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EURAC

Securing European Radiological Protection and Radioecology Competence to Meet the Future Needs of Stakeholders

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1 Context

Postgraduate education is a matter of social concern in general, and within the nuclear field in particular. Thus, strengthening the competence within the nuclear field is consistent with the EU aim to produce an educated workforce that is able to meet the future economic and social needs of the developing EU. Radiological protection of the environment, including man, has also become a matter of significant public concern. It follows that the establishment of public confidence in nuclear technologies will depend upon the availability of well-educated personnel and independent experts/advisors within the fields of radiochemistry, radioecology and radiation protection. It is intended that the courses proposed in this report will provide appropriately educated professionals that meet the needs of European stakeholders within these fields.

In 2000 the OECD Nuclear Energy Agency produced a report: *Nuclear Education and Training: Cause for Concern?* This document was compiled using information supplied by 200 organisations in 16 member countries. The agency demonstrated that it was possible that many nations were training too few scientists to meet the needs of their current and future nuclear industries. In addition, a number of studies over the past five years, by different European governments, have also identified that too few scientists were being trained to meet the needs of their current and future nuclear industries. This has been attributed to decreased student interest, decreased course numbers, aging faculty members and aging facilities. Consequently, the European education skill base has become fragmented to a point where universities in most countries lack sufficient staff and equipment to provide education in all, but a few, nuclear areas. Of particular concern appeared to be special skill-base deficits within nuclear radiological protection, radioecology and radiochemistry at masters and doctorate levels.

Skills in these areas are required not only to deal with currently installed nuclear capacity and decommissioned facilities, but also to meet the needs presented by likely new-build nuclear capacity. As recently stated by several EU politicians and experts, there are increasing pressures to build new nuclear power stations in many EU member nations. This pressure comes from the need to meet Kyoto greenhouse gas emission targets at a time when many currently installed, CO_2-clean, nuclear power stations are coming to the end of their useful lives. They also come from the decreasing stocks of domestic fossil fuels, with an increasing reliance upon politically unstable nations for the provision of oil and gas and from the increasing prices of domestic and imported fuels. Finally, the pressures are facilitated by new improved reactor systems that are being developed in Europe and the USA. Therefore, the need for nuclear competence is probably greater now than was earlier anticipated.

The EURAC Project has aimed to assess the current and potential levels of postgraduate provision in selected linked disciplines associated with radiological protection and radioecological competence within universities and other higher education institutes (HEIs) of the EU and new entrant nations in the context of demand. Based on consultations with European stakeholders EURAC is proposing those actions that could be taken by European Institutions and relevant organisations in Member States to secure the future of nuclear radiological protection, radiochemistry, and radioecology postgraduate education in an expanded EU.

The overall objectives of the EURAC project were to:

- Assess the needs for co-ordinated postgraduate education in the EU and new entrant nations in order to:
    - Strengthen the scientific academic competence and analytical skills within radiological protection, radiochemistry and radioecology.
    - Secure the future recruitment of appropriately skilled postgraduates to meet the needs of European stakeholders.
- Recommend, following consultations, actions that could be taken by the higher education sector within the EU to help meet the postgraduate education needs identified.

In order to achieve these objectives, the work undertaken by the EURAC team was organised within four work packages – each of which addressed different aspects of the project:

<u>Work package 1 (WP1)</u>: Determination of existing competence and infrastructures
<u>Work package 2 (WP2)</u>: Estimation of future scientific needs
<u>Work package 3 (WP3)</u>: Development of possible postgraduate education solutions
<u>Work package 4 (WP4)</u>: Assessments, recommendations and final report.

2 Current status, future needs and possible solutions

The reports produced by the Work Packages 1 and 2 teams are appended to this report (Appendices A and B, respectively). These detail the status of relevant competence within Europe and the future education needs within radiological protection, radioecology and radiochemistry – as identified by key stakeholders. The WP1 report provides a database for identifying key institutions that possess the necessary competence, facilities and/or infrastructures to participate in co-ordinated, post-graduate, education systems. The WP2 report sets the standard for the scientific competence needed in future university-trained, post-graduate education (at Master and PhD levels).

The WP3 report (Appendix C) describes the different models (tools) that can be used to achieve the required co-ordinated education system in Europe. The aim being to provide possible solutions that will produce candidates well suited for their future jobs - with an appropriate level of competence, as defined by international standards, within the identified areas of radiological science.

While the data collected for the workpackages was sufficiently detailed to meet the objectives of the project, it was not intended to produce encyclopaedic lists of institutions, courses and capabilities nor an encyclopaedic list of employment opportunities within the EU. Instead, the WP3 report describes several models that could be used to produce a co-ordinated, post-graduate, education system and assesses their merit. Particular attention was given to alternative models that could be implemented at different levels, either at a national level (e.g. within the UK or France), a regional level (e.g. by the Nordic countries) or at a pan-European level (EU-Master, EU-PhD).

Existing competence

The survey findings indicate that the provision of postgraduate training at Master level, specifically designed to meet the requirements of each of the above-mentioned fields is, with some important exceptions (highlighted below), diffuse and insufficient in most of the Member States of the EU. Nevertheless, it is evident that competence in these fields at training level is being eroded through natural wastage and is not being replaced at a rate adequate to satisfy expected future demand for these specialised skills. Finally, the survey evidences strong support for an EU-wide Master training programme in radiation protection and allied fields as well as considerable willingness to participate in and/or host such a programme.

Currently running Master programmes

The important exceptions were those institutions currently running relevant MSc programmes. They breakdown as follows:

MSc level programmes in Radiation Protection are offered by the following institutions:

- Dresden University of Technology, Germany
- Jozef Stefan International Postgraduate School (to commence 2006), Slovenia
- Norwegian University of Life Sciences, Norway
- Radiation Protection Office, Oliver Lodge Laboratory, UK
- Swedish University of Agricultural Sciences, Sweden
- Universita’ degli Studi di Firenze, Italy
- University of Oslo, Norway
- University of Surrey, UK
- University of Tartu, Estonia.

Of these institutions, two, namely the Norwegian University of Life Sciences and the Swedish University of Agricultural Sciences, have expressed interest in hosting a European Training course. Both would appear to have most (if not all) of the required facilities and equipment necessary and both can offer on-campus accommodation.

MSc level programmes in Radiochemistry are offered by the following institutions:

- University of Helsinki, Finland
- University of Ljubjana, Slovenia
- Norwgian University of Life Science, Norway
- Université Paris XI (with ENSCP, Université d’Évry-Val d’Essonne, and INSTN), France.

Of these, Université Paris XI has expressed an interest in participating in and hosting a European training course, but it is not clear whether they have sufficient facilities/equipment available, or that they can provide convenient accommodation for participants and tutors.

MSc level programmes in Radioecology are offered by the following institutions:

- Comenius University, Slovakia
- Lund University, Sweden
- Norwegian University of Life Sciences, Norway (specialises in Arctic Radioecology).

Again, the Norwegian University of Life Sciences has indicated that they would be interested in hosting such a European Training course. Lund University Hospital also expressed an interest, but would prefer to host in collaboration with Risø National Laboratory in Denmark. Both Lund and Risø have sufficient facilities and equipment, though limited availability of accommodation for participants and tutors.

MSc programmes in Radiobiology/Radiation Biology are offered by the following institutions:

- Grey Cancer Institute (Part of European MSc), UK
- INSTN with seven regionally-located universities, France
- Université Paris XI (with Université Paris XII, Université Paris V and INSTN), France
- University of Birmingham, UK
- University College London (Part of European MSc), UK
- University of Stockholm, Sweden.

Of these, four, namely Grey Cancer Institute, Université Paris XI, University of Birmingham and University of Stockholm, have expressed interest in hosting a European Training course. All, with the exception of Université Paris XI, who did not supply such information, appear to have adequate facilities and accommodation for this purpose.

MSc level programmes in Radiometrics are offered by the following institutions:

- Liverpool University, UK
- University of Oslo, Norway.

Neither of these institutes indicated whether they would be interested in hosting a European Training course, nor whether they have the necessary facilities, equipment and accommodation.

Of the twenty-four identified MSc programmes in the areas of interest, all but six are offered by just four countries, i.e. France, Norway, Sweden and the UK.

Diploma/certificates

There are, however, many institutions which are running Higher Diploma/Certificate programmes, modules in postgraduate programmes (PhD, MSc and Diploma level), or short training courses which are relevant to this study (see Tables 3 and 4). For example, Masaryk University in the Czech Republic, who offer a module in Radiochemistry as part of their MSc programme in Nuclear Chemistry.

In summary, there are some radiation protection-related courses within the field of nuclear science held in Europe today, but many of these will not be organised in the future due to the reduced number of students. Within the field of Radiochemistry, Université Paris XI has expressed an interest in participating and hosting a European training course, but it is not clear whether they have sufficient facilities/equipment available, or that they can provide convenient accommodation for participants and tutors. Lund University Hospital also expressed an interest. Within the field of Radiation protection, the Norwegian University of Life Sciences and the Swedish University of Agricultural Sciences, have expressed interest in hosting a European Training course. Both would appear to have most (if not all) of the required facilities and equipment necessary and both can offer on-campus accommodation. Within the field of Radioecology, again, the Norwegian University of Life Sciences has indicated that they would be interested in hosting a European Training course. Lund University Hospital also expressed an interest, but would prefer to host in collaboration with Risø National Laboratory in Denmark. Both Lund and Risø have sufficient facilities and equipment, though limited availability of accommodation for participants and tutors.

It is, however, essential that diplomas obtained be validated by higher education institutes and there is little support within the higher education sector for the excessive involvement of industry and government in the provision and designation of degree structures. Thus, a joint degree system should be developed between collaborating academic institutions (universities) across Europe, rather than by a consortium of industry, government and private providers. Nevertheless, these agencies can play an important role in the execution of post-graduate degrees by the provision of facilities for research projects. They must also play a key role in the specification of needs.

Future needs

The survey of European Stakeholders confirms that there is a significant current and future need for personnel trained to masters-level and beyond in the broad area of radiological protection. From the questionnaire data alone, a need for some 30 technical advisors and 67 professional experts — qualified to at least masters-level — per annum was identified. Given, that the WP 2 survey did not reach/received no response from many potential employers it can be reasonably concluded that the need for appropriately qualified post-graduates per year probably exceeds 100. Moreover, it is likely that the responses given were based on the needs of the current industry, regulators etc. and take no account for possible growth in the nuclear power industry.

Market

There appears to be a consensus that recruits will have to be obtained from other than the traditional engineering route. The implications of this are that 'nuclearisation' of programmes in other areas such as environmental science would attract sufficient numbers of students to make them viable – provided that careers in the nuclear sector were made sufficiently attractive and/or were seen to offer a secure future career. Furthermore, it suggests that 'nuclear-related' masters programmes would have a ready market given that much of the recruitment to the nuclear sector is made at this level.

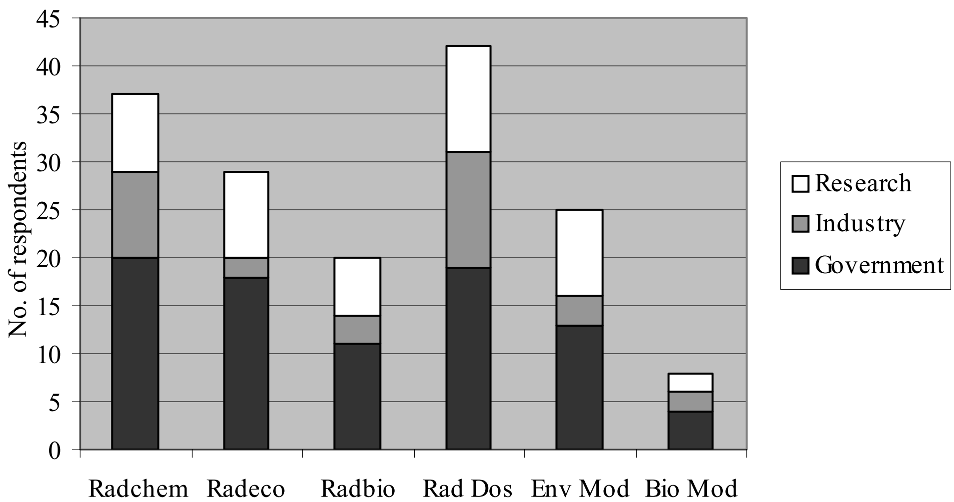

Figure 1
Stakeholder requirements — Areas of preferred expertise for recruits within radiochemistry, radioecology, radiobiology, radiation dosimetry, environmental modelling and biological modelling

Qualification

Over and above the qualification needs of employers, it is clear that a significant amount of training in radiological protection is, and will be into the future, undertaken by stakeholders for those non-qualified personnel (both in technical areas and in management positions). About 75 % of such training is delivered outside the university sector, either in-house or through contracted training organisations. There is clearly an opportunity to build into formal qualifications accreditation of such training. This could be achieved using mechanisms developed in the fast growing area of “professional degrees” (such as the MProf and DProf) and in degrees that give credit for “work-based learning. However, in such cases it is important that HEIs remain in control of academic assessment and the setting of standards. It is worth noting that for NEN countries there is a significant budget within IAEA set aside for radiological protection training.

Subjects

With regard to curriculum content for postgraduate qualifications, radiochemistry, radiation protection and dosimetry, and analytical techniques were most commonly identified as needs. However, environmental pathways, environmental impact and radioecology were also strongly indicated, particularly from the ‘government’ and ‘research’ stakeholders (Figure 1).

It was not possible from the data to specify particular laboratory or field needs except to say that measurement and analysis were highlighted by a number of respondents as being an important component of future scientific needs.

Exchange programmes

At the research end of the spectrum, the data suggests that there are widespread opportunities across Europe for students to undertake nuclear-related projects and utilise specialist facilities. However, it has been noted in previous research that exchange of students or faculty members between universities in different countries was rare. Therefore, this issue should be addressed in the generation of any co-ordinated programmes of teaching or research training.

In many European countries, the national demand for experts in certain strategic subjects, for example in radiation protection and radiochemistry, may be too small to maintain national education programmes. Increased international cooperation is therefore needed to maintain and enhance postgraduate education and research in these nuclear areas.

In summary, the general outcome from the WP2 report is that there is a significant latent and future need for personnel trained to masters-level and beyond in the broad area of radiological protection. From the questionnaire data alone, some 30 Technical Advisors and 67 Professional Experts qualified to at least masters-level will be recruited per annum. Reports from the literature project indicate that even higher numbers will potentially be recruited. Moreover, it appears that recruits will have to be obtained from other than the traditional engineering route.

Data suggests that 'nuclear-related' masters programmes would have a ready market given that much of the recruitment to the nuclear sector is made at this level. With regard to curriculum content for postgraduate qualifications, radiochemistry, radiation protection and dosimetry, and analytical techniques were most commonly identified. However, environmental pathways, environmental impact and radioecology were also strongly indicated, particularly from the 'government' and 'research' stakeholders.

Potential solutions

The outputs from WP 1 (Existing competence and infrastructure) and WP 2 (Future needs) were used to guide the development of a European educational solution to meet the stakeholder needs. For example, only a few key institutions possess the necessary competence, facilities and/or infrastructures to participate in a co-ordinated post-graduate education system. It follows that it is not possible to recommend education solutions based around national post-graduate education systems/programmes enhanced by a European dimension. Although such programmes would be possible in some countries most do not have the capabilities and competence to provide post-graduate courses in the target specialist areas. Consequently, in order to meet the needs of EU members in relevent disciplines it will be necessary to specify either regional or pan-European solutions utilising the identified avcademic competences.

The stakeholder needs assessment clearly showed that, at the European level, there is a significant and constant demand for post-graduates with skills in radiochemistry, radioecology, radiation dosimetry and environmental modelling and a smaller, but still important, demand for radiobiologists and bio-modellers. Most of this demand is from government organisations. If only the nuclear industry is considered, then the largest demand is for radiochemists and radiation protection dosimetrists. Given this spectrum of need and existing capacity in the areas of radiobiology (including the European Masters in Radiobiology hosted by the Grey Laboratory in the UK) it was concluded that the needs identified would be most efficiently met by three new courses:

- European MSc Radiation Protection

- European MSc Analytical Radiochemistry
- European MSc Radioecology

All three masters programmes would be developed using the framework provided by the Bologna Convention and then would be taught within a network of collaborating universities. Plans have been developed for the above degrees. These plans envisage each degree comprising three modules that are common to all the degrees (3 x 10 ECTS credits), three specialist modules (3 x 10 ECTS credits) and a research project (1 x 30 ECTS credits).

Geographical distribution of education providers

It is essential that the proposed degrees be taught as widely within the EU as possible. However, this objective will be difficult to achieve when the specialist facilities and staff are available only at a few locations. It may be possible to teach the common core modules more widely than the specialist modules. This is for two main reasons. First, there will be three times more students studying the core modules than the specialist modules and, secondly, their less specialist nature requires few specific facilities. In addition, research projects can be based in most countries in association with potential employers (linked to work experience) or employers (in the case of employed part-time students and employees released for continuing professional development (CPD)). Nevertheless, it is predicted that most teaching will take place only in a small fraction of EU member countries. It follows that the student experience will be quite variable. Some students will follow common and specialist modules and perform their research project in their own country (where all competence can be found). While other students will either follow common and specialist modules in their own country, but perform their research project in another country where necessary facilities are existing, will follow common modules in their own country, but specialist modules and perform research projects in another country where competence and facilities are existing or will come from countries without competence and facilities, will have to follow course and perform research project in (an)other European country (-ies) of their choice possessing the necessary competence and facilities.

In summary, there is a significant need for appropriately skilled postgraduates. And in consultation with stakeholders EURAC has identified three European Masters' programmes: Master in Radiological Protection; Master in Analytical Radiochemistry; Master in Radioecology; that would meet their needs.

3 Programme structure and assessment

Bologna agreement compliant course structures in radiochemistry, radioecology and radiological protection have been developed for each degree (Appendix D).

European Masters, common and specialist modules

The courses should be aimed, not only to fill the identified European postgraduate education gap in radiological sciences, but also to provide a modular structure that is easily accessed by stakeholders for CPD training. It is anticipated that the European Masters in Radiological Protection will meet the academic training requirements of "qualified experts", as defined by the European Commission and the IAEA.

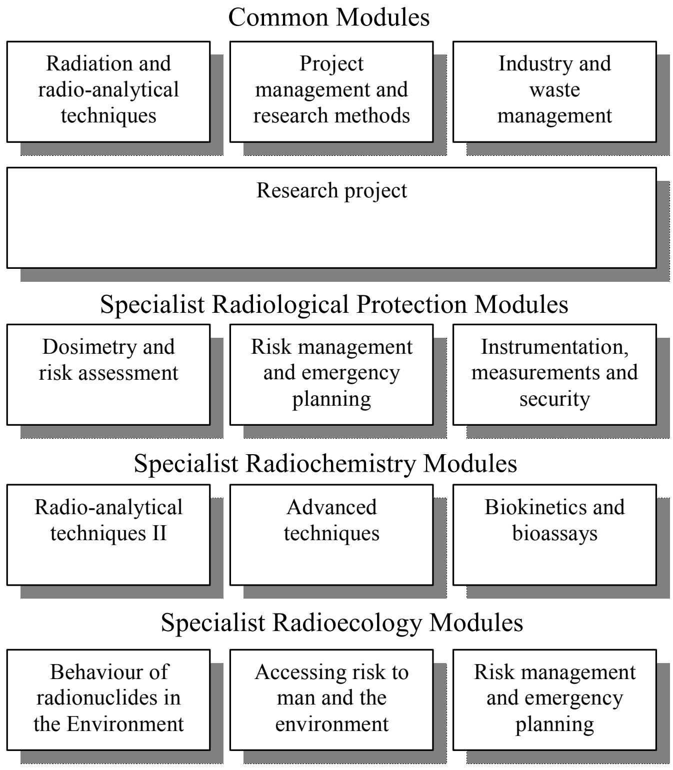

Figure 2
Outline of proposed module structure for European Masters' degrees as identified in the EURAC project

Implementing common courses/modules

Within the proposed European Masters' degrees there is a set of common courses/modules that need to be implemented before the final masters can start. There is a need to finalise arrangements for the common modules, advertise for and recruit students either for the entire degree programme or for parts as CPD, and to coordinate the delivery of the common taught modules with the students and participating host higher education institutions. There is also a need for feedback after the first run of the common modules and to make necessary adjustments to the modules prior to their second run.

Description of necessary work

- Receive course details and confirm acceptability of programme with participating universities;
- Offer courses to stakeholders for CPD;
- Enrol students for courses starting;
- Ensure the smooth provision of the courses, meeting the coordination needs of both participating universities and registered students;
- Check and approve module assessments;
- Obtain feedback at the end of the course from students and stakeholders;
- Recommend a modified, sustainable course for post-project implementation.
- Develop/implement existing Joint Master's Degree systems.

Masters in Radiation Protection, Analytical Radiochemistry and Radioecology

There is a need to finalise arrangements for the radiological protection degree, the radiochemistry degree, the radioecology degree, advertise for and recruit students either for the entire degree programme or for parts as CPD, and coordinate the delivery of the specialist modules for the degree programme. There is a need to ensure the smooth provision of the courses, meeting the coordination needs of both participating universities and registered students, check and approve module assessments and obtain feedback at the end of the course from students and stakeholders. After feedback, there must be recommended a modified, sustainable course for post-project implementation.

Description of necessary work

- Receive course details and confirm acceptability of programme with participating universities;
- Offer courses to stakeholders for CPD;
- Advertise the degrees through university prospectuses, via stakeholders and through professional bodies and learned societies – as appropriate;
- Enrol students for courses;

- Ensure the smooth provision of the courses, meeting the coordination needs of both participating universities and registered students;
- Obtain feedback at the end of the course from students and stakeholders;
- Recommend a modified, sustainable course for post-project implementation.

Criteria to be fulfilled

There are some criteria that need to be fulfilled in these European Masters' degrees:

- Use common use of the ECTS;
- A need to coordination of Specialist competence from different systems;
- Identification of suitability of research facilities;
- The need for intensive courses with mobile human resources;
- The need for web-based communication and teaching materials:
- Solution of administrative constraints, formal procedures, QA systems and requirements;
- Costs and funding requirements associated with Master and PhD courses must be solved;
- Accommodation (students and teachers) and travel distance (teachers) must be in place.

Course syllabus and teaching materials development

There is a need to produce an outline modular structure and syllabus for each of the proposed European Masters courses, their structure and content having been agreed with stakeholders. Additionally, in the case of the Radiological Protection degree there is need to make sure that the course content is compatible with syllabi published by the EU and by the IAEA – for reasons of validation and accreditation. The tasks undertaken should be concerned with transforming the agreed outline into detailed module structures. In addition, an identification of the physical premises and staff resources needed to run the modules and the method of module delivery and assessment. An end product will be a series of module handbooks, which will:

- Provide information concerning the academic institute and the resources available to students at this institute;
- List and describe the roles of the staff that will resource the modules;
- Provide contact details for staff;
- Detail the module teaching timetable and the programme of study;

- List the educational outcomes expected;
- List learning materials – including on-line resources — that will be provided to the students;
- Provide a reading list;
- Detail the module assessment method and required coursework tasks.

Delivery team development

For the future, there will be a need to identify those postgraduate research institutes/universities that are willing and able to resource each of the proposed masters-level degrees. There should be produced degree timetables for each specific master's degree, listing the modules to be undertaken at each participating university, the staff that will deliver content and the time and place of each lecture. These resources could be physical resources that could provide a base for the issue of degrees, for the teaching of modules, for practical sessions or for the supervision of research projects. Alternatively, they could be staff, teaching materials or even existing validated modules that either meet, or could be modified to meet the needs of the courses.

Description of necessary work

- Identify an initial 'roll-out' host that is able and prepared to validate and issue each degree;
- Identify the locations where each degree module is to be taught; checking that the required staff and resources are available;
- Identify the QA and validation requirements of each participating university;
- Check that the proposed module arrangements are acceptable to the host university;
- Iterate to produce workable degrees that are acceptable to universities, their staff and potential students in terms of travel requirements, accommodation, timetable, location and cost;
- Produce a final degree timetable for each degree.

In selecting locations, the following should be considered:

- Geographical location of institutes;
- Available facilities and existing competences;
- Validation and QA procedures required by different universities;
- Timetable implications;
- Fee implications and university charges for use of resources;
- Availability of reasonably priced accommodation for students and peripatetic teachers.

Geographical location is important for three reasons. First, teaching should be distributed throughout the EU to the greatest extent possible and should include the new central European members' institutes and, secondly, because it is important that students are not expected to travel too often and too widely within Europe to complete the degree. Finally, where modules are offered for CPD they should be conveniently close to stakeholders. With respect to facilities and competences it is expected that the host institutes should have experience of relevant teaching and have the facilities, e.g., laboratories and equipment, required for teaching the practical components of the course and/or the supervision of research projects. Facilities must also be available to meet the timetabling requirements of the degrees. Onerous QA and validation requirements and/or inappropriate/disproportionate/uncompetitive fee structures imposed by any organisation would adversely impact upon the realisation of the objectives. Consequently, universities that impose heavy fees on degree registration will not be selected to host degrees. They may, however, be selected to provide modules that are charged at a reasonable rate. Finally, any selected institute must have access to reasonably priced accommodation for students and peripatetic staff.

4 Constraints

In WP3, a number of constraints were identified:

- Courses should be distributed among semesters and precaution should be taken to break them properly in order to allow the students to appropriately follow them when they are taught in different European locations (universities, institutes, etc.). Such course distribution should also not impair the necessary students and staff mobility.
- Courses are classified into modules (either common or specialised). It is important to adequately choose the size and content of these modules in order to make possible their use as training modules for professionals (continuous education and training — CPD).
- It must be ensured that the proposed courses contain all the current knowledge in the specified fields (i.e. radiochemistry, radiation protection, and radioecology). Moreover, the separation of these courses between theoretical and practical components of degrees (or even modules, taught at different locations) does not lead to gaps in knowledge - keeping in mind that theoretical modules may be taught in one place and practical ones in another place.
- The validation of the proposed modules is another major constraint to be faced. Indeed, such European Masters of Sciences must be validated as degrees by specific awarding bodies. These bodies will be national and European. These European Masters of Sciences must be accepted in all the European Union countries in order to be European even if part of or most of the courses will not be taught in and validated by a national institution (university, institute of higher education, etc.).

Funding

This is one of the major constraints to be overcome. Indeed, EU and stakeholders should find a way to help students pay their student fees, keeping in mind the notorious heterogeneity between the different EU universities concerning these fees (for instance between Germany and the United Kingdom).

Provisions should be made to cover the cost of staff movements. Indeed, experts able to deliver courses in the different modules will, most likely, come from different European countries but will have to deliver their courses in dedicated locations. Therefore, their travel expenses should be reimbursed or prepaid.

Ethical issues

Some of these concern issues relating to finance (commercial in confidence) and to student progress, are normal ethical issues relating to university operation and should be managed via the procedures existing within the academic providers. In addition, some student projects might involve ethical issues. Where these occur student projects should be cleared through the normal ethics committee procedures of the host university.

Societal implications

Postgraduate education is a matter of social concern and strengthening the competence within the nuclear field is consistent with the EU aim to produce an educated workforce that is able to meet the future economic and social needs of the developing EU. Radiological protection of the environment, including man, has also become a matter of significant public concern. It follows that the establishment of public confidence in nuclear technologies will depend upon the availability of well-educated personnel and independent experts/advisors. It is intended that the proposed courses will provide appropriately educated professionals that meet the needs of European stakeholders.

Quality Control

Quality control will be the responsibility of a designated programme leader for each degree. This leader will be aided by designated module leaders who will be responsible for the quality and delivery of their modules.

The quality-related aspect concerns the QA requirements of the educational institutes participating in the planned degree courses. All course materials prepared will have to meet the QA requirements of the host universities as part of their validation procedures. Meeting the QA requirements of the educational institutes will be a task within the work concerned with developing the course delivery teams for each degree. To ensure the quality and relevance of the course syllabus and research projects (thesis) within the EU Masters, there is a need to establish strong links to organisations such as the:

- IUR (International Union of Radioecology, presidency at NRPA, Norway), giving their approval for the European Master of Sciences in Radioecology;
- IRPA (International Radiation Protection Association) giving their approval for the European Master of Sciences in Radiation Protection;

- IUPAC (International Union of Pure and Applied Chemistry) giving their approval for the European Master of Sciences in Radiochemistry.

Performance Indicators

The key performance indicator, to measure the success of the implementation of the European masters is the successful recruitment of students onto the Radiological Protection, Radiochemistry and Radioecology courses, respectively. Ideally, these should be recruited from a wide range of EU-member states since the aim is to achieve excellent coverage of all 25 EU member states plus Norway, Iceland and Switzerland. The team considers that the target for the courses should be 15 students for the first run of the radiological protection masters programme and then 45 students for each degree course – recruited from 6 or more member states. Another performance indicator relates to the academic performance of the students. It is expected that most students will complete and pass their degree courses. A failure rate of 10-20 % is acceptable, but a failure rate higher than this would indicate either deficiency in the courses and their delivery or in the standard of students accepted at the degree registration stage.

In order to achieve the above it will be necessary to:

- Finalise a detailed syllabus for each of the proposed degrees and develop the course/module materials that are required to teach it;
- Seek and obtain recognition and accreditation for each of the proposed European Masters courses from recognised bodies;
- Confirm the co-ordinating (roll-out lead) university and its partners for each degree and module and agree timetables that facilitate staff and student movement between participating institutes;
- Check the laboratory facilities offered by academic institutions and that the equipment available for teaching is fit for purpose;
- Obtain degree course and module validation from each of the participating postgraduate education institutions;
- Offer agreed modules to end-users as CPD (continued professional development) courses;
- Recruit students and run courses for each degree/CPD course during 2007 to 2010;
- Obtain feedback from stakeholders (end-users, students and staff) and review each programme for implementation in 2011 as freestanding and sustainable European Masters courses;
- Identify the funding mechanisms and sources for sustainability.

The degrees proposed are directly relevant to the provisions of the Euratom treaty that are related to the promotion of research and the establishment, and enforcement, of uniform standards to protect the health of workers and of the general public — Title II, Article 2. In addition, under Title III, Article 4 of the treaty the European Commission has a responsibility for a community research and training programme. It is inconceivable that the Commission could meet its above obligations within areas reliant on radiological protection, radiochemistry and radioecology expertise without recourse to an appropriately trained European workforce.

Shared resources with other degree programmes

In order to achieve economies of scale it is likely that the modules that comprise the proposed degrees will incorporate elements of modules that form part of existing degrees – or even entire modules, where they can be shown to provide the appropriate learning outcomes. In addition, the modules developed may be offered as parts of other degrees. Two specific examples were considered by the EURAC team. Firstly, it is possible that the common taught modules will be developed in association with the current European Masters in Radiobiology, as organised by the Grey Laboratory and validated by University College London. If so, they would then provide a common core of modules for all the degrees. Secondly, it is possible that the three common modules proposed could be linked to three existing risk management modules to form a new degree at Middlesex University – Risk Management Radiological Protection. These are examples and all the participating HEIs will be encouraged to both utilise EURAC modules for their degrees and to offer modules/parts of modules for inclusion in the European Masters programmes.

5 Recognition and accreditation

The objective should be to identify international organisations that are appropriate to and willing to recommend and/or accredit each degree and to obtain this recommendation/accreditation and identify opportunities for certification of graduates as 'competent persons' — at the national level. The future courses and detailed course content should be approved by stakeholders and financial and other support for students undertaking the degrees from stakeholders should be secured. To ensure the quality and relevance of the research projects (thesis) within the European Masters, there is a need to establish strong links to the IUR (International Union of Radioecology) network with respect to the European Master of Sciences in Radioecology to the IRPA (International Radiation Protection Association) with respect to the European Master of Sciences in Radiation Protection and to IUPAC (International Union of Pure and Applied Chemistry) with respect to approval for the European Master of Sciences in Radiochemistry.

Description of necessary work

- Identify the key stakeholders and check that the detailed programmes produced by WP1 meet their needs – both in terms of recruitment opportunities and as 'stand alone' modules for continued professional development (CPD), i.e. training of existing staff;
- Request tangible support from stakeholders – either in the form of the financial sponsorship of students or the provision of facilities for students undertaking research projects;
- Identify accreditation/approval bodies and request either formal approval or formal accreditation of the three European Masters degrees offered;
- Liase with national regulatory bodies regarding national criteria for defining 'competent persons' as required by EC Directives and determine any benefits that might be passed on to graduates.

6 Interaction with other EU initiatives

EURAC is one of a number of EU FP6 projects funded to help promote higher education in fields related to reactor technology, nuclear engineering and nuclear, as opposed to medical, radiological sciences. These were described in the recent ETRAP 2005 meeting held in Brussels, 23-25 November. EURAC was also represented at an earlier meeting of the relevant project groups, which was organised by the Commission. The EURAC team made two presentations at the ETRAP meeting describing the results of WP1 (poster) and WP2 (oral presentation), respectively. It is accepted that some of the projects described have aims that are very similar to, or even in one case overlapping, those of the EURAC project. Accordingly, the EURAC team accept that it is likely that considerable benefit could be derived by all parties from appropriate collaboration. At one level, such collaboration has already taken place. For example, discussions have taken place with the MSCRB project with a view to the development of common modules for use by the EURAC proposed degrees and by the existing European Masters in Radiobiology. In addition, survey results produced by the EURAC team have been passed to other projects, e.g. ENETRAP, to avoid duplication of effort. It is hoped that such collaboration will continue and the EURAC team see significant potential in collaboration – particularly with the European Masters in Radiobiology (which is essentially a HEI initiative).

It is also recognised that the degrees proposed by the EURAC team should, if possible, be consistent with the radiation protection training and education strategy as developed by the European Commission, Radiation Protection Unit. This involves the creation of a European radiation protection, training and education platform to improve the cooperation between member state competent authorities, training centres, employers and trainees in the radiological protection field. However, it is important that HEIs maintain academic control of the masters programmes that they offer to students and it is difficult to see how the integration of academic education programmes with industry training would be best achieved. One possible mechanism for this is via the European Nuclear Education Network (ENEN) created by a FP5 project in September 2003. This network was created to coordinate postgraduate education and training activities in the field of nuclear engineering and several European universities have agreed to collaborate using this mechanism. However, control of the validation of degrees and modules and the allocation of ECTS credits must remain with the universities offering the degrees.

7 Conclusions

The objectives of EURAC were to assess the current and potential levels of post-graduate university provision in radiological protection, radioecology and radiochemistry, to survey the needs of European stakeholders and to develop innovative solutions to meet their identified needs. The EURAC project has demonstrated a significant need for appropriately skilled postgraduates and in consultation with stakeholders identified three European Masters programmes: MSc Radiological Protection; MSc Radiochemistry; MSc Radioecology; that would meet these needs. The Bologna agreement compliant course structures have been developed for each degree, and these incorporate a number of common and specialist modules.

There is a need to produce module materials required for course implementation; obtain support and accreditation for each degree programme from independent bodies; assemble the lead centre and university network required to implement the degree courses; recruit students and facilitate the running of the courses during the future academic years. It is intended that the proposed courses will provide appropriately educated professionals that meet the needs of European stakeholders.

8 Recommendations

EURAC demonstrated a significant need for appropriately skilled postgraduates and in consultation with stakeholders identified three European Masters programmes: Master in Radiological Protection; Master in Analytical Radiochemistry; Master in Radioecology; that would meet their needs. Bologna agreement compliant course structures were developed for each degree. These incorporated a number of common and specialist modules.

Our recommendation to the interested Academic Institutes is that they facilitate the introduction of the proposed degrees by:

- The production of the module materials required for course implementation;
- Obtaining support and accreditation for each degree programme from independent bodies;
- Assemble the lead centre and university network required to implement the degree courses, recruit students and facilitate the running of sustainable courses – starting during the academic year 2007/2008, as described in the EURAC II project proposal.

In order to do this they will require financial support from the European Union.

The project team comprises mostly European providers of higher education, many of which will be involved in the provision of the courses. The courses will be aimed not only to fill the identified, European postgraduate education gap in radiological sciences, but also to provide a modular structure that is easily accessed by stakeholders for CPD training. It is anticipated that the European Masters in Radiological Protection will meet the academic training requirements of “qualified experts”, as defined by the European Commission and the IAEA.

It is suggested that the EURAC project be followed by a EURAC-II project, which will implement the degrees proposed. As for EURAC, EURAC-II would be undertaken by academic institutions and specialists with strong industry links that are both appropriately qualified and have a responsibility for the development and implementation of post-graduate programmes and the supervision of research students. The EURAC-II team would include the members of the EURAC team plus additional members that have indicated their willingness to help implement the identified degrees.

Appendix A

WP1 Report: Existing Competence and Infrastructures

Report prepared by:
P.I. Mitchell and L. Bowden

21 September 2005

Acknowledgements

The authors wish to thank the following people/institutes for their invaluable help and contributions to this project:

Dr Ted Lazo of the NEA/OECD for providing us with contacts and allowing us access to NEA's own survey of Radiation Protection in Europe.

1. Introduction

The main objectives of EURAC are to:

- Assess the needs for co-ordinated postgraduate education in the EU and new entrant nations in order to:
  - Strengthen the scientific academic competence and analytical skills within radiological protection, radiochemistry and radioecology;
  - Secure the future recruitment of appropriately skilled postgraduates to meet the needs of European stakeholders.
- Recommend, following consultations, actions that could be taken within the EU to help meet the postgraduate education needs identified.

In order to achieve these objectives EURAC is addressing a number of linked sub-goals through work packages:

1. Determination of existing competence and infrastructures;
2. Estimation of future scientific needs;
3. Development of possible postgraduate education solutions;
4. Assessments and Recommendations.

Work Package 1: Existing Competence and Infrastructures

Work Package 1 formed the database for identifying key institutes that possess the necessary competence, facilities and/or infrastructure to participate in co-ordinated, post-graduate education systems.

The tasks of WP1 were to identify the current scientific, administrative and infrastructural requirements and constraints with respect to the development of appropriate co-ordinated post-graduate, education programmes - in particular Masters and PhD programs - on one of the following key areas:

1. Radiation Protection
2. Radiochemistry
3. Radioecology
4. Radiobiology.

2. Methodology

The aims of WP1 were achieved by reviewing documentation, published reports and internet web pages, as well as meetings, telephone interviews and questionnaires. In particular, data and background information were gathered by means of (i) an e-mail questionnaire to universities, research institutes and other third-level educational institutes throughout the EU and new entrant states, (ii) scrutinising similar surveys conducted previously by other bodies (e.g. OECD-NEA), (iii) surveying relevant educational/research institute websites, and (iv) a considerable number of enquiries through personal contact. Information sought included the nature and level of postgraduate courses presently offered (i.e. Master's, Diploma or Certificate), staffing complement and areas of expertise, laboratory facilities in place, availability of student accommodation, and willingness to participate in a possible future European Master's Training Programme in the broad field of Radiation Protection.

A fact-finding mission to the NEA/OECD in Paris took place in February 2005. There, we met with Dr Ted Lazo, who has previously co-ordinated a similar survey to that which we were carrying out. He provided us with some useful contacts as well as a copy of the OECD's survey results. In exchange, we promised him a copy of our final results.

The following detail the issues addressed during the course of this work package:

(a) Current Scientific Competence

The key issues/questions addressed in relation to scientific competence were:

- Where are master level programmes in radiological protection, radioecology, radiobiology and radiochemistry taught?

- Which Universities/Institutes give formal Masters and PhD education within these areas, and which have the competence, expertise and facilities to teach courses or course components/modules at postgraduate level?

- The scientific content of Masters and PhD courses, the qualifications of teachers and tutors, and the strength of the research underpinning these taught programmes

- Definition of Masters, Doctorate and other levels (e.g. Certificate/Diploma) and equivalence between states, structure of taught courses' components and research projects

- Academic prerequisites required for entry into postgraduate programmes.

(b) Current Administrative Status

The key issues/questions addressed in relation to administrative requirements were:

- Definitions of Certificates and Diplomas at Masters and Doctorate levels, differences/equivalence between states

- Structure of courses, do they use an existing module structure?

- Barriers to new courses

- Are courses accredited and what are the mechanism/s for accreditation?

- Are students and teachers mobile?

- Recruitment and funding of students.

(c) Current Available Infrastructure

The key issues/questions addressed in relation to infrastructure were:

- Availability of research facilities, equipment and methods

- Web-based education facilities and the existence of distance learning modules

- Accommodation - how many foreign students and teachers/ tutors can a specific university accommodate?

Most of the answers to the above questions were determined using a common-format questionnaire. This questionnaire was based on a similar questionnaire used in the UK to collect data on taught nuclear courses, but had additional questions concerning the syllabus, the potential for involvement in future courses/programmes, and the local resources available to support such activities. Other sources for these answers came from a previous survey carried out by the NEA/OECD as well as the above-mentioned UK questionnaire.

The data collected was entered into a database maintained by the WP1 co-ordinator. The purpose of this database was to identify major players and highlight institutes that potentially could participate in a postgraduate education network in Europe. It would also form a useful resource for subsequent studies of radiation protection education in the EU.

3. Results

Number of universities/institutes that responded:
A total of 96 completed surveys were returned from 24 countries.

3.1 Existing courses/modules:

- **Dedicated MSc programmes in key or related areas:**

32 full-length courses in over 30 separate universities/institutes in 11 countries (Fig. 1). See also Table 1 for details.

- **Dedicated MSc programmes in Medical Radiation Physics & related topics:**

13 full length courses in 13 separate universities/institutes in 5 countries (See Table 2).

- **Dedicated Postgraduate Diploma/Certificate/Professional Training Courses in one or more of the defined areas:**

20 courses run at Postgraduate Diploma/ Certificate level in 16 separate universities/institutes in 9 countries (see Table 3).

- **Dedicated modules/lecture packages in one or more of the areas of interest:**

42 modules in 32 universities/institutes in 11 countries (See Table 4).

Included in the above is a series of short training courses that came to our attention courtesy of Dr Uwe Waetjen (EC-JRC-IRMM), a member of the executive committee of the Virtual European Radionuclide Metrology Institute (VERMI). VERMI aims to provide training programmes for young researchers in radionuclide metrology. It has already run two workshops and a third is planned for the autumn of this year (Oct. 2005) in Bulgaria. Topics to be covered during this workshop include:

- General Metrology Structure in Radionuclide Metrology
- Primary standardization techniques
- Gamma Spectrometry
- Nuclear Data
- Statistics & Uncertainties
- Liquid Scintillation counting
- Sodium Iodide counting
- Ionization chambers
- Radionuclide calibrators
- Quality assurance.

Previous workshops focussed on the following:

- Classical coincidence counting
- Gas counting
- Solid angle techniques
- Single detectors
- Source preparation
- Low level counting.

The relevance of the above listed modules to advanced training programmes in Radiation Protection, Radiochemistry and Radioecology is obvious and, accordingly, the executive committee of VERMI were invited to send a representative to the final meeting of the EURAC Group, scheduled for the University of Seville in September 2005, with a view to contributing to the preparation of a proposal to establish dedicated European MSc programmes in the above-mentioned fields.

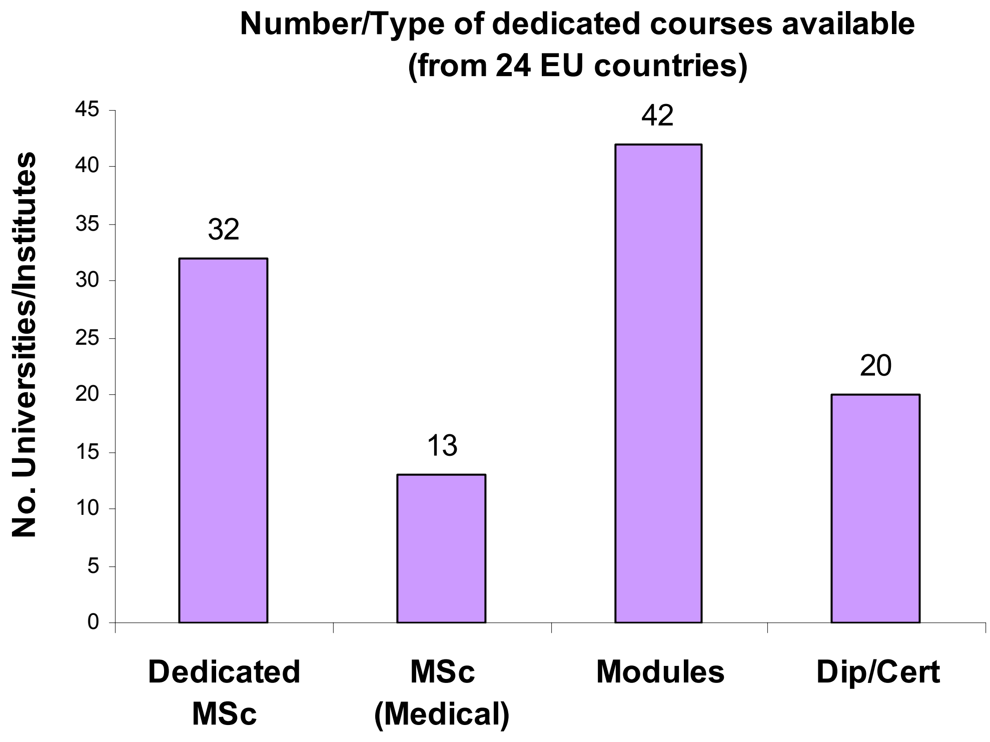

Figure 1
Institutes/universities running appropriate courses/modules

3.2 Existing Infrastructure

3.2.1 Interested in hosting a European training course?

A total of 31 universities/institutes from 11 countries expressed interest in hosting a European Training Course in one or more of the above-mentioned fields (See Table 5).

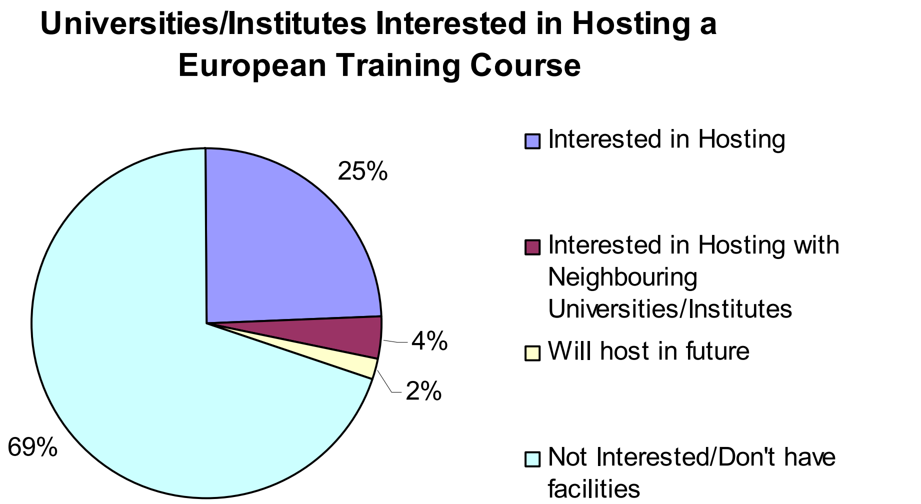

Figure 2
Universities/institutes Interested in hosting a European Training Course

3.2.2 Considering the above 31 universities/institutes who say they could host a European Training Program (alone or otherwise), could they provide some or all of the following?

a) Laboratories/Equipment
See Laboratory Equipment table (Table 6).

b) Staffing/Administration
Key scientific staff/contact persons identified; however, insufficient information presently available on the level of administrative support available.

c) Accommodation for participants and tutors
Yes – 18. Out of term time only – 4. None available – 6. Not specified – 3.

3.3 Mobility to help/support elsewhere

43 Institutes/universities from 12 countries expressed interest in participating in a collaborative European Master's programme in one or more of the above-mentioned fields (see Table 7).

Specifically, could they:
Provide Lectures – 23
Provide laboratory equipment – 15
Help in coordination of programme – 1
Send students – 5
Various other comments – 13.

4. Conclusions

The survey findings indicate that the provision of postgraduate training at Master's level, specifically designed to meet the requirements of each of the above-mentioned fields, is, with some important exceptions (highlighted below), diffuse and insufficient in most of the Member States of the EU. Nevertheless, it is evident that competence in these fields at training level is being eroded through natural wastage and is not being replaced at a rate adequate to satisfy expected future demand for these specialised skills (see Work-package 2 Report). Finally, the survey evidences strong support for a EU-wide Master's training programme in Radiation Protection and allied fields as well as considerable willingness to participate in and/or host such a programme.

The important exceptions, of course, were those institutions currently running relevant MSc programmes. They breakdown as follows:

MSc level programmes in Radiation Protection are offered by the following institutions:

1. Dresden University of Technology, Germany
2. Jozef Stefan International Postgraduate School (to commence 2006), Slovenia
3. Norwegian University of Life Sciences, Norway
4. Radiation Protection Office, Oliver Lodge Laboratory, UK
5. Swedish University of Agricultural Sciences, Sweden
6. Universita' degli Studi di Firenze, Italy
7. University of Oslo, Norway
8. University of Surrey, UK
9. University of Tartu, Estonia.

Of these institutions, two, namely the Norwegian University of Life Sciences and the Swedish University of Agricultural Sciences, have expressed interest in hosting a European Training course. Both would appear to have most (if not all) of the required facilities and equipment necessary and both can offer on-campus accommodation.

MSc level programmes in Radiochemistry are offered by the following institutions:

1. University of Helsinki, Finland
2. University of Ljubjana, Slovenia
3. University of Oslo, Norway

4. Université Paris XI (with ENSCP, Université d'Évry-Val d'Essonne, and INSTN), France.

Of these, Université Paris XI has expressed an interest in participating in and hosting a European Training course, but it is not clear whether they have sufficient facilities/ equipment available, or that they can provide convenient accommodation for participants and tutors.

MSc level programmes in Radioecology are offered by the following institutions:

1. Comenius University, Slovakia
2. Lund University, Sweden
3. Norwegian University of Life Sciences, Norway (with an option to specialise in Nordic Radioecology).

Again, the Norwegian University of Life Sciences has indicated that they would be interested in hosting such a European Training course. Lund University Hospital also expressed an interest, but would prefer to host in collaboration with Risø National Laboratory in Denmark. Both Lund and Risø have sufficient facilities and equipment, though limited availability of accommodation for participants and tutors.

MSc programmes in Radiobiology/ Radiation Biology are offered by the following institutions:

1. Grey Cancer Institute (Part of European MSc), UK
2. INSTN with seven regionally-located universities, France
3. Université Paris XI (with Université Paris XII, Université Paris V and INSTN), France
4. University of Birmingham, UK
5. University College London (Part of European MSc), UK
6. University of Stockholm, Sweden.

Of these, four, namely Grey Cancer Institute, Université Paris XI, University of Birmingham and University of Stockholm, have expressed interest in hosting a European Training course. All, with the exception of Université Paris XI, who did not supply such information, appear to have adequate facilities and accommodation for this purpose.

MSc level programmes in Radiometrics are offered by the following institutions:

1. Liverpool University, UK
2. University of Oslo, Norway.

Neither of these institutes indicated whether they would be interested in hosting a European Training course, nor whether they have the necessary facilities and accommodation.

Of the 24 identified MSc programmes in the areas of interest, all but 6 are offered by just 4 countries, i.e., France, Norway, Sweden and the UK.

There are however many institutions who are running Higher Diploma/Certificate programmes, modules in postgraduate programmes (PhD, MSc and Diploma level), or short training courses which are relevant to this study (see Tables 3 and 4). For example, Masaryk University in the Czech Republic, who offer a module in Radiochemistry as part of their MSc programme in Nuclear Chemistry.

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Table 1: Dedicated MSc programmes in one or more of the defined areas

Country	**University/Institute**	**Course Title**
Austria		No taught Masters' programmes offered
Belgium		No taught Masters' programmes offered
Bulgaria		No taught Masters' programmes offered
Cyprus		No taught Masters' programmes offered
Czech Republic		No taught Masters' programmes offered
Denmark		No taught Masters' programmes offered
Estonia	University of Tartu	(1) Environmental Dosimetry and Radiation Protection
Finland	University of Helsinki	(1) Radiochemistry
France	Université Paris XI (with ENSCP, Universite d'Evry-Val d'Essonne, & INSTN)	(1) Radiochemistry with one of two options, i.e., Nuclear Fuel Cycle or Radioecology
	Université Paris XI (with Université Paris XII, Université Paris V & INSTN)	(1) Radiobiology with one of two options, i.e., Physiopathology of Irradiated Tumours or Biological Basis for the Protection of Man and the Environment
	Université Joseph Fourier (with Institut National Polytechnique de Grenoble & INSTN)	(1) Scientific and Technological Management of Radioactive Wastes (2) Clean-up & Dismantling of Nuclear Plants
	INSTN with seven regionally located universities	(1) Radiopharmacy & Radiobiology
	Université de la Med	(1) Risk Prevention and Technological Risk Assessment
Germany	Dresden University of Technology	(1) Radiation Protection Physics
	Karlsrhule University	Title to be advised
Greece		No taught Masters' programmes offered
Holland		No taught Masters' programmes offered
Hungary		No taught Masters' programmes offered
Ireland		No taught Masters' programmes offered
Italy	Universita' degli Studi di Firenze	(1) Radiation Protection Physics
Latvia		No taught Masters' programmes offered
Lithuania		No taught Masters' programmes offered
Malta		No taught Masters' programmes offered
Norway	Norwegian University of Life Sciences	(1) Radioactivity and Radiation Protection (2) Radioecology (3) Radioecology: Nordic course in

		Radioecology
	University of Oslo	(1) Radiochemistry (2) Radiometrics (3) Radiation Dosimetry & Radiation Protection
Poland		No taught Masters' programmes offered
Portugal		No response
Slovakia	Comenius University	(1) Nuclear Chemistry and Radioecology
Slovenia	University of Ljubjana	(1) Radiochemistry
	Jozef Stefan International Postgraduate School	(1) Radiation Protection (to commence 2006)
Spain	CIEMAT	(1) Nuclear Technology
Sweden	Lund University	(1) Radioecology (with Medical Radiation Physics)
	Swedish University of Agricultural Sciences	(1) Radiation Protection and Risk Assessment
	University of Gotenborg	(1) Nuclear Waste Management
	University of Stockholm	(1) Radiation Biology
Switzerland		No taught Masters' programmes offered
UK	Grey Cancer Institute	(1) Radiation Biology (Part of European MSc)
	Lancaster University	(1) Safety Engineering (2) Decommissioning and Environmental Clean-up
	Liverpool University	(1) Radiometrics
	University College London	(1) Radiation Biology (Part of European MSc)
	University of Birmingham	(1) Radiation Biophysics
	University of Surrey	(1) Radiation and Environmental Protection
	Radiation Protection Office/Oliver Lodge Laboratory, UK	(1) Radiation Protection

Table 2: Dedicated MSc programmes in Medical Physics and related topics

Country	University/Institute	Course Title
France	INSTN with seven regionally located universities	(1) Nuclear Medicine
Greece	Athens University	(1) Medical Physics
	Democrition University	(1) Medical Physics
	University of Patras	(1) Medical Physics
Ireland	University College Dublin	(1) Radiological Sciences
	University College Galway	(1) Medical Physics
Latvia	Riga Technical University	(1) Medical Physics
UK	Aberdeen University	(1) Medical Physics
	King's College London	(1) Medical Physics
	Lancaster University	(1) Radiation Physics (Medical Applications)
	University of Birmingham	(1) Medical Radiation Physics
	University of Surrey	(1) Medical Physics
	University of Wales	(1) Medical Radiation Physics

Table 3: Dedicated Higher-level Diploma/Certificate Courses in one or more of the key areas

Country	University/Institute	Level of Module	Course Title
Belgium	SCK·CEN	Professional Cert	(1) International School for Radiological Protection
	Université Catholique de Louvain	Cert	(1) Radioprotection and application of ionising radiation
Estonia	University of Tartu	Dip	(1) Environmental Dosimetry and Radiation Protection I (2) Radiation Protection Basics
France	INSTN (with other EC Member States)	Dip (ERPC)	(1) Radiation Protection (European Radiation Protection Course – see Directive 96/29 Euratom, 13/5/96)
Germany	GSF Forschungszentrum fur Umwelt und Gesundheit	Short Professional Courses	(1) Radiation Protection
Greece	Athens University	Professional Cert	(1) Radiation Protection
Hungary	Eötvös Loránd University	Cert	(1) Extended Training Courses on Radiological Protection
	Zrínyi Miklós National Defence University	Cert/Dip	(1) Radiology (2) Radiation Protection (3) Nuclear Protection of the environment (4) Prevention of Nuclear Accidents
Slovenia	Jozef Stefan Institute Reactor Centre	Dip	(1) Radiation Protection/ Reactor Physics/Reactor Engineering
	University of Ljubjana	Dip	(1) Radiochemistry
Spain	CIEMAT	Dip	(1) Radiological Protection
	Universidad de Extremadura	PG course	(1) Radioactivity in waters
	Universidad de La Laguna	Dip	(1) Operator of Radioactive Installations for Medical Use (Radiotherapy and Nuclear Medicine)
UK	HMS Sultan	Dip	(1) Radiation Protection
	University of Birmingham	Cert/Dip	(1) Radioactive Waste Management and Decommissioning
-------	VERMI	Short Professional Course/ Workshop	(1) Radiometrology, with focus on: • General Metrology Structure in Radionuclide Metrology • Primary standardization

			techniques • Gamma Spectrometry • Nuclear Data • Statistics & Uncertainties • Liquid Scintillation counting • Sodium Iodide counting • Ionization chambers • Radionuclide calibrators • Quality assurance

Table 4: Dedicated Course Modules in one or more of the defined areas

Country	University/Institute	Level of Module	Module Title
Belgium	Université Libre de Bruxelles & Université D'Europe	Dip	(1) Elements of Radiation Protection (2) Radiation Physics, Dosimetry and Radiation Protection Medical (3) Radiation Protection with radiological techniques (4) Legislations and regulation in radiation protection (5) Work practices in radiation protection: Physical Aspects
	Vrije Universiteit Brussel, Universiteit Gent, Katholieke Universiteit Leuven, Université de Liège, Université Catholique de Louvain, SCK·CEN	NS	(1) Radiation Protection and Nuclear Materials
	Université de Liège, Ulg	Dip	(1) Radiation Protection (2) Radiobiology
	XIOS Hogeschool Limburg	MSc	(1) Environmental technology: radiochemistry
Denmark	Copenhagen University	Dip/Cert	(1) Isotope Techniques
Estonia	University of Tartu	Dip	(1) Basis of environmental radioactivity
Czech Republic	Charles University	NS* NS* PhD NS*	(1) Nuclear & Radiation Safety (2) Radioanalytical Methods (3) Semiconductor sources and detectors of radiation (4) Biological Effects of Ionising Radiation
	Masaryk University	MSc	(1) Nuclear Chemistry with practical courses on Radiochemistry
	Czech Technical University	MSc	(1) Dosimetry and Application of Ionising Radiation
Finland	University of Kupio	MSc/PhD	(1) Environmental Science
	Helsinki University of Technology	MSc	(1) Radiation Protection
Hungary	Budapest University	MSc	(1) Radiation and Environmental Protection
	Debrecen University	MSc	(1) Radiation Protection and Dosimetry (84hrs) (2) Radioecology (28hrs)

			(3) Environmental Radioactivity (84hrs)
	Eötvös Loránd University	MSc	(1) Radiochemistry and Radiometrics
	University of Veszprém	Cert/Dip/ MSc/PhD	?
Italy	Universita' degli Studi di Genova	NS*	(1) Radiation Protection
Slovakia	Technical University of Zvolen	MSc	(1) Radioecology
	University of Agriculture	NS*	(1) Environmental Radioactivity
Slovenia	University of Ljubjana	MSc/PhD	(1) Fundamentals of Radioecology
Spain	Universidad Cantabria	PhD	(1) Environmental Radioactivity I, II & III
	Universidad de Extremadura	PhD PhD	(1) Radioecology (2) Stable and radioactive isotopes
	Universidad de Huelva	MSc	(1) Applied Nuclear Physics (2) Environmental Radioactivity
	Universidad de León	MSc	(1) Environmental Radiological Protection
	Universidad de Salamanca	PhD PhD	(1) Nuclear Physics and Fundamental Interactions (2) Ionising Radiations & Environmental Radiological Surveillance
Sweden	Linköping University	MSc	(1) Radiation Protection
	Swedish University of Agriculture	MSc	(1) Radioecology
	Uppsala University	Cert/Dip	(1) Applied Environmental Radioactivity (2) Coupled Interactions in Complex Surface Water Systems
UK	Cranfield University	MSc	(1) Radiation Protection

*NS: Not specified.

Table 5: Universities/institutes capable of hosting a European Training Course

Country	Institute	Comments
Denmark	Risø National Laboratory	Key staff giving lectures within our fields of expertise Hosting short laboratory courses on practical matters
Finland	STUK	
France	Joseph Fourier University	Yes, when the EMNT would operate in 2007-2008
	Paris XI University	
	Université de la Mediterranée (Aix-Marseille II)	
Hungary	Budapest University of Technology and Economics	Yes (but preferable with other institutes, like in the "Wigner Course")
	Debrecen University	
	Eötvös Loránd University	
	University of Veszprém	
Ireland	RPII	**?**
	Trinity	Possible
	University College Dublin	Possible in conjunction with RPII
Latvia	Riga Technical University	
Lithuania	Radiation Protection Centre	Yes - When the training centre is established. There are plans to have it as a regional training centre
Norway	Norwegian University of Life Sciences	
Spain	CIEMAT	
	Universidad Cantabria	Through the European Union ALFA Program
	Universidad de Extremadura	
	Universidad de Salamanca	
	Universidad de Sevilla	
Sweden	Linköping University	
	Lund University	Preferably in collaboration with Risoe, Denmark
	Sahlgrenska University Hospital	Yes, perhaps in collaboration with some other department
	University of Stockholm	
	Swedish University of Agricultural Sciences, SLU	

UK	Cranfield University	
	Grey Cancer Institute	
	Health Protection Agency	
	Lancaster University	
	Loughborough University	
	University of Birmingham	

Table 6: Facilities/equipment available

Country	University/Institute	Equipment
Denmark	Risø National Laboratory	Chemical laboratories Analytical equipment including several gamma and alpha spectrometers, a liquid scintillation counter, an ICP-MS
Finland	STUK	Several radiochemical laboratories with pre-treatment and radionuclide separation facilities Gamma-, alpha- and beta measuring systems with several different size detectors Liquid scintillation measuring systems Environmental sampling systems Whole-body counting systems Mobile environmental monitoring system Cell culture facility Proteomics facility Narrow-beam alpha-particle exposure facility Biological dosimetry facility Radiation metrology laboratory
France	Joseph Fourier University	Laboratoire de Physique Subatomique et de la Cosmologie - for training students on the different detection methods used in the nuclear industry CEA Marcoule — for training students on the radioactive spectrum of real waste parcel
	Paris XI University	NS*
	Université de la Mediterranée (Aix-Marseille II)	University of Méditerranée: PRNT Laboratory, risk management CEA INSTN, area of Cadarache Center, Radiation Metrology CEA Cadarache, Safety and Security Department: Environmental Monitoring and Radiation Dosimetry for Radiological Protection
Hungary	Budapest University of Technology and Economics	Training reactor (100 kW maximum thermal power, swimming pool type reactor vessel, 24 EK-10 fuel assemblies, horizontal beam tubes for reactor physics and radiation protection experiments vertical tubes and rabbit systems for activation analysis) Radiochemical Laboratory Whole Body counter and low-level background environmental laboratory

		Compound environmental monitoring station
	Debrecen University	Instrumentation for basic radioactivity measurements, including gamma spectrometry Low background gamma spectrometry (2 complete systems) Alpha spectrometry Low level beta measurement facilities Dose rate probes and monitors Radiochemistry laboratory
	Eötvös Loránd University	C level laboratory for open isotope handling Several other labs for sealed sources Labs for: Mössbauer spectroscopy, positron annihilation spectroscopy, gamma spectroscopy (scintillation and semiconductor detectors)
	University of Veszprém	Complete equipment for alpha, beta and gamma measurements, for water-radon, air-radon, B and C level workplaces for high and low level radiation samples, whole body counter, semi-conductor detectors, liquid scintillation detector, electrochemical units,.....
Ireland	RPII	The Institute has a state-of-the-art accredited environmental and radiochemical laboratory, sample preparation laboratory, radon measurement laboratory, and dosimetry and calibration facilities.
	TCD	NS*
	UCD	Radiometric and Radiochemical Laboratory 6 HPGe gamma spectrometers 24 Alpha spectrometers 2 high sensitivity liquid scintillation spectrometers Carbon-14 dating laboratory
Latvia	Riga Technical University	X-ray diagnostic laboratory to train for radiation safety and protection on medicine. The lab is equipped with the following x-ray units; Conventional Mammography

		Dental Surgery
Lithuania	Institute of Physics	Radiochemical laboratories Alpha, beta and gamma spectrometers Liquid scintillation spectrometer Computer Modelling
	Radiation Protection Centre	Measurements of radioactivity (including chemical separation and nuclear spectrometry), external internal dosimetry, quality control of radiological equipment.
Norway	**University of Life Sciences**	**The university has laboratories available for alpha-, beta-, and gamma- measurements as well as ICP-MS at the Isotope laboratory. Facilities are available for sample preparation and measurements, including speciation studies and tracer experiments.** In addition, UMB has a gamma radiation facility for studies of biological effects of gamma-induced free radicals.
Spain	CIEMAT	Environmental Radioactivity laboratories Laboratories of Dosimetry Radiology laboratories Laboratories of Radiation protection Measurements
	Universidad Cantabria	Laboratory for sample preparation (fully equipped) Alpha-beta low background counter Si Alpha spectrometry NaI(Tl) gamma spectrometry Gross alpha counter
	Universidad de Extremadura	Low-level counting laboratory equipped with Ge gamma spectrometers, alpha-spectrometer (PIPS), low-background liquid scintillation counting (Quantulus), alpha-beta gas proportional counter, etc. Radiochemistry laboratory (well equipped)

	Universidad de Salamanca	Research laboratory equipped with: 2 alpha counters 1 alpha-beta counter 2 alpha spectrometers of high resolution 2 gamma spectrometers with HPGe detectors In the student lab, there are several GM counters 1 alpha spectrometer 2 gamma spectrometers with NaI detectors
	Universidad de Sevilla	Detector laboratories fully equipped (gamma-ray spectrometers, alpha-spectrometry systems, low-level liquid scintillation counters, gas-flow proportional counter, ICP-Ms system) Sample preparation laboratories fully equipped National Center for accelerators, including a 3 MV tandem accelerator, a 20 MV cyclotron, and 1 MV tandem accelerator mass spectrometer.
Sweden	Linköping University	1 Radiochemistry laboratory 2 Radiometry laboratories 1 ESR/EPR laboratory 1 Irradiation laboratory
	Lund University	Radiochemistry Lab 7 HpGe detector systems 23 Alpha spectrometers 10 anticoincidence-shielded beta counters
	Sahlgrenska University Hospital	Radiochemistry laboratory

		Field-gamma spectrometry equipment (2 systems) HPGe (4 systems) Liquid scintillator Vacuum cells for alpha-spectroscopy Whole-body counter (totally shielded)
	University of Stockholm	Excellent laboratory facilities, including three radiation sources for different applications
	SLU	Normally facilities for soil science including ICPMS and HP-Germanium and NaI detectors
UK	Cranfield University	Fully equipped radiation laboratories, wide selection of high and low activity (microcurie - kilocurie) radio-isotope sources, range of x-ray generators and diffractometers, Van de Graff Positive Ion Accelerator
	Grey Cancer Institute	Full range of experimental radiation sources for radiation biology, including X-rays, ^{60}Co, ^{137}Cs, accelerator protons, helium ions, neutrons, microbeams, pulsed and continuous electrons. Cell & molecular Biology Labs Imaging Suites In vivo facilities
	HPA	Necessary laboratory facilities available
	Lancaster University	Facilities are currently being planned for refurbishment to support our decommissioning course.
	Loughborough University	Purpose built radiochemistry laboratories with up to date counting equipment and facilities.
	University of Birmingham	Wide range of irradiation sources (alpha, beta, gamma, x-ray, neutrons) Radiobiology laboratory (cell culture, hot rooms, cell counting, etc) Dosimetry laboratory (TLD, ion chamber, radiochromic dye film, gamma spectrometry, scanning electron microscopy, etc.)

Table 7: Universities/institutes interested in collaborating in a European Masters course and the services they can offer

Country	**University/Institute**	Services Offered
Estonia	University of Tartu	Presenting lectures (course or part of it) on environmental radioactivity and radiation protection, radiological risk assessment Upgrading an academic co-ordination of existing lecture courses and practising facilities in the field in Uni Tartu Participation of Estonian student in the collaborative courses
Finland	STUK	Giving lectures, place for training courses, places for doing theses (if funding exists), offering supervisors for PhD students
	University of Helsinki	Could send students
France	Joseph Fourier University	JFU leads an European consortium for an "European Masters in Nuclear Technology: Decommissioning, waste management and Non Power Applications" inside the SOCRATES programme, ref. 210377-IC-1-2003-1-Fr-ERASMUS-PROGUC-1
	Paris XI University	Some university teachers could give lectures on actinides electronic structure related to the spectroscopic technique, solid-state chemistry of actinides, transmutation, and radiolysis
	Aix-Marseille II	Formation of experts in Radiation Protection
Hungary	Budapest University of Technology and Economics	The Institute of Nuclear Techniques (INT) could offer 1. Lectures in various disciplines of reactors physics, reactor technology, radiochemistry and radiation protection 2. Laboratory exercises at the Training reactor in the above fields
	Debrecen University	Conduct and supervise laboratory practical on principle radioactivity and dosimetric measurements, environmental radioanalytical measurements as part of an MSc course
	Eötvös Loránd University	Could provide teaching in nuclear chemistry, radiological protection in English, including laboratory practices. Staff could also be sent to other institutes as guest lecturers
	University of Veszprém	Mobility programmes
Ireland	DIT	We would be interested in taking project students or could contribute to teaching radiobiology

		modules
	RPII	By provision of relevant staff as guest or part-time lecturers and the provision where possible of laboratory facilities for research under supervision.
	Sligo IT	Interested but could offer very little
	TCD	Possible with more info
	UCD	Willing to provide lectures, courses modules or parts thereof in Radiation Protection, Radiometrics, Radiochemistry and Radioecology
Latvia	Riga Technical University	Deliver teaching and training Sending students
Lithuania	Institute of Physics	Would be interested in sending PhD students to improve their knowledge in other European countries or inviting PhD students from other countries Institute has experience in organising laboratory practice for Masters and PhD students and some specialised lectures on radioecology, radiation protection and radiochemistry could be given by scientific staff from the institute
	Radiation Protection Centre	Hosting training sessions Arrangement of practical exercises Participating of members of staff of the RPC in teaching
Norway	University of life sciences	
	University of Oslo	In any practical way
Poland	Institute of Oceanology of the Polish Academy of Sciences	Providing supervised hands-on training in radioanalytical techniques in our laboratory premises (short or long tem stay), up to two trainees at a time. Organising proficiency tests and intercomparison exercises for a limited number of participants (up to 20)
Spain	CIEMAT	
	Universidad de Cantabria	Through the European Union ALFA Programme
	Universidad de Extremadura	Lecturing some specific courses

	Universidad de Huelva	Collaborating organising courses Providing facilities and training…
	Universidad de la Laguna	Theory and practice in the areas of radionuclide measurements in environmental samples Practical measurement of doses in hospitals
	Universidad de León	Collaborating in teaching courses relating to environmental radioactivity, measurements and detections of low levels of radiation and radiochemistry
	Universidad de Málaga	
	Universidad de Salamanca	Yes-Collaborate organising, hosting and giving courses
	Universidad de Sevilla	Organising courses Lecturing Providing facilities
Sweden	Linköping University	Participate in a European network for education in Radiation protection in emergency situations/disaster medicine at Masters and PhD level. Could contribute in the areas of general radiation physics, radiation protection, dosimetry and forensic radiometry. These programmes could be given in Linköping in close co-operation with the National Centre for Teaching and Research in Disaster Medicine and Traumatology in Linköping
	Lund University	Sending students Act as lecturers Host courses in radiochemistry, nuclear measurement techniques, dosimetry, radiation protection
	Sahlgrenska University Hospital	Teaching in theoretical and practical matters Sending students
	University of Stockholm	Could host part of the Masters Course
	SLU	Teaching and project work in radioecology and radiation protection
	Uppsala University	Coordination/compilation of relevant courses, including field and lab experiments Building reference databases/materials for tests/calibration of models/facilities and participation in suitable research exercises

		Comment: *It would be interesting to link and integrate this field to other areas in global change studies in order to attract more people form other disciplines, to adopt the scope/content to newly emerging sciences and to contribute in structuring the European Research Area*
UK	Cranfield University	Yes by provision of accredited modules using the Bologna system
	Grey Cancer Institute	Could integrate existing modules of the MSc Radiation Biology and share resources
	Health Protection Agency	Would be worried because validation of PG RP courses not seen to benefit students and was difficult to achieve.
	Lancaster University	Provision of teaching materials, facilities and expertise
	Loughborough University	
	University College London	Already collaborate in the European course on Medical Physics organised by the University of Patras. We could also contribute to teaching and research projects.
	University of Birmingham	

Addendum

EURAC project: Questionnaire for WP1 (Existing Competence and Infrastructures)

Context/objective

The objective of this survey is to identify the current and potential level of post-graduate (Certificate, Diploma, Masters and Doctorate) provision in radiological protection, radioecology and radiochemistry within the EU and new entrant nations. This will facilitate an assessment of the scientific, administrative and infrastructure requirements and constraints with respect to the development of appropriate co-ordinated academic education programmes, in particular at Masters and PhD level, across the EU.

It forms part of an EU programme aimed at securing the future recruitment of appropriately skilled post-graduates to meet the needs of European stakeholders.

The results of the survey will inform recommendations for actions that can be taken within the EU to help meet the post-graduate education needs identified within the project.

To aid your responses, the baselines from which we are exploring radiological protection are the relevance of scientific competencies within:

- Radiochemistry and radiometrics
- Radioecology
- Radiobiology – radiation sensitivity
- Radiation dosimetry
- Environmental modelling
- Biokinetic modelling
- Radioactive waste storage/disposal
- Radiological risk assessment
- Radioactive threat detection (including transport of illicit nuclear materials)

SECTION 1 (RESPONDENT INFORMATION):

Country
Name and address of university/academic institution
Name:
Postal address:

Key contact details
Name:
Address (if different from above):
Position:
Tel.:
Fax:
Email:

SECTION 2 (COURSES AND FACILITIES):

Title/s and level/s (Certificate, Diploma, Masters) of relevant course/s taught at postgraduate level

Number of places available on these course/s

Do you undertake relevant short training courses for industry etc? If so, what are these?

Are there significant relevant parts of other courses that are taught in your institute?

Names of key staff and their areas of interest/expertise

Number of doctorate /PhD students in related area

Laboratory facilities available for training purposes

Availability of on-campus accommodation

SECTION 3 (RESEARCH):

Does your institution undertake research in the area of Radiological Protection?
YES/NO

13. If so, in what research area?

If YES**, in what way do you support such research?**

Provision of facilities for research (YES/NO):
Provision of projects and supervision for postgraduates (YES/NO):
Finance: (YES/NO):

SECTION 4 (FUTURE):

14. In principle would your institute be interested in participating in a collaborative European Masters Course?

YES / NO

If yes, how?

15. In principle, could your institution host a European training course?
YES/NO

16. Do you consider that your institution would benefit from European cooperation in these areas?
YES/NO

SECTION 5 (CONTACTS):

17. Could you advise us on other institutes, within your country, that offer/could potentially offer (because they have an appropriately skilled staff) relevant postgraduate/doctoral courses/supervision?

Appendix B

WP2 Report: Future Education Needs

Report produced by:

A. Abbott

July 2005

1. INTRODUCTION

BACKGROUND

A number of studies over the past five years, by different European governments, identified that probably too few scientists were being trained to meet the needs of their current and future nuclear industries, with decreased student interest, decreased course numbers, aging faculty members and aging facilities. Consequently, the European education skill base has become fragmented to a point where universities in most countries lack sufficient staff and equipment to provide education in all, but a few, nuclear areas. Of particular concern appeared to be special skill-base deficits within nuclear radiological protection, radioecology and radiochemistry at masters and doctorate levels.

The EURAC Project is consultative/consensual and aims to assess the current and potential levels of postgraduate provision in selected linked disciplines associated with radiological protection and radioecological competence within universities and other higher education institutes (HEIs) of the EU and new entrant nations in the context of demand. Based on consultations with European stakeholders EURAC will propose those actions that could be taken by European Institutions and relevant organisations in Member States to secure the future of nuclear radiological protection, radiochemistry, and radioecology postgraduate education in an expanded EU.

The overall objectives of EURAC are to:

- Assess the needs for co-ordinated postgraduate education in the EU and new entrant nations in order to:
  - Strengthen the scientific academic competence and analytical skills within radiological protection, radiochemistry and radioecology.
  - Secure the future recruitment of appropriately skilled postgraduates to meet the needs of European stakeholders.
- Recommend, following consultations, actions that could be taken within the EU to help meet the postgraduate education needs identified.

In order to achieve these objectives EURAC is addressing a number of linked sub-goals through work packages:
Work package 1: Determination of existing competence and infrastructures
Work package 2: Estimation of future scientific needs

Work package 3: Development of possible postgraduate education solutions
Work package 4: Assessments and recommendations.

Objectives

The objective of Work Package 2 is to identify the scientific competence needed for future university-trained postgraduates, at masters- and doctorate-level, within radiological protection, radioecology and radiochemistry through the involvement of key European stakeholders. The data would be utilised to identify the future needs for higher education in the sector and determine the needs for underpinning research facilities, equipment and technology.

Scope

The objectives were fulfilled through investigation of available documentation and consultation with stakeholder organisations across Europe and New Entrant Nations. These included representatives of authorities (radiation protection authorities, agencies, ministries), research communities (universities, institutes and consultancies), the nuclear industry and its contractors. Quantitative and qualitative data was collected on current and future recruitment needs at masters and doctorate levels, training needs of stakeholders in the areas of interest and its impact on recruitment, and research activities and needs. Data collection concentrated, initially, on those countries with an established nuclear industry because they were likely to have the highest perceived need for qualified graduates. Nevertheless, it was recognised that skills would be required in all countries and the needs of "non-nuclear countries" was canvassed.

2. SURVEY METHODOLOGY

Within the EURAC Consortium, those members that are not universities undertook the study. Data collection for Work Package 2 was geographically allocated with partners covering specific areas with which they were most familiar.

The survey methodology was as follows:

- Review of existing literature
- Creation of agreed questionnaire framework for use by all partners (Appendix 1)
- Partner compilation of contact list (Appendix 2)
- Phase one survey of stakeholders through e-mail questionnaire
- Consultation of stakeholders through face-to-face networking and/or telephone dialogue
- Follow up to questionnaire responses through telephone dialogue
- Compilation of data into a summary spreadsheet (Appendix 3)
- Presentation of broad findings at partner meeting
- Agreed criteria for analysis and clustering of data
- Analysis and reporting of survey.

In analysing the data from the survey, attempts were made to discriminate by the type of organisation (Government, Industry or Research); by country; by region; and by nuclear or non-nuclear countries. In many cases, the limited size of the respective samples mitigated against such analysis but where possible trends are illustrated.

3. REVIEW OF EXISTING LITERATURE

National and international surveys have confirmed concerns by international organisations and key stakeholders in the nuclear field that the ability of HEIs to deliver postgraduate nuclear education is diminishing. A report by the Nuclear Energy Agency (NEA) (OECD/NEA, 2000) identified a failure chain that has resulted in the under-provision of academic training in nuclear technology-related disciplines, including radiological protection. This report urged the national governments to take steps to secure sustainable expertise to meet the needs of their current and future nuclear industries. A follow-up survey (OECD/NEA, 2004) reported some initial improvement with various countries undertaking a range of initiatives. One of its main recommendations was to pursue a greater degree of international collaboration, particularly to retain expertise in certain strategic nuclear areas for which the required number of experts per nation may be small, such as radiochemistry and radiation protection.

Two international surveys investigated the status of education programmes in radiation protection. The Nuclear Energy Agency Committee on Radiation Protection and Public Health published a report on "Education Programmes in Radiation Protection" (OECD/NEA, 2002) which addressed university-level programmes producing radiation protection professionals. Its findings were that not all countries offered degrees specific to radiation protection and that it was rare for there to be any exchange of students or faculty members between universities in different countries. It usefully identified laboratories/research facilities that offered opportunities for postgraduate research. Those highlighted within the EU were:

CEA, IPSN, EdF and Cogema in France
ENEA and CNR in Italy
CIEMAT in Spain.

The report *The Status of the Radiation Expert in EU Member Countries and Applicant Countries – Study on Education and Training in Radiation Protection* for the European Commission (RP 133, 2003) identified that within the EU only Luxembourg depended on training courses given by other countries. It was also noted that, except in Hungary and Poland, education and training programmes in NEN are supported by IAEA within their Regional Technical Co-operation Project. It is pertinent to note that of its 70m$ budget, IAEA spends 30% on training programmes.

Reviewing the most recent NEA Annual Report (OECD/NEA, 2005), it is apparent that a key guide to curriculum development in the field of radiological protection will be the emerging recommendations by the International Commission on Radiological Protection (ICRP). Originally planned for completion in 2005, draft recommendations have triggered significant reactions within government and industry. As a result, the final approval of new recommendations has been postponed until no earlier than 2006. The key contentious issues include:

- dose restraints (their nature, relationship with dose limits, and numerical values)
- the matrix expression of the collective dimension of group dose (previously collective dose)
- the characterisation of the individual (previously the critical group)
- the nature and order of the Commission's three main principles (justification, dose restriction and optimisation).

The report also highlighted the emergence of new challenges arising from scientific studies on the effects of radiation on organisms. For example, the model currently used to relate radiation exposure to health risk (linear no threshold, LNT) seems to overestimate the risk to bone cancer, liver cancer and leukaemia for low alpha doses. It has raised the question as to whether the current risk estimate techniques appropriately estimate risks from chronic exposures. Another aspect of significance that was noted was the radiological aspects of national and international preparedness to respond to chemical, biological, radiological and nuclear (CBRN) incidents.

On a national level, the UK is one of the countries that have carried out their own investigations into the status and problems of postgraduate nuclear education, and investigated possible solutions to reverse the negative tend. The following findings from workshops and reports from the UK provide a useful illustration of the concerns of key stakeholders and steps that could be taken by governments, industries and educational institutes to retain or enhance the provision of nuclear education and secure the future recruitment of nuclear specialists.

During the 'Nuclear Education and Training' forum held in 2001 (HSE-DTI, 2001) the United Kingdom Atomic Energy Authority (UKAEA) and British Nuclear Fuels Limited (BNFL) noted the diminishing number of available engineering students to recruit from, whilst British Energy (BE) stated that only 5% of the 25 graduates recruited per annum had qualifications that stated nuclear in their titles. The British Nuclear Industry Forum (BNIF), a trade association for the nuclear energy sector representing some 70 companies, expressed concern over filling radiological protection positions. They contended that the customary strategy of recruiting generalists and training in-house was coming under stress because of a diminishing pool of expertise. However, at that time, one of the principle training providers, the National Radiological Protection Board (NRPB), did not report difficulty in recruiting to its staff. The concern expressed by BNIF was further highlighted in a report in 2002 commissioned by the UK Department of Trade and Industry (Coverdale, 2002). It was recognised that the ability of HEIs to deliver postgraduate nuclear education was diminishing and would be lost unless corrective action was taken This was reflected in the ability to deliver nuclear education at undergraduate level, and thus expose students to challenges that a career in the sector may offer. Of particular note, to the EURAC project, was that recruitment to Radiological Protection positions was being hampered by poor marketing of career opportunities. Furthermore, Radiochemistry expertise in the UK was still under threat despite BNFL's support for a Radiochemistry Centre of Excellence in Manchester. A report from the Health and Safety Executive and the Nuclear Industry Inspectorate of the UK recognised that the competition for engineering graduates was fierce and that the nuclear industry was losing out to other sectors (HSE-NII, 2003).

In terms of numbers needed for future recruitment within the UK, the Coverdale (2002) projected that within the Defence, Power, Fuel and Clean-up sub-sector, the requirements for professionals and associate professionals (minimum qualification of a Bachelors degree) would be 4,450 over the next 5 years, 10,000 over the next 10 years and 15,500 over the next 15 years. This equates to approximately 1000 graduates per year, of which 700 would be replacements for retirement and 300 in response to growth in the decommissioning market. A report prepared for the Learning and Skills Council, Cumbria, UK (NWDA, 2004) focussed on "Nuclear and Environmental Remediation Skills" needs in the North West of England. It stated that currently 30,000 people are employed in the nuclear industry in the NW of England, which accounts for about a half of the UK nuclear skill base. However, with the shift in emphasis away from power generation to clean-up, a significant decline in numbers employed is projected in the longer term (after 2012) such that only a third of the current numbers will be employed by 2018. Whilst this in itself was seen as a cause for concern, it was also recognised that maintaining an appropriate skills base in the shorter term remained a challenge. The study concluded that the move to decommissioning activity would generate a substantial increase in the number of training days over the period 2006-2012 (up to an additional 51,000 days per annum). It was envisaged that the workforce would need to become more flexible, risk aware and skilled in nuclear issues.

The future graduate requirement was thought to be lower than indicated in an earlier report (Coverdale, 2002) because of the assessment that decommissioning would require a higher proportion of technical as opposed to academic/managerial staff. A report by the Nuclear Task Force, commissioned by the nuclear industry in the UK, entitled "An Essential Programme to Underpin Government Policy on Nuclear Power" (Ruffles et al., 2003), quantified future recruitment needs within different nuclear subject areas. In those areas that overlap with EURAC's remit their estimates for annual recruitment were: radiation chemistry 32; safety and risk assessment 28; environmental impact assessment 41; and social science 10.

Two reports assessed in which nuclear subjects skill gaps were present or expected. Of relevance for the current EURAC project it is pertinent to note that the Nuclear Task Force report (Ruffles et al., 2003) highlighted the importance of radiation chemistry, analysis, instrumentation and control, environmental pathways, environmental impact and assessment, and stakeholder involvement in any skills training. In a broad assessment of skill shortages and gaps the NWDA report (2004) stated that, whilst there is not a current skills crisis within the industry, some critical skills areas were currently difficult to resource. It was believed that these areas could be plugged with people outside the industry if 'nuclearisation' of their experience was carried out. Particular areas of future skills gaps, of relevance to EURAC, were radiation protection advisors, safety case authors, criticality assessors and behavioural safety in the context of the nuclear industry.

A range of different recommendations were provided. The report by Coverdale (2002) indicated that action was required to establish the right level of provision of nuclear education in higher education that complements in-house training provided by employers whilst providing a viable infrastructure of education in universities. Among its recommendations was 'to promote modular nuclear higher education courses to enable their use as: 1. Taster units in undergraduate courses; 2. Building blocks to postgraduate qualifications'. The HSE report (HSE-NII, 2003) argued the case for inclusion of nuclear components in Environmental Masters degrees. The report illustrated links between the nuclear industry and 23 departments with expertise in environmental sciences within 17 universities in the UK. The exact nature of such links was not described but 15 were through research activities and 7 associated with taught Masters. Mostly the links were unique to individual companies but for some the links were with consortia of companies and regulators (Birmingham, Imperial College, Manchester's Nuclear Technology Education Consortium). Ruffles et al. (2003) indicated the necessity to maintain the skill base in nuclear technologies and waste management to contribute to a balanced energy research and development programme. It pointed to significant international investment in nuclear technology R&D and recommended that the UK government needed to:

- provide support for the existing nuclear programme in the UK
- maintain competence to select, license and operate new reactor systems
- keep abreast of international developments in nuclear technologies
- maintain and develop competence in nuclear waste issues.

The main conclusions that can be derived from the reviewed international and UK studies are:

1. Many industrial and government stakeholders are concerned about future recruitment as nuclear education is diminishing and competition for engineering graduates is fierce.
2. There will be an increase in needs for experts in decommissioning and nuclear waste issues in the near future.
3. Increased international cooperation is needed to maintain and enhance postgraduate education in certain strategic subjects for which the national demand may be too small to maintain national programmes, for example radiation protection and radiochemistry.
4. The new 2005 ICRP recommendations could be used to identify current and future skill gaps and which subjects need to be covered in any new postgraduate education in radiation protection.

4. Survey Results

Nature of Respondents

A total of 72 formal questionnaire responses were received from the following countries: Belgium; Germany; Denmark; United Kingdom; Estonia; France; Finland; Hungary; Italy; Latvia; Lithuania; Luxembourg; Norway; Netherlands; Poland; Republic of Ireland; Sweden; and Spain. Whilst no formal questionnaire responses were received from Austria, Cyprus, Czech Republic, Greece, Malta, Portugal, Slovakia, and Slovenia, views of representatives of these countries were sought and noted through personal contact.

Responses were obtained from most of the national radiation protection authorities within the EU, in addition to nuclear power industries, nuclear waste management companies, consultancies and national research institutes. Breakdown of questionnaire respondents into sectors followed the pattern shown in Table 1. Governmental authorities included national radiation protection authorities, government institutes, federal agencies and ministries, national nuclear waste management bodies. Industrial stakeholders came from nuclear power providers, waste management companies and companies providing services to the nuclear industry. Respondents identified in the research category were national research centres and university research institutes; other respondents were professional or trade associations.

Table 1

Sectoral breakdown of questionnaire respondents

Sector	No. of responses	% of total
Government	29	40
Industry	21	29
Research	20	28
Other	2	3

Although no absolute numbers in terms of recruitment and education needs can be derived from this study, the results described in this report are thought to be representative of the current and future employment and recruitment situation and educational needs in radiological protection within the EU. Furthermore, the report indicates in which areas current and future skill gaps are present or expected according to the key stakeholders within the EU, and thus provides a guideline for the content required in potential new postgraduate education and training programmes.

The majority of respondents employed nuclear-trained staff, and undertook training programmes for their staff. Over three-quarters engaged in research.

EMPLOYMENT OF RADIOLOGICAL PROTECTION-ORIENTED STAFF

The stakeholders were asked to indicate the approximate numbers of new recruits per annum for positions at different professional levels: manager, technical advisor, professional expert or other. The numbers to be recruited per annum per company vary from less than 1 to greater than 20, depending on the size and remit of the company or organisation. Table 2 shows the total number of new recruits per annum divided over the different professional levels, giving some indication of the demand for trained staff within the EU. Figure 1 indicates the relative demand for new recruits for the different professional levels.

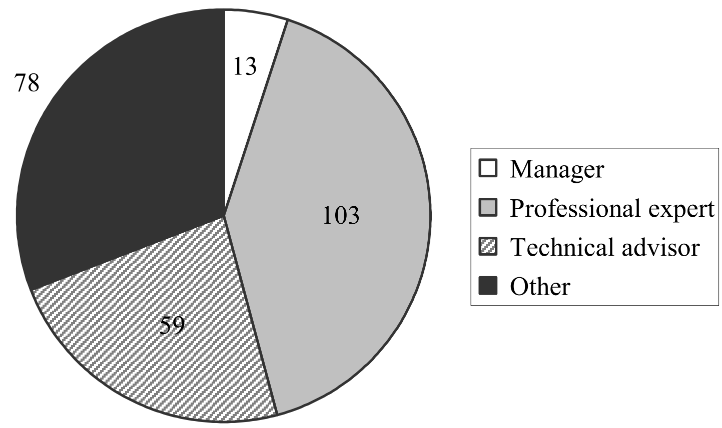
Table 2

Total numbers of staff recruited annually in radiological protection (in full time equivalents (fte)) and education requirements at each professional level

Professional level	Total recruited annually (in fte)	Percentage of employers that required ≥ MSc level
Manager	13	80 %
Professional expert	103	70 %
Technical advisor	59	50 %
Other	78	40 %
Total	253	

Figure 1

Relative demand at different professional levels



In response to the level of qualifications expected of recruits in radiological protection, two-thirds indicated that at least masters-level qualification were required for recruitment of professional experts, while over half required masters-level qualifications for technical advisors (table 2). The precise definitions of these terms may have differed between different countries but it was evident that for recruitment of individuals in the technical area of radiological protection masters-level qualifications were favoured.

National trends for recruiting "Professional Experts" were relatively consistent, though UK, Finland, Italy and Sweden indicated some recruitment below masters-level, backed up with appropriate in-house training. Where specified, "Technical Advisors" were recruited at all levels, except respondents from Denmark, France, Poland, Spain and Sweden who indicated predominantly post-masters-level recruitment.

In order to identify the relative demands for different areas of specialisation within radiological protection, stakeholders were asked to tick all areas of specialisation that are of interest to them. The preferred areas of expertise from which such staff were recruited are shown in Figure 2 and Table 3. Figure 2, which shows for each area of expertise the total number of respondents that ticked this particular category, clearly indicates that radiation dosimetry and radiochemistry are in highest demand. Table 3 shows the total number of respondents that ticked a particular category of specialisation as well as the total number of respondents per sector, so as to identify the sectoral differences in interest for particular specialisations.

Figure 2

Areas of expertise preferred for recruits in radiological protection

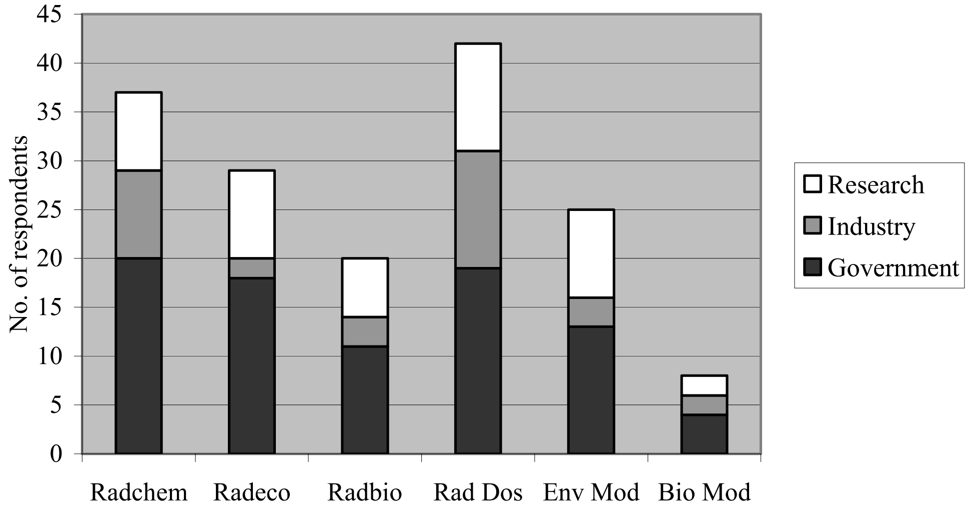


Table 3

Areas of expertise preferred for recruits by different sectors

Area of expertise	**Total**	**Gov**	**(%)**	**Ind**	**(%)**	**Res**	**(%)**
Radiochemistry	37	20	*69*	9	*43*	8	*40*
Radioecology	29	18	*62*	2	*10*	9	*45*
Radiobiology	20	11	*38*	3	*14*	6	*30*
Dosimetry	42	19	*66*	12	*57*	11	*55*
Environmental Modelling	27	13	*45*	3	*14*	9	*45*
Biokinetic Modelling	8	4	*14*	2	*10*	2	*10*
TOTAL of RESPONDENTS	72	29	40	21	29	20	28

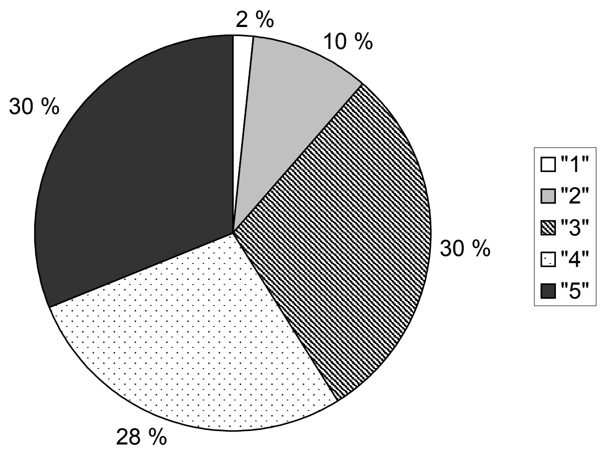
Other 3%

Areas of expertise preferred for recruitment showed some sectoral differences: radiochemistry, radioecology, radiation dosimetry and environmental modelling were the subjects that received the most interest from both government organisations and research institutes, while industrial respondents showed interest mostly in recruiting specialists in radiochemistry and radiation dosimetry. It should be noted that the majority of industrial respondents were power generation companies.

A particularly interesting finding from the survey was the apparent difficulty that most respondents indicated they had in recruiting the right people. Over half of the respondents rated the recruitment difficulty at 4 or 5 on a scale from 1 to 5 (Figure 3).

Figure 3

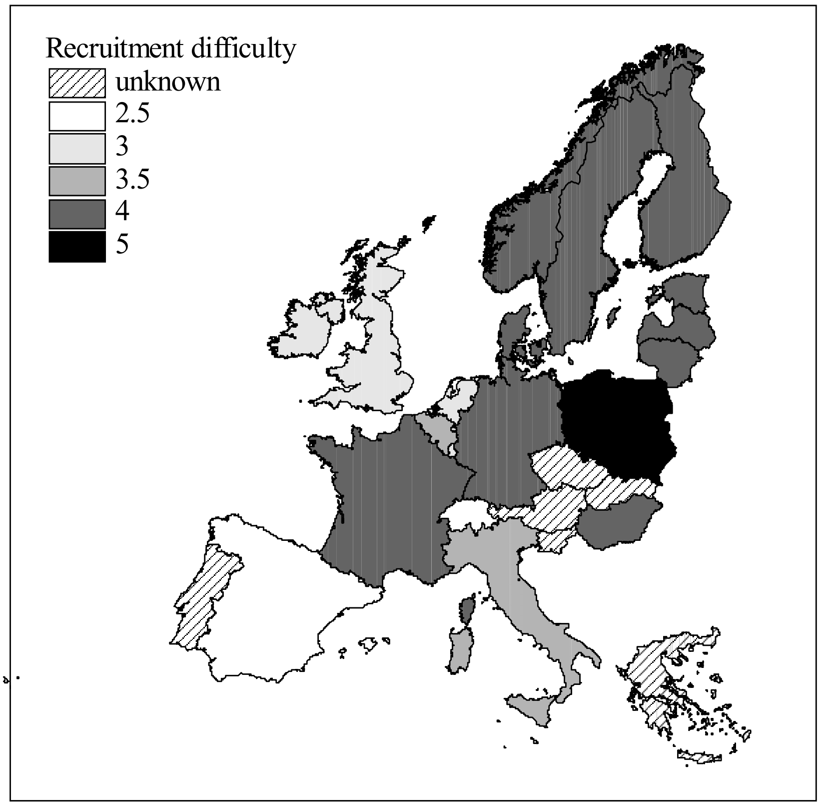
Rating of difficulty in employing appropriate staff in radiological protection (where 1 is easy and 5 most difficult)



There were notable differences in regional responses to the question of difficulties in recruitment, with southern and western Europe rating difficulty less than northern and eastern Europe. Crude averages illustrate this point: Spain 2.5, Luxembourg 3; Netherlands 3, UK and ROI 3, Italy 3.5, Belgium 3.5; France 4; Denmark 4, Sweden 4, Norway 4, Finland 4, Estonia 4, Lithuania 4, Latvia 4, Germany 4, Hungary 4; Poland 5. This is illustrated in Figure 4.

Figure 4

Average recruitment difficulty in radiological protection across Europe



TRAINING

This section deals with the provision of training by the stakeholders for their employees, both in terms of subject and level of the training as well as the location of the training. All but a few of the stakeholders indicated that they provide either in house training or send staff to training courses. The reasons for providing training vary. Research institutes indicated legal requirement and maintaining competitiveness as the two main reasons, while government organisations and industry indicated a wider range of reasons (Table 4). Additional reasons that were given include the need to upgrade staff, to keep staff up-to-date and maintain competence and accreditation, to ensure high quality throughout the company and to develop specialist knowledge.

Table 4

Reasons for providing training, in total numbers of respondents and in numbers and percentages per sector

Reason for training	Total	Gov	(%)	Ind	(%)	Res	(%)
Legal requirement	34	14	*48*	8	*38*	11	*55*
Help recruitment	21	11	*38*	5	*24*	5	*25*
Help retention of staff	32	19	*66*	8	*38*	4	*20*
Maintain competitiveness	37	14	*48*	9	*43*	13	*65*
Staff demand	28	15	*52*	7	*33*	7	*35*
Company ethos	32	16	*55*	7	*33*	8	*40*
TOTAL of RESPONDENTS	72	29	40	21	29	20	28

Responses to the question on how or by whom the training was provided showed that across all sectors company trainers from within the establishment are used most, but other types of training provision are also common, particularly in the government sector (Table 5). A breakdown of the types of provision of training is shown in Figure 5.

Educational establishments are utilised by over 40 % of all respondents, across all sectors, but there is a clear regional preference for this type of training, with the Nordic and Baltic countries and United Kingdom making more use of educational establishments than elsewhere in Europe. In terms of academic level of the training provided, over half of the respondents indicated that they provided training at masters-level and beyond.

Figure 5

Types of provision of training in radiological protection across respondents

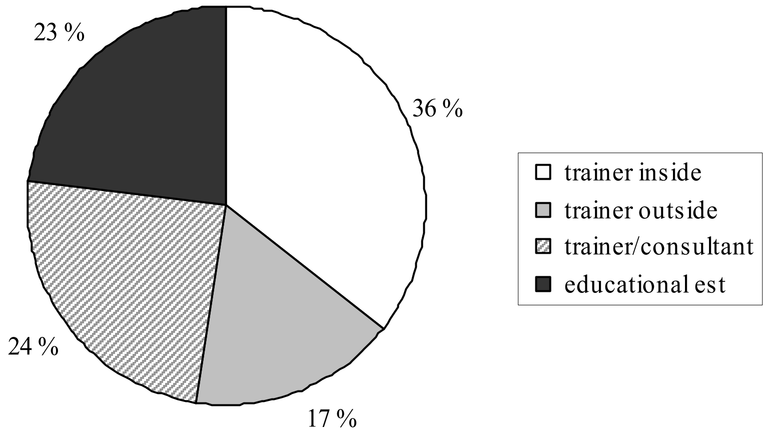


Table 5

Provision of training

Provision of training	Total	Gov	(%)	Ind	(%)	Res	(%)
Trainer from within company	49	18	*62*	15	*71*	16	*80*
Company trainer from outside	22	14	*48*	4	*19*	4	*20*
External trainer/consultant	33	20	*69*	8	*38*	5	*25*
Educational establishment	32	15	*52*	8	*38*	9	*45*
TOTAL of RESPONDENTS	72	29	40	21	29	20	28

The stakeholders were asked to identify in which particular skills further training was needed within their company (Table 5). The responses show that technical (radiological protection) training was undertaken across all sectors and countries. In probing the provision of training outside the specific technical areas, analytical skills and project management skills were identified by nearly half of the respondents, while the government sector also shows interest in training in general, leadership, and language and writing skills. This is illustrated in Figure 6.

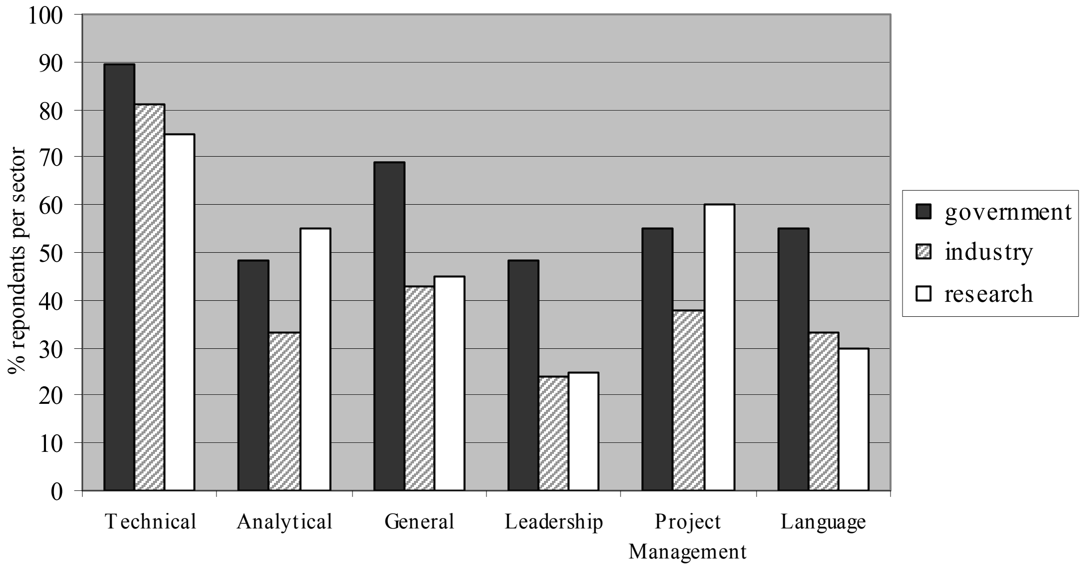
Table 6

Training needs, total numbers and number of respondents per sector

Training needs	Total	Gov	(%)	Ind	(%)	Res	(%)
Technical (radiation protection)	58	26	*90*	17	*81*	15	*75*
Analytical and Research	31	14	*48*	7	*33*	11	*55*
General skills	37	20	*69*	9	*43*	9	*45*
Leadership skills	24	14	*48*	5	*24*	5	*25*
Project Management	34	16	*55*	8	*38*	12	*60*
Language/writing	29	16	*55*	7	*33*	6	*30*
TOTAL of RESPONDENTS	72	29	40	21	29	20	28

Figure 6

Training needs per sector



The survey attempted to identify specific training needs, both currently undertaken and gaps envisaged in the future. Current skills gaps were recognised by 19 respondents, gaps within the next 5 years by 26 respondents, and in the next 10 years by 9 respondents. A breakdown of the 'curriculum' areas that are currently addressed in training and/or identified as a future need is presented in Table 7. The four areas that are of most interest to the stakeholders both as current as well as future training needs are radiological protection, radiation dosimetry, radiochemistry and measurement and analysis.

Table 7

Specifically identified training needs

Training	**Current Gaps**				**Future Gaps**				
	Sectors (G = Government, I = Industry, R = Research)								**Comments**
Subject Areas	**G**	**I**	**R**		**G**	**I**	**R**	**T**	
Radiation Protection	13	3	6		3		4	**29**	
Radiochemistry		2	3		5	2	2	**14**	Broadly
Radiology	1	2	1		1			**5**	
Dosimetry	3	4	3		4	1	2	**17**	
Radiobiology/ Radioecology		1	2		4		2	**9**	Market principally in Scandinavia
Environmental Awareness	1		1					**2**	
Environmental behaviour/modelling					2			**2**	
Measurement and Analysis	4	1	3		4		2	**14**	Greater interest in NEN
Emergency/Accident	3	2	1					**6**	
H&S	6	1	1					**8**	
Risk	1		1					**2**	
Safety Case Writing	1							**1**	
Leadership	1					2		**3**	
Project Management	3							**3**	
Legal	2	1	2					**5**	
Languages		1				1		**2**	
Technologies	1				1	2		**4**	
IT	2	2						**4**	
Radiation Physics	1	2	1					**4**	
Decommissioning	2				2	1		**5**	
Waste Management	2				3			**5**	
Geology					1			**1**	
General					1		1	**2**	

RESEARCH

Over three quarters of the respondents answered that they undertook or supported research in the area of radiological protection whilst 60% of the respondents indicated that they were actively involved in research training of students. Of those 60% of the organisations engaged in research training, 90% indicated that the research was done at masters- or doctorate-level.

Table 8

Research support

Research support	Total	Gov	(%)	Ind	(%)	Res	(%)
Financially	23	15	*52*	3	*14*	4	*20*
In-house research programmes	35	16	*55*	7	*33*	11	*55*
Provision of facilities	22	9	*31*	2	*10*	11	*55*
Provision projects/supervision	29	12	*41*	7	*33*	10	*50*
TOTAL of RESPONDENTS	72	29	40	21	29	20	28

A third of respondents indicated that they were able to provide research facilities for students, and this applied across most countries but mainly in the government and research sectors. Over 40% of the respondents provided research projects and/or supervision of postgraduate students, and this applied across most countries and all sectors. The industry sector is mainly engaged in in-house research programmes and the provision and supervision to research students, while most of the financial support comes from the government sector. Financial support to students tends to be more prevalent in Northern Europe.

5. CONCLUSIONS

The survey of European Stakeholders confirms that there is a significant latent and future need for personnel trained to masters-level and beyond in the broad area of radiological protection. From the questionnaire data alone, some 30 Technical Advisors and 67 Professional Experts qualified to at least masters-level will be recruited per annum. Reports from the literature project or recommend that even higher numbers will be required to be recruited.

There appears to be a general consensus that recruits will have to be obtained from other than the traditional engineering route. The implications of this are that 'nuclearisation' of programmes in engineering, environmental sciences or other appropriate routes would have a ready market for students if careers in the nuclear sector were made sufficiently attractive. Furthermore, it suggests that 'nuclear-related' masters programmes would have a ready market given that much of the recruitment to the nuclear sector is made at this level.

Over and above the qualification needs of employers, it is clear that a significant amount of training in radiological protection is, and will be into the future, undertaken by stakeholders for those non-qualified personnel (both at the technical end and management positions). 75% of such training is delivered outside the university sector, either in-house or through contracted training organisations. There is clearly an opportunity to build into formal qualifications accreditation of such training. It is worth noting that for NEN countries there is a significant budget within IAEA set aside for radiological protection training.

With regard to curriculum content for postgraduate qualifications, radiochemistry, radiation protection and dosimetry and analytical techniques were most commonly identified. However, environmental pathways, environmental impact and radioecology were also strongly indicated, particularly from the 'government' and 'research' stakeholders.

It was not possible from the data to specify particular laboratory or field needs except to say that measurement and analysis was highlighted by a number of respondents as being an important component of future scientific needs.

At the research end of the spectrum, the data suggests there to be widespread opportunities across Europe for students to undertake nuclear-related projects and utilise specialist facilities.

However, it has been noted in previous research that exchange of students or faculty members between universities in different countries was rare and this is an issue that has to be addressed in the generation of any co-ordinated programmes of teaching or research training.

In many European countries, the national demand for experts in certain strategic subjects, for example radiation protection and radiochemistry, may be too small to maintain national education programmes. Increased international cooperation is therefore needed to maintain and enhance postgraduate education and research in these nuclear areas.

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Appendix C

WP3 Report: Potential Solutions

Report produced by:

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October 2005

ABSTRACT

EURAC is a Coordinated Action of the 6th FP whose role is to strengthen in Europe the scientific academic competence and analytical skills within radioprotection, radiochemistry and radioecology and to secure the future recruitment of appropriately skilled post-graduates to meet the needs of European stakeholders. In order to achieve these objectives EURAC is addressing a number of linked sub-goals through work packages (WP):

WP1: Determination of existing competence and infrastructures
WP2: Estimation of future scientific needs
WP3: Development of possible postgraduate education solutions
WP4: Assessments and recommendations.

This report details the outputs of WP3. Based on the outputs of WP1 and WP2 and general consideration on the future of nuclear energy in Europe, we propose the creation of a series of European Masters in Radiological Sciences comprising a Master in Radioprotection, a Master in Radiochemistry and a Master in Radioecology. This proposal, modified in order to satisfy a certain number of constraints which are detailed in this report, will allow us to formulate final recommendations (in WP4) to the European Commission.

INTRODUCTION

A number of studies over the past five years, by different European governments, identified that probably too few scientists were being trained to meet the needs of their current and future nuclear industries, with decreased student interest, decreased course numbers, aging faculty members and aging facilities. Consequently, the European education skill base has become fragmented to a point where universities in most countries lack sufficient staff and equipment to provide education in all, but a few, nuclear areas. Of particular concern appeared to be special skill-base deficits within nuclear radiological protection, radioecology and radiochemistry at masters and doctorate levels.

The EURAC project is consultative/consensual and aims to assess the current and potential levels of postgraduate provision in selected linked disciplines associated with radiological protection and radioecological competence within universities and other higher education institutes (HEIs) of the EU and new entrant nations in the context of demand. Based on consultations with European stakeholders EURAC will propose those actions that could be taken by European Institutions and relevant organisations in Member States to secure the future of nuclear radiological protection, radiochemistry, and radioecology postgraduate education in an expanded EU.

The objectives of EURAC are to strengthen the scientific academic competence and analytical skills within radiological protection, radioecology and radiochemistry and to secure the future recruitment of appropriately skilled post-graduates to meet the needs of European stakeholders.

EURAC is assessing the current and potential levels of post-graduate university provision in these disciplines within the EU and new entrant nations - paying particular attention to scientific and administrative issues, infrastructural requirements, constraints and issues of human mobility.

Based on consultations with stakeholders EURAC is focussing on innovative solutions and best co-ordinated practice within the current provision base.

Actions that could be taken by European institutions to secure the future of radiological protection, radiochemistry and radioecology post-graduate education in an expanded EU will be recommended.

In order to achieve these objectives EURAC is addressing a number of linked sub-goals through work packages:

Work package 1: Determination of existing competence and infrastructures
Work package 2: Estimation of future scientific needs
Work package 3: Development of possible postgraduate education solutions
Work package 4: Assessments and recommendations.

In this WP3, we are assessing possible models for national, regional and European co-ordinated education programmes that could be developed to meet the needs of European stakeholders. The assessments are based on the results of the fact-finding missions (*Report on existing competence and infrastructure from P. Mitchell, UCD)* in WP1 and the scientific goals for the future (*Report on future scientific needs from A. Abbott, Westlakes)* identified in WP2.

1. Possible post-graduate education solutions

In order to enhance and perpetuate post-graduate education in Radiochemistry, Radiation Protection and Radioecology in Europe, three different models for co-ordinated post-graduate education system can be developed to meet the needs of European stakeholders:

- Co-ordinated national post-graduate education systems/programmes enhanced or not by a European dimension
- Co-ordinated regional post-graduate education systems/programmes
- Co-ordinated European post-graduate education systems/programmes.

These models focus on:

- Use of established European Credit Transfer System
- Co-ordination of specialist competence from different education systems
- Suitability of research facilities
- Intensive courses with mobile human resources
- Web-based communication and teaching materials (for possible distance-learning application)
- Administrative constraints, formal procedures, QA systems and requirements
- Costs and funding requirements associated with Master or PhD courses
- Accommodation (for students and teachers) and travel distance (for teachers)

• Human mobility (students and teachers)

• Collaboration between universities and industry in line with the Bologna 1999 agreement.

1.1. The core of the different models

The goal of this Coordinated Action is to ensure the continuity of post-graduate education in three major fields of nuclear science in Europe:

- Radiation Protection
- Radioecology
- Radiochemistry

To do so, whatever the model chosen, courses have to be implemented to adequately provide the necessary scientific information. Such courses have been defined in designing specific masters curricula:

- Master in Radiation Protection
- Master in Radioecology
- Master in Radiochemistry

These masters are explicated in the Annexes I, II and III.

1.2. Model I: Co-ordinated national post-graduate education systems and programmes

In such a model, education systems and programmes are driven at the National level.

It is corresponding to the current situation with an additional European co-ordination.

This model requires very few changes from the current situation.

But only the countries with a strong nuclear industry and an already solid post graduate education system and programme will secure the future of radiation protection, radioecology and radiochemistry.

Indeed, the European co-ordination will implicate only these countries.

The other European countries will be kept apart and may partially secure the future of these fields of science in sending some of their students in the nuclear-strong countries for post-graduate education.

1.3. Model II: Co-ordinated regional post-graduate education systems and programmes

In such a model, education systems and programmes are driven at the Regional level i.e. European countries will form regional groups. In each group, there will be a strong co-ordination between the different countries and there will be an additional European co-ordination.

This model requires substantial changes from the current situation (Nordic countries excepted).

But the countries with a strong nuclear industry and an already solid post graduate education system and programme will be inclined either to take the lead of such groups (Nordic group excepted) or to regroup in one strong regional group.

Some regional groups (in Eastern Europe) will be “weak” when compared with other groups. Therefore, some European countries will partly be kept apart from the decision making in such groups.

Moreover, the European co-ordination will implicate only the “strong” countries representing their “own” group.

1.4. Model III: Co-ordinated European post-graduate education systems and programmes

In such a model, education systems and programmes are driven at the European level i.e. there will be only one level of co-ordination.

This model requires major changes from the current situation.

The countries with a strong nuclear industry and an already solid post graduate education system and programme will have to share the responsibilities with the other European countries.

In such a model, strong emphasis will be put on the evolution of the Bologna Process and the development of a European Higher Education Area (EHEA). It requires a strong implication of all the countries and a maximal level of co-ordination.

On a mid- and long-term basis, this model will ensure the future of radiation protection, radioecology and radiochemistry with the highest level of probability.

1.5. List of criteria to be fulfilled by the different models

Because of the different needs imposed on the creation of national, regional and/or European based diploma, the different models proposed in this work package should fulfil some criteria, most of them being quite obvious.

This list of criteria is clearly described in the following table.

Table I

List of criteria to be fulfilled by the different models

Criteria	*Model I: National*	*Model II: Regional*	*Model III: European*
Use of ECTS	X	XX	XXX
Coordination of Specialist competence from different systems	O	XX	XXX
Suitability of Research Facilities	X	X	X
Intensive courses with mobile human resources	O	XX	XXX
Web-based communication and teaching materials	X	XX	XXX
Administrative constraints, formal procedures, QA systems and requirements	X	XX	XXX
Costs and funding requirements associated with Master and PhD courses	X	XX	XXX
Accommodation (students and teachers) and travel distance (teachers)	O	XX	XXX
Collaboration between Universities and industry in line with 1999 Bologna agreement	X	XX	XXX

XXX: mandatory criterion; XX: strong criterion; X: weak criterion; O: non valid criterion.

2. Ouputs from WP1 (existing competence and infrastructures) and WP2 (future scientific needs)

2.1. Current competence and infrastructures in Europe

The general outcome from the WP1 report is that the provision of postgraduate training at Master's level, specifically designed to meet the requirements of each of the specified fields (Radiochemistry, Radioprotection and Radioecology), is, with some important exceptions (that will be outlined hereafter), insufficient in most of the Member States of the European Union. Nevertheless, it is evident that competence in these fields at training level is being eroded through natural wastage and is not being replaced at a rate adequate to satisfy expected future demand for these specialised skills. Finally, the survey evidences strong support for a European Union-wide Master's training programme in Radiation Protection, Radiochemistry and Radioecology, as well as considerable willingness to participate in and/or host such programmes.

The important exceptions, of course, were those institutions currently running relevant Master of Sciences (MSc) programmes.

MSc level programmes in Radiation Protection are offered by 9 institutions in Europe. Of these institutions, two, namely the Norwegian University of Life Sciences and the Swedish University of Agricultural Sciences have expressed interest in hosting a European Training course.

MSc level programmes in Radiochemistry are offered by 4 institutions in Europe. Of these institutions, one, namely the University of Paris XI (along with the INSTN, the ENSCP and University of Évry-Val d'Essonne) has expressed interest in hosting a European Training course.

MSc level programmes in Radioecology are offered by 3 institutions in Europe. Of these institutions, two, namely the Norwegian University of Life Sciences and the Swedish University of Lund have expressed interest in hosting a European Training course.

2.2. Future scientific needs in Europe

The general outcome from the WP2 report is that there is a significant latent and future need for personnel trained to masters-level and beyond in the broad area of radiological protection. From the questionnaire data alone, some 30 Technical

Advisors and 67 Professional Experts qualified to at least masters-level will be recruited per annum. Reports from the literature project or recommend that even higher numbers will be required to be recruited.

Moreover, it appears that recruits will have to be obtained from other than the traditional engineering route. It suggests that 'nuclear-related' masters programmes would have a ready market given that much of the recruitment to the nuclear sector is made at this level.

Over and above the qualification needs of employers, it is clear that a significant amount of training in radiological protection is, and will be into the future, undertaken by stakeholders for those non-qualified personnel (both at the technical end and management positions). 75 % of such training is delivered outside the university sector, either in-house or through contracted training organisations. There is clearly an opportunity to build into formal qualifications accreditation of such training. It is worth noting that for NEN countries there is a significant budget within IAEA set aside for radiological protection training.

With regard to curriculum content for postgraduate qualifications, radiochemistry, radiation protection and dosimetry and analytical techniques were most commonly identified. However, environmental pathways, environmental impact and radioecology were also strongly indicated, particularly from the 'government' and 'research' stakeholders.

It was not possible from the data to specify particular laboratory or field needs except to say that measurement and analysis was highlighted by a number of respondents as being an important component of future scientific needs.

At the research end of the spectrum, the data suggests there to be widespread opportunities across Europe for students to undertake nuclear-related projects and utilise specialist facilities. However, it has been noted in previous research that exchange of students or faculty members between universities in different countries was rare and this is an issue that has to be addressed in the generation of any co-ordinated programmes of teaching or research training.

In many European countries, the national demand for experts in certain strategic subjects, for example radiation protection and radiochemistry, may be too small to maintain national education programmes. Increased international cooperation is therefore needed to maintain and enhance postgraduate education and research in these nuclear areas.

3. Proposal for a European post-graduate programme in Radiochemistry, Radiation Protection and Radioecology

3.1. Context

Given the outputs from the EURAC Work Package I (Existing competence and infrastructure) and EURAC Work Package II (Future Scientific needs), we may envision a preferential choice from the potential solutions explicated in the first chapter of this report

The first point is that only few key institutions possessing necessary competence, facilities and/or infrastructures to participate in a co-ordinated post-graduate education system are identified from data collected in WP1 survey. This point obliges us to forbid completely a national post-graduate education systems/programmes enhanced by a European dimension. Indeed, in such a model I, all European countries should have the capabilities and competence to provide post-graduate courses in Radiochemistry, Radiation Protection and Radioecology.

As a matter of fact, if we focus more precisely on WP1 survey data, we can arrange in an ascending order of national capabilities the three specialised fields Radiochemistry > Radiation Protection > Radioecology.

On an historical point of view, post-graduate courses in Radiochemistry have been proposed. Then, advanced training and post-graduate courses in Radiation Protection have been developed, with a focus on the former ones. It is only recently that advanced training and post-graduates courses in Radioecology have been presented.

The second point is the following: from WP2 survey data, we are sure that, at the European level, there is a constant and quite important core of positions in the nuclear-related work market for persons with post-graduate diploma (Masters and PhDs) in Radiochemistry, Radiation Protection and Radioecology. Such conclusion is not valid at the national level, with some notable exceptions.

Indeed, the Future of Radiochemistry, Radioecology and Radiation Protection is greatly dependent on the future use of Nuclear Energy. Concerning the military use of nuclear energy is changing, the current tendency is in:

• a decrease of the number of nuclear weapons (especially in the 5 original nuclear countries: USA, Russia, China, France and UK)
• an increase in the number of countries possessing the « bomb » or currently working actively to have it in a near future.

The civil use of Nuclear Energy seems to regain impetus because of:

- the Climate change (greenhouse effect),
- the surge of new energy-demanding developing countries (such as China and India),
- the declining in the finding of new fossil fuel energy in the World.

Moreover, nuclear waste management and NPP decommissioning are now key points both for Public and Nuclear industry. Indeed, Health and Environmental problems related to the use of nuclear energy are gaining interest in the Public. This reinforces the need for more scientific personnel with strong background in Radiation Protection, Radioecology and Radiochemistry in the near future.

3.2. Proposal

When we look at the contents of courses to be provided in the selected Masters (see appendices I, II and III), one can order them and realise that some of them are commonly found in these masters (in all of them or only in two of them). Therefore, according to the Bologna agreement, a new skeleton is proposed for these three masters, which is explicated in Annex IV.

A series of 3 European Masters in Radiological Sciences is proposed:

- MSc Radiation Protection
- MSc Analytical Radiochemistry
- MSc Radioecology.

All three masters will utilise 3 common modules (= 3 x 10 ECTS credits) plus 3 specialist modules (= 3 x 10 ECTS credits) plus research project (= 1 x 30 ECTS credits).

Geographical repartition of these modules will be based upon the capabilities of the different European countries. Wherever possible, the common modules will proposed in a maximal number of countries. On the contrary, specialist modules will be proposed in countries and institutions where sufficient infrastructures and competence are existing.

Therefore, there will be different types of student curricula according to the geographical distribution of competence (capability to deliver master courses belonging to the common and/or specialist modules) and facilities (where research projects could be performed):

- Some students will follow common and specialist modules and perform their research project in their own country (where all competence can be found).
- Some students will follow common and specialist modules in their own country but they will perform their research project in another country where necessary facilities are existing.
- Some students will follow common modules in their own country but they will follow specialist modules and perform research projects in another country where competence and facilities are existing.
- Some students from countries without competence and facilities, will have to follow course and perform research project in (an)other European country (-ies) of their choice possessing such competence and facilities.

3.3. Constraints

In order to determine the final recommendations, to be published in the WP4 Report, it is necessary to face a series of constraints which are imposed to us by the nature of the solutions proposed.

- Logistics,
- Adaptation of module length to training needs,
- Filling gaps,
- Validation of modules,
- Finance,
- Mapping with existing courses,
- Professional body recognition.

3.3.1. Logistics

Courses should be distributed among semesters and precaution should be taken to break them properly in order to allow the students to appropriately follow them when they are taught in different European locations (universities, institutes, etc.). Such course distribution should also not impair the necessary students and staff mobility.

3.3.2. Adaptation of module length to training needs

Courses are classified into modules (either common or specialised). It is important to adequately choose the size of these modules in order to make possible their use as training modules for professionals (continuous education and training).

3.3.3. Filling gaps

We must ensure that the proposed courses contain all the current knowledge in the specified fields (i.e. radiochemistry, radiation protection, and radioecology). Moreover, the repartition of these courses between theoretical and practical modules does not have to leave some gaps, keeping in mind that theoretical modules may be taught in one place and practical ones in another place.

3.3.4. Validation of modules

The validation of the proposed modules is another major constraint to be faced with. Indeed, such European Masters of Sciences must be validated as awarding degrees by specific awarding bodies. These bodies will be national and European. These European Masters of Sciences must be accepted in all the European Union countries in order to be European even if part of or most of the courses will not be taught in and validated by a national institution (university, institute of higher education, etc.).

3.3.5. Finance

This is one of the major constraints to be overcome. Indeed, one should find a way to help students pay their student fees, keeping in mind the notorious heterogeneity between the different EU universities concerning these fees (for instance between Germany and the United Kingdom). Provisions should be done to cover the cost of staff movements. Indeed, experts able to perform courses in the different modules will come from different European countries but will have to deliver their courses in dedicated locations (the number of those locations being still under discussion). Therefore, their travel expenses should be reimbursed or prepaid.

3.3.6. Mapping with existing courses

There are already existing training courses organised by industries and/or related institutes (NRPB, JRC, INSTN, IR5SN, Technicatome, Electricité de France, etc.). Moreover, there are also existing Masters of Sciences in related nuclear fields such as Radiobiology, Radiometrics, etc. Therefore, it seems mandatory at least to try to figure out commonality between all these courses.

3.3.7. Professional body recognition

We must have the help of international bodies to give their approval of the different Masters of Sciences syllabus and running afterwards.

It seems logical that:

- IUR (International Union of Radioecology) should give their approval for the European Master of Sciences in Radioecology;
- IRPA (International Radiation Protection Association) should give their approval for the European Master of Sciences in Radiation Protection;
- IUPAC (International Union of Pure and Applied Chemistry) should give their approval for the European Master of Sciences in Radiochemistry.

The basic syllabus for qualified expert in radiation protection is expressed in Annex V alonf with the syllabus of the IAEA Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources.

Comparison between the syllabus of the proposed European Master of Science in Radiation Protection and the Basic Syllabus for Qualified Expert in Radiation Protection (list of topics to be covered by these people according to Commission Communication 98/C 133/03) is made in Annex VI.

Comparison between the syllabus of the proposed European Master of Science in Radiation Protection and the syllabus of the IAEA Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources is made in Annex VI.

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ANNEX I: Master in Radiation Protection

Modules	*Credits*	*Topics covered in the course*
Introduction	TBD	Radioactive decay, Radiation Interaction with matter
Definitions	TBD	Quantities and Units, ICRP, ICRU, Risk-Effect, UNSCEAR, Sources, Ethical aspects, Legislations, Regulations
Dose Assessment	TBD	Internal-External modelling, NORM, TENORM, Waste Management, Neutron Dosimetry, Case studies, RP in workplaces
Measurements/Instrumentation	TBD	General Instrumentation, Field gamma spectrometry, Practical work, TLD, OSL, RP in emergency situations, Non invasive Inspection Techniques
Project/Dissertation	30	
TOTAL	90	

ANNEX II: Master in Radioecology

Modules	*Credits*	*Topics covered in the course*
Basic Principles	TBD	Ecology, Biology, Nuclear Physics
Behaviour of radionuclides in the environment	TBD	Dispersion & transfer of RN in the atmosphere, in terrestrial, freshwater and marine ecosystems
Effects of radionuclides on man & the environment	TBD	Biological effects, doses, dose-models, biological endpoints, cancer, RBE, radiation ecotoxicology, doses to biota, etc
Field course studies	TBD	Studies of RN in terrestrial, freshwater and marine ecosystems, sampling and environmental radiation monitoring
Modelling	TBD	Notions of models, definition of models, databases, GIS, etc
Legislation, Regulations	TBD	At European and national levels, release of RN, safety issues
Radiation Metrology	TBD	Source preparation, yield, γ- and α- spec., β-scint, $\alpha-$ β- and γ-spectra, geometry, quenching, effectiveness, calibration, interferences, Quality Assurance / Quality Control, clean room practices, Standsard reference materials, in-house standards
Radioactive Waste Management	TBD	Notion of radioactive waste, nuclear fuel cycle, waste management, transportation, handling and storage
Great accidental releases of RN in the environment	TBD	Hiroshima/ Nagasaki, chernobyl, Three Mile Island, Mayak, etc
Risk Assessment	TBD	
Research Methods	TBD	Statistics and data handling, database and literature resources, critical analysis of publications, efficient scientific writing
Project/Dissertation	30	
TOTAL	90	

ANNEX III: Master in Radiochemistry

Modules	*Credits*	*Topics covered in the course*
Nuclear physics I	TBD	The nucleus, stability/instability, Disintegration, T1/2, statistics, mass and energy, α- β- and γ-radiation, spontaneous fission, induced fission, cluster decay, mother/daughter relationship and decay chains,
Interaction of radiation with matter	TBD	Interaction mechanisms of radiation in matter, including shielding (density, absorbtion) and in active materials (detectors)
Analytical radiochemistry I	TBD	Basic chemistry, equations/reactions, precipitation, Function of holdback carrier / carrier / scavenger, Tracer techniques,Extraction: liquid-liquid extraction, solid-liquid extraction, ion-exchange
Analytical radiochemistry II	TBD	Speciation techniques: Physical and chemical fractionation such as micro-filtration, ultrafiltration, extraction, exchange chromatography (particles, colloids, pseudo-colloids, complexes, LMM species). Solid-state speciation, Oxidation states, sequential extraction procedures, hot particles,
Radiometrics I	TBD	Source preparation, yield, γ- and α-spec, β-scint, γ-spectra, α-spectra, β-spectra, Geometry, quenching, effectivety, calibration, interferences, Quality Assurance/Quality Control, clean room practice, Standard reference materials, in-house standards,
Nuclear physics/chemistry II	TBD	Radioactivity and Nuclear reactions, Nuclear power, nuclear fuel cycle
Advanced measurement techniques	TBD	TIMS, AMS, ICP-MS. Quality assurance, Standard reference material, reference material, in-house standards,
Radiation Protection/Legislation	TBD	Biological effects, doses, dose-models, biological endpoints, cancer, RBE, Shielding, distance, time, Regulatory issues, Waste handling and disposal
Environmental sampling	TBD	Environmental sampling and sample handling / processing techniques, Kriging, GIS
Research Methods	TBD	Statistics and data handling, database and literature resources, critical analysis of publications, efficient scientific writing
Project/Dissertation	30	
Total	90	

ANNEX IV: Proposed organisation of the Masters in Radiochemistry, Radiation Protection and Radioecology

Common 10 ECTS Modules for all Masters' programmes

1) Radiation and radioanalytical techniques	*2) Project management and research methods*	*3) Industry and waste management*
Basic principles: The nucleus, stability/instability, Disintegration, T1/2, statistics, mass and energy, α- β- and γ-radiation, spontaneous fission, induced fission, cluster decay, mother/daughter relationship and decay chains,	**Research methods:** Statistics and data handling, database and literature resources, critical analysis of publications, efficient scientific writing	**Industry and waste management:** Notion of radioactive waste, nuclear fuel cycle, waste management, transportation, handling and storage
Interaction with matter: Interaction mechanisms of radiation in matter, including shielding (density, absorption) and in active materials (detectors). Overview of radiation protection	**Project management:** Design, implementation and management of projects. Introduction to generic management tools e.g. MS Project.	**Legislation, regulations:** At European and national level, release of RN, safety issues. Quantities and Units, ICRP, ICRU Risk-Effect, UNSCEAR
Radioanalytical techniques: Environmental sampling and sample handling / processing techniques, Source preparation, yield, γ- and α-spec, β-scintillation counting, γ-spectra, α-spectra, β-spectra, Geometry, quenching, efficiency, calibration, interferences, Good laboratory practice, Quality Assurance/Quality Control, Clean room practice, Standard reference materials, in-house standards,	**Research proposal:** Design and development of a research proposal to be undertaken as a Master's project.	**Radiation protection:** Biological effects, doses, dose-models, biological endpoints, cancer, RBE, Shielding, distance, time. Regulatory issues Waste handling and disposal

+ 30 ECTS RESEARCH PROJECT

Specialist Modules: Radiochemistry (10 ECTS)

4) Radioanalytical techniques II	***5) Advanced techniques***	***6) Biokinetics and bioassays***
Analytical radiochemistry I: Basic chemistry, equations/reactions, precipitation, Function of holdback carrier/ carrier/scavenger, Tracer techniques, Extraction: liquid-liquid extraction, solid-liquid extraction, ion-exchange	**Analytical radiochemistry III:** Speciation techniques: Physical and chemical fractionation such as micro-filtration, ultra-filtration, extraction, exchange chromatography (particles, colloids, pseudo-colloids, complexes, LMM species). Solid-state speciation, Oxidation states, sequential extraction procedures, hot particles,	**Biokinetics and bioassay:** Radiotoxicology/ Epidemiology as inputs to risk assessment. Different types of epidemiological study. Biokinetic models for dosimetry and bioanalysis. Metabolism and ICRP models for important radionuclides.
Analytical radiochemistry II: Quality assurance, Standard reference material, reference material, Preparation of in-house standards,	**Advanced techniques:** Neutron activation, INAA, isotope production. Mass spectrometry; TIMS, AMS, ICP-MS, Other; ESEM, Synchrotron etc.	**Tracer techniques:** Autoradiography. Environmental tracers. Animal studies. Human volunteer studies.
Nuclear reactions: Nuclear Chemistry/Physics II, n-□, n-□, etc. Fission		

Specialist Modules: Radioecology (10 ECTS)

7) Behaviour of radionuclides in the Environment	***8) Accessing risk to man and environment***	***9) Risk management and emergency planning***
Environmental behaviour of radionuclides: Dispersion and transfer of radionuclides in the atmosphere, dispersion and transfer of RN in terrestrial, freshwater and marine ecosystems	**Effects of radionuclides on man and the environment:** Biological effects, doses, dose-models, biological endpoints, cancer, RBE, radiation ecotoxicology, dose to biota, etc	**Risk management:** Countermeasures in different ecological systems. Land utilisation post-contamination. IAEA BSS. Maralinga and Semipalatinsk as case studies. Oil industry and uranium industry wastes.
Principles of ecology: Introduction to ecological biology	**Risk assessment:** Environmental risk, principles of Radiotoxicology/ Epidemiology	**Source terms:** Accidents and accidental releases of radionuclides in the environment. Sources: Hiroshima/Nagasaki, Chernobyl, Three Mile Island, Mayak, etc
GIS and modelling: Kriging, Notion of models, definition of models, databases, etc. Use of ArcView/ArcGIS	**Field courses studies:** Studies of radionuclides in terrestrial, freshwater and marine ecosystems, sampling and environmental radiation monitoring	**Case study:** Nuclear accidents, countermeasures, security facility

Specialist Modules: Radiation Protection (10 ECTS)

10) Dosimetry and accessing risk	***9) Risk management and emergency planning***	***11) Instrumentation, measurements and security***
Dosimetry: Health effects, Radiotoxicology/ Epidemiology. Metabolism of important radionuclides. ICRP models. Uncertainties	**Risk management:** Cost-benefit. Fault tree analysis. Decision analysis. Risk. Perceived risk and sociological aspects of risk. Risk management methods.	**Instrumentation:** General Instrumentation Practical work TLD, OSL
Dose assessment: Internal vs.External modelling NORM, TENORM Waste Management Neutron Dosimetry Case studies RP in workplaces	**Source terms:** Large accidental releases of radionuclides in the environment / Sources; Hiroshima/Nagasaki, Chernobyl, Three Mile Island, Mayak, etc. Countermeasures in different ecological systems.	**Security:** Triage. Field gamma spectrometry RP in emergency situations Non-invasive inspection techniques
Personal dosimetry: Gamma, neutron and radon dosimetry. Bioassay (urine, blood and faeces).	**Case study:** Nuclear accidents, countermeasures, security facility	

ANNEX V: Legal requirements for education in radiation protection in EU directives and European national legislation

Introduction

The EU project EURAC, Securing European Radiological Protection and Radioecology Competence to Meet the Future Needs of Stakeholders, investigated the need for MSc level education in radiation protection, radiochemistry and radioecology. Work package 2 (WP2) of the EURAC project showed that stakeholders experience difficulty in finding employees with the desired education and identified current and future knowledge gaps. Following on from this, EURAC WP3 has developed the outlines for 3 European MSc programmes in radiation protection, radiochemistry and radioecology that would help to solve the knowledge gap. As there are also legal requirements for education and training in radiation protection - the EU member states are obliged to implement Directive 96/29/Euratom which includes certain requirements for education and training in radiation protection for those that work or supervise work with radioactivity - the European MSc programme in radiation protection recommended in WP3 has been developed such that it is compliant with EU legislation. Those graduating from these programmes, in particular from the radiation protection programme, will have the knowledge required for a qualified expert, although the necessary years of experience will need to be acquired elsewhere.

The report Radiation Protection No. 133 (RP133, 2003), 'The status of the radiation protection expert in the EU member states and applicant countries', issued by the EU, provides an overview of how the education and training requirements in Directive 96/29/Euratom have been or will be implemented in the national legislation of the EU member states. *One of the recommendations in this report is that the EU member states should try to harmonise the qualification, recognition/certification and training of the qualified expert, radiation protection expert and radiation protection officer within the EU.* A European MSc program in radiological protection as recommended by the EURAC project, which incorporates the educational requirements for the qualified expert, would contribute to the harmonization of education in radiological protection and would further improve future international networking and mobility of graduates.

This appendix summarises the European legislation on radiation protection as relevant for the EURAC project. It further gives some examples of national legislation and national education requirements based on additional feedback from several of the radiation protection authorities in the EU member states that had responded to the WP2 questionnaire.

Terminology

In the national radiation protection legislation within the EU countries a range of terms is used to indicate those that work with radioactivity and are required by law to have a certain amount of knowledge in radiation protection. Some of the terms used are: radiation worker, qualified worker, radiation protection officer, radiation safety officer, radiological protection inspector, responsible person, supervisor, radiation protection expert, qualified expert. Although the different terms cannot always be compared directly and are sometimes used differently in different countries, a rough distinction can be made:

- Radiation worker or qualified worker is commonly used for any employee that works with radioactivity. They are usually required to have had basic training in radiation protection and safe working methods, but may not need to have attended an organized training course, passed an exam or be registered.
- Radiation safety officer, radiation protection officer, radiological protection inspector, responsible person or supervisor is used for those that are responsible for safe working practices and radiation protection in their company and are the contact person for the national authorities. They are usually recognized or registered to some extent by the national authorities, must either have passed a radiation protection exam or have a number of years experience, and are responsible for the training and supervision of their coworkers in the safe use of radioactivity.
- The terms radiation protection expert or qualified expert tend to be used for persons with expert knowledge of radioactivity and radiation protection. They usually have several years of experience and extensive training in radiation protection and are recognized or registered by the national authorities. They can for example provide expert advice in more complex situations, carry out dose assessments, advice on work area layout and work procedures. However, the term radiation protection expert is also used as a general term for all who are required by law to have certain qualifications and knowledge of radiation protection regardless of the level or sector (for example in Van der Steen et al., 2002).

General EU legislation

According to Council Directive 96/29/Euratom, undertakings, that is those persons or companies that carry out practices or work activities which involve a risk from ionizing radiation, are legally responsible to (1) provide information and training to their staff, (2) to ensure that working arrangements are safe, and (3) to assess and monitor environmental exposure and risk.

(1) All undertakings in the member states are required to inform exposed workers, apprentices and students on the health risks involved in their work and in particular on the general radiation protection procedures and precautions to be taken. The undertakings are further required to arrange for *relevant training* in the field of radiation protection to be given to exposed workers, apprentices and students (Article 22). However, no specific details as to what this training should cover are given.

(2) Undertakings are responsible for the assessment and implementation of arrangements for the radiological protection of exposed workers and are required to consult with the *approved occupational health services* or the *qualified experts* on the necessary arrangements and working instructions in the working area and examination and testing of protective devices and measuring instruments (Articles 19, 20, and 23). In controlled areas, that are areas that are subject to special rules for the purpose of protection against ionizing radiation, only individuals who have received appropriate instructions are allowed to enter and work (Article 19). It is the undertaking's responsibility to ensure compliance with the rules.

(3) Undertakings are responsible to conduct their practices in accordance with the principles of health protection of the population and environment and *qualified experts* and *specialized radiation protection units* shall be concerned in the discharge of these duties (Article 47). These duties include the regular calibration of measuring instruments, the use of equipment and procedures for measuring and assessing exposure and radioactive contamination of the environment and the population, and the regular checking of the effectiveness of technical devices for protecting the environment and the population.

Although the BSS clearly outlines the responsibilities and duties of the undertakings it does not provide specific details regarding the knowledge, qualifications and/or experience required of the undertaking or their staff. The main reference to a certain level of knowledge and experience is the *qualified expert*, who can provide specific advice and assessment on radiological protection during the design and implementation of practices.

The 96/29/Euratom definition of a qualified expert is '*a person that has the knowledge and training needed to carry out physical, technical or radiochemical tests enabling doses to be assessed, and to give advice in order to ensure effective protection of individuals and the correct operation of protective equipment, whose capacity to act as a qualified expert is recognized by the competent authorities. A qualified expert may be assigned the technical responsibility for the tasks of radiation protection of workers and members of the public'* (Article 1).

A basic syllabus describing the topics that should be covered in the training and qualification of the qualified expert is provided for in Annex 1 of the Commission Communication 98/C 133/03 (Table 1).

In 96/29/Euratom it is further stated that each member state shall make arrangements to recognize the capacity of the qualified experts, the approved occupational health services, the approved medical experts and the approved dosimetric services (Article 38). To this end, *each member state shall ensure that the training of such specialists is arranged*. The competent authorities in the member states will decide which installations will require a *specialized radiation protection unit*, authorized to perform radiation protection tasks and specific advice (Article 38).

IAEA

The IAEA published the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) in 1996. The BSS require that a safety culture ensures that *the responsibilities of each individual, including those at senior management levels, for protection and safety be clearly identified and each individual be suitably trained and qualified* (article 2.28). *The government should ensure that an adequate legislative framework is established which requires appropriate training for all personnel engaged in activities relating to nuclear, radiation, radioactive waste and transport safety. The legislation should assign responsibilities for the provision of training* (article 2.1). In order to comply with regulatory requirements and with the principles of radiation protection, adequate training in radiation protection and the safe use of radiation sources is needed for any person who is occupationally exposed to ionizing radiation or who may be exposed in the course of his or her work. The IAEA organizes training courses to assist the IAEA member states in this training and in their report 'Training in radiation protection and the safe use of radiation sources' (IAEA Safety Report Series No. 20 (2001)), they have provided detailed guidelines for the training of qualified experts, such that the requirements in the BSS are complied with. The length of this course is 18 weeks: a summary of the course content is provided in table 2. The content of the training course is similar to the requirements for the qualified expert as described in Council Directive 96/29/Euratom.

General national legislation

According to RP133, most member states have implemented the definition of a qualified expert and/or radiation protection expert in their national legislation. The requirements for prior education, professional experience or the attendance of certain specific radiation protection training courses or exams, however, vary widely. In general, there are distinctions between 2 to 5 different sectors, mainly medical, non-medical and nuclear installations and power plants, in addition to a range of different levels in radiation protection officers. In some countries the content of the radiation protection training and exams is determined by law and radiation protection officers need to have passed the relevant exams before being granted a licence. In other countries radiation protection officers need certain academic qualifications and a number of years working experience in radiation protection before they can be granted a licence to work as radiation protection officer. In general, all organizations that have been granted a licence to work with radioactivity need to appoint a radiation protection officer and it is the duty of the radiation protection officer to organize training in practical radiation protection and safe use of radiation for all workers that work with radiation.

Below follow the details of the training and competence requirements in radiation protection in those European countries that provided further information. This is meant as an example of the varying national education and training requirements in radiation protection and is not a complete overview. The requirements are summarized in table 3.

Belgium

The Royal Decree of 20 July 2001 lays down the education and training requirements for the radiation protection expert (Article 73). A radiation protection expert must have an appropriate academic or technical qualification and must have successfully followed a university level training course in radiation protection of at least 120 teaching hours. This course must include at least the following topics in addition to a practical component:

- nuclear physics

- radiation physics
- radiochemistry
- radiobiology
- nuclear measurement techniques
- practical dosimetry
- basic principles of radiation protection
- practical radiation protection
- European and Belgian legislation and regulation.

The licensed organization (undertaking) is further required to inform and train employees on basic radiation protection, good working practices and emergency procedures (Article 25).

Denmark

All licences to sealed and unsealed radioactive sources in Denmark are held by a person, the responsible leader and all responsible leaders are registered by the National Institute of Radiation Hygiene (NIRH). The terms radiation protection officer and qualified expert are not used. NIRH requires that the responsible leader for licences to sealed radioactive sources or licenses to NORM has at least a technical degree. For gammaradiography devices and nuclear surface gauges there is a further requirement that the responsible leader attends a training course. The length of the gammaradiography training course is four days and the length of the surface gauge training course one day. For unsealed radioactive sources NIRH requires that the responsible leader has attended a training course in isotope techniques and passed the examination. The training course has to be approved by NIRH and there are currently three institutions of higher education in Denmark that offer an approved training course. The length of a training course is typically 150-200 hours (lectures and exercises) with a 3-4 hour written examination. It is the responsibility of the responsible to ensure that all co-workers working under his license are properly instructed about the safe handling of radioactive sources etc.

Estonia

The licence holder has to organise training in radiation protection for those that work with radiation. The training is usually provided by the local radiation protection officer, but the length and content of the training required is determined case-by-case. The radiation protection officer has to have at least a university diploma and 3 years of working experience with radiation protection. A qualified expert must have at least a university diploma and at least 5 years experience in the field of radiation protection. The national authorities have the right to examine the applicant before granting a licence of qualified expert.

Finland

According to the Finnish Radiation Act, each radiation user's organisation must nominate a radiation safety officer responsible for safety in the use of radiation. In certain cases a qualified expert must also be nominated or a separate radiation protection unit must be established (Guide ST 1.4). The radiation safety officer must have passed a radiation safety officer exam; the qualification and competence requirements and the content of the radiation protection training needed depend on the type of radiation user's organisation and are described in detail in Guide ST 1.8. Courses and exams have to be approved by the national authority. The general requirements state that radiation protection training of a radiation safety officer must include the following matters in all fields of competence (no less than five hours):

- fundamentals of radiation physics
- radiation sources
- radiation quantities and units
- measurement of radiation
- the biological effects of radiation and radiation risks
- the fundamental principles of radiation protection
- radiation protection legislation
- organizational arrangements in the use of radiation
- regulatory control of radiation practices
- operational radiation protection at the workplace
- monitoring of radiation exposure
- principles of reckoning radiation doses
- medical surveillance of workers engaged in radiation work
- warning signs for radiation sources.

Besides these general requirements, the radiation protection training of a radiation safety officer in the various fields of competence must also include more specialised subjects. The amount of specialised training must be no less than two study credits (one study credit corresponds to about 40 hours of study) for the general use of radiation in the medical sector, no less than 0.5 study credits for X-ray practices in health care, nuclear medicine, radiotherapy, and dental X-ray practices, no less than

10 hours for installation, repair and servicing of radiation appliances in health care, use of unsealed sources in industry, research and education, use of sealed sources and X-ray appliances in industry, research and education, and industrial radiography, and no less than five hours for veterinary X-ray practices and trade in radioactive substances. The radiation safety officer is responsible for the training of other personnel working with radiation and it is recommended that this training includes applicable elements of the same subjects as are covered in the radiation protection training described above.

A qualified expert could be a hospital physicist who is qualified to serve as a radiation safety officer for the general use of radiation in the medical. In non-medical uses of radiation, the qualifications required of a qualified expert will be identified in each individual case by the national authority. A separate radiation safety exam may be arranged if this is necessary to verify the competence of a qualified expert nominee.

Germany

The education and training requirements are laid down in detail in a series of guidelines covering the various nuclear work sectors. The requirements detail both prior education, length of appropriate work experience as well as length of training in radiation protection. For example, for those working with unsealed radioactive substances, prior technical or academic qualification is required, as well as 6-24 months of practical experience and a radiation protection course of 40-80 hours. Other workers affected by ionizing radiation need to be informed and instructed in basic radiation protection and safe working methods.

Italy

There are 3 levels of radiation protection officers or qualified experts in Italy, of which the 3rd level is the highest. For each of the levels the candidate must pass an exam organized by a ministerial commission after which the candidate can be registered as a qualified expert. The content of the exams is described in detail in the Italian legislation D.Lgs 230/1995. Training courses in radiation protection are provided by the universities and the professional organization of qualified experts. One of the duties of the radiation protection officers is the provision of radiation protection training to other staff in their organization working with radiation. The radiation protection officer decides the content and length of this training. All workers must have received training and passed a written test before being allowed to work with radioactivity. The content of the basic radiation protection officer’s exam includes:

- nuclear physics
- basic biology
- properties of radiation and interaction with matter
- biological effects of radiation
- radiation protection principles, epidemiology
- emergency procedures
- work procedures, operational radiation protection
- ICRP principles
- national legislation and international conventions
- radiation dosimetry
- protection of the population and environment
- measurement methods and instruments
- practical radiation protection
- risk management.

Latvia

According to Cabinet Regulation No. 290 (adopted 3 July 2001), employees working with radioactivity must have secondary education and must have completed an accredited vocational secondary further education programme in the field of radiation safety and nuclear safety. Accredited vocational secondary or higher further education programmes in the fields of radiation protection and nuclear safety shall include:

- radiation safety and nuclear safety, protection of the health of employees
- theoretical studies and practical training on safe working methods, radiation safety and nuclear safety.

The minimum qualifications of the *supervisor (radiation protection officer*) are a higher technical degree plus either 3 years work experience or having completed an accredited higher education programme in the field of radiation safety and nuclear safety; or a higher medical degree and a certificate in the speciality of diagnostic radiologist or dentistry. For a *radiation safety expert* and *radiation safety and nuclear safety expert* the minimum qualification is training appropriate to the work sector and level of responsibility plus between 7 and 17 years of experience depending on the degree. All experts shall be approved by radiation safety and nuclear safety expert attestation committee.

The Netherlands

According to the Dutch legislation all practices or work activities that involve radiation must be carried out or supervised by a registered radiation protection expert. There are 5 levels of radiation protection experts, all of which can only be achieved by attending an approved radiation protection course, with registration following upon passing the exams. No prior experience is required, but for levels 4 and 3 prior further education is required, and for level 2, an academic qualification is required. The highest level, level 1 internationally recognized expert has not yet been operational.

Courses for level 3, 4 and 5 radiation protection experts have similar content, but differ in depth and total course length (approximately 4 weeks of lectures and practical exercises for level 3, 2 weeks for level 4, and 7 days for level 5). The courses cover:

- mathematics and statistics
- nuclear physics
- interaction of radiation with matter
- measurement techniques
- radiation dosimetry
- radiobiology and radiation genetics
- legislation radiation protection
- practical radiation protection.

Norway

In the Norwegian radiation protection legislation (Act No. 36 of 12 May 2000 on Radiation Protection and Use of Radiation; and Regulations No. 1362 of 21 November 2003 on Radiation Protection and Use of Radiation (Radiation Protection Regulations)) it says that undertakings are responsible to ensure that staff working with radiation or at risk of exposure to radiation should have *adequate* competence in radiation protection and safe use of radiation (Article 7). Undertakings are further required to appoint one or more radiation protection officers who are able to use measuring instruments and assess results, and instruct other staff in radiation protection and the safe use of radiation (Article 8). The accompanying guidance on the legislation provides guidelines on what is considered to be *adequate* competence. Training of the staff should include at least:

- work procedures, intern control system, division of responsibility
- physical and chemical properties of materials used
- radiation doses; internal and external radiation
- risk
- radiation protection measures: how to reduce risk
- use of measuring and protection equipment
- waste handling
- accident and emergency procedures.

In undertakings which use open sources, the radiation protection officer should have at least 2 years experience working with open sources and should have knowledge on:

- radiation protection legislation and guidance
- radioactivity and radiation
- measuring of radioactivity, including contamination
- radiation doses, biological effects of radiation
- principles of reducing external radiation
- principles of reducing internal radiation
- practical radiation protection
- personal dosimetry
- how to deal with accidents, including decontamination
- waste handling
- transport of radioactive materials.

It is advised that the radiation protection officers attend an organised training course in radiation protection with a duration of at least 3 days. There is no reference to qualified experts in the Norwegian legislation and guidance.

Poland

The Regulation of the Council of Ministers of 18 January 2005 on the positions important for ensuring nuclear safety and radiological protection and on radiological protection inspectors and the annexes to the regulation describe the requirements for qualification and training for those who work with radioactivity. All workers in responsible positions need to have higher education in an appropriate subject and basic training (ca. 10 hours) in the fundamentals of radioactivity, principles of radiation protection and radiation protection legislation. There are additional requirements for specific jobs. A radiological protection inspector needs to have appropriate education and a number of years work experience depending on the work sector. In addition they need to have attended an accredited training course and passed the examination in order to be registered. The content of the training course depends on the type of work and is described in the annexes to the regulation. The following course content description is suitable for a range of positions, with additional topics needed for those working in the medical sector and the nuclear industry:

Lecture topics (min. 60 hours):

- Selected atomic and nuclear physics fundamentals – radioactive decay
- Radioactive isotopes, natural and artificial
- Radiation-matter interaction
- Biological impacts of ionizing radiation
- Ionizing radiation detectors
- Physics and technique fundamentals for X-ray tubes and accelerators
- Ionizing radiation dosimetry: basic quantities and units
- Dosimetric devices
- Basic principles of radiological protection
- Act of Parliament – Atomic Law and relevant implementing regulations, basic international regulations in the area of nuclear safety and radiological protection, including relevant European Union legislation
- Licencing procedures
- Safety principles for work with sealed and unsealed radioactive sources
- Transport of radioactive materials
- Dose rate and radioactive contamination measurements
- Control of exposure for workers and members of general public
- Examination of sealed radioactive sources for leakage
- General information on radioactive waste management
- Basic principles for the transport of radioactive sources and waste

- Radiological emergency management
- Organization of radiological protection in organizational entity, duties and powers of the head of the entity, radiological protection inspector and the workers (including external workers), work in the conditions of enhanced exposure to natural radiation
- Preparation of documents in organizational entity: work regulations, work instructions, dose registers, source registers, on-site emergency management plan
- Basic labour law issues
- Professional practices and intervention measures
- Principles for dosimetric measurements in the work environment, delimitation of controlled and restricted areas, decontamination of equipment's working surfaces, of personal contamination, exposure assessment for the members of general public, reference groups concept
- Safety principles for work in X-ray and accelerator laboratories
- Descriptions of known radiological emergencies involving the use of ionizing radiation generating devices
- Internal contamination
- Identification of radioactive materials and nuclear materials
- Examples of typical nuclear technology applications and related potential risks.

Computational exercises (min. 8 hours): Computation of activity changes with time, shielding computation, optimization of conditions for work in exposure conditions, individual dose assessment based on dosimetric measurements in work environment, evaluation of acceptable time spend in the room with enhanced radiation level.

Laboratory exercises (min. 8 hours): Selection of parameters for dosimetric device, dose rate measurements, iso-dose plotting, radioactive contamination measurements, gamma spectrum measurements.

Appendix D

Module Structure and Content of Proposed European Masters' Programmes

Common 10 ECTS Modules for all Masters' programmes

1) Radiation and radioanalytical techniques	**2) Project management and research methods**	**3) Industry and waste management**
Syllabus:	***Syllabus:***	***Syllabus:***
Basic principles: The nucleus, stability/instability, Disintegration, T1/2, statistics, mass and energy, α- β- and γ-radiation, spontaneous fission, induced fission, cluster decay, mother/daughter relationship and decay chains	**Research methods:** Statistics and data handling, database and literature resources, critical analysis of publications, efficient scientific writing	**Industry and Waste management:** Notion of radioactive waste, nuclear fuel cycle, waste management, transportation, handling and storage
Interaction with matter: Interaction mechanisms of radiation in matter, including shielding (density, absorption) and in active materials (detectors). Overview of radiation protection	**Project management:** Design, implementation and management of projects. Introduction to generic management tools e.g. MS Project.	**Legislation, Regulations:** At European and national level, release of RN, safety issues. Quantities and Units, ICRP, ICRU Risk-Effect, UNSCEAR
Radioanalytical techniques: Environmental sampling and sample handling/processing techniques, Source preparation, yield, γ- and α-spec, β-scintillation counting, γ-spectra, α-spectra, β-spectra, Geometry, quenching, efficiency, calibration, interferences, Good laboratory practice, Quality Assurance/Quality Control, Clean room practice, Standard reference materials, in-house standards	**Research proposal:** Design and development of a research proposal to be undertaken as a Master's project	**Radiation Protection:** Biological effects, doses, dose-models, biological endpoints, cancer, RBE, Shielding, distance, time. Regulatory issues Waste handling and disposal

+ 30 ECTS RESEARCH PROJECT

Specialist Modules: Analytical Radiochemistry (10 ECTS)

4) Radioanalytical techniques II	**5) Advanced techniques**	**6) Biokinetics and bioassays**
Syllabus:	***Syllabus:***	***Syllabus:***
Analytical radiochemistry I: Basic chemistry, equations/reactions, precipitation, Function of holdback carrier/carrier/scavenger, Tracer techniques, Extraction: liquid-liquid extraction, solid-liquid extraction, ion-exchange Alpha-, Beta- and Gamma-spectrometry	**Analytical radiochemistry II:** Speciation techniques: Physical and chemical fractionation such as micro-filtration, ultra-filtration, extraction, exchange chromatography (particles, colloids, pseudo-colloids, complexes, LMM species). Solid-state speciation, Oxidation states, sequential extraction procedures, hot particles	**Biokinetics and bioassay:** Radiotoxicology/Epidemiology as inputs to risk assessment. Different types of epidemiological study. Biokinetic models for dosimetry and bioanalysis. Metabolism and ICRP models for important radionuclides
Analytical radiochemistry II: Quality assurance, Standard reference material, reference material, Preparation of in-house standards	**Advanced techniques:** Neutron activation, INAA, isotope production. Mass spectrometry; TIMS, AMS, ICP-MS, Other; ESEM, Synchrotron etc.	**Tracer techniques:** Autoradiography. Environmental tracers. Animal studies. Human volunteer studies
Nuclear reactions: Nuclear Chemistry/physics II, n-γ, n-α, etc. Fission		

Specialist Modules: Radioecology (10 ECTS)

7) Behaviour of radionuclides in the environment	**8) Accessing risk to man and environment**	**9) Risk management and emergency planning**
Syllabus:	***Syllabus:***	***Syllabus:***
Environmental behaviour of radionuclides: Dispersion and transfer of radionuclides in the atmosphere, dispersion and transfer of RN in terrestrial, freshwater and marine ecosystems	**Effects of radionuclides on man and the environment:** Biological effects, doses, dose-models, biological endpoints, cancer, RBE, radiation ecotoxicology, dose to biota, etc.	**Risk management:** Countermeasures in different ecological systems. Land utilisation post-contamination. IAEA BSS. Maralinga and Semipalatinsk as case studies. Oil industry and uranium industry wastes
Principles of ecology: Introduction to ecological biology	**Risk Assessment:** Environmental risk, principles of Radiotoxicology/Epidemiology	**Source terms:** Accidents and accidental releases of radionuclides in the environment. Sources: Hiroshima/Nagasaki, Chernobyl, Three Mile Island, Mayak, etc.
GIS and Modelling: Kriging, Notion of models, definition of models, databases, etc. Use of ArcView/ArcGIS	**Field courses Studies:** Studies of radionuclides in terrestrial, freshwater and marine ecosystems, sampling and environmental radiation monitoring	**Case study:** Nuclear accidents, countermeasures, security facility

Specialist Modules: Radiation Protection (10 ECTS)

10) Dosimetry and accessing risk	**9) Risk management and emergency planning**	**11) Instrumentation, measurements and security**
Syllabus:	***Syllabus:***	***Syllabus:***
Dosimetry: Health effects, RadiotoxicologyEpidemiology. Metabolism of important radionuclides. ICRP models. Uncertainties Ethics	**Risk management:** Cost-benefit. Fault tree analysis. Decision analysis. Risk. Perceived risk and sociological aspects of risk. Risk management methods	**Instrumentation:** General Instrumentation Practical work TLD, OSL
Dose assessment: Internal vs. external modelling NORM, TENORM Waste Management Neutron Dosimetry Case studies RP in workplaces	**Source terms:** Large accidental releases of radionuclides in the environment/Sources; Hiroshima/Nagasaki, Chernobyl, Three Mile Island, Mayak, etc. Countermeasures in different ecological systems	**Security:** Triage. Field gamma spectrometry RP in emergency situations Non-invasive inspection techniques
Personal Dosimetry: Gamma, neutron and radon dosimetry. Bioassay (urine, blood and faeces)	**Case study:** Nuclear accidents, countermeasures, security facility	