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European Nuclear Society
Rue Belliard 65
1040 Brussels, Belgium
Phone + 32 2 505 30 54
Fax +32 2 502 39 02
E-mail ens@euronuclear.org
Internet www.euronuclear.org

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Radiation Protection

RESULTS OF THE EUROPEAN NETWORK ON EDUCATION AND TRAINING IN RADIATION PROTECTION (ENETRAP 6FP)

MICHELE COECK
Communication, Education and Knowledge management Group, SCK•CEN
Boeretang 200, BE 2400 Mol – Belgium

P. LIVOLSI, S. MOEBIUS, A. SCHMITT-HANNIG, A. LUCIANI, J. VAN DER STEEN, M. MARCO, J. STEWART

ABSTRACT

Occupational, public and environmental radiation protection is a major challenge in the industrial applications of ionising radiation. As is the case with all nuclear expertise, there is a trend of a decreasing number of experts in radiation protection. Maintaining a high level of competencies in this field is crucial for (i) the future research and development of applications of ionising radiation and (ii) the assurance of the protection of workers, the public and the environment.
In answer to the need for a harmonised European approach of education and training (E&T) programmes in radiation protection and, based on that, the mutual recognition of Qualified Experts, the ENETRAP project (EC contract number FI6O-516529) made a study of the current European E&T issues.

1. Introduction

This project deals with the development of an E&T structure in radiation protection (RP), based on an analysis of needs, qualification requirements, etc of the different Member States. Studies [1] have shown that a wide variety of national approaches for E&T of the qualified expert, as required in the European Basic Safety Standards, exist in the EU Member States, the New Member States and the Candidate States. The development of a common European radiation protection and safety culture and, based on that, the mutual recognition for experts becomes a real need. The harmonisation of E&T is a good starting point. Moreover, finding a common basis for E&T will favour the mobility of workers and students throughout the European countries.

The main objectives of this project were:

- to better integrate existing E&T activities in the RP infrastructure of the European countries in order to combat the decline in both student numbers and teaching institutions;
- to develop more harmonised approaches for E&T in RP in Europe and their implementation;
- to better integrate the national resources and capacities for education and training;
- to provide the necessary competence and expertise for the continued safe use of radiation in industry, medicine and research.

These objectives were reached by the establishment of a European E&T network in radiation protection that addressed following tasks:

- assess training needs and capabilities;
- identify the potential users and their future involvement in order to insure the sustainability of the network;
- launch a consortium of universities with the aim of create an European Master in Radiation Protection (EMRP);
- review the scientific contents of E&T activities;
- explore the effectiveness of on-the-job training and identify options for additional programmes;

- propose recommendations for the recognition of courses and competencies of radiation protection experts (RPEs);
- make recommendations for revising the current European Radiation Protection Course (ERPC) to include a system for credit points and modern educational tools, such as distance learning.

An important tool developed and used during this project was the ENETRAP questionnaire, which allowed to study the education and training needs for radiation protection experts, officers and workers. More then 40 questions covered topics such as adequateness of RPE's, self-sustainability of national E&T programmes, regulation and recognition, implementation of on-the-job training, availability of distance and/or e-learning, etc.
This study enabled us to put forward recommendations for a harmonised approach of the education and training schemes and to promote the quality of the E&T programmes, the mutual recognition of skills and mobility of workers and students.
The outcome of the questionnaire also served as an input for the EUTERP Platform [2].

2. Project outcome

The results of the ENETRAP study concern the following main subjects:

- Assessment of training needs and capabilities, and recognition of competencies and diploma's within the EU Member, the New Member States and the Candidate States;
- Analysis of existing IAEA and EC requirements related to E&T in radiation protection
- On the job training and work experience;
- New concepts and tools : distance and e-learning;
- Developments with regards to training: suggestions for the creation of a European "reference" training scheme;
- Developments with regard to education: establishment of a consortium of universities and a European Master in radiation protection.

All deliverable report can be foud on the project website www.sckcen.be/enetrap.

2.1 Assessment of training needs and capabilities, and recognition of competencies and diploma's within the EU Member, the New Member States and the Candidate States

A questionnaire, structured around the above mentioned objectives, was prepared and distributed to 31 countries. Constructive responses were obtained from 28 countries.
A significant amount of data and information was provided. The results can be summarised in the following conclusions:

i) There are significant differences in interpretation of the roles of the RPE and the radiation protection officer (RPO) across Member States. These differences have a strong influence on specified legislative requirements with respect to RPE and RPO as well as on the approaches taken with respect to Education and Training. There are wide ranging approaches to the latter.
ii) On the basis of the information provided via the ENETRAP questionnaire and given the significant issues with the interpretation of key roles, it is difficult to conclude a workable "de-minimus" level of training for the RPE (or RPO). Further investigation of this issue is required.
iii) The majority of Member States have mechanisms in place for the recognition (and re-recognition) of the Radiation Protection Expert. However, the approaches taken vary significantly and are difficult to compare.
iv) Only a minority of countries have a formal system for mutual recognition or RPEs (RPOs and workers) and the study did not elicit a consensus view as to what could constitute minimal requirements for mutual recognition.

Issues ii), iii) and iv) above all warrant investigation beyond the scope of the current ENETRAP project. For pursuing these issues further, the results have been presented in the first EUTERP workshop. This resulted in 8 recommendations, mainly to the European

Commission, which have been discussed in the Expert Group according to Article 31 of the Euratom Treaty for their relevance in the revision of the Euratom BSS.

2.2 Analysis of existing IAEA and EC requirements related to E&T in RP

For European Union Member States, requirements related to RP training are laid down in the European Basic Safety Standards and appending documents. The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, issued by the International Atomic Energy Agency (IAEA) were co-sponsored by a number of international organisations, among these organisation such as the World Health Organization (WHO), the International Labour Organization (ILO) and the Nuclear Energy Agency. However, only the IAEA is running an extensive training programme in radiation protection.

Within the framework of the ENETRAP project, the content of the current European Radiation Protection Course (ERPC) has been compared with the requirements published by the EC and by the IAEA. This in order to be able to develop a revision of the current ERPC which can serve as a "reference" European training scheme.

It was found that the scientific/technical content of the ERPC is totally in accordance with the Basic Syllabus of the Qualified Expert in Radiation Protection in Communication 98/C133/03. The Additional Material of this Communication is also covered in detail to a great extend. In the ERPC, 50% of the training is theoretical courses and 50% is practical, exercises, demonstrations and scientific visits. In addition to this distribution, 3-6 months of practical experience in a company is mandatory (postgraduate) or offered (professionals). This approach fits entirely the statement in Communication 98/C133/03 that training needs are to be supplemented by practical experience.

The aim of the IAEA Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources (PGEC) is to meet the initial training needs of professionals at the graduate level or equivalent in order to acquire a sound basis in radiation protection and the safe use of radiation sources. It is tailored for a wide range of professionals but not specifically addressing the qualified expert as defined in the European Basic Safety Standards. In the PGEC syllabus, the legislative framework and regulatory system is covered in more detail than in the ERPC. However, in comparing the curricula they can be considered as very much equivalent.

ENETRAP takes into account the requirements of both EC and IAEA when developing a common basis for European radiation protection training schemes. It also recommends that IAEA and EC cooperate more closely with the objective of further developing common standards with regard to education and training in radiation protection and waste safety, and exchanging information and training materials, in order to make efficient use of resources.

2.3 On the job training and work experience

A suitable qualification for responsible personnel in RP (e.g. RPE, RPO, and Medical Physicists) must be in general a combination of theoretical knowledge, and the ability (competency) to practice RP.

While the theoretical knowledge is acquired by suitable education and by attending training courses, competency and skills can only be obtained by appropriate on-the-job training OJT followed by a period of work experience (WE).

In order to identify fields for OJT, provide feedback from existing OJT programmess and to compare the different practical approaches, some questions in the ENETRAP questionnaire dealt with OJT and WE. The evaluation with respect to OJT and/or WE has shown that:

- two-third of the EU-Member States have implemented some kind of OJT and/or WE in their national legislation, however clear definitions are rarely found;
- only few countries have levels or classifications for OJT and/or WE, with a duration of several weeks up to some months (OJT);
- OJT and WE is especially required in all medical sectors and nuclear installations like power plants.

Based on the feedback from trainees of existing OJT programmes, it can be concluded that OJT provides better chances for future job opportunities and increases international flexibility among EU partners. Training providers for all practices are only available in some countries; thus a list with facilities for foreign trainees would be helpful.
As result of its evaluation ENETRAP recommends covering OJT together with E&T in the EU Basic Safety Standards and their guidelines for implementation. OJT should be specified by its content (syllabus, learning objectives), availability of necessary facilities and infrastructures as precondition for OJT, assessment of the competence of the participant, format of certificate, recognition of OJT, and responsibilities of host organisation and trainees. OJT should be a key element in both the training and education programmes in RP.

2.4 New concepts and tools: distance and e-learning

A study was performed which included an analysis of e-learning methodologies and resources. The study was performed in two ways: 1) e-learning educational models or methodologies (the method to management didactical resources in time, pace and environment); and 2) e-learning platform to indicate which one is the most adequate for fitting the requirements for the implementation and validation of European E&T programmes. The study of the current existing e-learning platforms and pedagogical methodologies was an important part to choose the best e-learning tools and develop the future activities in E&T in RP.
Different platforms had been studied in order to guess which one could fit better to ENETRAP objectives. In order to obtain the most appropriate platform for ENETRAP needs was necessary the analysis of certain aspects and compare them among all the studied platforms. Some of these aspects were: functionality, architecture, course organisation, design possibilities, communication tools, files management, multilanguage possibilities, assessment tools, methodological resources, multimedia resources, compatibility with other platforms, use and access conditions, necessary requirement, cost and security.
The obtained results had been used to select the best way to host learning activities in the framework of the ENETRAP project.

2.5 Developments with regard to training: suggestions for the creation of a European "reference" training scheme

In this context, a syllabus has been developed. It has been named "ENETRAP Training Scheme" ETS The existing syllabi have been studied for the development of ENETRAP Training Scheme; the one of the post graduate course of IAEA, the one of the former ERPC and the one of the second year of the French Master of radiation protection called M2RP. It was point out a by the surveys carried out by the Commission indicate a wide diversity of current practice in Member States. The ETS has been developed with the aim of harmonizing the training dispensed through out Europe because of the report of a large diversity of approaches for E&T.
It is a modular approach that has been carried out for ENETRAP Training Scheme. The scheme is structured around three modules constituting the "Common basis" and five other specific modules (NPPs, Research reactors – Waste management, decommissioning – Non-nuclear research, oil & gas – Medical – NORM). The total duration is eight weeks and a half with an On the Job Training period for each specific module.
With this modular structure, participants will have more flexibility to compose their own training in respect of ENETRAP training Scheme in order to become "Qualified Expert". It is possible by this way to customise a professional curriculum.
Possibilities of usage of new modalities of education and training such as e-learning, web casting have been studied. The objectives and purposes were to introduce Information and Communication Technologies ICT in order to improve the E&T in RP by facilitating on the one hand the access to resources and services, and on the other hand, the exchanges and collaborative works between learners and teachers.

The use of Open and Distance Learning (ODL) is one of the means to ensure the future supply of appropriately educated and skilled personnel for those who use ionising radiations across Europe and secondly, to meet the increasing demand and decreasing number of radiation protection experts available in Europe. Open and Distance Learning contributes to promote mobility of workers and students throughout the European countries where students can be taught at "Anytime, Anyplace, Anywhere".

2.6 Developments with regard to education: establishment of a consortium of universities and a European Master in radiation protection

This European Master in Radiation Protection (EMRP) is used to harness and coordinate European expertise in this field in order to develop a high level education Master's programme as called for Bologna declaration. This will ensure the future supply of appropriately educated and skilled personnel for those who employ ionizing radiations across Europe.
The EMRP will thus respond to both the increasing demand and decreasing number of radiation protection experts available in Europe and help local skills shortages by facilitating the mobility of graduates through mutual recognition of their qualifications. Finally, an important part of the Masters programme will allow candidates to achieve the status of a Qualified Expert as defined in the 96/29 European directive.
Progress has been made to harmonise the training of radiation protection experts in the health, industrial or nuclear regulation fields. The present project will use an educational approach to provide harmonisation in this highly specialised field. By building on the expertise available in some universities who have experience in this field, this educational and training programme will be opened to all European Member States. The new qualification will ultimately allow a greater mobility to the future workers in this field across Europe.
This educational and training programme will last one year as a 2nd year of master degree.
The final diploma will be a joint diploma recognised by all the partner countries (France, Scotland and Czech Republic). It will be awarded after completion of written examinations on theoretical matters and a public defence of a personal work done during an on job 6 months training. To obtain the join diploma the students will have to fulfil requirements regarding European mobility of at least 6 months in one of the partner institutions during 2 years of their master studies. Students will come either from undergraduate scientific domains, mostly from physics background, but also from health, environmental and chemical sciences, or from professional positions as a part of livelong learning.
On line and e-learning modalities will be used by some partners to cope with the challenge of distance, multiple languages and on the job training requirements.
Accreditation or validations will be gained according to the academic and governmental rules of the respective participant countries.
The European Master in Radiation Protection will welcome its first students in September 2008. The four partners in this project are:

- The University Joseph Fourier Grenoble 1, Grenoble, France (EMRP project leader)
- The North Highland College, Thurso, Schotland - UK,
- The Czech Technical University, Prague, Czech Republic,
- The Institut National des Sciences et Techniques Nucléaires, Gif-sur-Yvette, France.

3. Conclusions

The development of a common European radiation protection and safety culture and, based on that, the mutual recognition of radiation protection courses and the acquired competencies of radiation protection experts is a real need. The harmonization of E&T is a requisite starting point and will furthermore help and promote the mobility of workers and students throughout the European countries.
ENETRAP was a study programme, with the aim to gather information on several key-issues with regard to E&T in RP. The results of the ENETRAP project were transferred to the umbrella organization EUTERP, which was launched in 2006. The main objectives of this Platform are to better integrate E&T into occupational radiation protection infrastructures in the Member, Candidate and Associated States of the European Union, to facilitate the

transnational access to vocational education and training infrastructures, to harmonise the criteria and qualifications for and mutual recognition of RPEs and to remove obstacles for the mobility of these experts within the European Union.
The collaboration from almost all European countries to the ENETRAP questionnaire and the positive response to the first EUTERP workshop confirm the European need and interest to a harmonised approach of E&T in RP in all domains where ionising radiation is used.
Future initiatives should deal with establishing reference training schemes that meet the requirements for the RPE and the RPO, methodologies for comparison of training courses to that reference scheme, evaluation of training material, events and providers and the implementation of a mutual recognition system for RPEs.

4. References

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Long-term program on education and training of the professionals involved in nuclear safety and radiological protection in Poland within the confines of EU project “Transition Facility”

P. KRAJEWSKI
Central Laboratory for Radiological Protection,
Konwaliowa st.7, PL 03-194 Warsaw, POLAND

S. CHWASZCZEWSKI, B. MYSŁEK-LAURIKAINEN
Deapartment of Nuclear Energy, Institute of Atomic Energy, Swierk,
05-400 Otwock-Świerk, POLAND,

ABSTRACT

In December 2007, in a frame of EU action Transition Facility, the new long term program “Nuclear Safety and Radiological Protection” (CRIS No 2005/017-488.03.06) of extended education and training for the groups professionally involved in nuclear safety and radiological protection was established. The basic target of the project is to elaborate a system of teaching and training that best responds to the national needs and makes the best use of the national experimental facilities. The project is coordinated by Central Laboratory for Radiological Protection and will be evaluated and implemented together with Institute of Atomic Energy at Swierk (working with highly radioactive substances, running the only one in Poland nuclear reactor). Moreover, a numerous of high skilled experts from various research and technological institutes have been involved. This program meets requirements to establish framework for central orientated education system and urgent need of more harmonized approaches for education of specialists involved in development of nuclear energy in Poland as well as for education of high skilled physicians in rapidly developing nuclear medicine sector.

Introduction

It has became clear that professional education of qualified personnel employed in places where ionising radiation is used or made, needs support by the basic education that should result in much better preparation of beginner students to adopt a higher educational level. In Poland number of hours dedicated at primary and secondary schools to nuclear physics is too small to make the teaching of this subject truly effective. Moreover, high-school students encounter series of difficulties in perception of the nuclear science. These result from not only small number of lecture hours dedicated to nuclear physics, but also from the lack of appropriate school laboratories. This requires an urgent promotion of more harmonised approaches for education in the nuclear sciences and engineering. Currently, the national education and training framework is developed to link together institutes and universities and governmental atomic agency as well as regional institutions responsible for radiological safety.

National regulation on education in the fields of nuclear safety and radiological protection

The national regulation (Atomic Law - Act of Parliament of 29 November 2000 with subsequent amendments) [1] established legal basis for people professionally involved in nuclear safety and radiological protection. The National Atomic Energy Agency’s President certificates educational centres, assigns of examines board and issues authorization relevant to the particular type of position. This new legal provision establishes framework for central orientated education system and prompts an urgent promotion of more harmonized approaches for education in the nuclear sciences and engineering.

In chapter 3 of the Act that is dedicated to the nuclear safety, radiological protection and employees health protection one implements position of an authorized radiological protection inspector. Although, responsibility for compliance with nuclear safety and radiological protection requirements shall rest with the manager of the organizational unit, the inspector of radiation protection holds internal supervision for compliance with nuclear safety and radiological protection requirements in the unit conducting the activities/practices involving exposures according possessed by him authorization [3]. An employment of inspector is obligatory and is indispensable condition to possess a license for such kind of activity. In a frame of his duties the inspector performs particularly:

i. control of activities in respect of labour instruction relating to the nuclear safety and radiation protection and work conditions permissible for particular worker groups,
ii. registry of workers and different persons, staying in conditions at the risk exposure,
iii. control state of education and training standard,
iv. elaboration of dosimetric monitoring programme in work environment and implementation of individual doses records system for acceptance by manager of organizational unit,
v. co-operation with security institutional services and the labour hygiene, persons implementing the programme of assurance of quality, the fire - fight services and environment protection service in extension of protection against ionizing radiation,
vi. applying to manager of organizational unit with conclusion about inhibition of work, when the conditions violate permission (license) or regulations of nuclear safety and radiological protection,
vii. supervision of conduct action according the facility emergency preparedness plan in a case of radiation emergency.

The scope of radiation protection inspector's capabilities comprises (inter alia):

i. formulation of illation to manager of organizational unit about changes of working conditions, in peculiarity in situation, when the results of measurements of individual doses motivate such conclusion;
ii. monitoring the workers' qualification and protective measures in respect of nuclear safety and radiation protection and formulation conclusions to manager.

Furthermore, according to the Act obligation, The Council of Ministers, issued in the form of regulation, the types of positions important for ensuring nuclear safety and radiological protection [2], detailed conditions and proper procedures for the Agency's President for issuing authorizations for radiological protection inspectors and people occupying positions mentioned above, together with required scope of training, requirements for the bodies conducting the training, taking into account the training curriculum and organizational forms, standard form of authorization certificate and overall scope of inspector's authority and duties. Types of positions having the essential importance for assurance of nuclear safety and radiation protection jointly with obligatory scope of education [3] are presented in Tab.1 and Tab. 2.

The currently crucial problem is tutoring and authorisation of medical physics experts which specialization has been recommended by Council Directive 93/47/EURATOM and implemented recently by polish regulation. The new educational system (3 years specialization) has been worked out and submitted for acceptance by Ministry of Health [4]. National Society of Radiation Protection Inspectors organizes every year workshops that offer great help to the groups professionally working with ionising radiation: medical technicians, State's borders' officers, officers of local governments etc. by disseminating the recent achievements in the field of nuclear physics and radiation protection.

Recently, the basic principles of the educational framework have been formulated in the long term programme of the Ministry of Economy "The Energy Policies in Poland until 2030". This framework will evolve in the course of the development of Nuclear Energy in Poland (first Nuclear Power Plant is foreseen in 2021) and will be shaped by present requirements in European countries.

This new legal provision establishes framework for central orientated education system of the groups professionally connected with the nuclear radiation. This is forcing the national educational centres to elaboration of such a system of teaching and training that responds best to the national needs and makes the best use of the national experimental facilities [5].

Tab 1: Types of positions having the essential importance for assurance of nuclear safety and radiation protection jointly with obligatory scope of education.

Position	Required education		Seniority (years) in hazard condition	scope of training and examination
	high level	secondary level		
research reactor operator	physicist, chemist, electrician, mechanic, computer scientist	nucleonic science engineer, power industry specialist engineer, electrician, electronic engineer	2 year in nuclear reactor unit	R-O
dosimetry specialist in research reactor, senior dosimetry specialist in research reactor	physicist, chemist, electrician, mechanic, computer scientist	electrician, electronic engineer	1 year in dosimetry department of nuclear reactor unit	R-D
manager of research reactor shift	physicist, chemist, electrician, mechanic, computer scientist	electrician, electronic engineer	1 year (high educ. level) 3 years (secondary educ. level) reactor operator post	R-OK
manager of research reactor	physicist, chemist, electrician, mechanic, computer scientist		1 year as manager of research reactor shift	R-OK
assistant director on the nuclear safety and radiation protection in unit exploring of research reactor	physicist, chemist, electrician, mechanic, computer scientist		1 year as manager of research reactor	R-OK + R-D
expert on the nuclear material inventory records	any	any	1year in the unit with storage of nuclear materials	S-E
operator of spent nuclear fuel storage facility	physicist, chemist, electrician, mechanic, computer scientist	electrician, chemist, mechanic, nucleonic science engineer	1 year in the unit exploring of spent nuclear fuel storage facility	S-O
manager of radioactive waste disposal facility	physicist, chemist, electrician, mechanic, computer scientist		1 year (high educ. level) 3 years (secondary educ. level) radioactive waste neutralization plant	S-O
manager of radioactive waste neutralization plant	physicist, chemist, electrician, mechanic, computer scientist	electrician, chemist, mechanic, nucleonic science engineer	3 years spent nuclear fuel storage facility or radioactive waste neutralization plant	S-O
operator of accelerator used in non medical purposes, excluding accelerators used for vehicles control on border gates	physicist, chemist, electrician, mechanic, computer scientist	electrician, chemist, mechanic, nucleonic science engineer	0 year (high educ. level) 1 years (secondary educ. level) in accelerator laboratory	A-A
operator of accelerator used in used for vehicles control on border gate	any	any	0	A-A
operator of accelerator used in medical purposes and radiotherapy devices	physicist, chemist, biologist, medical, technical	electrician, electronic specialist mechanic, nucleonic specialist	0 year (high educ. level) 1 years (secondary educ. level) level in accelerator laboratory	S-A
operator of devices used in brachytherapy	physicist, chemist, biologist, medical, technical	electrician, electronic specialist mechanic, nucleonic specialist	0 year (high educ. level) 1 years (secondary educ. level) in radiotherapy laboratory with radioactive sources	S-Z

Tab. 2. Detailed conditions of authorization the particular type radiation protection inspector, with regard on kind of activity connected with level of risk of radiation exposure, ad quem supervising inspector gets authorization.

Activities and practices involving exposures	seniority (years) in hazard condition		scope of training and examination
	higher education	secondary education	
Storage, transport, turnover or use of sealed radioactive sources, instalaling, use and maintenance of equipment containing radioactive sources with activity leas than 10 fold specified value, item needs to be declared or permitted.	1	0	IOR-0
i. Manufacturing, conversion, storage, disposal, transport or use of nuclear materials, radioactive sources, radioactive waste, and turnover them, excluding usage of radioactive sources for medical purposes, and also storage, transport, turnover or use of sealed radioactive sources, installing, use and maintenance of equipment containing radioactive sources with activity less than 10 fold specified value, that needs to be declared or permitted. ii. Construction, exploitation, closure and decommissioning of radioactive waste disposal facility. ii. Manufacturing, installation, use and maintenance of equipment containing radioactive sources and turnover such equipment; excluding radioactive sources devices used for medical purposes, and also, installation, use and maintenance of equipment containing radioactive sources with activity less than 10 fold specified value, item needs to be declared or permitted. v. Activation and application of the ionizing radiation generating devices used for not medical purposes and activation of laboratories and workrooms for application of RTG devices. v. Intended addition of radioactive substances in the processes of manufacturing consumer and medical products and trade in such products as well as importation to the Republic of Poland territory and export from this territory consumer and medical products, with the addition of radioactive substances.	3	1	IOR-1
i. Conversion, storage, disposal and transport of spent nuclear fuel. ii. Constructing, commissioning, operation and decommissioning of nuclear facilities as well as spent nuclear fuel disposal facility, and constructing, exploitation of spent nuclear fuel storage facility.	4	2	IOR-2
i. Use radioactive sources for medical purposes, manufacturing, installation use and maintenance of equipment containing radioactive sources for medical purposes as well as activation of laboratories and workrooms where these devices will be used, excluding RTG devices used for medical diagnostic purposes, surgical radiology, surface radiotherapy and non cancer radiotherapy as well as laboratories used these devices. ii. Intended administering of radioactive substances people and animals for medical and veterinary diagnostic, treatment or scientific investigation.	4	2	IOR-3

EU action “Transition Facility - Nuclear Safety and Radiological Protection”

In December 2007, in a frame of EU action Transition Facility, the new long term program “Nuclear Safety and Radiological Protection” (CRIS No 2005/017-488.03.06) of extended education and training for the groups professionally involved in nuclear safety and radiological protection was established. The project is coordinated by Central Laboratory for Radiological Protection and will be evaluated and implemented together with Institute of Atomic Energy at Swierk (working with highly radioactive substances, running the only one in Poland nuclear reactor). Moreover, a numerous of high skilled experts from various research and technological institutes have been involved, i.e.: The Institute of Nuclear Chemistry and Technology in Warsaw (inventors of many nuclear methods for technological processes, irradiations, for environment protection), Warsaw University of Technology (Institute of Precision and Biomedical Engineering, which is leading unit on development and safety of radiological equipment and medical software), Warsaw University (Faculty of Physics, Nuclear Physics Division) and National Atomic Energy Agency (regulatory body). The basic target of the project is to elaborate a system of teaching and training that best responds to the national needs and makes the best use of the national experimental facilities. The special efforts has been made to prepare module structured of education materials that consist of lectures, experimental demonstrations, videos, laboratory practices, information on accessible e-learning systems and, excursions to the nearby nuclear centres. Apparently the courses organised must be attractive and responding precisely to the established needs.

This extended program of training will covers all positions having the essential importance for assurance of nuclear safety and radiation protection (Tab 1., Tab 2.) with special emphasis on nuclear facilities inspectors. The program consists of 360 hours of lectures, 40 hours of laboratory exercises, and 12 hours of computing skills and covered a wide range of topics, inter alia: basis of nuclear physics and ionising radiation, radiochemistry, natural and man-made sources, detection of ionising radiation, application of ionising radiation in medicine, technology, and science, biological effects of ionising radiation, basic quantities and units of radiation dosimetry, dosimetric instrument and measurement devices, principles of nuclear safety and legal provisions concerning radiological protection. The tree levels of training i.e: basic, extended, specialization has been elaborated. The 20 lecturers and trainers are involved. The program will evolve in the course of the system development and will be shaped by current European and International recommendation i.e.: SAT (Systematic Approach to Training) [7-9]. The program will stimulate and enhance the efficiency of the training actions in universities, research and technological institutes, and the teachers' educational centres [10].

The close collaboration with EC various education centres is necessary for understanding the technological progress made in various countries and for updating current knowledge and to provide the public with sufficient and competent information.

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IAEA Education and Training in Radiation Protection, Transport and Waste Safety- Status and New Developments for Sustainability.

G. Sadagopan , K. Mrabit and J.Wheatley

Regulatory Infrastructure and Transport Safety Section
Division of Radiation, Transport and Waste Safety
IAEA, Vienna

Abstract

IAEA's education and training activities in radiation, transport and waste safety follow the resolutions of its General Conferences and reflect the latest IAEA standards and guidance. Since 2001 IAEA has been implementing a "Strategic plan on Education and Training in Radiation Protection and Waste Safety", which is aimed at establishing sustainable education and training programmes in Member States by 2010. In implementing the strategy, IAEA organizes post-graduate educational courses in Arabic, English, French, Russian and Spanish at regional training centres around the world. Additional training events aimed at specific audiences, such as Regulators, are run at the national and regional level. In total, more than 30 standardized training packages have been developed and translated to facilitate global consistency and harmonization of training events. To promote sustainability and self-dependency, IAEA also organize Train the Trainers events to develop a pool of qualified trainers, with the appropriate skills, and who are familiar with IAEA developed training package. Additional initiatives aimed at building capacity in Member States include: establishing eLearning; developing a syllabus and teaching aids for training of Radiation Protection Officers; and developing information materials for radiation workers.

I. Introduction:

The statutory safety functions of the International Atomic Energy Agency cover the establishment of and provision for the application of safety standards for protection of health, life and property against ionizing radiation. Education and training is a major element of the IAEA's mechanism for the application of safety standards and for strengthening radiation safety infrastructures in its Member States. The education and training activities follow the resolutions of its General Conferences and reflect the latest IAEA standards and guidance. IAEA prepared a "Strategic Approach to Education and Training in Radiation and Waste Safety" (Strategy on Education and Training) aiming at establishing, by 2010, sustainable education and training programmes in Member States, which was endorsed by the GC(45)/RES/10C in 2001. In line with this resolution, the IAEA has developed a number of different training schemes. The Steering Committee for education and training in radiation protection and waste safety advices the Agency on the implementation of the long term strategic plan. Regional, national and collaborating training centres, international organizations like European Commission and International Radiation Protection Association (IRPA) are represented in the steering committee.

II. Training Schemes

Post-Graduate Educational Courses (PGECs).

This long duration post-graduate educational course in radiation protection and safety of radiation sources constitutes a comprehensive and multidisciplinary programme with theoretical and practical training aims. It is aimed to educate and train young professionals, to provide the necessary basic tools for those who will be recognized as qualified expert in radiation protection in the later years and be involved in education and training in radiation protection and safety of radiation sources. PGEC is hosted by the Regional Training Centres (RTCs) around the world with the Agency support and delivered in line with the IAEA Standard Syllabus (Ref:1) in five of its official languages. They include Argentina (Spanish), Syria (Arabic), Morocco (French),

Belarus (Russian), Malaysia, Greece and South Africa (English). Every year over100 participants benefit out of this educational course which is the initial training to acquire sound basis in radiation protection and safety of sources.
Presenter's material as PowerPoint slides are developed by the Agency in line with the Standard Syllabus in all the languages of the course delivered and provided to the RTCs. This ensures that the same message is conveyed at all the training centres.
.
Specialized Training Courses (STCs)& Workshops.
The training courses are usually shorter in duration. They are run for one or two weeks and are aimed at participants who already have attended PGECs. Workshops are task or practice -specific and provide more opportunity to the participants for in depth training and exchange of information. Topics covered are wide ranging and include the regulatory framework, occupational exposure (external and internal), patient protection (diagnostic radiology, radiotherapy and nuclear medicine), radioactive waste management, transport of radioactive materials, safety of radioactive sources and safety in industrial applications. They are regularly organized as national or regional courses for different target audiences, such as regulators or radiographers. Each year about 25 such regional training events are organized in different Member States. Customized training materials are developed that are used in training programmes. The training materials are also translated to Agency official languages, (Annex-I)

Other Training Mechanisms:
The other training mechanisms are aimed at achieving the training objectives through field training (On the Job Training), Distance Learning or Training the Trainers.

On the Job Training (OJT)
This is expected to be supplementing the classroom training, with a prerequisite of attendance to either PGEC or STC. The objective of this technique is to provide individual practical training in a chosen practice for a longer duration, under the direct supervision. The duration is dictated by the training theme, varying from 1-3 months. The added value is the opportunity to work in well developed centers. The successful completion of PGEC, STC and OJT could make an individual eligible to be recognized as qualified expert.

Distance Learning (DL)

IAEA successfully concluded a `Distance Learning' project in Radiation Protection in the Asia and the Pacific region. The participating countries were Australia (coordinator), Korea, Indonesia, Mongolia, Thailand, The Philippines and New Zealand. This learning method was used both nationally and internationally. Distance learning complements the class room training and found useful where only small number of people need training or where target population is scattered or live far from national training centers. This is good tool for refresher training or as pre training to prepare an individual to attend a training course. The exemplary quality learning material developed for the distance learning is now being used for providing pre training for PGEC participants. The objective is to harmonize the level of knowledge in radiation protection of all the PGEC participants coming from different educational and cultural background. The selected participants receive the pre training CDROM in their home country and prepare themselves for the long duration PGEC. The material is translated to Arabic, Russian and Spanish.

Training the Trainers:

This training mode covers mainly lectures on pedagogical skills. This methodology is adopted to build competence at the national level a sufficient number of trainers in radiation protection with

competencies in radiation protection and teaching. Consequently the training syllabus includes teaching and communication skills to be a good lecturer, organization of training events including laboratory exercises and to introduce to the participants IAEA developed training CDs so that they are used effectively in future training courses. The training course is designed to be interactive with presentations by the participants. In addition to national trainers, it is also intended to develop a pool of international trainers through train the trainers workshops. The selection of participants to the workshops takes into account these requirements. IAEA has so far conducted more than 10 train the trainers workshops for radiation protection in medicine, radiation protection in industrial applications at national, regional and interregional level. The workshops have facilitated in developing expert trainers and create a Data Base of trained trainers.
In addition, IAEA through its PGEC has introduced this module to the participants, who in later years may become trainers

III Development of training material for other job categories

Radiation Protection Officers

Ssignificant effort and progress has been made with respect to the establishment and consolidation of the PGEC as the primary training route for new professionals in the field of radiation protection in Member States. That being the case it was felt that it was appropriate to increase emphasis on the promotion and development of training for Radiation Protection Officers (RPO), this being a significant element with regard to the successful implementation of the strategic plan. A standard syllabus was developed taking in to consideration that the primary role of the RPO is one of "supervision" which if effective, will assist the employer/registrant/licensee in ensuring the application of relevant standards. The syllabus is divided into core and supplementary modules. While the core module is a compulsory module, the supplementary module is practice specific. Training material for the core module is developed and the material pertinent to the nine supplementary modules is also complete.

Information materials

The recommendations of the Conference on `Occupational Radiation Protection' in Geneva,2002, relate to information exchange between interested parties, wider dissemination of information and more active involvement of workers, employers, regulators and radiation protection specialists in information exchange leading to a better and broader understanding of radiation protection practices and promote the evolution of safety cultures in the workplace. This led to the development of information material like cautionary posters intended for display at workplaces, designed to reduce the number of near misses and the risk of serious accidents. The materials include topics like use of high-activity or high-dose rate sources such as irradiators and industrial radiography devices, in order to reinforce the need for safety procedures to be followed at all times.

IV. The Way Forward

Considerable work has been undertaken in pursuance of the strategic aims for education and training and in completing the key functions. In order to be able to achieve overall objective of self-sustaining training activities within Member States, there is a need to establish a national strategy for education and training. It is possible to establish a national strategy only if the training needs are systematically assessed and identified**.** The *Appraisal Methodology* adopted by the Agency provides solution to identification of training needs

The Agency has developed an Education and Training Appraisal (EduTA) protocol document which describes the objectives, the methodology for carrying out a detailed appraisal and the expected results of the appraisal. The objective of the EduTA mission is to carry out a detailed appraisal of the status of the provision for education and training in radiation protection including the identification of the national education & training needs and areas where provisions should be improved to meet the national E & T needs as well as international standards and best practices. Member States will benefit by identifying the training needs and in planning future E & T strategy.

An EduTA becomes most appropriate and beneficial to a country when the provisions for education and training in radiation safety have been established or are at an advanced stage of development and implementation. The Agency has already completed four such appraisal missions and two more are planned for this year.

Elearning :.. The objective of eLearning is to create from the existing distance learning course material an e-learning course to demonstrate the pertinence and efficiency of such an approach to training. IAEA has made the training material available in the web format, to be introduced as a training course. Elearning is challenging as it is self learning, and is expected to provide learners a perspective that is difficult to achieve through classroom or paper-based training programmes.

VI. Conclusions

The Agency continues to implement the Strategic Plan, however the ultimate effectiveness of the strategic approach to education and training and other IAEA initiatives rests upon the commitment of Member States to develop national strategy and sustainable training programmes in radiation safety. By working together more progress can be made towards the realization of a harmonized approach for education and training. These steps are essential ingredients for maintaining high standards of radiation safety worldwide.

Annex- 1

Training Packages developed by the Division of Radiation, Transport and Waste Safety

Regulatory Oversight

- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Nuclear Medicine (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Nuclear Gauges and Well Logging (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Industrial Radiography (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Radiotherapy (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Industrial Irradiators (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Diagnostic & Interventional Radiology (E,S,A,F)*
- IAEA Training for Regulators on Authorization and Inspection of Cyclotron Facilities (E)
- IAEA Training Course on Customs Radiation (E,F,S)*
- IAEA Training Course for Lawyers (E,F,A)*

Patient Protection

- IAEA Training Course on Radiation Protection in Diagnostic and Interventional Radiology (E,A)*
- IAEA Training Course on Radiation Protection in Nuclear Medicine
- IAEA Training Material on Radiation Protection in Radiotherapy
- IAEA Training Material on Radiation Protection in Cardiology
- IAEA Training Material on Prevention of Accidental Exposures in Radiotherapy.

Source Safety & Security

- IAEA Training Course on Radiation Protection and Safety in Industrial Radiography
- IAEA Training Course on Radiation Protection and Safety at Industrial Irradiation Facilities
- Concepts of Radiation Protection and the Safety of Sources

Occupational Radiation Protection

- IAEA Training Course on Assessment of Occupational Exposure due to Intakes of Radionuclides (E,S)*
- IAEA Training Course on Assessment of Occupational Exposure due to External Radiation Sources (E,R)*
- IAEA Training Course on Occupational Radiation Protection
- Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry
- IAEA Training Course on Neutron Dosimetry
- IAEA Training Course on Workplace Monitoring

Quality Management

- Quality Management Systems for Technical Services in Radiation Safety

Waste Management

- IAEA Training Material on Safety Assessment of Near Surface Low and Intermediate Level Radioactive Waste Disposal Facilities
- IAEA Training on Safety of Radioactive Waste Management
- IAEA Training on Management of Mining and Milling Waste
- IAEA Training on Management of NORM Residues
- IAEA Training Material on Remediation of Contaminated Sites
- IAEA Training Material on Decommissioning of Nuclear Facilities

Transport Safety

- IAEA Publication – Safe Transport of Radioactive Material – Third Edition - Training Course Series 1-2002 (some training courses in Spanish)*
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PGEC

Part I to XI (E, A, F, S, R)
Instructions to Practical lessons

Distance Learning

23 lessons in 4 Modules (E, A, S, R)*

Elearning

The distance learning modules in web format

*** All the training materials are available in English. Few are translated to other official languages as indicated in the paranthesis. E –English, A-Arabic, S-Spanish, F-French, R-Russian**

IAEA PUBLICATIONS IN THIS AREA

[1] *Safety Standards Series RS-G-1.4, Building Competence in Radiation Protection and the Safe Use of Radiation Sources, IAEA, Vienna, 2001.* This Safety Guide provides guidance for the regulatory bodies for the establishment of training and qualification requirements and a strategy for building competence. The Safety Guide is jointly sponsored by WHO, PAHO and ILO;

[2] *Safety Report Series No.20, Training Courses on Radiation Protection and Safe Use of Radiation Sources, Vienna 2001.* This report provides assistance to trainers and training providers on how to set up training courses, distance learning and on the job training as well as to establish training centres. It addresses the development and provision of training in protection and safety in a range of activities involving work with ionizing radiation. It supersedes the IAEA Technical Reports Series No. 280 on Training Courses on Radiation Protection that was published in 1988.

[3] Training Course Series 18, Standard Syllabus for the Postgraduate Educational Course in Radiation Protection and the Safe Use of Radiation Sources, IAEA, Vienna 2001 is intended to facilitate the implementation of such courses by Universities and training centres. The course is aimed at professionals in the early stage of their careers. The structure of the syllabus follows the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. This syllabus supersedes the one published in 1995.

SUBJECTS AND COURSES RELATED TO RADIATION PROTECTION IN HUNGARIAN UNIVERSITIES

PÉTER ZAGYVAI
Institute of Nuclear Techniques, Budapest University of Technology and Economics (BME)
Műegyetem rakpart 9-11., 1111 Budapest, Hungary

BÉLA KANYÁR
Health Physics Service, Semmelweis University (SE)
Üllõi út 26. 1085 Budapest, Hungary

ZOLTÁN HOMONNAY
Laboratory of Nuclear Chemistry, Eötvös Loránd University (ELTE)
Pázmány Péter sétány 1/A. 1117 Budapest, Hungary

ABSTRACT

In the present Hungarian academic system 11 universities provide courses where nuclear science and/or applications of ionising radiations are read. To some extent all of them include radiation protection, but forms, synopses and subject titles show great variety. Main types of undergraduate and graduate university courses where radiation protection is taught: engineering (chemical, mechanical, environmental), medical, natural sciences (physical, chemical, geological etc.), military, agriculture and forestry. There is no direct “nuclear engineering” education in Hungary, only “nuclear techniques” can be chosen as major subject group.
Topics of some subjects read in the engineering physicist courses of BME are discussed in details, as well as some aspects concerning the transformation of a single-level academic system to a multi-level one and the contradictory effects of budget deficiencies. RPE and RPO training required by European guidance also have a close connection to university education.

1. Introduction

Radiation protection is a typical interdisciplinary science. It is basically related to nuclear physics, human biology, physical- and radiochemistry, but has some “contact points” with military, social and economical sciences as well. It is of course, however, that if a national higher education system contains a separate university faculty for either “nuclear science” or – more frequently – “nuclear engineering” several subjects covering the topics of health physics, or with a somewhat more practical nomination, radiation protection are offered as parts of the major course. This is not the case in Hungary. Generally speaking, radiation protection is taught at universities where ionising radiation is applied and thus its health effects should be explained and accounted for.

2. Pertinent university courses

In the past years the Hungarian higher education system experienced a major change as the country accepted the Bologna Process. Since the signing of the Bologna Declaration in 1999, Europe has gradually been moving toward a two-phase system of separate bachelor’s (BS) and master’s degrees (MS) see for example reference [1]. As an obligatory part of this process, Hungary phases out the traditional “long first degrees” one phase system. In addition to the introduction of the BS – MS structure and its temporary co-existence with the traditional one phase educational scheme, PhD programs and various types of graduate education are also present in the profiles of Hungarian universities. As a logical consequence of these modifications, new courses and “core subjects” are introduced, nevertheless the situation of radiation protection-related subjects do not show fundamental changes.

Generally a subject means a series of lectures and – possibly and in our case desirably – laboratory and/or calculus exercises. A subject normally takes a single academic semester. The value and degree of difficultness of a subject is expressed with a credit number. In keeping with the general practice of two-phase academic scheme subjects are categorised as compulsory and elective ones. The former type is compulsory for all students of a faculty course; the latter belongs to certain specialisations only (“branches” in the Hungarian academic terminology.)

It is high time to define as accurately as possible the topics of radiation protection oriented subjects. Considering at least 50 subjects of 11 different Hungarian universities, this “universal curriculum” is the following:

- I. Dose definitions
- II. Biological effects of ionising radiations
- III. Scientific bases of the regulatory system
- IV. Components and sources of dose exposure
- V. Measurement and calculation of doses
- VI. Protective actions against population, workplace and accident doses

Main types of undergraduate (BS and one phase) and graduate (MS, special post-gradual and PhD) university courses where radiation protection is taught are the following:

- Engineering (chemical, mechanical, environmental) – Type “E” (see Table 1 in Chapter 5 below)
- Medical – Type “Me”
- Science (physical, chemical, geological etc.) – Type “S”
- Military – Type “Mi”
- Others (agriculture, forestry etc.) – Type “O”

Future secondary school physics teachers attend courses of type “S”. Detailed descriptions of all these courses are available from the web sites of the appropriate universities; see e.g. [2], [3] and [4].

3. Detailed syllabi of radiation protection subjects of the Faculty of Natural Sciences at the Budapest University of Technology and Economics (BME)

3 out of the 8 faculties of BME offer radiation protection oriented subjects for undergraduates. These faculties and courses are: Faculty of Natural Sciences/course of physics; Faculty of Mechanical Engineering/course of energetic engineering, Faculty of Chemical and Biotechnology/course of environmental engineering. At present BS and one-phase courses are running. The following detailed syllabi belong either to the new BS courses or to the one-phase courses; but the latter will be part of the MS courses the first of which will start in September 2009.

3.1. Radiation Protection I.

This subject is offered in the frame of Physics BS course as a compulsory subject. It includes fundamentals of each topic of the “universal curriculum” given in Chapter 2, including an important introductory part on nuclear physics, especially on the nature of radioactive decay and radiation types, as well as the types of interaction between ionising radiation and matter. It is a minor deficiency of the present curriculum that this new version does not include laboratory exercises; however, calculus is part of the lectures to some extent. Credit value: 2. (The former one-phase subject included laboratory exercises for a joint credit value of 4.)

3.2. Radiation Protection II.

This subject will be offered at the Physics MS course as an elective for students attending the branch of nuclear techniques, at present it is read at the one-phase course. Laboratory exercises accompany the lectures for a total credit value of 4. Topics I to III of the "universal curriculum" are revised; then focus is put on the measurement, calculation and mitigation of external and internal dose exposure (topics IV to VI). Nuclear analytical methods related to the analysis of samples for the calculation of internal exposure are emphasised, details of spectral evaluation are also added. Laboratory exercises: whole body counting, radon and radon EEC measurements, environmental monitoring with on-line aerosol sampling and measurement.

3.3. Radioactive Waste Management

This subject is offered as an elective one for the students of the one-phase courses of Physics. It is distributed into two subjects for the BS – MS scheme. The new versions will have credit values 2 and 3, respectively, the MS course will "inherit" the laboratory exercises (analysis projects for "delicate" waste streams of NPP origin) now belonging to the one-phase course. The BS version is offered to students of Mechanical Engineering as well. Details of topics IV and VI of the "universal curriculum" are presented. The first classes are devoted to classification of wastes; discussing exemption and clearance levels in details as well. Then the origin of waste streams are described and relevant components are introduced: operational and decommissioning wastes of NPP's, wastes from research facilities, wastes from industrial and medical applications, weapons and – last but not least – TENORM (technologically enhanced naturally occurring radioactive material) wastes are the categories. Finally waste processing technologies are summarised, presenting methods of volume reduction, conditioning procedures and assessing temporary and final disposal. The option of reprocessing spent fuel is compared to disposal; new research areas as transmutation are also included.

3.4. Migration of radiocontamination in the environment

This subject is also offered as an elective one for the students of the one-phase courses of Physics and will be part of the MS scheme. The credit value is and will be 3, covering the lectures and calculus exercises. The migration of radioactive substances in environmental media connects emissions to immissions, dose constraints to dose limits. That is, this subject gives interesting details on topics III to V of the "universal curriculum". Migration processes are described for homogeneous and heterogeneous media (atmosphere, surface waters, ground water, biological systems) by means of dynamic and static models. Differential and integral equations are presented and discussed in details.

3.5. Question marks

University courses should reflect comprehensive scientific facts based on recent research results. However there are numerous contradictory or still not unambiguous areas and problems in health physics which should be presented and explained in a holistic manner for interested young people introducing "pros" and "cons" and still unconfirmed assumptions as well. Some of these "question marks" are the following:

- Validity of LNT theory, facts confirming or refuting hormesis and supralinearity;
- Individual cell doses, extension of microdosimetry to tissues,
- Applicability of radiation weight factors and relative biological effectiveness for different exposure situations;
- Generation of dose constraints, validation of exposure scenarios;
- Clearance versus exemption;

- Potential dose exposure: how probabilities can be multiplied with doses.

4. RPE/RPO training at Hungarian universities

The standardisation of terminology concerning the special tasks of radiation protection professionals is a current item workshops and conferences. Terms like qualified experts, medical physics experts, radiation protection workers, radiation protection officers and radiation protection experts are regularly defined and re-defined. The training and in-service training of radiation protection workers, experts and officers (the two latter professions are not completely distinguished in Hungary) has a three-level national system: basic, advanced and comprehensive degrees are to be obtained depending on the positions and job type of the experts. The Hungarian RPW/RPE/RPO scheme was presented at the 2007 EUTERP Workshop in Vilnius, see ref. [5]. It is of course that advanced and comprehensive courses can be based on appropriate university subjects, however, practical, legal and regulatory aspects should be emphasised. About half of the universities having radiation protection in their curricula offer RPE/RPO graduate courses for professionals. In addition to them, students who attend a whole series of RP subjects (such as described in Chapter 3.1. – 3.4) are entitled to sit for an appropriate RPE examination as an integral part of their graduation. About 20 % of new RPE/RPO degrees are obtained this way. Data are summarised in Table 1 in the next Chapter.

5. Summary

The various types of pertinent university courses and subjects are summarised in Table 1 below. Figures in the table cells mean students per year for the appropriate courses and programmes. Separate columns indicate the frame figure of BS and traditional "one-phase" students attending RP subject courses, diploma theses in RP per year, PhD school applicants for RP programs and the presence or absence of separate RPE/RPO training at the appropriate university.

University	Type	Students of RP subjects	RPE/RPO courses	Diploma thesis in RP	RP PhD programs
BME Budapest	E	50-80	Yes	1-3	1-2
DE Debrecen	S	10-20	No	2-5	1-2
ELTE Budapest	S	10-15	Yes	2-4	-
SE Budapest	Me	70-80	Yes	2-5	1-2
SZTE Szeged	S, Me	5-10	Yes	1-2	-
PE Veszprém	E	15-20	Yes	5-7	1-2
ZMNE Budapest	Mi	15-20	Yes	4-6	1-2
SZIE Gödöllő	O	25-30	No	1-2	-
PTE Pécs	S, Me	15-20	No	1-2	-
KE Kaposvár	Me	10-15	No	1-2	-
NYME Sopron	O	15-20	No	2-4	-

References

[1] World Education News and Reviews (WENR) volume 17 (2004) Issue 1. http://www.wes.org/ewenr/04jan/Feature.htm

[2] ELTE Budapest: http://www.elte.hu/egyetemrol

[3] SE Budapest: http://dataweb-systems.hu/usnen/index.php

[4] DE Debrecen: http://www.cic.klte.hu/ttk50/fiztcs.htm

[5] Pellet, S. et al. “Radiation Protection Training in Hungary since 1988” at “First EUTERP Platform Workshop Definitions, Qualifications and Requirements for Radiation Protection Experts, Radiation Protection Officers and Radiation Workers Vilnius, 2007.

Transdisciplinary aspects of education and training in radiological risk governance.

- Integrating ethics for a new expert culture -

Gaston Meskens[1], Michèle Coeck [2]
SCK•CEN

Summary

This text argues for a transdisciplinary and inclusive approach to education and training in radiological risk governance. The focus on the 'governance' approach implies that the area of application is taken broader than occupational radiological protection. Therefore the text addresses as well radiological protection officers and experts as nuclear engineers and policy makers.

Starting from four cases to 'set the scene', we first reflect briefly on what it would mean for a nuclear engineer, a radiological protection expert or any other person with a certain responsibility in radiological risk governance to 'do the right thing' in cases where ethics come into play. A substantial volume of contemporary literature has been written on ethics and risk, not only from out of academic moral philosophy programmes, but also in research and policy related to radiological protection. Until today however, none of these reflections and recommendations have led to considerations among nuclear policy makers from research and industry on the need to adapt nuclear training and education programmes accordingly.

Our aim is to seek connection between theory and practice of making moral judgements in face of uncertainty and complexity on the one hand and expert culture and the supporting ways of – interactively - generating insight into these uncertainties and complexities through research and education and training on the other hand. Instead of putting 'what is right and wrong' when it comes to making decisions in complex ethical cases, we make an argument for the need to foster 'reflexivity' as a central attitude in 'expert culture' for anyone with a specific responsibility or interest in the case. In the last paragraphs, we argue that the methodological characteristics of reflexivity can be extrapolated as methodological characteristics of expert culture, research and related education and training, and that they emerge as two central principles for 'good risk governance': transdisciplinarity and inclusiveness of 'stakeholders'. The text then concludes with some examples of courses in ethics and radiological risk governance, as organised by the Belgian Nuclear Research Centre SCK•CEN.

Structure

1. What could be happening in the world while you are reading this.
2 'Doing the right thing': on justification in face of uncertainty and complexity.
3 Ethics and expert culture: moral judgement through interaction.
4 Ethics and radiological risk governance: the importance of joint justification.
5 Reflexivity as a central attitude in expert culture.
6 'E&T^{plus}': transdisciplinarity and inclusiveness as 'tools' to foster reflexivity.
7 SCK•CEN's courses on ethical aspects of radiological risk governance.

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[1] Adviser, Applied Systems Analysis and Technology Assessment, PISA (Programme of Integration of Social Aspects into nuclear research) - SCK•CEN (Belgium), gaston.meskens@sckcen.be
[2] isRP programme manager; Communication, Education and Knowledge Management group leader - SCK•CEN (Belgium), michele.coeck@sckcen.be

1. What could be happening in the world while you are reading this.

(1) A worker needs to execute a special task in the controlled area of a nuclear power plant. The group that is ‘on shift’ consists of two workers, of which one of them is female. The female worker says to her colleague: ‘You go into the area to do that work. I want to minimise my risk, as I plan to become pregnant in the near future’.

(2) The medical sector makes use of volunteers to test medicines and pays them as a compensation for potential side effects and risks. Although candidates have to undergo health tests and psychological tests, it is observed that mainly poorer people present themselves as candidates.

(3) A national radioactive waste agency looks for a candidate municipality to host a RW disposal site. It insists that the siting decision has to be taken democratic, and with the involvement of all stakeholders. Together with the local citizens of two volunteering municipalities, the agency designs a package of socio-economic compensation and a system for the future involvement process and the long-term management of the compensation fund. As the process develops, one can observe that it gets more and more the character of a competition to get the disposal site.

(4) A nuclear expert is inquired about the aspects of radioactive waste production of the 4th Generation nuclear power plant technology during a hearing in a parliamentary commission. The expert claims that this future technology will be more 'sustainable', as the waste volumes will be reduced due to optimised use of uranium resources and especially because the decay time can be brought back to a few hundred years with the use of transmutation.

Apparently, apart from the observation that the four cases all deal with 'risky situations' in one or another way, at first sight, they seem to have nothing extra in common. There are three nuclear cases and one non-nuclear. The first case is connected to occupational radiological protection while the others relate to a broader notion of 'risk governance'. Moreover, the involved people 'act' from out of different interests and responsibilities, in different roles and situations, while the time frames at stake vary from 'now' to 'the far future'.

What the cases do have in common on a more conceptual level is the fact that all involved people deal with situations that are characterised by uncertainties and complexities that complicate the assessment of the 'risk' involved. These uncertainties and complexities emerge with the question (1) on what basis the involved people would be able to 'justify' their 'act' and its consequences as a kind of accountability towards others, and with the question (2) to what extent a reflection on this first question would help them in judging whether they are 'doing the right thing'.

2 'Doing the right thing': on justification in face of uncertainty and complexity.

The above presented cases are just four realistic examples (that is: existing in reality) of situations where ‘responsible acting’ is needed

- for which there exists no factual logic or procedures ‘in the books’;
- that you cannot train in class or in the laboratory;
- for which you cannot always rely on similar (comparable) cases from the past.

In other words, the cases show situations in which responsible acting is needed 'in face of uncertainty and complexity' in the presence of a certain risk. What becomes clear anyway is that, in these cases, 'responsible acting' is apparently more than 'correctly executing procedures and tasks connected to the job' with the aim of 'managing' the risk, and that one can essentially not rely on acquired natural sciences and technology insights and expertise for this. This 'more' could be described as making use of a 'moral stance', or the ability to make a 'moral judgement', and the four cases hopefully illustrate that this moral stance even goes beyond the eventually existing ethical code connected to the job (the 'mandate') to trigger personal morality.

In this, one should also take into account the possibility that not all involved people are aware of the envisaged risk, or of the own or others' responsibility. Not only in less complex situations of our daily life, but also in the above sketched cases, people tend to 'justify' their acts based on widely held common-sense beliefs and thus on conscious or unconscious judgements that do not take full account of all relevant knowledge, norms, values and different views and value judgements. One could immediately state that it is not always (or even never?) possible to do this 'holistic' justification exercise 'before acting'. In real life, we all tend to do something that can be called 'narrow framing of justification'. This narrow framing can be based on several factors, such as fear, urge, interest or belief, but also on 'accountability' with regard to the own mandate. The woman in the first case apparently misinterprets the occupational radiological protection specifications related to pregnant women from out of a urge for protection of her future child. The poorer medicine test volunteer may oppress the fear for detrimental side effects due to an urgent need for money, while the new medicine project manager, in need for test persons, tries to take this situation of 'injustice' ('poor people to test medicines for the rich') into account as much as possible by eventually protecting volunteers 'against themselves'. The waste agency mandatory may act through a top-down 'means-ends' approach from out of his/her government mandate 'to find a solution for the waste', while local municipalities, eager to receive the compensation, may end up in a competition to get the site. The nuclear expert founds his thesis on scientific insights into phenomena of radioactive decay and transmutation and translates his reasoning into a 'vision' that is (al but not consciously) also supported by his belief in science and technology, while the politician may trust or distrust the expert and thus accept or reject the argument according to how it would fit into his/her political programme.

3 Ethics and expert culture: moral judgement through interaction.

A more elaborated analysis of the four presented cases is beyond the scope of this text. Rather, based on this 'problem setting' and in the context of this text, we want to reflect briefly on what it would mean for a nuclear engineer or policy maker, a radiological protection officer or any other person with a certain responsibility in radiological risk governance to 'do the right thing'. Both the nuclear scientist and the moral philosopher would agree that rationalist and logic reasoning based on either 'pure' natural sciences or one 'pure philosophy' would not deliver a satisfying answer to this question, at least not an answer that would univocally generate consensus among all involved people. Both could agree however that the best way would be to explore 'cross-over' thinking, based on elements brought in from various sides; that is: not only experts' nuclear or moral-philosophical knowledge, but also practical, normative, cultural and historical knowledge. The biggest challenge here would not be to extract a solution (a 'product') out of this spectrum of knowledges, but the act of jointly identifying what knowledge (explanatory, normative, …) is relevant and how it can be used in the judgement.

A substantial volume of contemporary literature has been written on ethics and risk, not only from out of academic moral philosophy programmes, but also in research and policy related to radiological protection. Until today however, none of these reflections and recommendations have led to general considerations among nuclear policy makers from research and industry on the need to adapt nuclear education and training programmes accordingly.

If it would appear to be impossible to inscribe guidance for every realistic 'complex' situation where responsible acting in face of the radiological risk is needed into transparent and unambiguous procedures (and the above sketched cases could be seen as proof for this), then it would turn out that 'expert judgement' necessarily will need to incorporate the use of additional 'moral judgement' that could deal with this uncertainty and complexity[3].

What this specific expert moral judgement is about, what the (practical) implications are for traditional science & technology research and related policy and communication is the subject of ethics and expert culture research. Ethics and expert culture research relies on interactive reflection between human scientists and nuclear and radiological protection experts and practitioners. Research on expert culture focuses specifically on the decision support context of expert functioning, including the expert's work methods, constraints, used underlying hypotheses, limitations of current knowledge (or of knowledge as such) and dynamics of interactions with other experts, policy makers and civil society.

What this kind of research proves in the first place is that 'classical expertise' is relative, not in the way that provided expertise would be true or false depending on the context, but rather in terms of its limitations to generate insight and advice if not taking into account all scientific, social and normative aspects. In addition, Paragraph 6 on transdisciplinarity will state that this generation of insight is more than adding up 'complementary expertise'.

For now, we would like to state that, given the focus on the interactive character of the research, the distinction between 'research' on the one hand and education and training on the other hand becomes vague and irrelevant in the context of ethics and expert culture. Rather than the traditional uni-directional teaching or 'advisory' approach, the interaction 'beyond disciplines' and beyond areas and levels of expertise becomes the essential learning experience and way of generating knowledge and insight. In this approach, the notions of reflexivity, transdisciplinarity and inclusiveness become essential (see paragraphs 5 and 6). The central idea of expert culture in connection to the introduced 'additional moral judgement' for now is that this judgement should not be understood as the experts sole and definite recommendation, advice or view on the case, but that it is essentially generated *through interaction*.

4 Ethics and radiological risk governance: the importance of joint justification.

Referring back to the previous paragraph, the question remains then how 'moral judgements' could help in these cases, and how they could be 'instrumentalised' in expertise in risk governance. Classical moral philosophy deals with the inquiry of the potentialities and impotentialities connected to these kinds of justification exercises, and tells us that, in order to make good decisions, it is not enough to simply know what 'rules' (or procedures) we should follow. We have to know how to adapt those rules to our circumstances, and to do that effectively we must know why specific moral norms are justified, and what the boundary conditions are to using them in combination with factual (scientific) knowledge. This is a philosophical question, but with practical (and sometimes far-reaching) consequences. Anyway, in the frame of this text and referring back to the presented cases, one could ask whether there exists a 'special morality' (behaviour, value set, normative framework, code of conduct, justification method) typical for radiological risk governance that would (need to)

[3] A short introduction of what this uncertainty and complexity can mean in the context of radiological risk governance was given in the related article 'A transdisciplinary approach to education and training in radiological protection and nuclear engineering', Michèle Coeck, Gaston Meskens, Gilbert Eggermont , SCK•CEN, European ALARA Network Workshop 2006 Prague, Czech Republic, September 2006

come on top of our personal morality and the common-sense moral ideas that make up a good society (such as equity, freedom of speech and helping those in need)? Or maybe there exists a specific radiological risk governance morality that would even affect our personal morality and those common-sense moral ideas?

Everyone familiar with radiological risk assessment knows about the special character of the radiological risk at low doses. Insight into the stochastic character of the cause-effect relation at low doses led to the nowadays broadly accepted regulation based on the linear non-threshold hypothesis and the basic principles of radiological protection (justification – limitation – optimisation). This regulation obviously does not exclude a possible effect, but it enables the organisation of a 'reasonable' occupational safety culture for both industrial and medical workers. The bigger problem comes of course when risk assessment has to take into account complex 'unpredictable' pathways of radioactivity in space and time on the one hand, and unforeseen events 'from outside' that would increase the risk and/or make it less controllable. Running ahead of the further elaboration, we state that here morality comes in. It will appear that there is no 'special' morality specifically connected to the radiological risk, but that rather one of those common-sense moral ideas that 'make up a good society' will come into the picture.

In the context of occupational risk management, the issues of unpredictable pathways and unforeseen events 'on the work floor' are principally inscribed into the regulation. That is: of course safety regulations and safety culture should ensure everything reasonably possible (1) to minimise the radiological risk 'in daily routine practice' and (2) to avoid events (incidents and accidents) that would enhance the risk. However, in occupational context, the radiological risk 'as such' is *justified*. Every technician or manager working in or around controlled nuclear areas is (or should be) aware of the risk, and accepts it as such, together with (or thanks to) a guarantee of an organised safety culture of 'protection' that aims at optimising doses and takes into account fixed and rigid dose limits. This is why the basic principles of occupational radiological protection start with the principle of justification: first, the risk is *jointly* justified, and then the management to minimise and optimise can start.

If we would apply these basic principles of radiological protection to the context of risk management of the ecosystem and the so-called 'general public', the picture becomes different. There the full complexity of risk assessment and subsequent governance emerges by way of those complex 'unpredictable' pathways of radioactivity in space and time, and those unforeseen events 'from outside' that would increase the risk and/or make it less controllable. The disintegration of a waste disposal site in the future, and the consequent migration of radioisotopes and possible uptake in the food chain is a typical example of the first problem, while human error causing a nuclear accident or unintended human intrusion in a waste disposal site are typical examples of the second problem.

There is no highbrow historical analysis needed to understand that joint justification processes with civil society supporting the existence of (peaceful) nuclear activity have never happened in the past, and that the evidence of involving civil society in the siting of radioactive waste repositories has only been acknowledged recently by industry and authorities. One can of course immediately add that this is not a typical nuclear problem, as it also appears in the context of other risk-inherent technological applications such as genetic manipulation, nanotechnology or fossil fuels. Indeed, it is generally said that these phenomena are typical symptoms of the 'technocratic approach' originating from late-modern industrial and technological optimism, and that any 'reform' of these approaches for the better of society would need to touch upon the deep roots of how our modern democratic societies work. However complex the question might be, this can – speaking in moral terms - of course not be used to evade it.

As a kind of conclusion to this reasoning, we could state that good risk governance starts with joint justification involving all possibly affected people. In the case of occupational risk governance, this condition is principally taken up in the basic safety regulations. In the case of risk governance towards society and the ecosystem, it is not.

This text relates to education and training, and is not aiming to make suggestions to reform existing regulations and political decision making systems to include joint justification as an essential part of 'good risk governance' (although this kind of suggestions indeed deserve attention more than ever). Our aim is to seek connection between theory and practice of making moral judgements in face of uncertainty and complexity on the one hand and expert culture and the supporting ways of generating insight into these uncertainties and complexities through research, education and training on the other hand. In this respect, morality in connection to risk governance has thus to do with the willingness to create conditions for joint risk justification, and the willingness to critically inquire all factual-scientific and normative aspects that come into play in this justification exercise. Acceptance of this argument would immediately lead to an understanding of its implications in terms of responsibility of each actor or 'moral agent' (being it the nuclear expert, the politician or the civil society representative) related to the way we look at issues and to the way we are able to deal with - or even transcend – our so-called 'narrow framing'.

5 Reflexivity as a central attitude in expert culture.

Paragraph 3 and 4 give us now the necessary elements to describe the 'moral stance' we talked about in paragraph 2. While this stance was still explicated there as synonym to 'the ability to make a moral judgement', recalling paragraph 3, we would rather describe it now as 'the ability to *contribute to* making a moral judgement'. The combination of the willingness to recognise 'other expertise' (experts or laypersons knowledge) in the interest of making moral judgements through interaction (paragraph 3) and the willingness to create conditions for joint risk justification or justification of a 'risky practice' (paragraph 4) automatically implies a critical stance towards the own knowledge or expertise. The moral stance appears thus to be one of 'attitude of openness or intention' in combination with a critical attitude towards 'the own expertise'. This stance can also be described as 'reflexivity', or as the attitude of being sensitive to the conditions in which (own and others) knowledge is produced and can be used.

We don't want to fall into our own trap here by making an attempt to 'define' what 'reflexivity' is. The concept of reflexivity originates from social theory and the very short meaning in that context could be boiled down to the attitude of 'agreement' that theories in a discipline should apply equally forcefully to the discipline itself. Obviously, the concept has direct relevance for theories of knowledge, including the way knowledge is produced and can be used in 'real cases', and the implications for the way knowledge producers and disseminators (experts, scientists, stakeholders) can act in these real cases.

Instead of going deeper into these philosophical reflections, we prefer to present some 'characteristics' of reflexivity that could serve as basis for reflection and discussion.

inside (starting with the ‘self’)
→ awareness of own knowledge
→ recognise incompleteness and relativity of own knowledge
→ recognise own ‘sense for justice’
→ awareness of - and insight in - own values
→ value own reputation with regard to ‘credibility’

outside (looking towards the situation, the others / in context / in perspective)
(curiosity / 'the beginner's mind')
→ awareness of (other's) knowledge
→ recognise incompleteness and relativity of knowledge as such
→ awareness of - and insight in - values / context / perspective
→ recognise others 'sense for justice'
→ value others reputation with regard to 'credibility'

We propose that these methodological characteristics of reflexivity could then as well be extrapolated as methodological characteristics of expert culture, research and related education and training. They emerge as two central principles for 'good risk governance' and the related research and education and training: transdisciplinarity and inclusiveness of 'stakeholders'. To conclude this article, we will sketch how these principles could be inscribed in an 'E&T^{plus}' for the case of radiological risk governance (paragraph 6) and give an example on how this could be put in practice in education and training programmes (paragraph 7).

6 'E&T^{plus}': transdisciplinarity and inclusiveness as 'tools' to foster reflexivity.

It is true that a young engineer, in order to become an expert in stress corrosion cracking of NPP vessel steel, does not need to be able to make value judgements on the national energy policy of his/her country, or on how to involve civil society in RW disposal siting. But regardless of the specific content of the nuclear job, the question of whether he/she has a responsibility to reflect upon aspects of risk and societal justification of 'his/her' technology is more difficult to answer. Instead of going into deeper discussion on societal accountability of (nuclear) scientists and engineers, we would like to focus on the importance of the balance between 'specialist' and 'generalist' – or rather 'transversalist' – education in this respect.

We state that, in this context, to learn to develop and use skills 'to think out of the box' is not the young engineers duty, but his/her *right*. Given the fact that nuclear technological applications are in the centre of the recent societal debates related to technology, sustainable energy policy, globalisation and environmental challenges (such as the climate change debate), any existing portfolio of courses on nuclear technology would be incomplete without an additional introduction on ethics and risk governance, philosophy of technology and on aspects of sustainable development in relation to economy and ecology. A student or young professional in nuclear engineering or radiological protection should have the chance to enrich his/her education and training with insights into political, economical and social dynamics around nuclear technology applications and the chance to learn to develop and test own critical opinion on all dynamics in front yet behind the scenes.

Just as for the four cases of the introduction, there are no procedures or norms to learn, develop and acquire 'proper' ethical or moral skills. Making reference to the previous paragraphs, we could state that education and training programmes on ethics and risk governance, similar to the above sketched cross-over research, have a character of transdisciplinarity and inclusiveness.

It is only since the last decade that nuclear technology assessment studies and related critical reflection on societal aspects have been taken up also 'within' the nuclear community instead of only in the academies philosophy departments. Thanks to the recognition of the intrinsic social dimensions of the complexity of 'impacts of technology on society', well-known disciplines such as 'technology assessment' and 'risk assessment' gradually start to move away from a pure 'rationalist' exact sciences - approach to a more transdisciplinary approach by way of including other disciplines such as philosophy and sociology. Transdisciplinarity can be seen as a principle 'for a unity of knowledge beyond disciplines'. In this respect, it could be understood as a principle of integrative forms of research, comprising a family of methods for relating scientific knowledge and extra-scientific experience and practice in problem-solving. In this understanding, transdisciplinary research addresses issues of the real world, not issues of origin and relevance only in scientific debate. This connection to the real world is of course crucial in the envisaged E&T programmes.

Through transdisciplinary learning, young professionals should f.i. become able to

- use factual knowledge from natural sciences and technology in critical analysis;
- interpret and learn from historical lessons;
- recognise, state and accept uncertainties instead of trying to exclude them;
- better understand social mechanisms, also in the working environment;
- broaden the risk scope to ‘multifactorial concerns’ in complex (hazardous) situations;
- recognise the relativity of expert knowledge.

In this sense, transdisciplinarity can be seen as an attitude of 'standing in the middle of reality' (professional, social) while seeing this reality as the learning environment. It requires an interactive practice of problem solving oriented thinking and acting across disciplines, taking into account that own (disciplinary) knowledge is always relative. In extension, transdisciplinarity also incorporates so-called ‘indigenous knowledge’ (knowledge brought into the group by ‘non experts’ or (local) stakeholders). Discussing ethical cases should thus be done with everybody involved, or thus 'inclusive', in these cases, whether in occupational circumstances (workers, nuclear policy makers, radiological protection officers, patients, …) or in the broader social context (engagement of civil society).

7 SCK•CEN's courses on ethical aspects of radiological risk governance.

The Belgian nuclear research centre has build up a thorough experience with education and training in radiological protection for the industry, the medical sector and for interest groups of civil society. Since five years, the research centre is also offering courses on ethical aspects of radiological risk governance for the broad audience of industry, the medical sector, the academic sector and policy makers. The course is a joint initiative of the International School for Radiological Protection (isRP) and the PISA group (Programme of Integration of Social Aspects into nuclear research).

The course is lectured in three different formats depending on the target audience (see below), but the basic structure and lecturing approach is essentially the same. During the first part, course participants are taken on an introductory journey through basic risk governance and philosophy of ethics (see table, part 1). During this theoretical part, the group is already invited to comment on presented philosophical ideas (deontologism, utilitarianism, anthropocentric world views, …) and ethical considerations in relation to practical cases (such as smoking, use of radioactivity in consumer products, climate change, biodiversity…)

Course on ethical aspects of radiological risk governance

Part 1 – theoretical introduction to ethics and risk governance

1 On risk, transparency and free choice
2 Justification in face of complexity
3 Basic philosophy of ethics
3 Basic philosophy of ethics
4 Dealing with uncertainty and ambiguity in the ‘real world’
5 Ethics and technology
6 Reflections with regard to the application of the principles of radiological protection
7 Some ethical considerations

In the second part, course participants gather in groups. Each group chooses one of a series of presented cases (similar to those of the introduction to this text) and discuss the case on the basis of a set of investigating questions (table, part 2)

Course on ethical aspects of radiological risk governance

Part 2 – group work on case studies - investigating questions

- what are the relevant norms involved ?
- what are the relevant values ?
- what are the aspects of justification ?
- where is the uncertainty ? what are the aspects of complexity ?
  (scientific ? normative ? both ?)
- who is responsible for what ?
- what could be a recommendation (‘solution’) in this case ?

Based on the above described structure, the course programme is currently lectured in three formats:

Format 1 – 1,5 hours – lecture with plenary group discussion
Introduction to ethics and radiological protection for technical staff and radiological protection officers.

Since a few years; the standard course on radiological protection for technical staff of the industry contains an introduction to ethics and radiological risk governance. The theoretical introduction is kept concise and to the point, and the cases are oriented to realistic situations on the work floor.

Format 2 – 4 hours – lectures with discussions in groups
Extended course on ethical aspects of radiological risk governance

This course is part of the curriculum of the postgraduate programme Radiological Protection Expert organised by the XIOS Technical University (Diepenbeek, Belgium) and the international school for Radiological Protection (isRP) of the Belgian Nuclear Research Centre SCK•CEN. Course participants come from the wide spectrum of professions (industrial and medical). Therefore, cases cover as well societal policy issues as medical and nuclear-industrial cases.

Format 3 – 3 hours – lecture with discussions in groups
Round table discussion on ethical aspects of radiological and nuclear safety for engineers, as part of the SPERANSA course (an initiative of the CHERNE Network)

The course starts with an introduction to the philosophy of ethics and to the actual discourse on ethics and technology. In a second part, reflections on the applications of the radiological protection principles are made. In a third part, based on a number of key 'investigating questions' derived from part one and two, course participants work in small groups to analyse a selection of 'complex problems' (or 'ethical cases' such as those presented in the introduction of this text) that are taken from the real world of applications of radioactivity. In a fourth concluding part, the whole group discusses the reflections made by the different working groups and will make an attempt to draw some 'guidelines' that could assist practical complex problem solving with regard to radiation safety.

Suggestions for further reading

A transdisciplinary approach to education and training in radiological protection and nuclear engineering. Michèle Coeck , Gaston Meskens , Gilbert Eggermont , SCK•CEN
European ALARA Network Workshop 2006 Prague, Czech Republic, September 2006

Ethics and Radiological Protection, Gilbert Eggermont and Bernard Feltz (eds)
Bruylant Academia, 2008, ISBN 978-2-87209-894-1

SCK•CEN – PISA projects on Risk Governance
http://www.sckcen.be/pisa

Network for transdisciplinarity in sciences and humanities
http://www.transdisciplinarity.ch/

European Nuclear Society

Rue Belliard 65
1040 Brussels, Belgium
Telephone +32 2 505 30 54
Fax + 32 2 502 39 02
nestet2008@euronuclear.org
www.euronuclear.org