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Education and training in radioecology during the EU-COMET project - successes and suggestions for the future

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Abstract. The 2014 Strategic Research Agenda (SRA) for Radioecology identified that the key challenge in education and training (E&T) was "to maintain and develop a skilled workforce in Europe and world-wide, through university candidates and professionals trained within radioecology" since "scientific research in radioecology and application of that knowledge… requires scientists and workers with adequate competence and appropriate skills." Radioecology is a multidisciplinary science and E&T is needed by both students and professionals within research, industry and radiation protection. In order to address these needs, COMET has developed an E&T web platform and arranged a number of field courses, training courses, PhD and MSc courses, refresher courses and workshops, drawing on the COMET consortium to assemble relevant experts. In addition, COMET has been engaged in discussions with stakeholders for more long-term solutions to maintain the sustainability of radioecology E&T after the end of the project. Despite much progress in some areas, many of the challenges outlined in the 2014 SRA remain, mainly due to the lack of sustainable dedicated funding. Future plans within the ALLIANCE radioecology platform and CONCERT-European Joint Programme for the Integration of Radiation Protection Research must urgently address this lack of sustainability if radioecological competence is to be maintained in Europe.

1. Introduction

Many European radioecologists have expressed concern that radioecology is undergoing a major decline. Radioecology in Europe was well-recognized and funded following the Chernobyl accident. However, the accident's declining influence on funding, as well as a reduced support for nuclear power within many

countries, resulted in substantial decreases in resources and personnel. Three previous EC-funded projects, EURAC (2004-5), FUTURAE (2006-8) and STAR (2011-15), have evaluated the current state of radioecology, both for the job market and education within Europe, and found that the science 1) was fragmented, with poor coordination among the national strategies and programmes, 2) was suffering from a steadily decreasing funding base, 3) could soon be hampered by the closing of important infrastructures and retirement of key personnel, 4) required recruitment of young scientists to ensure relevant expertise was available for ensuring radiation protection and emergency response, 5) required maintenance of facilities to be able to respond to society's future radiological needs, and 6) could be enhanced by efficiently pooling resources and prioritizing group efforts (EURAC 2006, Gariel *et al* 2008, Real *et al* 2015).

The 2014 Strategic Research Agenda for Radioecology (Hinton *et al* 2013, 2014) identified that the key challenge in education and training (E&T) was "To maintain and develop a skilled workforce in Europe and world-wide, through university candidates and professionals trained within radioecology" since "Scientific research in radioecology and application of that knowledge in the radiation protection of man and the environment requires scientists and workers with adequate competence and appropriate skills."

Those in need of E&T in radioecology are both students and professionals within research, industry and radiation protection. At university level, radioecology is a 'minority' subject that is often not provided as part of the curriculum, and students are often not aware of its existence. The Norwegian University of Life Sciences (NMBU) is the only university giving a full MSc programme in Radioecology, but radioecology courses can be (and are) easily given as part of radiochemistry, radiobiology or other closely related disciplines. In addition, radioecology is a multidisciplinary science, requiring teachers from many fields, and needing to reach out to students with a range of backgrounds. Being a relatively small science, teachers and learners are widely scattered geographically, which leads to the need for intensive courses to minimize costs, and/or a requirement for online E&T.

Stakeholders from authorities, industry and regulators and experts with insight into the overarching drivers for radioecology in society were consulted about the current and future demands within the workforce at two workshops during the EC-STAR project (Oughton *et al* 2012). A main conclusion from these workshops was that recruitment of people with knowledge of radioecology would be needed well into the future, due to the range of existing and potential inputs of radionuclides into the environment (e.g., from the nuclear fuel cycle and spent fuel reprocessing and waste management, legacy sites, hospitals, NORM/TENORM, accidents and terrorism). This in turn leads to a need for science-based regulations, risk assessments, remediation, source-term evaluation, decision making, and public outreach. Three main ways to increase recruitment of new students were highlighted: increasing visibility of radioecology as a science; offering practical laboratory and field courses, particularly connected to real life problems; and networking. During these consultations considerable effort was made to identify specific training requirements with respect to radioecology. Those requirements ranged from a solid theoretical understanding of biosphere processes to expertise in risk and impact assessment. Of particular relevance to the subsequent EC-funded COMET (COordination and iMplementation of a pan-Europe instrumenT for radioecology) project were: informed application of models and tools; laboratory courses that provide hands-on instrumental training; and field studies that provide opportunities for different disciplines to work together. This paper provides an overview of the E&T achievements during the COMET project that were designed to address some of the issues identified in the stakeholder workshops and discusses future ideas and challenges for E&T in radioecology.

2. Objectives of COMET E&T

The overarching objective of COMET's 'Knowledge Exchange' work package was to "enhance and maintain European capacity and skills in radioecology by establishing a dynamic interaction promoting effective collaboration between researchers, tool developers, regulators and industry". Education and training was one of the main components of this work package, whose specific objectives were to: establish an interactive website for COMET including supporting materials for the user community, providing informed and regular updates of developments; develop training packages to maintain and enhance professional competence; and facilitate discussion of topical radioecological issues between students, researchers and users to support radiation protection in Europe.

3. COMET contribution to radioecology E&T

In order to address the needs outlined above, COMET developed an E&T web platform and arranged a number of courses and workshops for students and professionals. Courses and workshops were as short and time-efficient as possible to allow the participation of professionals with many demands on their time. For the same reason, activities were arranged (if possible) to coincide with other meetings and conferences to save travel costs for participants. COMET also gave refresher courses in conjunction with conferences, field-courses, hands-on training courses and full PhD and MSc courses for an international audience. In this section we give an overview of these activities; in section 4 we discuss the added value of carrying out these activities in the framework of the COMET project and in section 5, there are brief details of COMET discussions on more long-term solutions to maintain the sustainability of radioecology E&T after the end of the project.

3.1. Platform (Radioecology Exchange E&T website)

Within the Radioecology Exchange website, COMET has further developed the E&T platform which was first set up by the EC-STAR project. It is a focal point for students and professionals interested in radioecology, linking education in different nuclear disciplines together (Skipperud *et al* 2017; http://www.radioecology-exchange.org/content/training-education). The ultimate aim of the E&T platform is to sustain and develop competence in radioecology by giving the possibility to network, find information on courses, and interact with the field of radioecology. The platform presents an overview of E&T course modules within radioecology/environmental radioactivity offered by members that were in the COMET consortium, ranging from MSc and PhD courses to workshops and professional development. Information on course curricula and learning outcomes are provided, with recommended pathways to obtain academic merited education or training courses. Information on the Radioecology PhD Network is also available (see section 3.3). This network is a virtual forum intended to promote networking and interaction between students and scientists and the rest of the radioecology community.

The E&T platform also provides links to other E&T platforms, such as those within Radiochemistry, Radiobiology and Radiation Protection. This is an important outreach mechanism for the Radioecology E&T platform, as – for example – many of the basic course modules within radioecology are also relevant for other nuclear science students, and vice versa. The joint information on courses, programmes and workshops on this platform will hopefully enable training and educational solutions that will encourage the streamlining of the European education system with respect to the provision of radioecology and courses in related discipline at post-graduate level, and will encourage the move towards the creation of a standardized certification system for postgraduate qualifications throughout the EU. This, in turn, will enable the identification, by employers, of personnel with the specific skills that meet their needs. It will also maximize the use of disparate existing resources through the sharing of personnel and facilities and reduce the duplication of expensive course modules and encourage optimisation of resources (human resources, tools, investments). It will also encourage collaboration and increased utilisation of joint

resources with other training and education providers such as IAEA and ENEN. In the future it will be important to link to E&T activities within the on-going CONCERT European Joint Programme (http://www.concert-h2020.eu/) and CONCERT-funded projects (e.g. TERRITORIES (https://territoriesweb.wordpress.com/), CONFIDENCE (https://portal.iket.kit.edu/CONFIDENCE/index.php)).

3.2. E&T courses given during COMET

During COMET, several courses were held. Ongoing MSc and PhD courses were revised and given as intensive courses making it possible for international students to attend. These courses utilized experts from the COMET consortium as lecturers. A highlight was the two new field courses that were developed, designed and held, with teachers from several of the COMET partner organisations. All course materials are freely available on the Radioecology Exchange (http://www.radioecology-exchange.org/content/training-courses). Both courses had more applicants than available places and received very positive feedback from the participants. The practical field and laboratory aspects, as well as the diversity of participants and the range of expertise of the teachers were particularly appreciated (table 1). The European Radioecology Alliance (ALLIANCE: http://www.er-alliance.eu/) intends to develop these or similar courses and their continuation will be explored among the ALLIANCE partners participating in the E&T working group (WG).

3.2.1. Field course on "Naturally Occurring Radioactive Material (NORM) in the Environment"

The intensive (4 day) course, held at the Silesian Centre for Environmental Radioactivity, Central Mining Institute (GIG), Katowice, Poland in 2015, was aimed at both students and professionals, and focused on most aspects of environmental radiation impact and risks associated with enhanced natural radioactivity released from different NORM industries and accumulated in the environment. Key processes controlling the behaviour of naturally occurring radionuclides in different ecosystems were outlined in the light of recent radioecology research, including basic concepts, variables/parameters and kinetic information needed for modelling purposes. Application of appropriate methods for assessing radiation impact and risk in the context of the complex suite of natural radionuclides were discussed and then used during the field exercises. Lectures and exercises covered the whole impact assessment process starting with sampling strategies and protocol preparation, sampling campaign, sample pre-treatment and preparation, the use of state-of-the-art measurement techniques and ending with the use of environmental risk assessment models (ERICA Tool; Brown et al. 2016). The two days of field exercises were carried out at sites contaminated by NORM due to former and current industrial coal mining activities in the Upper Silesian Coal Basin.

3.2.2. Field course on "Chernobyl fallout in the environment"

This intensive (4 day) course was aimed at PhD and Masters students and focused on the impact and risks associated with enhanced radioactivity in the environment due to the Chernobyl accident fallout. It was held at held at the National University of Life and Environmental Sciences of Ukraine (NUBiP) at the Ukrainian Institute of Agricultural Radiology (UIAR) in Kiev in 2016, and covered key processes controlling the behaviour of radionuclides in different ecosystems, including basic concepts, variables/parameters and kinetics that should be taken into account in modelling. There was a strong focus on selecting and applying appropriate sampling strategies and methods for assessing radiation impact and risk in the context of the complex suite of radionuclides present in the environment. The course included theory (lectures) and training in the laboratory (radiochemistry and radiation measurements) and one day in the field within the heavily contaminated Chernobyl 10km zone.

3.2.3. Training Course on "Radiological Protection of the Environment"

This course covered a number of aspects of environmental (non-human biota) radiological assessment, including application of the ERICA Tool, radionuclide transfer, dosimetry, effects, benchmarks, dispersion and how to model atmospheric noble gases. The course (the ninth in a series;

https://www.ceh.ac.uk/training/radioecology) was aimed at students and professionals wishing to obtain a basic understanding of radionuclide transfer, dosimetry and radiation effects, become more familiar with radiological assessment objectives and tools, be able to interpret the results provided by these tools and understand the implications of how the tools are used.

3.2.4. Intensive courses (some as part of European Radioecology Masters Programme).

COMET partners have also continued to develop, teach and participate in the European Masters Programme in Radioecology, held at NMBU, Norway. This programme is important in promoting radioecology as an academic discipline and in providing E&T for students and professionals, and courses are Bologna-accredited through the European Credit Transfer and Accumulation System (ECTS). Modules of the programme (e.g. the MSc course in Radioecology and Environmental Radioactivity and the PhD course in Environmental Radiobiology), as well as separate courses held at individual COMET organisations (e.g. the Radiobiology course at SCK•CEN) have also benefited from collaboration and co-financing from other European platforms such as DOREMI (http://www.doremi-noe.net/training_and_education.html), CINCH II (https://www.cinch-project.eu) and CONCERT (http://www.concert-h2020.eu). Students from all over Europe have participated in these intensive courses (table 1).

3.2.5. Refresher courses

COMET held two refresher courses at the International Conference on Radioecology and Environmental Radioactivity in Barcelona, 2014. These were on a) revisions to the ERICA Tool and b) assessment of noble gases in exposure of wildlife, and attracted 30-50 scientists. NERC-CEH also gave a short session entitled 'Protection of biota: Methodologies and assessment tools' at the 14th Congress of the International Radiation Protection Association (IRPA), Cape Town, South Africa in May 2016 as part of the IRPA's refresher course programme.

3.2.6. Vocational Education and Training (VET)

During COMET, the need for future VET within radioecology has been explored. There was a clear consensus on the need for clear learning outcomes from courses given; COMET courses have therefore been quite specific when defining the expected learning outcomes to meet stakeholder needs. For the future, exploration of how to convert learning outcomes (and academic credits) into vocational education credits (VET) is needed.

3.3. Actions to promote and enhance networking of young scientists

More than thirty PhD students and a large number of Masters students have been associated with COMET-related research and are part of the Radioecology PhD network, which is also open to non-COMET students. The Radioecology PhD network is an international networking forum aimed primarily at PhD students in radioecology and other relevant nuclear sciences. There is a full list of students, with their research topics and contact details on the Radioecology Exchange E&T Platform, giving students a forum to make contact with each other. Students in the network are also given priority on courses organized by COMET such as the PhD course in Environmental Radiobiology held at NMBU in collaboration with COMET.

An Early Career / Young Scientists Session was co-organized by COMET at the Radiation Protection Week in Oxford (September 2016), to highlight research by early career scientists across the various EU platforms (e.g. MELODI, EURADOS, NERIS and ALLIANCE) and provide a meeting place for scientists at this stage of their career.

Due to the rather fragmented nature of radioecology in Europe, as well as its multidisciplinarity, PhD students and young scientists in radioecology are often part of quite small research groups. Feedback from these groups showed the value of discussing their research and other issues among peers and not just their supervisors or close research group. Meeting fellow students at courses and conferences forms networks that the students can continue to utilise after finishing their PhDs.

3.4. Workshops

A number of workshops were held during COMET and a number of students and professionals benefitted from the chance to participate and discuss scientific issues with international researchers and stakeholders. The freely available workshop reports (http://www.radioecology-exchange.org/content/workshops-0) also provide valuable summaries of the discussions and ideas for future research and policy directions.

3.4.1. Transgenerational and Epigenetic Mechanisms of Radiation Toxicity at Chronic Doses

The workshop was held in Oxford, UK, in December 2014, and was intended as an integrating activity between related research fields. The meeting focused on theoretical discussions on epigenetics and on the role of epigenetics in (eco)toxicology and radioecology, including biological processes such as development, aging and neurological diseases, adaptation and the use of epigenetic endpoints as generalized or even stressor-specific biomarkers. As well as a series of presentations, priority was given to two discussion sessions on 'Epigenetics and transgenerational effects' and 'Epigenetics and systems biology' to allow cross-fertilisation of ideas across disciplines. Outcomes of the discussions identified promising approaches and ideas to advance the field and fed into recommendations for future research priorities in the ALLIANCE (Spurgeon *et al* 2015), who will incorporate this input into their work plan (see roadmap: http://www.radioecology-exchange.org/sites/www.radioecology-exchange.org/files/T1_WG_for%20Radioecology%20Roadmap_Effects_Jan%202015.pdf).

3.4.2. ICOBTE and Fukushima workshop

The 2nd COMET workshop comprised three events in Japan in July 2015. There was a session in the 13th International Conference on the Biogeochemistry of Trace Elements (ICOBTE 2015), held at Fukuoka, an associated excursion with 26 participants to contaminated areas near the Fukushima Daiichi NPP and a COMET Fukushima Workshop, held at Iizaka. The Symposium was on "Understanding and mitigating the environmental behaviour of radiocaesium after the Fukushima accident". There were 73 presentations, including 25 posters, from 9 countries. The COMET Fukushima workshop, organized by the Institute for Environmental Radioactivity, Fukushima University, had 42 participants from 6 countries. The speakers covered a wide range of topics and summarized current key findings and issues. Among other things, the workshop concluded that comparisons with the situation in Chernobyl showed similarities and also differences which will need to be documented and incorporated into international literature, understanding and models (Howard *et al* 2015).

3.4.3. Modelling fit for purpose workshop

The objective of this workshop was to discuss whether modelling is fit for purpose, by organising a dialogue and obtaining feedback from modellers, experimentalists and stakeholders on this subject. A key aspect of the workshop was to improve the interaction between modellers and experimentalists, since closer cooperation is expected to create a better compatibility between model developments and experimental studies. In addition, the workshop provided guidance on the development of radioecological models for specific purposes, including the desired degree of conservatism, the acceptable level of uncertainty and the optimisation of model complexity. Developing strategies to minimize the overall predictive uncertainty of model output is one of the challenges. The benefits and limitations of process-based approaches and extrapolation methodologies to fill data gaps were addressed in this context. Approaches to the validation of radioecological models were reviewed and evaluated. The workshop initiated a dialogue that will improve the quality and robustness of radioecological models and make them

more suitable for scientific applications and a broad range of assessment purposes, bridging to other radiation protection platforms and taking into account their specific needs.

3.4.4. Thirty years after the Chernobyl accident: what do we know about the effects of radiation on the environment?

The aim of the workshop was to discuss what we have learnt from studies of the effects of radiation on the environment (i.e. wildlife) in the Chernobyl Exclusion Zone (CEZ), and what questions still remain, given that there is a lack of consensus in the scientific community on the extent of these effects. This leads in turn to conflicting information being published in the media and difficulties in communication between scientists and the general public and policy makers. The workshop was held in Chernihiv, Ukraine, and included a study visit to the Chernobyl Exclusion Zone. An attempt was made to address how we can resolve the anomalies between field and laboratory studies and what the implications of Chernobyl (and Fukushima) studies are for current benchmark dose rates. Discussions benefitted from the wide range of different types and nationalities of participants (table 1). Recommendations were made by the workshop which can be found in the workshop report (Barnett & Welch 2017). A series of papers resulting from the workshop will be published in a special issue of the Journal of Environmental Radioactivity in 2017.

Table 1. A summary of the multi-partner, diverse and international nature of the courses and workshops held by COMET.

Activity	COMET participants involved in organizing / teaching	Course attendees
Environmental Radiobiology PhD course, Norway, June 2015	NMBU, SU	28 students; 12 PhD and 8 MSc, 8 postdoc/professionals, from 12 countries: Argentina, Belgium, Croatia, Czech Republic, Denmark, Norway, Portugal, Russia, Sweden, Turkey, UK, USA
NORM field course, Poland, Sept 2015	GIG, NMBU, SU, NRPA	16 participants from 11 countries: Angola, Belgium, Estonia, Finland, Germany, Greece, Norway, Poland, Spain, Sweden, UK. Participants from universities, authorities, companies involved in radiation protection, research institutes and national waste repository authorities
MSc course: Radioecology and Environmental Radioactivity, Norway, Oct 2015	NMBU, SCK•CEN, CIEMAT, NRPA	15 participants (PhD and MSc students) from 6 countries: Finland, Germany, Nepal, Norway, Russia, Sweden
Chernobyl course, Ukraine, Sept 2016	UIAR, NMBU, SU	28 participants (PhD and Masters students) from 11 countries: Austria, Czech Republic, China, Finland, France, Japan, Norway, Spain, Sweden, Ukraine, UK
Transgenerational and Epigenetic	CEH, IRSN, SCK•CEN	48 participants from 12 countries: Belgium, Canada, France, Germany, Japan, Norway, Portugal, Russia,

Effects workshop, Oxford, UK, Dec 2014		Spain, Sweden, UK, USA
ICOBTE/ Fukushima workshop, Japan, July 2015	NERC, Fukushima Univ., IRSN, NRPA, SCK•CEN	Series of events: 73 presentations, including 25 posters, from 9 countries. 42 participants from 6 countries: Australia, Belgium, France, Japan, Norway, UK
Modelling workshop, Seville, Spain, June 2016	NMBU, UoS, CIEMAT, SCK, BfS	55 participants from 17 countries: Austria, Belgium, Czech Republic, Estonia, Finland, France, Germany Japan, Norway, Romania, Portugal, Russia, Spain, Sweden, Ukraine, UK, USA. Participants were scientists, both experimentalists and modellers, and stakeholders
Chernobyl workshop, Ukraine, Aug/Sept 2016	CEH, IRSN, Chornobyl Center, University of Stirling[a]	39 participants from 11 countries: Belarus, Belgium, Canada, Finland, France, Japan, Spain, Sweden, Ukraine, UK, USA. Participants were from radioecology/radiation protection, regulatory organisations, nuclear related industries, an NGO, the media, ecotoxicology, social sciences and humanities

[a] COMET Steering Committee member

4. What was the added value of COMET's contribution?

Organizing E&T activities through the COMET consortium has had many benefits. Without the dedicated time and resources, as well as a critical mass of expertise within the consortium, most of these E&T activities would not have taken place. We strongly encourage future EC-funded programmes in the field to include work packages dedicated to E&T. It has been possible to draw on the partner organizations to assemble relevant experts to teach courses in a cost-effective manner, to reach out to a large international recruitment base for students and to utilize relevant infrastructure (e.g. laboratories, field site access) that has significantly contributed to the content and attractiveness of the courses. The fact that a total of 87 students attended the courses and an additional 184 people attended the workshops gives an indication of the need for, and the success of, these activities. Each time such courses were held, they were fully subscribed and got good feedback. The wide range of expertise in the COMET consortium has also enabled the provision of courses at different levels for different target groups (e.g. students, researchers and various stakeholders). COMET has therefore made good progress in enhancing and maintaining capacity and skills in radioecology, its original aim.

Another success factor has been the workshops where students, scientists, both modellers and experimentalists, and different stakeholders have had the opportunity to interact and give feedback directly. The outcome of these workshops have been proactive and given the opportunity to learn and direct future work within the areas discussed. The need of getting people together from both within the science field itself and also the users of the science, the stakeholders, have proven to very valuable.

The networking and collaboration facilitated by COMET have not only led to continued contact between and among professionals and students, but has also paved the way for several more formalised agreements of cooperation in future E&T efforts. Several COMET partners have been instrumental in starting the E&T working group of the ALLIANCE (see section 5) and Memorandum of Understanding (MoU)

agreements between COMET universities and institutions (NMBU, NuBIP, University of Fukushima, University of Seville, CIEMAT) have enhanced commitment between partners to continue the work started by COMET and to promote mobility of both students and professionals and cooperation on MSc-, PhD- and research projects. A cotutelle (joint supervision) agreement has also been signed between NMBU and the University of Seville (UoS), Spain, giving credits to both universities for taking on common PhD students, meaning financial support to both institutions for the PhD students. Current PhD students are connected to the COMET project RATE. Such cotutelle agreements could be utilized further between universities to share PhD students.

Co-funding from other E&T platforms (DoReMi) and institutions (CERAD) was obtained by the involvement of COMET partners in a range of European projects and platforms; these collaborations also enabled outreach to students in other nuclear disciplines in need of courses within radioecology.

5. Future ideas and challenges

In the future, E&T in radioecology will be led and promoted by the Radioecology ALLIANCE. An ALLIANCE E&T working group (WG) is already in place and currently comprises nine organisations from seven countries. This working group also connects to E&T efforts within CONCERT and other platforms, consortiums and projects (e.g., MELODI, OPERRA, TREE, PETRUS III). The aims of the ALLIANCE E&T WG are similar to those of COMET:

- to strengthen and secure a sustainable integrated European E&T platform in radioecology that will attract graduates;
- to ensure and maintain a sustainable workforce in radioecology, by interacting with radioecology stakeholders (e.g., students, teachers and employers) to meet future needs within nuclear sciences;
- to put students in contact with research projects;
- to put students in contact with potential employers, as well as to ensure that radioecology E&T meets the needs of those employers;
- to enhance the mobility of teachers and scientists as a means of securing competence building as well as dissemination of radioecological knowledge.

The aim is that this will be done through continuation of, and building on, existing activities (PhD and MSc courses, workshops, training courses, student networking etc.), which were started in STAR and continued in COMET, as well as the introduction of new initiatives. One of the first priorities is to expand and update the E&T web platform; a platform-coordinator will be selected from among ALLIANCE E&T WG partners. There is already agreement to continue holding the two COMET field courses (see sections 3.2.1 and 3.2.2) every second year. MoUs, as well as cotutelle agreements and Erasmus PhD funding to enable joint MSc or PhD students between organisations, should be encouraged between interested parties. During COMET, a survey was undertaken that established that there was sufficient support to form the basis for an application for a common European MSc in Radioecology through the Erasmus Mundus Joint Master Degree mechanism. This would be a way to consolidate and secure the future of the European MSc programme currently hosted by NMBU, and developed within STAR and COMET. This possibility should be further explored. The ALLIANCE has already agreed to provide financial support for short stays of MSc and PhD students within institutes of the ALLIANCE, as well as their attendance at workshops and conferences, and this should be continued.

Future activities should also include:

- having a consolidated offer of professional development courses with vocational credits (VET);

- initiating a mechanism by which students and future employers could make contact in order to arrange work placements, joint research projects, industrial MSc/PhD projects and summer jobs. This could be through summer schools focussed on particular topics, and/or through virtual fora;
- exploring the possibilities to give webinars and similar approaches where the need for hands-on training is not needed or practical;
- offering refresher courses and seminars at relevant regional and international conferences;
- searching for common activities and agreements with E&T projects, networks and consortia, in which some ALLIANCE institutions are already participating, for example:
    - CONCERT projects TERRITORIES and CONFIDENCE
    - European Training and Education in Radiation Protection (EUTERP; http://www.euterp.eu/)
    - European Network on Education and Training in Radiation Protection (ENETRAP; http://enetrap3.sckcen.be/)
    - European Nuclear Education Network (ENEN; http://www.enen-assoc.org/)
    - Advanced Networking for Nuclear Education and Training and Transfer of Expertise (ANNETTE; http://www.associazioneitaliananucleare.it/the-annette-project-advanced-networking-for-nuclear-education-training-and-transfer-of-expertise/)
    - Competence Maintenance, Education and Training (CMET) within IGD-TP (http://www.igdtp.eu/index.php/joint-activities/competence-maintenance-education-and-training-cmet)
    - Nuclear and Radiochemical Education Network (NRC; https://www.cinch-project.eu/nrc-network/)
    - Nuclear and Radiochemistry Division of the European Association for Chemical and Molecular Sciences (EuCheMS; http://www.euchems.eu/).
    - Other EURATOM initiatives

While collaboration with other programmes is essential and to be encouraged, care must be taken that radioecology as a science is not simply absorbed into other educational initiatives, but maintains a distinct profile of its own. Humans are often the focus of radiation protection, but competence must also be maintained in the specific skills and knowledge that underpin environmental protection, both in its own right and as a contribution to human radiation protection. A close eye should also be kept on the expected job market and how it might change in the short- medium- and long-term, for example in the context of building new nuclear plants or repositories or in increasing harmonization between radiation protection and chemical frameworks. Future E&T efforts would benefit from closer engagement with stakeholders.

Lastly, while some of these activities can, at least in part, be supported through the participating organizations and collaboration with existing initiatives and networks, their long-term success is highly dependent on the procurement of sustainable dedicated funding. Increasing student and teacher mobility, field courses, development of web-based learning tools and distance courses (including the engagement of experts in digital learning) all require sustainable funding mechanisms.

Even though the activities described in this paper have met the objective to “enhance and maintain European capacity and skills in radioecology” to a degree, there will be a continued need in the years to come, as new generations of students enter the education system and the job market changes with, for example, developments within radiation protection and the nuclear industry. Therefore, the ALLIANCE must plan to address the lack of sustainability if radioecological competence is to be maintained in Europe for the future.

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