**Ionization radiation applications and radiation safety procedures in Türkiye**

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| **Abstract**In this study, firstly, it is given all the application of the ionization sources and devices in Türkiye. The general information about radiation sources and devices and radiation application in Türkiye are given. Additionally, information is given regarding the authorization and control of radiation sources in our country. Until August 2018, Turkish Atomic Energy Authority (TAEK) was the regulatory body of Türkiye. After that time, the regulatory activities of TAEK have been transferred to the Nuclear Regulatory Authority (NDK). Thus, NDK has undertaken the regulatory activities concerning facilities (including nuclear power plants), devices, substances and activities related to nuclear energy and ionizing radiation as the regulatory authority of Türkiye. According to the NDK national radiation sources registration system, there are various radiation sources throughout our country, including radioactive sources and devices that produce or emit radiation (X-ray devices, closed and open radioactive sources and devices containing closed radioactive sources) [1]. Ionizing radiation has many beneficial applications in medicine, industry, energy production, agriculture, and research when it is used safely. But the use of ionizing radiation sources can be harmful effect to the health of human, and environment if it not properly used or not controlled [2]. In this scope, secondly, this study contains information concerning current the radiation safety procedures in scope of the regulatory body in Türkiye. |
| Keywords: Radiation, X-ray, Safety, Radioactivity, IAEA  |

1. **Introduction**

Radioactivity is a natural phenomenon. The natural sources of radiation are features of the environment. People are exposed to natural sources of ionizing radiation, such as cosmic radiation, terrestrial radiation, inhalation and ingestion in addition to the occupational exposure. There are also artificial sources of ionizing radiation in our daily life. Ionizing radiation has many useful applications, especially uses in medicine, industry, energy production, agriculture, safety and securty and research when it is used safely. The development of the nuclear and radiological fields and the more widespread application of radiation and nuclear technologies have led to increase of the number of workers who might be exposed to radiation in the course of their workday by day. The use of ionizing radiation can be harmful effect to the health of human, and environment when it not properly used or not controlled. According to a 2008 report by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), some 23 million workers worldwide are exposed occupationally to ionizing radiation, some 75 per cent of them working in the medical field [1]. Occupational exposure due to radiation sources and devices in Türkiye arises from mainly four different fields of activity, namely: 1- Medical activities (diagnostic radiology, radiotherapy, nuclear medicine, dental radiology, and others), 2- Conventional industry (industrial radiography, industrial irradiation, and others), 3- Control for security purposes, and 4- Research and education [2]. Regulating safety is a national responsibility, and many States have decided to adopt the IAEA’s standards for use in their national regulations. The mainly users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. These safety standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities and radiation applications involved in the use of radiation and radioactive sources. The standards are also applied by regulatory bodies and operators around the world to enhance safety in nuclear power generation and in nuclear applications in medicine, industry, agriculture, and research [3]. In this scope, The Nuclear Regulatory Authority (NDK) is responsible for regulating and supervising the activities in the nuclear energy sector and the facilities and activities related to radiation in Türkiye. In this study, firstly, it is given all the application of the ionization sources and devices in Türkiye. The general information about radiation sources and devices and radiation application in Türkiye are given. Additionally, information is given regarding the authorization and control of radiation sources in our country.

1. **Materials and Methods**

Radiation applications are in accordance with legal regulations in which radiation is used consciously and in a controlled manner. These regulations: occupatoinal, medical and radiation protection against public exposure to ensure radiation safety and radioactive rule on ensuring the safety of resources and includes standards, safe use of radiation sources scientific, technical and administrative requirements for its use determine. Until August 2018, Turkish Atomic Energy Authority (TAEK) was the regulatory body of Türkiye. After that time, the regulatory activities of TAEK have been transferred to the Nuclear Regulatory Authority (NDK). Thus, NDK has undertaken the regulatory activities concerning facilities (including nuclear power plants), devices, substances and activities related to nuclear energy and ionizing radiation as the regulatory authority of Türkiye. NDK has responsibilities for all purposes related to the establishment, operation, decommissioning or operations of nuclear facilities, radiation facilities or radioactive waste facilities. In this study, radiation sources (X-ray devices, indoor and outdoor radioactive sources and devices containing sealed radioactive sources) and in relation to these uses for authorization and control activities in the Türkiye to present the data.

The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled. Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety. Thus, regulating safety is a national responsibility. Both the government and the regulatory body have important responsibilities in establishing the regulatory framework for protecting people and the environment from harmful effects of radiation, including establishing standards. The government is also responsible for ensuring, as necessary, that provision is made for support services, such as education and training, and technical services. The NDK is responsible for carrying out its required regulatory functions, such as the establishment of requirements and guidelines, the authorization and inspection of facilities and activities, and the enforcement of legislative and regulatory provisions. In this scope, it is within the responsibilities of NDK to determine the principles and principles and maintenance responsibilities required to protect people, the environment, and future generations from the possible harmful effects of ionizing radiation during the sale of nuclear energy and ionizing radiation.

1. **Results and Discussion**
	1. **The application of the ionization sources and devices in Türkiye**

Radioactive sources and devices in Türkiye, X-ray devices, sealed and open (unsealed) radioactive sources and devices containing radioactive sources in industry, medicine, security, agriculture. It is also used and widespread in many fields such as research, education, etc. Production, transportation, storage, export, import, trade, possession, transfer, use, installation, modification, dismantling, maintenance and repair of radiation sources and devices, transfer, processing, transportation, storage, export, import and disposal of radioactive waste are among the main activities of NDK.

It is possible to categorize the radiation sources used in Türkiye under three main headings according to their physical properties:

*X-ray devices*

X-ray devices are used radiology within the scope of medical radiation applications and radiotherapy departments, mainly operating rooms and various fields such as orthopedics and cardiology diagnostics in clinics, dentistry, veterinary medicine and used for treatment purposes in Türkiye. X-rays are also widespread used in industrial radiography and nuclear measurement systems and package, luggage and for security scanning of vehicles.

*Sealed radioactive sources*

The sealed radioactive sources are radioactive materials that is permanently sealed in a capsule or bonded and in a solid form. The sealed radioactive sources are widely used for beneficial purposes in medicine, industry, and agriculture. This source is especially used in radiotherapy high activity found in gamma knife devices. Relatively high activity sealed sources used in industrial radiography and in well type (drilling) measurement applications and in the calibrations of other devices and laboratory low activity used in applications in various radiation applications [4].

*Open radioactive sources*

Open radioactive sources are not sealed radioactive material in in solid, liquid, gas, or powder form. The open sources are used in nuclear medicine and some radiotherapy applications in diagnosis and treatment, research, testing and calibration purposes in laboratories.

The radiation applications are divided four kinds of activity according to the occupational exposure due to radiation sources and devices in Turkey arises from mainly four different fields of activity. These are 1- Medical activities (diagnostic radiology, radiotherapy, nuclear medicine, dental radiology, and others), 2- Conventional industry (industrial radiography, industrial irradiation, and others), 3- Control for security purposes, and 4- Research and education.

* + 1. **Medical activities**

Medical uses of ionizing radiation are among the longest established applications of ionizing radiation. Medical uses of ionizing radiation take place in a variety of settings, including hospitals, medical centres, health clinics, specialist clinics, and dental practices. The number of such procedures has continued to increase day to day. These medical uses bring considerable public health benefits. Radiation sources used in the field of medicine in Türkiye are presented below [2]:

* Medical radiology applications (veterinary applications included); radiography/scopy, angiography, computed tomography, mammography, bone density measurement, microfilm devices,
* Dentistry practices; periapical (fixed/mobile), panoramic, dental tomography devices,
* Radiotherapy applications; linear accelerator (LINAC), postload brachytherapy, cyber knife, gamma knife, tomotherapy, MR-Lineer accelerator, Co-60 teletherapy devices,
* Nuclear medicine applications; SPECT/SPECT-CT, PET/PET-CT/PET-MR, radioisotope used inpatient treatment units, RIA laboratories, radioisotope production and education/research purpose accelerator facilities, radiopharmaceutical, radioisotope generator production/preparation and calibration source preparation facilities.
	+ 1. **Conventional industry activities**

Radiation has a variety of industrial uses such as nuclear gauges used to build roads to density gauges that measure the flow of material through pipes in factories, to estimate reserves in oil field, for sterilization and commonly used in non-destructive testing (NDT). Radiation sources used in the field of conventional industry activities in Türkiye are presented below [2]:

* Industrial radiography applications; X-ray radiography, X-ray radioscopy, gammagraphy devices
* Nuclear gauges applications; X-ray and radioactive source analysis, X-ray and radioactive welded process control and gauges devices with portable density and moisture gauges devices,
* Irradiation systems; gamma irradiation and electron beam irradiation facilities, blood irradiation and other irradiation devices.
	+ 1. **Control for security purposes**

X-ray and gamma rays are used to examine packages, baggage, containers or vehicles for security puroses in the public building, airport, shopping mall, business center, site, etc. Radiation sources used in the field of control for security purposes in Türkiye are presented below [2]:

* Package/baggage control X-ray devices, vehicle/container scanning devices, explosive/contraband detection devices.
	+ 1. **Research and education activities**

The radiation sources and devices are mainly used to material analyses, research and devolpoment activities in medical, agriculture, and education activities in Türkiye [2]. DNA studies (genetic engineering), seed improvement in agriculture, flow rate in streams measurements, detection of water leaks in dams, monitoring of water movements of activities, allocation of finds (burial, mound) in archaeometry studies, avoiding damage to the artifact storage, age determination, chemical storage location of the artifact, place of discovery determination of the material source or place of manufacture, allocation (real or fake), protection of products (physical protection), replacement (restoration), dissemination for research and educational purposes in very important areas such as devices containing sources are used. Preventing spoilage of agricultural and livestock areas and food products, prevention of loss of nutritional value, prevention of losses as a result of harvest (by preventing sprouting) or by delaying proliferation), to prevent insect infestation, to improve various tools and produced, animal disease diagnostic points are also widely spread devices containing sources are used. As X-ray analyzers in material analysis, single/powder crystal diffractometers (XRD-diffractometers), X-ray fluorescent devices (XRF, fixed and portable) are widely used.

The distribution of ionizing radiation application areas in Türkiye is given in Figure 1 according to NDK records [2].

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**Figure 2**. The distribution of ionizing radiation application areas in Türkiye [2].

* 1. **The radiation safety procedures in Türkiye**

Turkish Atomic Energy Authority (TAEK) was the regulatory body of Türkiye, until 2018. After that time, the regulatory activities of TAEK have been transferred to the Nuclear Regulatory Authority (NDK). Thus, NDK within the scope of the Decree Law No. 702 on the Organization and Duties of the Nuclear Regulatory Authority Laws, dated 02/07/2018, is a public institution that has "control over activities related to nuclear energy and ionizing radiation, within the scope of the principle of peaceful use". The organization are established institutionally, and their current services are maintained gradually.

As stated in the Nuclear Regulatory Law of Türkiye [5], “The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation.” The system of protection and safety in Türkiye aims to assess, manage and control exposure to radiation so that radiation risks, including risks of health effects and risks to the environment, are reduced to the extent reasonably achievable. The standards applied under this law and other relevant laws and regulations are based on the following safety principles briefly stated in the according to the Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards Fundamental Safety Principles (International Atomic Energy Agency-IAEA) in the country [3,7].

1. *Responsibility for safety*: The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.
2. *Role of government*: An effective legal and governmental framework for safety, including an independent regulatory body, must be established, and sustained.
3. *Leadership and management for safety*: Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.
4. *Justification of facilities and activities*: Facilities and activities that give rise to radiation risks must yield an overall benefit.
5. *Optimization of protection*: Protection must be optimized to provide the highest level of safety that can reasonably be achieved.
6. *Limitation of risks to individuals*: Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.
7. *Protection of present and future generations*: People and the environment, present and future, must be protected against radiation risks.
8. *Prevention of accidents*: All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.
9. *Emergency preparedness and response*: Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.
10. *Protective actions to reduce existing or unregulated radiation risks*: Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

An effective radiation security culture is dependent on effective planning, education, training activities and awareness, as well as the personnel who plan, operate, and maintain the security systems. Education and training (E&T) activities for radiation protection is a basic aspect of the optimization of all exposures to radiation. Education, training and continuing professional development is essential to improve safety and quality in the uses of ionizing radiation [7, 8].

1. **Conclusion**

Radiation and radioactive substances have many beneficial applications, ranging from energy generation to uses in medicine, industry, agriculture, research, and education activites. But the radiation risks to workers and the public and to the environment if the radiation souruces and exposures is not controlled. Many radiation facilities are in operation in the field of medical radiology, industrial radiography, industrial applications, nuclear medicine, transportation for radioactive materials and research for many years. Regulating safety is a national responsibility. But radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences. Türkiye does not operate any nuclear power reactors at now. But WWER-1200 (4x1200 MW) type reactors are under construction in Mersin Province under the agreement signed with the Russian Federation in 2010. Nuclear fuel loading to this facility, which will be Türkiye's first nuclear power reactor (Akkuyu NPP) to generate electric energy, was announced on April 27, 2023. Thus, the responsibilities of our country in terms of nuclear safety, security and the provision of nuclear security have increased significantly.

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