

DEVELOPMENT OF HUMAN RESOURCES THROUGH AWARENESS EDUCATION AND TRAINING ACTIVITIES ON OCCUPATIONAL RADIATION PROTECTION FOR INDUSTRIAL RADIOGRAPHY IN TURKEY

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ABSTRACT

Industrial radiography that uses both X-ray and gamma radiation are common widespread techniques of inspecting materials for hidden flaws. No matter what regulatory infrastructure is used, individual industrial radiographers are the most likely group of exposed workers to receive doses up to approaching relevant acceptable dose limits. In Turkey, the usage of ionizing radiation in industry is growing day by day in parallel with the technical developments in Turkey. This paper summarizes the Turkish experience in radiation protection (RP) education and training (E&T) in industrial radiography, regulatory requirements and the feedback obtained from various RP actions. The aim of this study is to provide a structural description of the course modules that are addressed to qualified experts, industrial radiographers and radiation protection officers (RPOs). The modules are mainly dedicated to radiation protection applications in industrial radiography. Assessment of this course also points out the benefits and inconveniences of pedagogical approaches in the Radiation Protection domain.

Keywords: *Education and training; radiation protection; industrial radiography; optimization*

INTRODUCTION

Industrial radiography is a very important and common method in non-destructive testing of materials. Gamma radiation sources, most commonly iridium-192 and cobalt-60, and X-ray are used to inspect a variety of materials. The vast majority of radiography concerns the testing and grading of welds on pressurized piping, pressure vessels, high-capacity storage containers, pipelines, and some structural welds. Other tested materials include concrete (locating rebar or conduit), welder's test coupons, machined parts, metal plates, or pipe walls (locating anomalies due to corrosion or mechanical damage). Even non-metal components such as ceramics used in the aerospace industries are also regularly tested by means of radiography. The integrity of

equipment and structures such as vessel, pipes, welded joints, castings and other devices is ensured by radiography. In other words, radiography is of vital importance in safety and quality of the products used by workers and the public. On the other hand, radiography produces high radiation dose rates so that one can be accidentally exposed to the beam. Besides, damaged or corroded radiation sources can cause environmental contamination during use, or disposal of them improperly. Safe use of ionizing radiation in radiography can be accomplished by means of an appropriate national regulation, organizational infrastructure, effective training of workers, compliance with safety requirements, as well as effective quality control, and maintenance of sources and devices.

In recent years, it has been observed that the need for radiographic inspections has increased

considerably in Turkey¹. Typically, facility radiation protection and safety programs for radiographic inspections revolve around a variety of radioactive material or x-ray machine uses. To maintain a high degree of professionalism in the field, first, these sources and devices should be designed and manufactured at the highest standards for better protection and tolerable against human errors, and the second, working environment should have a safety culture. These can be accomplished through an appropriate national regulation and effective training of radiation workers, also an effective quality control system. Education and training in RP is considered as one of the basic aspects for the optimization programs in occupational radiation exposures. The continuous training programs on RP is of paramount importance to ensure staff doses to be kept them in a minimum level. Council Directive 97/43/EURATOM, establishes in Article 7 that ‘Member States shall ensure that practitioners and individuals mentioned in related articles should have adequate theoretical and practical training for the purpose of radiological practices as well as relevant competence in RP. For this purpose, Member States shall ensure that appropriate curricula is established and shall recognize the corresponding diplomas, certificates or formal qualifications’². According to Article 9.2, ‘Member States shall ensure that practitioners and the individuals referred to above those who are performing high doses to workers, such as industrial radiography, obtain appropriate training in these radiological practices.

Earlier, we reported commentary on education and training for diagnostic radiology and education and training activities on personal dosimetry services in Turkey^{3,4}. The purpose of this study is to share our practice and experience on RP training in industrial radiography. In this study, the general learning objectives, main contents and course duration have been presented for industrial radiography that periodically held by the ANRTC between 2010 and 2013.

METHODOLOGY

Turkish Atomic Energy Authority (TAEA) is the competent national regulatory authority for radiological protection and nuclear safety and security. Main objectives of TAEA are policy making on nuclear energy, nuclear technology, regulation, licensing, inspection, research and training⁵. TAEA is also responsible for individual monitoring of radiation workers in all radiation facilities in Turkey as well. Ankara Nuclear Research and Training Center (ANRTC) affiliated with the TAEA has duties and responsibilities on national E&T and research on RP topics as it is in radiation safety. Public information on nuclear topics is also among the duties of the ANRTC. On the other hand, some specific training programs, which include irradiation of some specific food, non-destructive testing methods, comet assay analysis method, fundamentals of radio pharmacy, radiography and individual monitoring are carried out in the other two centers affiliated with the TAEA, Çekmece Nuclear Research and Training Center-(ÇNRTC) and Sarayköy Nuclear Research and Training Center-(SNRTC), under the coordination of the ANRTC. The Procedures and Principles for Implementation of Trainings in Radiation Protection (PP-E&T) was issued by TAEA on 03 May 2013⁶. According to this new PP-E&T, public and private enterprises can also take place in implementing radiation protection training/courses provided that they be approved and licensed by TAEA. Articles relevant with training objectives, training topics, selection criteria for lecturers and technical infrastructures are also defined in this PP-E&T.

The aim of our implemented training course in occupational radiation protection for industrial radiography is to meet the needs of professionals at specific level and certificate workers for initial training to acquire a sound basis experience in RP and licensing processing. The course also part of complementary basic tool for those who will become trainer in RP field. For this reason, our pedagogical approach will also be integrated

in as part of the courses for public and private enterprises in Radiation Protection which began in 2013.

PEDAGOGICAL APPROACH TO TRAINING

As in any training/teaching process, three elements are vital: A content to teach, one or more trainer and students to teach.

The specific training design should commence after the identification of the target group analysis of the training needs and should include

- *the aims of the training,*
- *the learning objectives,* and
- *the training syllabus.*

Here in this study, the target audience is industrial radiographers and the assistant radiographers performing gamma and X-ray radiography on-site and shielded enclosures. In general, they have undergraduate degree taken from universities generally in technical fields. The average age differs, e.g. 23 or over but the common point for all they are doing the same jobs even if the specific areas where they work vary.

Aims of the training

The aims of the training are determined by considering the needs of all interested parties, including the requirements set by the regulatory body (TAEA). These needs are always assessed by the TAEA and users of radiation sources right after having identification of the availability of trained personnel and the numbers of individuals needed in the various job categories.

The aim of this course is to provide a basic awareness of the radiation hazards associated with industrial radiography using gamma and X-ray devices. It also gives practical guidance on acceptable work practices to keep doses in limits compatible with regulatory requirements and also as low as reasonably achievable (ALARA) principle.

Learning objectives

Upon completion of the course the participant should be able to:

- Describe the nature and properties of gamma and X-ray radiation and its associated hazards;
- Use the standard terminology for RP;
- State the regulatory requirements related to the safe use of radiation sources;
- Apply basic concepts of radiation protection (time, distance and shielding) and practical methods for reducing doses;
- Measure correctly levels of dose rate ;
- Demonstrate acceptable work practices and the correct operation of equipment;
- Recognize an unusual situation and take appropriate immediate actions to control doses;
- Provide accurate records and reports.

The materials and equipment

The following materials and equipment are used in the RP courses for industrial radiographers:

- Survey meters: Geiger-Müller counters and ionization chambers.
- Personnel monitoring equipment (thermo luminescent personnel dosimeters).
- Standard radioactive sources.
- RP equipment.
- A demo industrial radiography device, source changer and associated equipment (Fig. 1).
- Course documents.

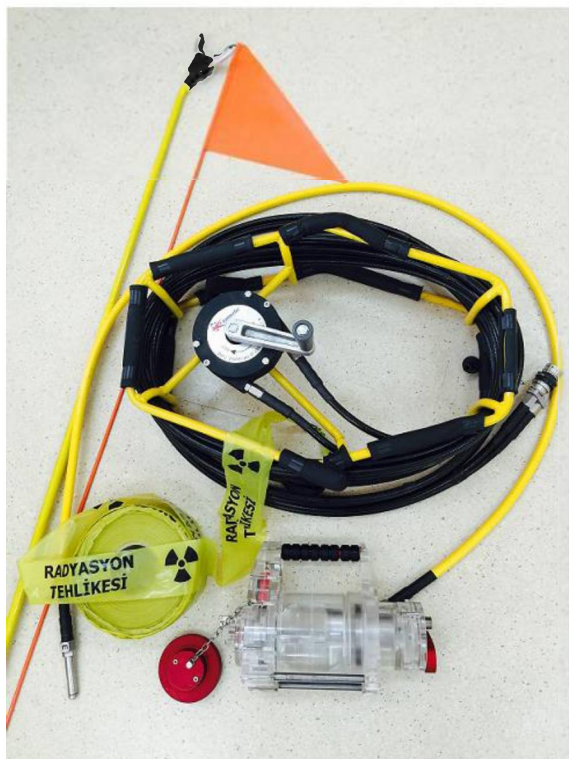


Fig. 1 A demo industrial radiography equipment for using on the job training in RP for industrial radiographers in ANRTC.

The training syllabus

Standard Syllabus Training Course Series of IAEA gives the objectives, standard syllabus and postgraduate educational course syllabus in radiation protection and the safe use of radiation sources⁷. In this series, objectives for protection against occupational exposure in industrial radiography are given in Module VII.6. A summary of the essential elements for basic training in radiation safety for industrial radiographers is also given in the IAEA-Specific Safety Guide SSG-11⁸.

The course syllabus on RP for industrial radiographers are being implemented by making use of the following three contents in the current course program according to IAEA recommendations:

1- Fundamental concepts and measurements:

- Fundamental ionizing radiation concept: The objective of this module is to become familiar with the basic knowledge in ionizing radiation. The main content given in this module are atomic structure, X-ray production, radiation sources, and radiation dose and exposure types – 2 hours.

- Radiation quantities, units and conversions: The objective of this module is to understand dose units, dosimetric quantities and to perform related calculations. The main contents in this module are dosimetric and RP quantities, application of dosimetric calculations and unit conversions – 2 hours.

- Radiation measurement and detection: The objective of this module is to be familiar with operating principles, characteristics and to be able to choose appropriate detector. The main content given in this module is interaction of X-rays with matters, different types of radiation detector, practical exercise for measurement – 2 hours.

- Biological effects of radiation: The objective of this module is to distinguish between somatic and genetic effects of ionizing radiation, to establish the most important characteristics of the stochastic effects, to describe deterministic effects, to explain that dose threshold and severity of deterministic effects can vary between individuals. Main contents in this module are the effects of radiation on cells, effects of whole body irradiation, and effects of partial body (skin, thyroid, eye lens, gonads etc.) irradiation, stochastic effects, and radiation detriment – 1 hours.

2- Principles of radiation protection:

- System of radiation protection: The objective of this module is to become aware of the ICRP's conceptual framework and international recommendation in RP, also to become acquainted with the role played by international organizations, to discuss the optimizations of procedures, designation of controlled areas and supervised areas; dose limits and investigation levels – 2 hours.

- National regulatory for radiation security: The objective of this module is to become familiar with the elements of a

regulatory infrastructure for radiation protection and safety in Turkey. The main content given in this module is the scope of National Regulation of Radiation Safety, safety requirements and guides, system of notification, registration, licensing and control of radiation sources, and training requirements – 3 hours.

- Personal monitoring, dose limits, dose levels: The objective of this module is to be able to use monitoring programs (whole body, extremity and skin dosimetry), also to implement the RP principles. The main content given in this module is monitoring programs, importance of the suitable location of personal dosimeters, dose rate, influence of the equipment positioning on occupational doses – 2 hours.

3- Practical radiation protection

- Radiation sources and application of the radiation sources: The objective of this module is to become aware of the radiation sources and uses of radiation to ensure the high quality and safety of our daily lives. – 2 hours.

- Safe transport of radioactive sources: The objective of this module is to become aware of the National Regulation on Safe Transportation of Radioactive Materials and IAEA's Transport Regulations. The main content given in this module is safe movement of the radioactive materials within the worksite and transport to another site– 3 hours.

- The properties of the radiography sources and devices: The objective of this module is to be familiar with a wide range of exposure devices, which are commercially available to carry out industrial radiography. The range includes equipment for performing gamma and x ray radiography, and a summary of their general characteristics- 2 hours.

- Radiation accidents: The objective of this module is to become aware of normal and accidentally potential working conditions. Possible accident scenarios and preventive comments are given. If an accidents occurs, then ensuring how to mitigate their consequences and controlling the accident under acceptable limits are taken into account in the module. Also possible doses due to accidents considered to be foreseeable before the accident happens.– 2 hours.

- Practices for radiation quantities, units and conversions: The objective of this module is to perform related calculations and problem solving related to radiation units, conversions, and calculation of radiation doses – 2 hours.

- On the job-training for site radiography work: The objective of this module is to practice exercises in the site by using knowledge learned in the content of the RP course. The main contents given under this module are application of dose reduction techniques, effects of time, distance and shielding, working practices to limit doses and maintaining them as low as reasonably achievable (ALARA), storage of radioactive sources, correct operation and maintenance of radiographic equipment, local rules, emergency plans for radiographer – 5 hours.

Fig. 2 presents the percentage of total course time devoted to each subject area in the course program.

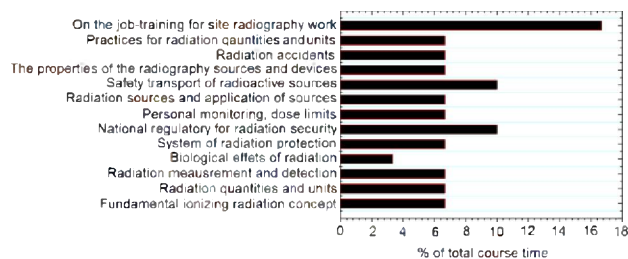


Fig. 2 Subject areas and relative percentages of the total course time in industrial radiography course program.

Implementation of national training activities for industrial radiography staff in RP.

In general, the annual course programs are prepared and announced on TAEA's website at the beginning of each year. As mentioned earlier, most of the courses are presented as four -day seminars (total 30 hours) by the instructors composed of physicists, radiation protection experts, radiation biologists, and medical physicists. Since it has a scientific background, the ANRTC team plays and performs important

role in delivering lessons with radiation protection specialists.

Training schedule

Day 1: Fundamentals and principles of RP, dose measurement, biological effects.

Day 2: Overview of sources and equipment, protection against radiation exposures.

Day 3: National regulatory requirements for radiation safety and security.

Day 4: Dose reduction techniques, practical RP.

Evaluation of the training

At the end of every course, trainers and the session materials are evaluated by the participants by means of questionnaire given. The feedback from participants (evaluation of questionnaires) about the quality and effectiveness of the training are used for the purpose of improvement of the next courses. Also, the trainers' performance and effectiveness are evaluated during sessions. It is better to state here that the trainers are chosen according to the data collected before for adjustments in the next courses.

Assessment of the competence of a participant and Certification

Tests and exercises are developed by the experts keeping in mind the goals of training. The tests are prepared in coordination with TAEK's other related units including ANTRC. A final test is given to participants at the end of each course by TAEA. All participants should take this approximately one hour test for measuring their achievement and certification. A Certificate for Achievement on the test is issued according to the test results by TAEA. For the sake of independent assessment the exam and the grading process are carried out by the TAEA's Research and Development Coordination Department as apart from the course delivering unit. On the other hand, since the similar courses are implemented by other approved organizations, the participants from these

organizations take the same tests. According to this test score, two different certificates are issued. If the examination score is 70-over 100 points, a 'Certificate of Achievement' which is necessary to become an approved RP in industry is granted. For lower scores, a 'Certificate of Attendance' is given to the participants.

Communication tools

All the course contents can be followed through the internet by the participants. If they want, they can also download course material (pdf and/or html format). They can also use communication tools such as forums, chat, e-mail, etc.

RESULTS

Radiation protection and safety objectives

In this topic, the primary objectives are protection and safety, respectively. Our major radiation protection objectives are to prevent the occurrence of deterministic effects in individuals by keeping doses below the relevant threshold and to ensure that all responsible measures are taken to reduce the occurrence of stochastic effects in the population at present and the way forward. It should always be kept in mind that the objective is to protect individuals, society and the environment from radiological harm by means of establishing and maintaining effective defense against radiological hazards from radiological sources. These objectives are applied to the operation, maintenance and decommissioning of exposure devices, sealed sources and fixed facilities for industrial radiography.

The Basic Safety Standards (BSS) assemble fundamental requirements for protection against the risks associated with exposure to ionizing radiation and for the safety of radiation sources that may deliver such exposure, so these are to be fulfilled in all activities involving radiation exposure⁹. The requirements of the BSS should be ensured during source's normal operation, maintenance and in emergency situations. ALARA (as low as reasonably achievable)

principle must be applied in radiation exposure for radiation workers and the public. At the same time, economic and social factors should be taken into account and kept below the relevant dose limits in industrial radiography. Therefore, TAEA considers safe operation, good engineering practice and quality assurance in compliance with dose limits besides appropriate qualifications and training of the workers in radiation protection programs.

Education and training activities of radiation protection officers

Education and training (E&T) in radiation protection (RP) is widely recognized as one of the basic components of radiological optimization programs for industrial exposures. The IAEA safety guide RSG-1.4¹⁰ states that “radiation protection officers are employees who should be designated by the registrant or licensee to supervise radiation safety within a facility and to ensure that work is carried out safely and in accordance with the relevant national requirements.

The continuous education programs on RP are of paramount importance to ensure that staff doses are kept in a minimum level. The IAEA presents information on the structure and content for training courses in radiation protection for industrial radiographers¹¹.

A radiation protection officer (RPO) is defined in the IAEA International Basic Safety Standard⁹ (BSS). BSS’s definition for an RPO is that “a person technically competent in radiation protection issues related to a given type of practice who is designated by the registrant or licensee to oversee the application of relevant requirements”. Similar definition can be found in Turkish “National Regulation of Radiation Safety, in Article 4-i, (No: 23999) as such that an RPO with his/her required qualifications they also must be qualified with basic safety standards for RP and implements these standards according to characteristic requirements of his/her job. Besides this, they must have a proven track of record of accomplishment that has been approved by TAEA, in this field¹². In the light of this information, license application to the Authority requires a qualified RPO who

successfully completed appropriate training courses in his/her field at the first stage. This requirement is stated in the Regulation’s Article 73 of the National Regulations of Radiation Security which says that any facility tackling with radiation, including radiation sources shall have an RPO that certified by TAEA. RPO distribution vs. their profession is shown in Fig. 3 for industrial activities in Turkey.

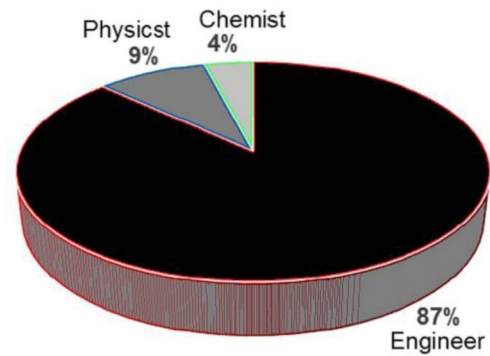


Fig. 3 The distribution of RPO% vs. profession for industrial activities in Turkey.

In Turkey, the national legislation requires specific training in RP¹³. ANRTC affiliated with the TAEA organizes and/or coordinates courses to implement training for RP in the country^{3,4}.

The specialized courses are organized according to the needs, arising from public and private sector, called “sector specific courses”. The course programs are announced in the beginning of each year in the TAEA’s website. As mentioned above, courses held by ANRTC by itself or in coordination with other nuclear research and training centers those which are affiliated with TAEA as well. The courses are carried out by qualified instructors who are currently working in the field from TAEA’s trainer/instructor repository or from the universities that have been studying similar subject.

The courses between 2010 and 2013 which were periodically held by the ANRTC have been summarized in this part of the study, such as

Courses' general learning objectives and main content and course duration and so on. In this period of time, total 28 RP course were organized and 812 participants trained between 2010 and 2013 (Fig. 4). This capacity was sustained at the same level in 2014. The appropriate training material and arrangements were used in theoretical and practical sessions. During each course, revised and updated training/course notes were delivered to the participants for using them as course notes and as a future reference. At end of the each training course, participants were given a test until the Procedures and Principles for Implementation of Trainings in Radiation Protection (PP-E&T) was put into effect by TAEA on 03 May 2013. After the issuance of PP-E&T, participants were tested by TAEA's Department of Coordination of Research and Development with a central examination system, covering the courses carried out by approved organizations out of TAEA as well.

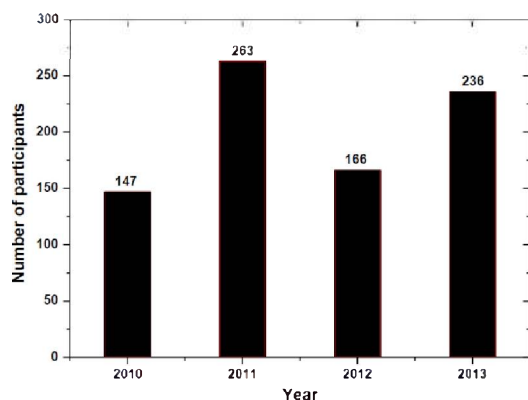


Fig. 4 Number of course participant for industrial radiography for the period of 2010 – 2013.

Two different certificates were issued for the participants. If the examination score was 70/100 a 'Certificate of Achievement' was granted which is necessary to become an RP in industry. For lower scores, a 'Certificate of Attendance' was given. According to the total evaluation of 812 participants, 770 of the participants were granted with "Certificate of Achievement".

Meanwhile, after each course, evaluation questionnaires were disseminated to the participants and their remarks requested for the future course's design. Feedbacks have been made use of to get the next course to be more efficient. The questionnaires' results ranged the best-and the worst-rated aspects of the training courses for the year 2011 – 2013 were taken into account in the assessment (Fig. 5).

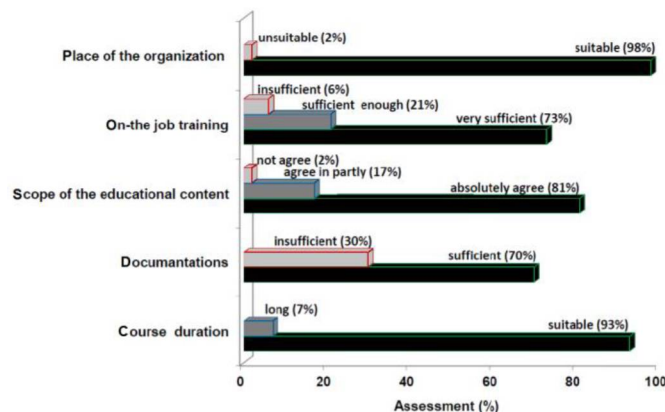


Fig. 5. The questionnaires' results ranged the best-and the worst-rated aspects (%) of RP training courses on industrial radiography for the year 2011 – 2013.

According to the overall assessments obtained, the course duration (suitable/short/long) was considered to be suitable by 93% of participants. 7% of participants believed that the course duration was too long. The documentations distributed to the participants, consisted of a hard copy of the slides presented in the lectures were found sufficient by 70% and the rest 30% of participants believed that the hard copies were insufficient. As for documentations that distributed as booklet and the scope of the educational content (absolutely agree/agree in part/don't agree) were considered by 81% absolutely agreed, 17% agreed in partly and the rest 2%, did not agree. Meanwhile, courses' practices were considered quite sufficient by 73%, sufficient enough by 21%, insufficient by 6%. On the other hand, the classroom and organization's facilities (lecture hall and transportation) were considered as suitable by 98% of participants.

The feedbacks on quality and effectiveness of the trainings were used in improvement of the next consequence courses. This can be observed from the performance indicators. Moreover, feedbacks from the field through the inspectors of TAEA have been taken into account in these assessments as well.

CONCLUSIONS

TAEA that provides technical and scientific help and data is an important national body for radiological protection policies in all fields of radiation application based on Turkish legislation. Here, in this study, some aspects concerning the role and importance of the TAEA have been discussed for practical RP in industry, especially industrial radiography in Turkey. The information on the nationwide distribution of the registered radiation sources or devices, the scope of authorization and inspection activities, implementation of individual monitoring program and education and training activities about radiation protection are the major indicators of a nationwide radiological program. Radiation protection and safety is determined by national legislation, but its implementation carried out by local authorities as defined by means of licenses. The national implementation of the regulations is strongly influenced by the public perception of radiation risks and by political and economic targets according to the ICRP recommendations.

Due to the growth of usage of ionizing radiation in industry with the technical developments, the importance of operational RP incrementally increases day by day. In this regard, national RP training programs are being continuously improved in parallel with this growing demand. In this study, we have briefly tried to describe the current regulations and requirements for RP in Turkey and wanted to share our experience in the organizational RP training courses and in educational programs in radiation physics, radiobiology along with RP definitions for radiographers.

As for comparison of other country applications, e.g. in Germany, each licensee needs at least one person who is in charge of radiation protection matters in relation to the licensee's type of

'practice'. This person, who could be for example a technician, an engineer, a physicist, a medical doctor etc., needs a task specific training course in radiation protection (mainly legal requirements, guidelines, practical issues) lasting from some number of days up to several weeks, ending with an examination; the training centers providing the courses need accreditation by the competent authority¹⁴. Radiation protection course duration is 32 h for expert knowledge using non-destructive testing with sealed radioactive sources in Germany. Gamma-radiographers in Austria have to have a certificate of the society of non-destructive materials testing¹⁵. To obtain the certificate, workers are supposed to complete a three steps education program which also contains training in radiation protection. For field work, radiographers have also to complete radiation protection education as demanded by the Austrian law. Such a curriculum based on a basic training course and several special courses, with each module containing a standardized test, is available at the Austrian Research Center Seibersdorf (ARCS), the largest research institution in Austria. About 75 percent of all industrial radiation workers in Austria have completed their education in radiation protection at the ARCS.

In our case, similar training courses for radiation workers can also be organized by institutions and organizations in accordance with the related Turkish regulations. In other words, the TAEA and the other approved relevant organizations meet the radiological training needs for RP. Therefore, RP training programs are accredited and sustained at the national level. This process is undertaken by the regulatory authority with the help of the ANRTC in Turkey. It is expected that academic institutions (universities) those which have similar experiences in their field of activity, can organize RP education and training courses.

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