon and parallel to the modular graded approach to remediation of chemical contamination used by the regional authorities. This process,

which starts with identification and characterisation of the site and ultimately leads to feasible remediation options, involves all stakeholders from public, operator to authorities.

A remediation project for the Winterbeek River has been initiated, justified by the high levels of cadmium, which also takes into account the radiological component. The project has started in 2017 and will run for 4 years.

The presentation explores this process from legacy to remediation and tries to identify some key points for further reflection on management and remediation of legacies with a mixed contamination, which are subject to a complex interplay of regulations, procedures and responsibilities.

- ***Public Concerns.*** Ferdiana Hoti, Bieke Abelshausen, Catrinel Turcanu, Tanja Perko (SCK•CEN, Belgium).

The aim of this research was two-fold. First, we wanted to see the current state of definitions and types of uncertainty in the literature. Second, we tried to make the link between theory and practice by collecting and analysing the existing uncertainties related to NORM contamination in Belgium.

In theoretical typologies, uncertainty is categorized mainly as: aleatory (ontic/ stochastic) uncertainties which are unpredictable, random or stochastic in nature and cannot be reduced; epistemic uncertainties which are caused due to lack of knowledge and/or information and can be reduced with new research; and uncertainties due to ambiguities which do not have a clear meaning (Walk et al., 2003, 2010; Fox & Ulkumen, 2011; Knoblauch et al., 2018; Kunz et al., 2011). However, practice reveals uncertainties that cannot be placed in any of these above-mentioned categories (French et al., 2017). For instance, judgmental uncertainties (e.g. setting of parameter values in codes), computational uncertainties (i.e. inaccurate calculations), modelling errors (i.e. however good the model is, it will not fit the real world perfectly), partially formed value judgements; and social and ethical uncertainties (i.e. how expert recommendations are formulated and implemented in society, and what their ethical implications are). Hence, this research bridges the gap between theoretical typology and practice.

In order to identify the definitions of uncertainties, we conducted a systematic review of the literature (n=224). Preliminary results show that there is some inconsistency between theoretical categorization and practical existing types of uncertainties. For instance, there are uncertainties related to communication, social, political, ethical, psychological, emotional, security and decision-making aspects that need to be further explored and clearly categorized.

To collect and analyse uncertainties related to NORM contamination, we did a document review, analysis of mass media reporting, interviews with the affected population in Tessenderlo (Belgium), as well as panel discussions with experts. The results show that uncertainties related to NORM arise mostly as a result of the socio-political and economic factors rather than technical factors. Uncertainties often originate due to different perceptions, attitudes, opinions, concerns and expectations of stakeholders towards the risks and benefits of remediation projects and due to the lack of stakeholder involvement in planning and implementation of remediation projects.

Understanding types and causes of uncertainties would open the path to the efforts of finding communication strategies and improve decision-making under uncertainty. By doing so, this research contributes to the overall goal of establishing the knowledge content pillars for risk analysis as a science in itself.

3.2. Summary of the presentations of the Case Studies Session

The session was chaired by Jordi Vives i Batlle (SCK•CEN, Belgium) and Kelly Jones (PHE, United Kingdom) and included the following presentations:

- ***Hunting for particles amongst the grains of sand.*** Richard Hill (Sellafield Ltd, United Kingdom).

Monitoring of the beaches has been part of the routine environmental monitoring programme at Sellafield since 1983. In 2003, during a routine survey, a radioactive particle was found which prompted a review of beach monitoring. Following agreement with the Environment Agency (EA) an intensive programme of beach monitoring commenced in 2006 using a vehicle-mounted array of radiation detectors.

The monitoring system was developed to allow detection of low energy emissions from Am- 241 and Sr-90 and high energy emissions from Cs-137 and Co-60. Detection of low energy emissions used eight 127 x 1.6 mm sodium iodide (NaI) Field Instrument for the Detection of Low Energy Radiation (FIDLER) detectors whilst five 76 x 400 mm NaI detectors were used to detect high energy emissions. The detector system includes a number of alarms to identify discrete radioactive objects. These alarms relate to generic changes to background levels, a high count rate alarm, and specific alarms to identify the presence of Sr-90 and Am-241, Co-60 and Cs-137. The detectors were configured within a carbon fibre case to provide a continuous monitoring swathe of two metres.

During 2017 a total area of 152 ha of Cumbrian beaches was surveyed. This identified 226 radioactive items, of which 191 were classified as particles (less than 2 mm in size) and 35 as larger objects (greater than 2 mm in size). A total of 167 of the finds were designated alpha rich, with higher Am-241 activity than Cs-137 activity and 59 were designated as beta rich, where Cs-137 was the major radionuclide. All of the larger objects were designated beta rich. As observed previously, the majority of finds were recovered from Sellafield beach (76%). The numbers of finds in all categories were typical of those found in recent years.

A sub-set of alpha rich and beta rich finds have also been analysed over recent years. Alpha rich particles were found to be mainly associated with iron and iron oxide and are likely to have originated from the use of flocculants during early reprocessing. An estimate of the age of these finds showed that they were mainly formed in the 1960s and 1970s, with releases stopping by 1983. Beta rich particles were associated with graphites, metals, rock fragments and minerals and were likely to be associated with materials that arrived at the Sellafield site several decades ago, although the exact age cannot be accurately determined. Beta rich larger objects were mainly associated with rock fragments and were of a similar age range to beta rich particles.

The Conceptual Site Model for the particles in the environment programme has been recently updated. The updated model identified that particles and larger objects originated from historic sources and the various pipeline retrievals. The intertidal transport pathways for particles were determined to be due to a predominantly northward drift and burial/ exposure. Transport from the beach to the sea and vice versa was identified to be associated with storm events.

The work conducted to date provides further evidence that the conclusion of the health risk assessment remains valid, and are as follows.

"The conclusion, based on the currently available information, is that the overall health risks to beach users are very low and significantly lower than other risks that people accept when using the beaches, Brown & Etherington, 2011".

- ***What information do we need?*** Wayne Oatway (PHE, United Kingdom).

The presentation described a case study on the uncertainty and variability in a risk assessment, focussed on objects on beaches in the vicinity of the Sellafield site.

Radioactive objects, with sizes ranging from less than 1 mm to several centimetres, have been detected on beaches near the Sellafield site for over two decades. These objects have several radionuclides present on them, principally Am-241 and isotopes of plutonium on 'alpha-rich' objects and Cs-137 and Sr-90 on 'beta-rich' objects. The total activity of these radionuclides present on an object can range from less than 1 kBq to over 100 kBq. The beaches where objects have been detected are a mixture of sand and rocks and are open to the public who used them for a wide range of purposes including leisure, walking and beach angling. Molluscs and crustaceans are also caught for consumption from along that part of the Cumbrian coast.

To manage the beaches with respect to their radiological hazard it is important to first evaluate the level of risk to health those objects pose. The International Commission on Radiological Protection (ICRP) classifies health effects from exposure to radiation as either deterministic or stochastic. In general, deterministic effects occur when a dose of radiation exceeds a certain level (threshold dose). For exposure to radioactive objects, the most important deterministic effect that may occur is localised skin damage.

The main stochastic effects are different types of cancer that may occur many years after the exposure. For radioactive objects, the most important stochastic effect is the risk of developing cancer following the accidental swallowing of a particle. The risk of cancer developing was estimated by multiplying together the chance that cancer may develop if a particle with some level of activity was swallowed with the chance of that particle being swallowed by someone using a beach or eating seafood.

When performing a risk assessment, a significant number of parameters are used to define the habits of those potentially exposed as well as what they are exposed to. Uncertainty and variability mean that these parameters can have several equally valid values within a range which can span several orders of magnitude. In many risk assessments, each parameter is defined using a single value which is taken from towards the upper end of the possible range. Whilst this approach ensures that the impact of uncertainty and variability is not underestimated it may result in a significant overestimation of the risk. If a more realistic estimate of risk is required then parameters need to be defined more suitably. For estimating the risk to health posed by objects on a beach, as many parameters as possible were defined as a distribution which considered both the possible range in values that a parameter could have and the probability that any specific value could exist. This approach estimated risks expressed as a probability density function. For this risk assessment, the typical and upper per bound of the risks to a member of the exposed population were defined as the 50th and 97.5th percentiles of that probability density function, respectively. Due to the approach used, there is potentially more than an order of magnitude difference between the estimated 50th and 97.5th percentile of the annual risk. Interpretation of the output of the risk assessment therefore needs care, especially with respect to its communication with the public.

- ***Sellafield particles - what's the story?*** Trevor Howard (EA, United Kingdom).

The presentation described the role of the Environment Agency (EA), its history of monitoring, the public and media interest in radioactivity-related issues, the work that the EA makes with other organizations and how the EA performs the communicating with the public.

The EA acts as regulator, operator and advisor. Its role is to protect and improve the environment. To this end, the main actions carried out by the EA are to help people and wildlife adapt to climate change and reduce its impacts; improve the quality of the water, land and air by tackling pollution; and work as part of the Defra group to create a better place for people and wildlife.

In Sellafield, the EA reviews the findings of monitoring programme and provides direction for future work. In addition, requires Sellafield Limited to undertake monitoring using the "Best Available Techniques", which will prevent any further release.

The EA has been doing the Sellafield monitoring since 1950s, when the discharges to sea commence. In 2006 there was an authorisation review, leading to the introduction of a new monitoring technique. In 2011, even though the risk assessment performed concluded 'very low risk', it was stated that monitoring should continue to provide reassurance that this remains the case. Offshore monitoring by grab sampling was done between 2011 and 2014.

Different pictures of brochures, documents, news published, etc. were shown in the presentation, to reflect both the public interest and the national media interest.

When the EA identifies an important area that needs to be studied, determines if (i) can achieve this working alone; (ii) can achieve this better, faster or cheaper working with others; or (iii) can only achieve this working with others. Once it is decided to work with others, the EA selects the most adequate organization for the work to be done. After the work has been finished, there is an evaluation on the success reached (applying success indicators identified in advance) and the feedback is used to revise plans. The EA has worked with: PHE, Sellafield Ltd., Food Standards Agency; Copeland; Nuclear Decommissioning Authority (NDA), among other organizations.

Regarding risk communication to the public, the EA has a communication strategy which includes meetings with local stakeholders and internet briefing note. The EA also has an Intervention plan which defines 'trigger values' that prompt further action and sets out who will do what

In summary, it can be highlighted that the public interest in radioactivity in the environment has grown. The monitoring of beaches will continue to provide reassurance to regulators and the public, and the intervention plan defined by EA will ensure action if anything changes. Communication of risk is not an easy issue.

3.3. Summary of the Early Stage Researchers Session

The session was chaired by Almudena Real (CIEMAT, Spain). The early stage researchers were asked to make a short presentation (1-2 slides) introducing themselves (including their status), the research subject in which they are working, and their point of view on "Reviewing and communicating the uncertainties of results".

The early stage researchers participating in the session were:

- Corynne McGuire, *PhD student at Stirling University (United Kingdom)*
- Sergi Lopez, *PhD student at CIEMAT (Spain)*
- Alana McNulty, *PhD student at Manchester University (United Kingdom)*
- Wirginia Tomczak, Post Doc at IRSN (France)
- Nona Movisyan, *PhD student at CENS (Armenia)*
- Blessing Oladele, *PhD student at Federal U. Technology(Nigeria)*
- Dolores Mäekivi, Student at University of Tartu (Estonia)

- Khaled Brimo, Post Doc at IRSN (France)
- Ferdiana Hoti, *PhD student at* SCK•CEN (Belgium)
- Natalie Byrd, *PhD student at University of Manchester (United Kingdom)*

All the presentations made by the early stage researchers are available in the TERRITORIES webpage (https://territories.eu/dissemination#oxford-2019).

3.4. Summary of the Round Tables

3.4.1. Round Table: Define what is meant by "Uncertainties" in the context of decision-making

The round table was chaired by Pascal Croüail (CEPN, France) and Juan Carlos Mora (CIEMAT, Spain), and had the participation of the panellists:

- *David Collier (WhiteOx, United Kingdom):* Consultant for decision-making on nuclear health-environmental.
- *Paul Dale (SEPA, United Kingdom):* Radioactive Substance Unit Manager, Sottish Environment Protection Agency.
- *Simon French (University of Warwick, United Kingdom):* Statistician- Bayesian approach structured expert judgment.
- *Susan Molyneux-Hodgson (University of Exeter, United Kingdom):* Sociology Professor University Exeter, with scientific background and connected to scientific actions.
- *Kimiaki Saito (JAEA, Japan; TSC):* Environmental radiation external exposure, Fukushima environmental monitoring.
- *Jeroen van der Sluijs (University of Bergen, Norway; TSC):* Research on controversy of environmental assessment for decision-making.

Three questions were proposed to the panellists to stimulate discussion:

- ✓ What is your definition of uncertainty?
- ✓ How should information to the public on uncertainty be presented?
- ✓ Is uncertainty in different parameters perceived differently?

What is your definition of uncertainty?

It has to be taken into account that there are different categories of uncertainty (epistemic, aleatory, analytical, methodological, ethical, etc.) and one single definition might not be helpful. The definition of uncertainty will depend on the stakeholder group considered and on the purpose pursued. For example in the TERRITORIES project, the definition of uncertainty is broad and is stated in CONCERT-TERRITORIES D9.65 (2018).

In the **decision-making** context, the uncertainty must be framed for the specific case/purpose. It is important to determine when the uncertainties will have consequences on decision making since in some circumstances might not be relevant. The acceptable level of uncertainty is highly dependent on the purpose.

The **public**, especially when living in a contaminated area, is mainly concerned about the risk to their health, that of their family and the environment in which they live, and therefore they want to know the risks as precise as possible. If the public is not informed in a rational way, they will be worried and stressed. Uncertainty needs to be communicated to the public in a simple useful way.

Scientists have different views on uncertainties and usually want to communicate very technical details related to uncertainty, which are generally difficult for the stakeholders (public, decision-makers, etc.) to understand.

In sociology there is no definition of uncertainty.

Regardless of its definition, uncertainty is "permanent" and therefore has to be well characterized and communicated. In addition, it is very important to assess the knowledge quality (for example performing pedigree scoring analysis).

It must be clear that a high level of uncertainty does not mean that science is of low quality. The uncertainty provides additional knowledge because in addition to a number (obtained in the assessment) it gives information on the "range" in which risk will occur (e.g. a confidence interval indicates the range where the true value lies). The more information you pack in, the better understanding you have of the situation.

How should information to the public on uncertainty be presented?

As humans, we deal with uncertainties quite often in our daily life. Uncertainty related to radiological risk assessment needs to be communicated to the public in a simple useful way. Probabilistic information is specifically difficult to communicate.

The way of presenting the information on uncertainty will be context-dependent and type of stakeholder dependent (Politicians, decision-makers, scientists, general public, etc.). It must be taken into account what the public wants to know, not what the experts want to tell them. The public demand an appropriate level of certainty. It is important to present the best informed view on the issue. If too many details about the uncertainty are included, it can lead to confusion, as the public might think that nothing is known at all.

The experts must be open and transparent in communicating uncertainties to the public, to reinforce their trust. Uncertainty is more than a number and the public must be informed about the context of the assessment and the types of uncertainties. In addition of informing on uncertainties, the expert should explain what can be done about these uncertainties. For example, in evolving situations (i.e. emergencies) it is important to inform the public on how the uncertainties can develop in the years to come and if it would be possible or not to reduce such uncertainties.

According to the experiences in Fukushima, is very difficult to let people understand uncertainty. Using reliable examples may help in the understanding, as well as getting the public involved in the decision making process (e.g. involved the public in the measurement of environmental radiation levels).

The communication method called **progressive disclosure of knowledge** can be very useful. In this method, the expert starts with a simple presentation and then, based on questions and interest from the listeners, gives more and more detailed information about the issue and uncertainties in the analysis.

The experts do not need to educate people on how to understand uncertainties, but instead, train them in risk understanding by comparing radiation risks with known risks.

Is uncertainty in different parameters perceived differently?

Regarding the perception of the uncertainties, it is important to address questions such as what is the social robustness of the knowledge or what aspects are relevant to be addressed in a specific situation. The researchers decide what has to be assessed, but that could be irrelevant for a given concerned population/area. The concerns of the public must be the starting point. For example, when living in legacy sites, what people often want to know is if they have to do something different or can continue to run their lives as is. They care about how "radioactivity" affects their normality.

For the public, it is difficult to know who to trust when there are contradicting messages from different leaders (Conflicting sources of information). In Fukushima, too simplistic measurement methods and too conservative assumptions led to a large overestimation of the external doses received by the public as well as too strict regulations for decontamination.

3.4.2. Round Table: From Science to Policy

The round table was chaired by Astrid Liland (DSA, Norway) and Matthew Pardo (PHE Press Officer, United Kingdom) and had the participation of the panellists:

- *Gilles Heriard Dubreuil (Mutadis, France):* Secretary of the Nuclear Transparency Watch Network. Mathematics professor and decision-making and governance.
- *Trevor Howard (EA, United Kingdom)*: Nuclear specialist, support to government and industries.
- *Bogusław Michalik (ENA; TSC):* Center for environmental radioactivity, measurement techniques for NORM.
- *Horst Monken-Fernandes (IAEA, Austria; TSC):* Chemical engineer. Since 2006 environmental remediation specialist. Safety standards IAEA policy and strategies in environmental remediation.
- *Almudena Real (CIEMAT, Spain; Secretary of the ALLIANCE Platform):* Expert in Radiation Protection of the public and the environment, Committee 5 ICRP member (2005-2017).
- *Thierry Schneider (CEPN, France; President of the NERIS Platform):* Economist, involved in ICRP dialogue with Fukushima, Committee 4 ICRP member.
- *Graham Smith (GMS Abingdon Ltd, United Kingdom; ICRP TG-98):* Practical experience in assessments all over the world.

Two questions were proposed to the panellists to stimulate discussion:

- ✓ How should new scientific finds be communicated to decision-makers to change the policy?
- ✓ Do politicians ignore experts?

How should new scientific finds be communicated to decision-makers to change the policy?

It must be noted that in most countries worldwide there is a complete lack of policies on radiation protection. Therefore, the first thing to do is to work to get all the countries to have policies.

It would be extremely useful to get scientists and decision-makers to work together on the process of decision-making and policy development. The integration between scientists and decision-makers is a key point. Scientist and policy-makers have different perspectives, also time frames with politicians being worried about the short-term. Science will not provide the whole answer. In the decision-making process, in addition to good science, an approach should be developed jointly with stakeholders. Since

the 70s it is acknowledged that social sciences play an important role in decision making, but specific actions are needed to improve their involvement.

Not only good policies are needed, but also good implementation of such policies. An example of this occurred in Japan, after the accident in the Fukushima-Daiichi nuclear power plant. A source related reference level between 1 and 20 mSv per year is recommended by IAEA and ICRP for public exposure in specific existing exposure situations (e.g. areas with residual radioactive material). The Japanese decision-makers chose 1 mSv per year as a reference level, which leads to millions of tons of radioactive waste because the decision taken was driven by decontamination and not remediation.

Do politicians ignore experts?

Scientists should keep in mind that in some cases explaining the complexity of the situation is possible and making coherent and understandable arguments are important. The role of politicians is not trivial. There is a need to open a dialogue between politicians and experts: collaborative deliberations are fundamental.

Scientists may also be acting as translators between different groups of experts. What is generally expected from scientists is to provide radioecological criteria for what is safe or not safe. Scientists should deliver simple information and clearly explain the benefits of the work done. Science is not determining decisions but is bringing evidence for decisions. The TERRITORIES project is useful because it shows how discussions and case studies can support the development of policy frameworks to involve stakeholders.

Communication of scientific information on risks may be sometimes misleading. For example, the tsunami affecting Fukushima caused more harm than the accident at the nuclear power plant (NPP), but everybody remembers only the NPP accident. In some cases the scientific information is misused, e.g. regarding radon associated risks, scientists claim that "Radon exposure causes lung cancer, but only above a certain concentration/dose", but sometimes only the first part of the sentence is used.

In addition to politicians, stakeholders can also have an important voice, although having a process-driven only by interested parties can also be dangerous. There is no single solution and many steps must be taken to converge on an agreed solution. There is a need to have follow-ups of the situations and to review the sustainability of the decision taken.

4. SUMMING UP AND CONCLUSIONS

The workshop was well-attended and included a diverse audience, with 100 participants from 15 different countries, 50% of whom were not members of the TERRITORIES project. The participants were highly active in the discussions held during the workshop. A specificity of this workshop was that it aimed to attract as many students and early career scientists as possible. This aim was fully met, with 32% of the attendees being students and early career scientists. This participation was made possible thanks to 25 travel scholarships funded by the TERRITORIES' flexible funds, i.e. far beyond the initial target of 4 granted trainees per workshop (CONCERT-TERRITORIES D9.79, 2017). The dissemination of the workshop advertisement in various networks was highly successful, as 87% of these students and early career scientists were not involved in the TERRITORIES project. This high level of students' and early career scientists' participation allowed the Programme Committee to devote a special workshop session, in which ten early stage researchers presented their work (see Section 3.3).

Thanks to this wide audience, this TERRITORIES' workshop was an important opportunity for the community of researchers involved in the TERRITORIES project, and with help of half of the audience external to the project, to collectively work out on some of the key subjects of the scope of TERRITORIES: the risk assessment process, the associated uncertainties and their communication.

Based on the presentations and discussions held during the workshop, we summarize the conclusions of the workshop and put them in the wider context of the TERRITORIES project.

The risk assessment process

The scientific concepts and the good practices of risk assessment have been shared during the workshop on the basis of four presentations given by scientists involved in the project. Three of them were given in the introductory session (see Section 3.1): "Protecting the public against radiations: Assessing the dose" by Juan Carlos Mora (CIEMAT); "What about the environment? Impact on non-human biota" by Karine Beaugelin-Seiller (IRSN) and "What do we mean by uncertainty when assessing the dose?" by Laura Urso (BfS). The last one was given in the case-studies session (see Section 3.2): "What information do we need?" by Wayne Oatway (PHE). These four presentations introduced to the audience many subjects also investigated in research tasks of the project, and then developed in other deliverables, such as radioecological modelling (further developed in CONCERT-TERRITORIES D9.61 and D9.62, 2019), exposure scenario (further developed in CONCERT-TERRITORIES D9.63, 2019), and relationship between effects and dose (which was not specifically addressed in other deliverables of the TERRITORIES project for human populations, but was approached for biota in CONCERT-TERRITORIES D9.63, 2019). Discussions raised by the audience emphasized that assessing risk of anthropogenic radioactivity is not fundamentally different to assessing risks of natural background radiation, or even of non-radioactive chemical toxicity, even when practices may differ.

This was completed by four presentations made by guest stakeholders such as regulators, authorities, and operators, who mentioned their expectations from risk assessment. Two of them were given in the introductory session (see Section 3.1): "Regulator's concerns – what do we want to see and how confident do we need to be?" by Paul Dale (SEPA) and "How do we control natural radiation – NORM? The Belgian experience" by Geert Biermans (FANC, Belgium). The other two presentations were given in the case-studies session (see Section 3.2): "Hunting for particles amongst the grains of sand" by Richard Hill (Sellafield Ltd) and "Sellafield particles - what's the story?" by Trevor Howard (EA). These presentations particularly emphasized the field monitoring data as central in the assessment of the situation. This subject of monitoring was also included in the TERRITORIES project, as it had previously been discussed in the Madrid 2018 workshop (CONCERT-TERRITORIES D9.74, 2018) and it was further developed in CONCERT-TERRITORIES D9.60 (2019).

Uncertainties

Persons concerned with the assessment or the management of hazardous activities – especially those increasing the exposure of human beings and wildlife to ionising radiations – are confronted with many forms of uncertainty. This is true for developers and implementers of radiation protection and remediation strategies. It is also the case for decision-makers and regulators, for agencies and Technical Support Organizations that provide guidance, and for researchers whose work provides the expertise. It is also true for bodies in charge of developing compensation frameworks or for those paying off indemnification victims' claims (e.g. insurance companies). Moreover, many other organizations and individuals such as residents living close to contaminated sites, local authorities, professionals in the medical field, NGOs including environmental associations, trade union

organizations, are even more concerned by the uncertainties surrounding the decisions made for the purposes of radiation protection in an existing exposure situation context.

Some of these uncertainties concern the nature of the hazards associated with land use, remediation activities undertaken on abandoned industrial sites, on-site and off-site after radiological incidents and accidents, transport and storage of wastes, etc. Other types of uncertainty are caused by changes in the scientific, legal, financial, and organizational contexts. Another category of uncertainties can arise given the changes in the human, social, political and natural context of human activities, in particular in a context of increasing new media usages as well as the evolution of the role played by different types of stakeholders.

The presentation "Public Concerns" by Ferdiana Hoti in the introductory session (see Section 3.1) and the first round table (see Section 3.4.1) have enabled to introduce to the audience this wide range of uncertainties, consistently with the broad definition of uncertainty stated at an earlier step of the project (CONCERT-TERRITORIES D9.65, 2018) and further developed in the final deliverables of the project (CONCERT-TERRITORIES D9.71 and 72, in preparation).

Communication of uncertainties

The way in which uncertainties are approached, managed, communicated and understood by the different stakeholders has become a major issue, in particular in numerous scientific debates, such as those concerning the precautionary principle which is, should it be reminded, the cornerstone of the system of radiological protection. Many tools and processes have been developed to analyse or account for uncertainties in risk assessment and decisions related to protection of human beings and wildlife (deterministic *vs.* probabilistic risk assessment, Monte-Carlo simulations, Cost-Benefit Analyses, Multi-Criteria Decision Aiding, Agent-Based Modelling, and related techniques). Some of them have been further investigated in this project, for example in CONCERT-TERRITORIES D9.62 (2019) and D9.70 (2019). Nevertheless, conservatisms, which are usually introduced by experts and scientists to account for uncertainties, may lead to sub-optimal decisions and oversized recovery countermeasures. The second round table (see Section 3.4.2) has raised attention to such situations and proposed that engagement of all stakeholders in decision-making, with shared knowledge of underlying uncertainties, can be helpful to avoid excesses.

Guidance on communication of uncertainties can be found in different guidance applicable to fields related to the scope of TERRITORIES and a list of suggested references in proposed in Section 5.2. Further recommendations will be proposed in the final deliverables of the project (CONCERT-TERRITORIES D9.71 and 72, in preparation).

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6. ANNEXES

6.1. Annex 1: Programme of the TERRITORIES workshop on "Assessing risks from radioactive legacy sites and how to better present uncertain information"

Tuesday 19 March 2019

Time	Title	Lecturer
Introductory Session. *Chaired by: Marie Simon-Cornu (IRSN, France) & Tiberio Cabianca (PHE, UK)*		
13:00 – 13:15	Welcome to Oxford and CONCERT introduction	Simon Bouffler (PHE, UK)
13:15 – 13:30	TERRITORIES introduction and scope of the workshop	Marie Simon-Cornu (IRSN, France)
13:30 – 14:10	Protecting the public against radiations - Assessing the dose	Juan Carlos Mora (CIEMAT, Spain)
14:10 – 14:40	What about the environment? Impact on non-human biota	Karine Beaugelin (IRSN, France)
14:40 – 15:00	What do we mean by uncertainty when assessing the dose?	Laura Urso (BfS, Germany)
15:00 – 15:30	*Coffee and tea*	
15:30 – 16:00	Regulator's concerns – what do we want to see and how confident do we need to be?	Paul Dale (SEPA, Scotland)
16:00– 16:30	How do we control natural radiation – NORM: The Belgian experience	Geert Biermans (FANC, Belgium)
16:30 – 16:50	Public uncertainties	Ferdiana Hoti and Bieke Abelshausen (SCK•CEN, Belgium)
16:50 – 17:15	Questions and Discussion	
17:30 –	Social event: Drinks and snacks, Shulman Foyer, The Queen's College	

Wednesday 20 March 2019

Time	Title	Lecturer
Case Studies Session. *Chaired by: Jordi Vives I Batle (SCK•CEN, Belgium) & Kelly Jones (PHE, UK)*		
09:00 – 09:30	Hunting for particles amongst the grains of sand	Richard Hill (Sellafield Ltd, UK)
9:30 – 09:55	What information do we need?	Wayne Oatway (PHE, UK)
9:55 – 10:20	Sellafield particles - what's the story?	Trevor Howard (EA, UK)
10:20 – 10:50	Coffees and tea	
10:50 – 12:15	**Presentations by Early Stage Researchers.** *Chaired by Almudena Real (CIEMAT, Spain)* • Corynne McGuire, *PhD student* (10:55 – 11:00) • Sergi Lopez, *PhD student* (11:00 – 11:05) • Alana McNulty, *PhD student* (11:05 – 11:10) • Wirginia Tomczak, *Post-doc* (11:10 – 11:15) • Nona Movisyan, *PhD student* (11:15 – 11:20) • Blessing Oladele, *PhD student* (11:20 – 11:25) • Dolores Mäekivi, *Student* (11:25 – 11:30) • Khaled Brimo, *Post doc* (11:30 – 11:35) • Ferdiana Hoti, *PhD student* (11:35 – 11:40) • Natalie Byrd, *PhD student* (11:40 – 11:45) Discussion with the audience (11:45 – 12:15)	
12:15 – 13:45	Lunch	

Wednesday 20 March 2019 (Cont.)

13:45 – 15:15	**Round Table: Define What is Meant by "Uncertainties" in the Context of Decision-Making** *Chaired by: Pascal Crouail (CEPN, France) & Juan Carlos Mora (CIEMAT, Spain)*	
	• David Collier (WhiteOx, UK) • Paul Dale (SEPA, Scotland) • Simon French (University of Warwick, UK) • Susan Molyneux-Hodgson (University of Exeter, UK) • Kimiaki Saito (JAEA, Japan; TERRITORIES-TSC) • Jeroen van der Sluijs (University of Bergen, Norway; TERRITORIES-TSC)	
15:15 – 15:45	Coffees and tea	
15:45 – 17:15	**Round Table: "From Science to Policy"** *Chaired by: Matthew Pardo (PHE Press Officer, UK) & Astrid Liland (NRPA, Norway)*	
	• Gilles Heriard Dubreuil (Mutadis, France; Nuclear Transparency Watch Network) • Trevor Howard (EA, UK) • Bogusław Michalik (European NORM Association; TERRITORIES TSC) • Horst Monken-Fernandes (IAEA, Austria; TERRITORIES TSC) • Almudena Real (CIEMAT, Spain; ALLIANCE Platform) • Thierry Schneider (CEPN, France; NERIS Platform) • Graham Smith (GMS Abingdon Ltd, UK; ICRP TG-98)	
17:15	Close of the workshop	Marie Simon-Cornu (IRSN, France) and Tiberio Cabianca (PHE, UK)

6.2. Annex 2: Questions to be discussed in the Round Tables of the Workshop

- ***Round Table: Define what is meant by "Uncertainties" in the context of decision-making***
  - What is your definition of uncertainty?
  - How should information to the public on uncertainty be presented?
  - Is uncertainty in different parameters perceived differently?
- ***Round Table: From Science to Policy***
  - How should new scientific finds be communicated to decision-makers to change the policy?
  - Do politicians ignore experts?

6.3. Annex 3: List of participant in the TERRITORIES workshop on "Assessing risks from radioactive legacy sites and how to better present uncertain information".

Students and early career scientists are marked in blue

#	Surname	Name	Organization	Affiliation
1	Abelshausen	Bieke	SCK•CEN (Belgium)	TERRITORIES
2	Ahmad	Faraaz	Manchester University (UK)	NO-TERRITORIES
3	Anderson	Tracey	PHE (UK)	NO TERRITORIES
4	Beaugelin-Seiller	Karine	IRSN (France)	TERRITORIES
5	Bertho	Jean-Marc	IRSN (France)	TERRITORIES
6	Biermans	Geert	FANC (Belgium)	NO TERRITORIES
7	Blundell	Mark	U. Manchester (UK)	NO-TERRITORIES
8	Bouffler	Simon	PHE (UK)	NO TERRITORIES
9	Brimo	Khaled	IRSN (France)	NO-TERRITORIES
10	Brown	Iain	PHE (UK)	TERRITORIES
11	Budd	Thomas	U. Birmingham (UK)	NO-TERRITORIES
12	Byrd	Natalie	U. Manchester (UK)	NO-TERRITORIES
13	Cabianca	Tiberio	PHE (UK)	TERRITORIES
14	Caplin	Hélène	IRSN (France)	NO-TERRITORIES
15	Clifford	Callum	Atkins (UK)	NO-TERRITORIES
16	Collier	David	WhiteOx (UK)	NO TERRITORIES
17	Croüail	Pascal	CEPN (France)	TERRITORIES
18	Curley	Emer	U. Manchester (UK)	NO-TERRITORIES
19	Dale	Paul	SEPA (Scotland)	NO TERRITORIES
20	Dickinson-Lomas	Alexandra	U. Birmingham (UK)	NO-TERRITORIES
21	Ding	Zengjie	U. Manchester (UK)	NO-TERRITORIES
22	Ekebas	Elif	U. Birmingham (UK)	NO-TERRITORIES
23	Février	Laureline	IRSN (France)	TERRITORIES
24	Fisher	Erik	PHE (UK)	TERRITORIES
25	Francis	Jonathan	U. Central Lancashire	NO-TERRITORIES
26	Foster	Matthew	PHE (UK)	NO-TERRITORIES
27	French	Simon	U. Warwick (UK)	NO TERRITORIES
28	Giner	Sabrina	IRSN (France)	NO-TERRITORIES
29	Guillevic	Jérôme	IRSN (France)	TERRITORIES
30	Hamburger	Thomas	BfS (Germany)	TERRITORIES
31	Hardcastle	Glenn	Aurora Health Physics (UK)	NO-TERRITORIES
32	Hardcastle	Julia	U. Birmingham (UK)	NO-TERRITORIES
33	Heriard Dubreuil	Gilles	Mutadis (France)	TERRITORIES
34	Hill	Richard	Sellafield Ltd (UK)	NO TERRITORIES
35	Hosseini	Ali	DSA (Norway)	TERRITORIES
36	Hoti	Ferdiana	SCK•CEN (Belgium)	TERRITORIES
37	Howard	Trevor	Environment Agency (UK)	NO-TERRITORIES
38	Howett	Elizabeth	Studsvik Ltd (UK)	NO-TERRITORIES
39	Iosjpe	Mikhail	DSA (Norway)	TERRITORIES

40	Jones	Kelly	PHE (UK)	TERRITORIES
41	Kaasik	Marko	U. Tartu (Estonia)	TERRITORIES
42	Kadam	Sandeep	U. Central Lancashire (UK)	NO-TERRITORIES
43	Kallio	Antti	STUK (Finland)	TERRITORIES
44	Kavi	Parthiv	U. Central Lancashire (UK)	
45	Kivan	Oguzhan	U. Birmingham (UK)	NO-TERRITORIES
46	Kokalova Wheldon	Tzany	U. Birmingham (UK)	NO-TERRITORIES
47	Lafranque	Eymeric	CEPN (France)	TERRITORIES
48	Lawrence	Sam	U. Manchester (UK)	NO-TERRITORIES
49	Liland	Astrid	DSA (Norway)	TERRITORIES
50	Lind	Ole Christian	NMBU (Norway)	TERRITORIES
51	López-Asensio	Sergi	CIEMAT (Spain)	TERRITORIES
52	Mäekivi	Dolores	U. Tartu (Estonia)	TERRITORIES
53	Maître	Mélanie	CEPN (France)	TERRITORIES
54	Masoudi	Pedram	IRSN (France)	TERRITORIES
55	McGuire	Corynne	U. Stirling (UK)	NO-TERRITORIES
56	McNulty	Alana	U. Manchester (UK)	NO-TERRITORIES
57	Michalik	Bogusław	GIG (Poland)	TERRITORIES TSC
58	Molyneux-Hodgson	Susan	U. Exeter (UK)	NO TERRITORIES
59	Monken-Fernandes	Horst	IAEA (Austria)	TERRITORIES TSC
60	Mora	Juan Carlos	CIEMAT (Spain)	TERRITORIES
61	Movsisyan	Nona	CENS (Armenia)	TERRITORIES
62	Mullan	Alanna	U. Manchester (UK)	NO-TERRITORIES
63	Newson	Rebecca	Quintessa Ltd (UK)	NO-TERRITORIES
64	Nugroho	Bangun Satrio	U. Hiroshima (Japan)	NO-TERRITORIES
65	Oatway	Wayne	PHE (UK)	TERRITORIES
66	Oladele	Blessing	Federal U. Technology Akure (Nigeria)	NO-TERRITORIES
67	Panter	Reuben	U. Birmingham (UK)	NO-TERRITORIES
68	Pardo	Matthew	PHE (UK)	TERRITORIES
69	Patton	Nina	SEPA (Scotland)	NO-TERRITORIES
70	Perez Sanchez	Danyl	CIEMAT (Spain)	TERRITORIES
71	Pons	Timothy	Atkins (UK)	NO-TERRITORIES
72	Punt	Adrian	RadEcol Consulting Ltd (UK)	NO-TERRITORIES
73	Real	Almudena	CIEMAT (Spain)	TERRITORIES
74	Rees	James	U. Liverpool (UK)	NO-TERRITORIES
75	Saito	Kimiaki	JAEA (Japan)	TERRITORIES TSC
76	Sala	Roser	CIEMAT (Spain)	TERRITORIES
77	Sangha	Pamandeep	U. Birmingham (UK)	NO-TERRITORIES
78	Schneider	Thierry	CEPN (France)	TERRITORIES
79	Sebin	John	U. Sheffield (UK)	NO-TERRITORIES
80	Sika-Boafo	Daniel Agyarko	U. Birmingham (UK)	NO-TERRITORIES
81	Simon-Cornu	Marie	IRSN (France)	TERRITORIES
82	Skipperud	Lindis	NMBU (Norway)	TERRITORIES
83	Skuterud	Lavrans	DSA (Norway)	TERRITORIES
84	Smith	Graham	GMS Abingdon Ltd (UK)	NO TERRITORIES
85	Smith	Justin	PHE (UK)	TERRITORIES

86	Sorwar	Mohammed	U. Birmingham (UK)	NO-TERRITORIES
87	Stokes	Tom	U. Birmingham (UK)	NO-TERRITORIES
88	Sweeck	Lieve	SCK•CEN (Belgium)	TERRITORIES
89	Tkaczyk	Alan	U. Tartu (Estonia)	TERRITORIES
90	Tomczak	Wirginia	IRSN (France)	NO-TERRITORIES
91	Urso	Laura	BfS (Germany)	TERRITORIES
92	van der Sluijs	Jeroen	U. Bergen (Norway)	TERRITORIES TSC
93	Van Oudheusden	Michiel	SCK•CEN (Belgium)	TERRITORIES
94	Vives i Batlle	Jordi	SCK•CEN (Belgium)	TERRITORIES
95	Walker	Sean	Atkins/SNC Lavalin (UK)	NO-TERRITORIES
96	Wilson	Allan	Urenco Nuclear Stewardship (UK)	NO-TERRITORIES
97	Yardimci	Merve Yagmur	U. Birmingham (UK)	NO-TERRITORIES
98	Yu	Charley	ANL (USA)	NO-TERRITORIES
99	Yu	Yasmin	Energus (UK)	TERRITORIES TSC
100	Zebracki	Mathilde	IRSN (France)	TERRITORIES

6.4. Annex 4: Survey distributed and feedback from participants on the workshop

6.4.1. Survey

Feedback for TERRITORIES Oxford Workshop

We thank you for attending the workshop held on March 19-20, 2019 in Oxford. To evaluate the effectiveness of the workshops, we ask for your assistance in completing this evaluation. Your feedback will help to improve future TERRITORIES events. Thank you in advance for your contribution.

This is an anonymous survey, but You will be given a chance to include Your name and e-mail at the end of the survey, if you would like more information about the survey results.

Specific questions

How did you enjoy the Introductory lecture session on the first day?

	1	2	3	4	5	
Did not enjoy	○	○	○	○	○	Enjoyed very much

How did you enjoy the Case Studies Session at the start of the second day?

	1	2	3	4	5	
Did not enjoy	○	○	○	○	○	Enjoyed very much

How did you enjoy the Early Stage Researcher session on the second day?

	1	2	3	4	5	
Did not enjoy	○	○	○	○	○	Enjoyed very much

How did you enjoy the first Round Table panel discussion (topic: "Define What is Meant by "Uncertainties" in the Context of Decision-Making") on the second day?

	1	2	3	4	5	
Did not enjoy	○	○	○	○	○	Enjoyed very much

How did you enjoy the second Round Table panel discussion (topic: "From Science to Policy") on the second day?

	1	2	3	4	5	
Did not enjoy	○	○	○	○	○	Enjoyed very much

General questions

The content was as described in publicity materials

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The material was presented in an organized manner

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The presentations were adequate in time and style

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The workshop was applicable to my job

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The pace of the workshop was suitable for me

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

The venue was suitable

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I would recommend this workshop to others

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I would be interested in attending a follow-up, more advanced workshop on this same subject

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Given the topic, the length of the workshop was

○ Too short

○ Appropriate length

○ Too long

Please rate the following

	Poor	Fair	Good	Very Good	Excellent
Visuals	○	○	○	○	○
Acoustics	○	○	○	○	○
Meeting space	○	○	○	○	○
The program overall	○	○	○	○	○

How did you hear about this workshop? (Optional)

What are your most valuable takeaways from this workshop? (Optional)

Which aspects of this workshop could be improved? (Optional)

Any further comments? (Optional)

Your Name (Optional)

Your E-mail (Optional)

6.4.2. Feedback from participants

The questionnaire was answered by 24 participants, mostly anonymously (only 7 persons identified themselves). The feedback received is shown in the tables below.

Specific questions

Question	Score*					
	1	2	3	4	5	NA
How did you enjoy the Introductory Session on the first day?	--	2	7	5	10	--
The How did you enjoy the Case Studies Session at the start of the second day?	--	1	1	6	16	--
How did you enjoy the Early Stage Researcher session on the second day?	--	--	3	6	14	1
How did you enjoy the first Round Table panel discussion ("Define What is Meant by "Uncertainties" in the Context of Decision-Making") on the second day?	2	3	5	5	8	1
How did you enjoy the second Round Table panel discussion (topic: "From Science to Policy") on the second day?	2	4	2	6	8	2

** 1: Did not enjoy; 5: Enjoyed very much. NA: Not answered*

General questions

Question	Score*					
	1	2	3	4	5	NA
The content was as described in publicity materials	1	2	3	6	12	--
The material was presented in an organized manner	--	--	7	3	14	--
The presentations were adequate in time and style	--	2	6	4	12	--
The workshop was applicable to my job	1	3	2	6	12	--
The place of the workshop was suitable for me	1	--	3	3	17	--
The venue was suitable	--	--	1	1	23	--
I would recommend this workshop to others	--	3	3	2	16	--
I would be interested in attending a follow-up, more advanced workshop on this same subject	--	3	2	3	16	--

** 1: Strongly disagree; 5: Strongly agree. NA: Not answered*

	Too short	Appropriate length	Too long
Given the topic, the length of the workshop was	5	18	1

Please rate the following	Poor	Fair	Good	Very good	Excellent
Visuals	--	1	6	10	7
Acoustics	--	1	4	9	10
Meeting space	--	1	5	8	10
The programme overall	1	3	5	6	9

For the other questions included in the survey, which were optional, the answers received were:

- How did you hear about this workshop?
  - TERRITORIES web
  - CONCERT web
  - Her/his institute
  - Colleagues
  - Invitation letter
  - Member of TERRITORIES project
  - SRP website or newsletter
- What are your most valuable takeaways from this workshop?
  - People are uncertain about uncertainties.
  - That there is no agreed approach to passing on or using uncertainty and variability in risk assessments. Important differences exist between practitioners (regulators) and scientists (modellers/in-field workers) which need resolving.
  - Conference/workshop experience and a better understanding of regulatory systems and approach outside the United Kingdom. Although the actual communication tools were not covered in depth (such as how best to relay information - presentations/posters/ reports to different audiences), I learned plenty about environmental monitoring/ sampling and how best to conduct and communicate results from site surveys. Regulator and industry interfaces were explored thoroughly, industry-public and regulator-public were not so deeply covered. That being said there was some good discussion around defining important terms such as "Is there a 'public? What is the definition of uncertainty?
  - The transparency of people communicating is important.
  - Knowledge and networking.
  - Understanding the atmosphere of radioecology.
  - The big contribution young researchers can make.
- Which aspects of this workshop could be improved?
  - Much of the workshop was focussed on current/planned activities which I don't think are legacy sites. There was very little discussion on true legacy sites.
  - More specific examples and more cases of actually presenting work to "the public".
  - Having a keynote speaker from a local university.
  - More control was needed by the chairs. Many presentations over-ran as presenters were unable to stick with the timetable or the chairs allowed too many questions. This made the sessions long. Given the topic of the workshop it should have been anticipated that there would be a lot of discussion - this could have been built into the timetable rather than assume it could all be done using the general format of 15 minutes presentation and 5 minutes of questions. The discussions during the round tables were interesting but a better way of summarising the discussion was needed to try and bring what was said together. Whilst the questions were interesting, having the panellists come up with some of their own questions would have also been interesting: this would allow them to discuss real life issues that they are aware of not just those that TERRITORIES think are interesting. A better way of rounding off the workshop was needed. For example, giving the concepts that attendees at the workshop generally agree with or at least highlighting the areas where there is disagreement and where work within TERRITORIES will be carried out to try and resolve.

- Stricter control/direction on the speakers in the Round Table discussions. More Q/A and engagement for panellists. Questions agreed with panel and sent to audience in advance.
- The respect of the schedule and especially the duration of the presentations.
- Academics need to shorten their presentations. The round table discussions should engage more directly with the audience, maybe in a similar style to BBC's Question Time.
- Speakers went round in circles in discussion.
- Everything was fun, it is important to involve students in such projects.
- Early stage researcher session.
- Bedrooms were a bit grim but very convenient and it was very good to be central to the city.

- Any further comments
  - The high proportion of younger researchers and students was a very good thing for the quality of the event but also for the future of the profession.
  - I thought the workshop was about the right length. I would have enjoyed a longer workshop to explore additional topics but I appreciate this would potentially limit numbers. The pacing of presentations was excellent and the quality of speaking and content from the presenters was outstanding. Special thanks must go to the foreign presenters, they spoke better than a number of English lecturers I have had in the past. Some more time for the PhD presentations would have been appreciated as I feel they weren't able to fully convey the work being covered. Potentially making the first day longer would have helped accommodate this. A discussion on the direction of research within selected universities would also have been an interesting addition for future workshops. The two round tables were insightful, but I think the 1st one lacked direction and would be better suited to short form lecture formats or debates with panellists providing the lecture(s) with the rest of the panel asking questions/providing thoughts on the topics and material covered. The 2nd benefited from a looser structure and made for a more engaging round table. The venue was really well suited to the event and the days were well organised. Thank you for having me, as a student I felt welcome and really enjoyed my time at the workshop.
  - I would have liked slightly more emphasis on "assessing the risk" and less on "communicating uncertainties" as I felt we were getting slightly repetitive with the latter topic by the end. I agree with comments made by some attendees that TERRITORIES should be careful about presenting risks from radioactive materials - they are *not* fundamentally different to risks from NORM, natural background radiation, or non-radioactive chemical toxicity. Otherwise, I found it a very interesting workshop and a good level for me as an early career nuclear consultant. The venue was ideal and attendance good. Case studies are useful.
  - The lunch took me back to my days in Oxford during the 1970s.... it really was not up to modern catering standards
  - Everything was great!