Education and training in radiation protection and nuclear safety: Bridging the gaps

The IAEA is placing added emphasis on helping national authorities to strengthen their development of human resources

by Karol Skornik

Education and training are indispensable to the development of human resources in industries around the world. In nuclear industries, efforts have intensified in these areas over recent years. In its programme plan to the year 2000, the IAEA has attached considerable importance to the development of human resources for nuclear and radiation safety, in keeping with its ongoing emphasis on providing technical assistance to strengthen national infrastructures and promote the safe use of nuclear technologies for peaceful applications in various fields.

In September 1993, the IAEA's General Conference approved the 1994-98 programme for education and training in radiation protection and nuclear safety. This article presents an overview of the programme within the context of global developments in the nuclear field, national priorities and needs, and policy directions.

The context of developments

The quest for excellence in nuclear and radiation safety calls for an integrated approach to education and training. Both radiation protection and nuclear safety are, by and large, multidisciplinary fields comprising interrelated parts of applied physics, chemistry, biology, nuclear technology, and other specialized areas. When it comes to the development of human resources, however, there are important differences and specific needs and problems. Some differences and problems stem from the wide variety and range of nuclear and radiation applications.

Today, radiation technologies and radioactive sources are widely used around the world, mostly in medicine (diagnostic radiology, radiotherapy, nuclear medicine) as well as in industry, agriculture, and research.

In medicine, for example, it is estimated that:

- more than 400 000 diagnostic X-ray machines are in use for about 1200 million medical X-ray tests annually,
- 320 million dental X-ray tests are carried out annually,
- 10 000 gamma cameras are installed worldwide, supporting a range of nuclear medicine procedures,
- 22 million *in-vivo* applications of radioisotopes (nuclear medicine) are performed per year,
- radiation therapy is applied to more than 4 million patients each year, and
- more than 60 countries have set up routine medical programmes involving the use of nuclear techniques.

There are indications that exposures of populations from the diagnostic and therapeutic uses of ionizing radiation are increasing worldwide. Much of this increase can be justified on clinical grounds, particularly in developing countries, where medical services are not yet sufficiently available. By the year 2000, the collective dose to the world's population from medical irradiation will probably increase by 50% and by the year 2025, it may more than double, according to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Over the past two decades, radiation processing has grown at a steady rate of 10%-15% per year, based on the number and total power rating of installed radiation sources. More than 135 industrial gamma irradiators and some 400 electron beam machines are operational in 42 countries. Radiation-processed products include foodstuffs, hospital and medical supplies, synthetic and rubber items, and wire and cabling.

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The total value of these products is estimated at more than US $2 billion annually.

In industrial sectors, applications of ionizing radiation are widespread. They include radiotracer techniques for measurement of fluid flows or detection of leaks, for example. Gamma radiography, as part of non-destructive testing of materials, also is widely used in inspection of casting defects, detection of welding defects in pipes and vessels, and for optimization of casting methods prior to mass production. Radioisotopes are used on a routine basis in well logging by oil and gas industries, in natural resource prospecting, and geophysical investigations. A number of industrial gauges and consumer products are based on or involve the use of radiation sources.

In fields of agriculture, nearly 1000 crop varieties derived from radiation induced mutations are grown worldwide on several million hectares, yielding economic gains estimated to be in the billions of dollars. Moreover, the use of radiation techniques in pest control has helped to combat the loss of crops to insects and the loss of livestock from diseases spread by insects.

Perhaps the most visible of the benefits derived from ionizing radiation are the 430 nuclear power plants now in operation worldwide, together accounting for more than 16% of the world's total electricity production. Another 55 power reactors are under construction to meet demands for reliable electrical power. Cumulative worldwide operating experience from civil nuclear reactors at the end of 1993 surpassed 6500 years. At the end of 1993, there also were 301 research reactors operating in 59 countries to support analytical studies in many scientific fields, and to produce radioisotopes for medicine, industry, and agriculture. This includes 51 reactors in 18 countries which are used for training purposes.

Specialists at an IAEA training course on radiation protection.

Such extensive uses of ionizing radiation are indicative of the international scope of education and training needs in areas of radiation protection and nuclear safety. Such programmes need to address practices in a growing number of installations, facilities, laboratories, and work places involving the use of ionizing radiation, radiation sources, or nuclear techniques.

Infrastructural aspects. A large body of both radiation and nuclear safety standards, including international standards, exists. However, this is not a guarantee for good safety practices. A proper national infrastructure is required for the application of safety standards to achieve and maintain the desired degree of protection and safety. The infrastructure is understood to comprise essentially the following main elements:

- legislation and regulations for setting forth legal, technical, and administrative requirements;
- an enforcement system for legislation, through regulatory mechanisms, such as notification, registration, licensing, inspection, and advice on how to satisfy safety requirements;
- human resources and know-how at all levels ranging from highly qualified work, including policy making and research and development, to specialized areas of applications, to technical support for routine operations and services;
- a capable technical base for the provision of various safety services such as radiation monitoring (personnel dosimetry, calibration of instruments, environmental monitoring), maintenance of equipment and components, and emergency response capabilities; and
- resources for setting forth and implementing the national programme for radiation safety.

The extent of any national infrastructure needs to be commensurate with the degree and volume of nuclear technological activities requiring safety efforts, ranging from electricity production by nuclear power plants to other applications of ionizing radiation.

IAEA Member States differ in their commitments to nuclear technologies and related safety infrastructures. Hence, their requirements and capabilities to adequately educate and train their nationals also differ. The Agency's policy in education and training reflects these differences. Relevant programmes are adjusted for different groups of countries. Emphasis is placed on the specific areas in radiation protection and nuclear safety which are consistent with the needs and priorities of these countries in their national programmes for the development of human resources. In this context, a national programme for education and training is seen as an essential part of the country's system designed to teach professionals, technicians, and members of the

general public about the benefits and risks associated with the use of ionizing radiation.

Analysis of needs

Radiation protection and nuclear safety are primarily a national responsibility. All countries using ionizing radiation or committed to nuclear power programmes are engaged in some education and training activities in these fields. Many developing countries still find it difficult, however, to set up and/or implement such programmes, due to budgetary constraints, shortage of qualified teachers, and other deficiencies in infrastructure. Hence, they have become increasingly aware of the benefits that can be derived in this connection from international co-operation and harmonization.

In analyzing the needs of its Member States, the IAEA has drawn upon insights and experience acquired through its technical co-operation programme (specifically in this case, safety services and interregional, regional, and national projects) and through its regular activities such as conferences, symposia, seminars, and other technical gatherings. IAEA safety services in both radiation protection and nuclear safety include Radiation Protection Advisory Teams (RAPAT); Operational Safety Review Teams (OSART); Assessment of Safety Significant Event Teams (ASSET); International Regulatory Review Teams (IRRT); Integrated Safety Assessment of Research Reactors (INSARR); and Engineering Safety Review Services (ESRS).

Radiation protection. An analysis of the RAPAT findings underscores the importance of strengthening international co-operation in the field of radiation protection. There is evidence that *radiation safety control mechanisms* today are inadequate in more than half of the IAEA's Member States. Many countries simply lack the necessary infrastructure for implementing a safety policy based on international recommendations. In some countries, national radiation protection facilities are inadequate; in others multiple institutions claim responsibility; and in several, including those relatively new IAEA Member States, national competent authorities have yet to be established. Too often, basic legislation and supporting up-to-date regulations are wanting.

Several radiological accidents outside the nuclear power field have underscored the importance of safety control mechanisms. For example, an international review conducted by the IAEA following a serious radiological accident at an industrial irradiation facility in San Salvador in 1989 revealed that this accident could have been avoided if a proper radiation protection system had been in place. Even in countries where appropriate national regulations exist, there is often a shortage of properly educated and trained nationals able to set up operative radiation safety systems, including licensing, inspection, and supporting technical services.

In 1991 the International Commission on Radiological Protection published its revised recommendations (ICRP 60) which constitute the basis for the revised *Basic Safety Standards for Protection Against Ionizing Radiation and the Safety of Radiation Sources*. These international standards are due to be issued jointly by the IAEA, International Labour Organization (ILO), Nuclear Energy Agency of the Organization for Economic Co-operation and Development (NEA/ OECD), World Health Organization (WHO), Pan-American Health Organization (PAHO), and Food and Agriculture Organization (FAO). Various types of assistance will have to be given to many developing countries. They will need help in incorporating international standards into detailed national regulations for radiation protection; in setting up authorities to supervise the implementation of such regulations; and in enhancing the performance of such authorities. IAEA assistance involving the use of radioactive materials and other radiation sources will necessarily involve the provision of education and training in radiation protection to groups of professionals.

An issue which will continue to receive emphasis is the enhancement of radiation safety for nuclear personnel in the workplace, an area in which training remains in high demand. Each category of workers has its own particular needs, depending on the occupation in question. Exposed workers or workers likely to be exposed can be grouped by various fields — the nuclear industry and transport of radioactive materials; hospitals and other medical institutions (radiotherapy, diagnostic radiology, nuclear medicine centres); industrial plants and projects using radiation sources; universities and research centres; institutions and groups involved in emergency operations (medical services, civil defense, local police, for example).

In industry, training must be accessible to the greatest number of workers and be based on a balance between the level of knowledge they require for the purposes of their occupation, and the level needed for radiation protection.

In medical teaching and research, training is needed for groups of professionals having a sound scientific education but inadequate knowledge of radiation protection. There is a particularly growing demand worldwide for training of radiation safety officers (health physicists) and medical personnel, including medical doc-

tors, in departments of radiotherapy, diagnostic radiology, and nuclear medicine. Refresher courses for this group are needed on a regular basis to keep personnel abreast of radiation safety requirements. Attention must be accorded to nurses, a group having a very important impact on public perception of radiation risk.

Radiation protection training for members of emergency teams should be seen as part of the national plan for dealing with nuclear accidents and radiological emergencies. The need for such training at all levels is persistent for many countries in all regions. Training and re-training in radiation protection thus concerns a wide range of groups with different levels of knowledge. Harmonization as an objective must first be directed at decision-makers, teachers, and specialists and then extended to all occupationally exposed workers.

Regarding general education, it should be noted that there is common omission of radiation health and safety areas in most countries and radiation protection is rarely covered in secondary education. Training in this field often lacks a basis on which to build. Teaching, if any, varies greatly from country to country. For many countries, achieving a critical mass of local educators and trainers, both knowledgeable about radiation safety and able to transmit their knowledge, remains elusive.

Nuclear safety. In analyzing needs for education and training in nuclear safety, a detailed classification of countries is necessary. In the IAEA's programme, the focus is being placed on three groups: a) developing and/or restructuring countries with ongoing programmes involving operation/construction of nuclear power plants or research reactors; b) countries in which the nuclear option is considered as a means of meeting growing demands for electricity, with ongoing research/training reactor programmes; and c) countries with no nuclear power programme whose use of technology involving nuclear safety is limited to research/ training reactors.

There is an acknowledged need worldwide for general education in nuclear safety, including the safety of future reactors, in conjunction with radiation protection. A range of general subject areas and groups of personnel has been identified by IAEA safety teams as priority areas, a number of them dealing with the development, organization, and administration of training programmes for different groups of personnel.

The difficulties in ensuring consistent levels of safety standards are rather obvious. Economic strengths, industrial traditions, legislative frameworks, and commercial policies all vary widely. Regulatory organizations must enforce national standards in their own way and these standards play a part in developing good national safety cultures. IAEA guidance is incorporated in the Nuclear Safety Standards (NUSS) — a series of documents which give recommendations on licensing, organizational, and technical matters relating to the safety of nuclear power and research reactors. They are available for use in support of national activities and they form the basis of the Agency's safety assistance. Training for national regulators will continue to play an important part in this process.

Training activities also will play key roles in upgrading the safety levels of nuclear power plants, and to some extent research reactors, that were built according to early safety standards, as well as plants facing problems because of various ageing processes.

Some problems particularly apply to WWER 440/230 nuclear power reactors operating in the countries of the former USSR as well as in Central and Eastern Europe. Issues related to ageing of nuclear facilities are of worldwide significance, on the other hand, and the IAEA has seen a growing demand for training programmes. It stems from the realization that knowledge of the fundamental physical processes than can occur in a power plant or research reactor as it ages can improve the ability of operators to respond to plant transients and other events. Furthermore, as the understanding of ageing phenomena is translated to changes in operations at reactor facilities, plant personnel will need training in the new procedures.

IAEA policies and programmes

The IAEA's programme for education and training in radiation protection and nuclear safety is based on the following objectives:

- the achievement of national self-sufficiency in education and training programmes;
- the strengthening of national radiation protection and nuclear safety infrastructures; and
- the meeting of immediate national needs in States requesting assistance.

The programme emphasizes strategic planning over the near and long term, so as to ensure the highest possible standard of education and training programmes and to avoid the pitfalls of ad-hoc individualized approaches. The fundamental guidelines in planning comprise two independent features: concentration, which denotes co-operation with Member States in arranging for IAEA-supported training events on carefully selected subjects reflecting the most persistent needs, and standardization of efforts, which is understood as the IAEA's activities for preparing standard syllabi for general education and specialized training courses.

Overall, the programme is characterized by a number of modalities and mechanisms.

Education. Post-graduate educational courses are designed to meet the educational and initial training requirements of junior staff of graduate level, holding or earmarked for positions in radiation protection (including health physics) or nuclear safety. The target audience includes young professionals who need to acquire a sound basis in these areas in order to become — in the course of time — trainers in their home countries. In addition to the established post-graduate educational course in radiation protection and nuclear safety held in Spanish, new courses will be held in English and French (radiation protection), and possibly in Russian (radiation protection and nuclear safety), at an interregional or regional level, in selected educational/training centres. The relevant courses in radiation protection will be based on a standard syllabus prepared by the IAEA. The syllabus is planned for distribution to Member States so as to facilitate the integration of educational courses in radiation protection into the curricula of their leading educational institutions.

Specialized training courses. Training courses are available for those seeking specialization in specific areas of radiation protection and nuclear safety. Typically, a course spans 3 to 8 weeks during which participants are provided with the opportunity to update and upgrade both their theoretical and practical knowledge and skills.

Interregional courses reflect specialized training needs that are common to Member States in more than one region, and they require special facilities and expertise not generally available during practical training. Their primary objective is to train people who will subsequently fill senior managerial or operational positions with the additional task of training others. In this "train the trainers" approach, the IAEA will continue to encourage countries to nominate candidates who, following their own training, will be willing and able to contribute to national staff development programmes in their respective countries. Also offered are regional training courses, which cover a wide range of topics and involve a number of host institutions in Member States, and national courses, which countries organize as part of their national programmes for the development of human resources, often in connection with IAEA technical co-operation projects.

Training workshops. Shorter (1 to 2 weeks), intensive training takes place at workshops designed to enhance skills of people working in both major fields. The emphasis is always on practical elements of training and upgrading "hands-on" experience. Generally, there is extensive laboratory, computer-aided, or field work. Apart from provision of expert services, training material, and demonstration kits, the IAEA provides laboratory equipment or instruments to enhance national training capabilities.

Other mechanisms. Fellowships are used primarily as a means of providing on-the-job training to individuals from developing countries. The IAEA's programme puts emphasis on selecting candidates who, after their fellowship training, can themselves contribute to national programmes for development of human resources. Scientific visits also are arranged for decision-makers who may become involved in strengthening the radiation protection and nuclear safety infrastructures in their countries.

The 1994-98 programme further includes a series of regional seminars for promoting education and training in radiation protection and nuclear safety. Such meetings serve as a timely forum for exchange of information and educational discussions by selected groups of specialists with common interests. In general, they provide opportunities for the exchange of ideas and experience for those involved in similar work (e.g. educators, health physicists, reactor safety specialists). They also serve as a focal point for the IAEA to elaborate on a new activity or service for which the active participation of Member States is essential, such as the IAEA Emergency Response System.

All these types of activities are supported by reference materials. These basically include the IAEA's safety-related publications (standards, guides, training series, radiation safety manuals, etc.) and other information materials specifically developed for educational and training courses.

Bridging the gaps

Whereas problems are more pervasive in developing countries, even the more advanced countries face the need for specialists able to bridge crucial gaps that are delaying understanding and communication in areas of radiation protection and nuclear safety.

From the international perspective, the problem can be more readily tackled through an integrated approach to education in radiation protection and nuclear safety, harmonization of the contents of courses, and assistance in training the trainers. Priority can be placed on better dissemination of experience and knowledge that is already available, and improved co-ordination of support mechanisms. Through its programme over the coming years, the IAEA will be working to help countries address these challenges. ❐