

SafeWork Information Note Series



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Radiation protection of workers

Shengli Niu

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Radiation protection of workers

The purpose of this Information Note is to provide information about the size of the workforce affected by, and the occupational activities associated with, exposure to radiation and the relevant ILO instruments on the protection of workers.

Radiation and the world of work

Ionizing radiations are part of the human environment (for example, cosmic rays and naturally occurring radioactive materials). They include X-rays and gamma rays (electromagnetic radiations) as well as corpuscular radiations (subatomic particles: alpha, beta and neutron radiations). Ionizing radiations can induce acute effects (for example, burns) and long-term effects (for example, cancer and hereditary diseases), which are also known as non-stochastic (deterministic) and stochastic effects.

Radioactive sources are used throughout the world for a wide variety of beneficial purposes in industry, medicine, research, agriculture and education. The combination of improved health services and an ageing population has resulted in an increased use of radionuclides and radiation in diagnosis and treatment. The threat of terrorism, the potential malicious use of radioactive sources, cost-related pressure and the spread of the use of nuclear devices oblige government authorities to take radiation protection and safety more seriously than ever before.

Green energy production and the rise of nuclear power

The demand for electricity is rapidly increasing in many developing countries. The use of nuclear power to produce electricity involves almost no CO₂ emissions. Climate change and

concerns about natural fossil fuels have thus once again put the use of nuclear power in the spotlight of political and public debate. Sufficient and affordable energy is essential for sustainable economic and social development in any society and is critical for poverty reduction and decent work.

In many industrialized countries, nuclear power is already a major source of electricity. Some developing countries, in particular those in transition, are increasingly relying on nuclear power to solve their shortages. In April 2011,¹ 439 nuclear power reactors, with an installed electric net capacity of about 375 GW, were in operation in 31 countries.

At present 60 nuclear power reactors, with an installed capacity of 64 GW, are under construction in 14 countries, as follows: 27 in China, ten in the Russian Federation, five each in India and the Republic of Korea, two each in Canada, Japan and Slovakia, and one each in Argentina, Brazil, Finland, France, the Islamic Republic of Iran, Pakistan and the United States.

Table 1. Nuclear share in electricity production, 2009 (per cent)

> 70	> 50	> 40	> 30	> 20	> 10	< 10
Lithuania 76.2	Slovakia 53.5	Ukraine 48.6	Switzerland 39.5	Japan 28.9	United Kingdom 17.9	Argentina 7.0
France 75.2	Belgium 51.7	Armenia 45.0	Slovenia 37.9	Germany 26.1	Russian Federation 17.8	Mexico 4.8
		Hungary 43.0	Bulgaria 35.9	Romania 20.6	Spain 17.5	South Africa 4.8
			Korea, Rep. of 34.8	United States 20.2	Canada 14.8	Netherlands 3.7
			Sweden 34.7			Brazil 3.0
			Czech Rep. 33.8			Pakistan 2.7
			Finland 32.9			India 2.2
						China 1.9

Source: <http://www.world-nuclear.org/info/reactors.html>

¹ <http://www.world-nuclear.org/info/reactors.html>.

Worker exposure to radiation in the world of work

The use of radioactive sources involves risks due to radiation exposure. Exposure to ionizing radiation occurs in many occupations. Artificial sources of radiation are commonly used in the manufacturing and service industries, in defence industries, in research institutions and universities, and in the nuclear power industry. They are extensively used by physicians and health professionals in diagnosis and in the treatment of diseases.

Some workers are also exposed to natural sources of radiation. This is particularly true of exposure to radon in mines and in ordinary workplaces in areas where radon levels are high. The dose limits are 20 mSv/year for occupational exposure (for workers engaged in radiation work) and 1 mSv/year for the general public (see Annex D).

Table 2. Global occupational exposures associated with artificial and natural sources of radiation

Industry	Number of workers monitored (2000–2002)	Average level of exposure (mSv/year)
Nuclear fuel cycle	660 000	1
Natural radiation	13 050 000	2.9
Coal mining	6 900 000	2.4
Other mining	4 600 000	3.0
Workplaces other than mines	1 250 000	4.8
Aircrew	300 000	3.0
Medical uses	7 440 000	0.5
Industrial activities	869 000	0.3
Military activities	331 000	0.1
Miscellaneous	565 000	0.1
Total	22 915 000	0.8

Note: "Nuclear fuel cycle" includes uranium mining, milling and enrichment, fuel fabrication, reactor operation, reprocessing and research; "natural radiation" includes civil aviation, coal mining, other mineral mining, oil and natural gas industries, and workplace exposure to radon other than in mines; "medical uses" includes diagnostic radiology, dental radiology, nuclear medicine, radiotherapy and all other medical uses; "industrial activities" includes industrial irradiation, industrial radiography, luminizing, radioisotope production, well logging, accelerator operation and all other industrial uses; "miscellaneous" includes educational establishments, veterinary uses and other occupations.

Source: United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR): Sources and effects of ionizing radiation, UNSCEAR 2008 Report, Vol. I (United Nations, New York, 2010).

With the exception of mining, average doses from most types of occupational exposure from artificial sources, including the nuclear industry, are now below 2 mSv per year. The dose in some mines could be much higher than the average doses shown in table 2. For example, in underground gold mines in South Africa the average annual dose in 2000 was 7 mSv and among the 123,333 workers in gold mines, 3,700 workers received doses above 20 mSv/year. The estimated average dose rate using individual monitoring for the mineworkers in Abu-Tartur phosphate mine tunnels is 15.55 mSv/year. While doses in the health professions – medical, dental and veterinary – are generally very low, some clinical procedures involving diagnostic radiology require the physician to be close to the patient and at risk of appreciable exposure. For example, the occupational dose per procedure (at thyroid level) for coronary angiography and percutaneous transluminal coronary angioplasty (PTCA) is 0.43 mSv, and for cardiac catheter ablation it is 0.28 mSv (left eye) and 0.2 mSv (thyroid). The annual effective doses incurred by positron emission tomography (PET) workers were reported to be 8 mSv.

About one fifth of the people considered to be occupationally exposed to enhanced natural radiation work in shops, offices, schools and other premises in radon-prone areas. Within these areas, the average dose is appreciable. The average dose for such workers is almost 5 mSv per year – higher than for the other groups of occupationally exposed workers.

Doses to aircrew from cosmic rays depend on the routes flown and the flying time. On average, the annual dose is around 3 mSv, but could be twice as much for long flights continually at high altitudes. By the nature of the radiation and the operations, such doses are unavoidable. With the relatively high dose rates experienced in air travel as a result of the elevated levels of cosmic rays at flying altitudes, some authorities consider that supervision is also required for aircrew.

The international regulation of the protection of workers against radiation

Radiation protection is part of the ILO's action on the protection of workers against sickness, disease and injury arising out of employment, as mandated by the Organization's Constitution. In

June 1960, the International Labour Conference adopted the Radiation Protection Convention, 1960 (No. 115), and its accompanying Recommendation (No. 114). The Convention applies to all activities involving the exposure of workers to ionizing radiations in the course of their work and provides that each Member of the ILO which ratifies it shall give effect to its provisions by means of laws or regulations, codes of practice or other appropriate means. So far, this ILO Convention has been the only international legal instrument on the protection of workers against radiation.

A basic principle expressed in Convention No. 115 and Recommendation No. 114 is that the exposure of workers to ionizing radiations shall be reduced to the lowest practicable level and that any unnecessary exposure should be avoided. Other requirements stipulated in Convention No. 115 include keeping dose limits for various categories of workers under constant review in the light of current knowledge and with “due regard” to the relevant international recommendations; fixing specific dose limits for different categories of workers, including workers aged 18 and over, workers under the age of 18, and workers not directly engaged in radiation work; and prohibiting workers under the age of 16 from working with ionizing radiations. A major contribution by the ILO to radiation protection is the promotion of the right of workers to safety and health while working with radiation, which includes participation, employer and worker cooperation, training and information.

In assessing compliance with these requirements, the ILO Committee of Experts on the Application of Conventions and Recommendations (CEACR) has frequently referred to current knowledge as embodied in relevant international standards and has developed principles in particular as regards the purpose and function of the dose limits, including exposure limits during and after an emergency and the provision of alternative employment to workers whose continued working with radiation is contra-indicated for health reasons.²

Convention No. 115 has been ratified by 48 countries.³ Of these, the following have nuclear power plants: Argentina, Bel-

² See in particular the 1992 General Observation on the application of Convention No. 115 by the CEACR – <http://www.ilo.org/ilolex/english/index.htm>

³ See <http://www.ilo.org/ilolex/english/index.htm>

gium, Brazil, Czech Republic, Finland, France, Germany, Hungary, India, Japan, Mexico, Netherlands, Russian Federation, Slovakia, Spain, Sweden, Switzerland, Ukraine and United Kingdom. A further four are planning and proposing to have nuclear power reactors: Egypt, Italy, Poland and Turkey.

Driven by a common interest to allow resources to be used effectively and prevent duplication of efforts, as well as to create synergy and maximize the impact of the relevant standards formulated separately by individual organizations, collaborations for internationally harmonized standards have been on the increase since the early 1960s. The ILO attaches importance to cooperation with other international organizations on the protection of workers against radiation through joint development and the preparation of international standards and guidance.

Together with other UN agencies, the ILO has actively taken part in the work of the Radiation Safety Standards Committee (RASSC) established by the International Atomic Energy Agency (IAEA). The ILO's participation in the RASSC ensures that employers' and workers' representatives and organizations participate directly in the formulation by the IAEA and other international organizations of international standards on radiation safety and on protection against occupational exposure to radiation. In the past, employers and workers did not have the opportunity to participate fully and systematically in developing the international standards which they were to apply.

An important outcome of the international cooperation in the field of radiation safety and protection has been the development of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), which build on earlier international recommendations by the International Commission on Radiological Protection (ICRP). The BSS are co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the IAEA, the ILO, the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), the Pan American Health Organization (PAHO) and the World Health Organization (WHO), and were formally published in 1996. The BSS provide a worldwide basis for harmonized radiation protection standards that complement ILO Convention No. 115. All the sponsoring organizations of the

BSS have worked closely in the harmonization and development of international standards and policies on radiation protection and safety, and have promoted the application of the BSS in their own fields of competence. Operations undertaken with the assistance of one of the other co-sponsoring organizations apply the BSS in the light of the relevant rules and regulations of the particular organization concerned. For the ILO, the BSS are used to support the implementation of Convention No. 115 and guide those whose duty it is to promote protection against occupational exposure to radiation at the national and enterprise levels. The BSS are also used by the ILO supervisory machinery to review and examine the application and implementation of Convention No. 115 and Recommendation No. 114 by member States.

Given their co-sponsorship by four United Nations (UN) specialized agencies and two international organizations, the BSS are regarded as “the” UN system requirements concerning radiation protection. The same is now true for Convention No. 115.

It is worth pointing out that the BSS are part of the IAEA safety standards. According to the established rules of the IAEA, its safety standards are binding on the IAEA in relation to its own operations and on countries in relation to operations assisted by the IAEA. The IAEA has been promoting these standards through its technical cooperation Model Project on Upgrading Radiation Protection Infrastructure in more than 100 countries. This Model Project helps member States to establish the infrastructure needed to adhere to the BSS. A concrete outcome of the IAEA Model Project is that the project countries have incorporated the BSS into their national laws, regulations and standards, providing a good basis to meet the requirements embodied in Convention No. 115 and Recommendation No. 114.

Within this framework of international cooperation, a variety of technical standards, requirements, guidelines, guides and technical documents have been developed. For example, the FAO and the WHO have established, through the Codex Alimentarius Commission, guideline levels for radioactive substances in foodstuffs moving in international trade. The WHO produces guidelines for drinking water quality that include criteria to assess safety with respect to radionuclide content. In the event of nuclear and radiological emergencies, both the IAEA and the WHO have a

role to play in providing technical assistance in relation to safety and health. In the field of the protection of workers (including emergency workers) against radiation, the IAEA and the ILO have jointly prepared a number of international guides on protection against occupational exposure to radiation, which include guidance on: protecting against occupational exposure to radiation in general; assessing occupational exposure, whether internal or external; protecting workers against radiation in the mining and milling of radioactive ores; controlling exposure to natural radiations at work; protecting emergency workers; monitoring the health of persons exposed to ionizing radiation at work; and protecting against radiation in hospitals and general practices. A more detailed listing of the IAEA/ILO joint publications can be found in Annex II.

Annex I

Excerpt from the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (1996, co-sponsored by the FAO, IAEA, ILO, OECD/NEA, PAHO and WHO)

Schedule II

...

Occupational exposure

Dose limits

- II-5.** The occupational exposure of any worker shall be so controlled that the following limits be not exceeded:
- (a) an effective dose of 20 mSv per year averaged over five consecutive years;³⁸
 - (b) an effective dose of 50 mSv in any single year;
 - (c) an equivalent dose to the lens of the eye of 150 mSv in a year; and
 - (d) an equivalent dose to the extremities (hands and feet) or the skin³⁹ of 500 mSv in a year.
- II-6.** For apprentices of 16 to 18 years of age who are training for employment involving exposure to radiation and for students of age 16 to 18 who are required to use sources in the course of their studies, the occupational exposure shall be so controlled that the following limits be not exceeded:
- (a) an effective dose of 6 mSv in a year;
 - (b) an equivalent dose to the lens of the eye of 50 mSv in a year; and
 - (c) an equivalent dose to the extremities or the skin³⁹ of 150 mSv in a year.

³⁸ The start of the averaging period shall be coincident with the first day of the relevant annual period after the date of entry into force of the Standards, with no retroactive averaging.

³⁹ The equivalent dose limits for the skin apply to the average dose over 1 cm² of the most highly irradiated area of the skin. Skin dose also contributes to the effective dose, this contribution being the average dose to the entire skin multiplied by the tissue weighting factor for the skin.

Special circumstances

- II-7.** When, in special circumstances,⁴⁰ a temporary change in the dose limitation requirements is approved pursuant to Appendix I:
- (a) the dose averaging period mentioned in paragraph II-5(a) may exceptionally be up to ten consecutive years as specified by the Regulatory Authority, and the effective dose for any worker shall not exceed 20 mSv per year averaged over this period and shall not exceed 50 mSv in any single year, and the circumstances shall be reviewed when the dose accumulated by any worker since the start of the extended averaging period reaches 100 mSv; or
 - (b) the temporary change in the dose limitation shall be as specified by the Regulatory Authority but shall not exceed 50 mSv in any year and the period of the temporary change shall not exceed five years.

Public exposure

Dose limits

- II-8.** The estimated average doses to the relevant critical groups of members of the public that are attributable to practices shall not exceed the following limits:
- (a) an effective dose of 1 mSv in a year;
 - (b) in special circumstances, an effective dose of up to 5 mSv in a single year provided that the average dose over five consecutive years does not exceed 1 mSv per year;
 - (c) an equivalent dose to the lens of the eye of 15 mSv in a year; and
 - (d) an equivalent dose to the skin of 50 mSv in a year.

⁴⁰ See Appendix I: the provisions for “alternative employment” set out in paragraph I-18 may be relevant.

Appendix V

Emergency exposure situations

Protection of workers undertaking an intervention

- V.27.** No worker undertaking an intervention³¹ shall be exposed in excess of the maximum single year dose limit for occupational exposure specified in Schedule II, except:
- (a) for the purpose of saving life or preventing serious injury;
 - (b) if undertaking actions intended to avert a large collective dose; or
 - (c) if undertaking actions to prevent the development of catastrophic conditions.

When undertaking intervention under these circumstances, all reasonable efforts shall be made to keep doses to workers below twice the maximum single year dose limit, except for life saving actions, in which every effort shall be made to keep doses below ten times the maximum single year dose limit in order to avoid deterministic effects on health. In addition, workers undertaking actions in which their doses may approach or exceed ten times the maximum single year dose limit shall do so only when the benefits to others clearly outweigh their own risk.

- V.28.** Workers who undertake actions in which the dose may exceed the maximum single year dose limit shall be volunteers³² and shall be clearly and comprehensively informed in advance of the associated health risk, and shall, to the extent feasible, be trained in the actions that may be required.
- V.29.** The legal person responsible for ensuring compliance with the foregoing requirements shall be specified in emergency plans.
- V.30.** Once the emergency phase of an intervention has ended, workers undertaking recovery operations, such as repairs

³¹ Workers undertaking an intervention may include, in addition to those employed by registrants and licensees, such assisting personnel as police, firemen, medical personnel and drivers and crews of evacuation vehicles.

³² If military personnel are involved, these requirements may not apply in some circumstances. Exposure of such personnel shall, however, be limited to ad hoc levels to be specified by the Regulatory Authority.

to plant and buildings, waste disposal or decontamination of the site and surrounding area, shall be subject to the full system of detailed requirements for occupational exposure prescribed in Appendix I.

- V.31.** All reasonable steps shall be taken to provide appropriate protection during the emergency intervention and to assess and record the doses received by workers involved in emergency intervention. When the intervention has ended, the doses received and the consequent health risk shall be communicated to the workers involved.
- V.32.** Workers shall not normally be precluded from incurring further occupational exposure because of doses received in an emergency exposure situation. However, qualified medical advice shall be obtained before any such further exposure if a worker who has undergone an emergency exposure receives a dose exceeding ten times the maximum single year dose limit or at the worker's request.

Annex II

ILO instruments and publications on the protection of workers against radiation

Radiation Protection Convention, 1960 (No. 115)

Radiation Protection Recommendation, 1960 (No. 114)

Employment Injury Benefits Convention, 1964 (No. 121)

Employment Injury Benefits Recommendation, 1964 (No. 121)

List of Occupational Diseases Recommendation, 2002 (No. 194)

Occupational Cancer Convention, 1974 (No. 139)

Occupational Cancer Recommendation, 1974 (No. 147)

ILO: *Encyclopaedia of Occupational Health and Safety*, 4 volumes (Geneva, fourth edition, 1998).

—: *Technical and ethical guidelines for workers' health surveillance*, Occupational Safety and Health Series No. 72 (Geneva, 1998).

—: *Radiation protection of workers (ionising radiations)*, an ILO code of practice (Geneva, 1987).

—: *Guidelines for the radiation protection of workers in industry (ionising radiations): Requirements for control of exposure to radiation of workers engaged in radiation work in specific installations and practices*, Occupational Safety and Health Series No. 62 (Geneva, 1989).

—: *Radiation protection in the mining and milling of uranium and thorium*, proceedings of a symposium organized by the ILO and the French Atomic Energy Commission, in cooperation with the WHO and IAEA and held in Bordeaux, France, 9–11 September 1974, Occupational Safety and Health Series No. 32 (Geneva, 1976).

Main publications jointly developed by the ILO and other international organizations

S. Niu, P. Deboodt and H. Zeeb (eds): *Approaches to attribution of detrimental health effects to occupational ionizing radiation exposure and their application in compensation programmes for cancer: A practical guide*, Occupational Safety and Health Series No. 73 (Geneva, ILO, 2010). Jointly prepared by the ILO, IAEA and WHO.

IAEA: *Arrangements for preparedness for a nuclear or radiological emergency: Safety guide*, Safety Standards Series No. GS-G-2.1 (Vienna, 2007). Jointly sponsored by the FAO, IAEA, ILO, OCHA, PAHO and WHO.

- : *Fundamental safety principles: Safety fundamentals*, Safety Standards Series No. SF-1 (Vienna, 2006). Jointly sponsored by Euratom, the FAO, IAEA, ILO, IMO, OECD/NEA, PAHO, UNEP and WHO.
- : *Regulatory control of radiation sources: Safety guide*, Safety Standards Series No. GS-G-1.5 (Vienna, 2004). Jointly sponsored by the FAO, IAEA, ILO, PAHO and WHO.
- : *Occupational radiation protection in the mining and processing of raw materials: Safety guide*, Safety Standards Series No. RS-G-1.6 (Vienna, 2004). Jointly sponsored by the IAEA and ILO.
- : *Preparedness and response for a nuclear or radiological emergency: Safety requirements*, Safety Standards Series No. GS-R-2 (Vienna, 2002). Jointly sponsored by the FAO, IAEA, ILO, OECD/NEA, PAHO, OCHA and WHO.
- : *Building competence in radiation protection and the safe use of radiation sources: Safety guide*, Safety Standards Series No. RS-G-1.4 (Vienna, 2001). Jointly sponsored by the IAEA, ILO, PAHO and WHO.
- : *Occupational radiation protection: Safety guide*, Safety Standards Series No. RS-G-1.1 (Vienna, 1999). Jointly sponsored by the IAEA and ILO.
- : *Assessment of occupational exposure due to intakes of radionuclides: Safety guide*, Safety Standards Series No. RS-G-1.2 (Vienna, 1999). Jointly sponsored by the IAEA and ILO.
- : *Assessment of occupational exposure due to external sources of radiation: Safety guide*, Safety Standards Series No. RS-G-1.3 (Vienna, 1999). Jointly sponsored by the IAEA and ILO.
- : *Radiation protection and the safety of radiation sources: Safety fundamentals*, Safety Series No. 120 (Vienna, 1996). Jointly sponsored by the FAO, IAEA, ILO, OECD/NEA, PAHO and WHO.
- : *International basic safety standards for protection against ionizing radiation and for the safety of radiation sources*, Safety Series No. 115 (Vienna, 1996). Jointly sponsored by the FAO, IAEA, ILO, OECD/NEA, PAHO and WHO.
- : *Radiation monitoring in the mining and milling of radioactive ores*, Safety Series No. 95 (Vienna, 1989). Jointly sponsored by the IAEA, ILO and WHO.
- : *Radiation protection of workers in the mining and milling of radioactive ores, 1983 edition: Code of practice and Technical addendum*, Safety Series No. 26 (Vienna, 1983). Jointly sponsored by the IAEA, ILO and WHO.

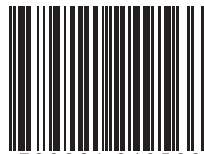
- : *Applying radiation safety standards in radiotherapy*, Safety Reports Series No. 38 (Vienna, 2006). Jointly sponsored by the ESTRO, IAEA, ILO, IOMP, PAHO and WHO.
 - : *Radiation protection against radon in workplaces other than mines*, Safety Reports Series No. 33 (Vienna, 2003). Jointly sponsored by the IAEA and ILO.
 - : *Health surveillance of persons occupationally exposed to ionizing radiation: Guidance for occupational physicians*, Safety Reports Series No. 5 (Vienna, 1998). Jointly sponsored by the IAEA, ILO and WHO.
- WHO: *Manual on radiation protection in hospitals and general practice*, Vol. 1: Basic protection requirements (Geneva, 1974). Jointly sponsored by the IAEA, ILO and WHO.
- : *Manual on radiation protection in hospitals and general practice*, Vol. 2: Unsealed sources (Geneva, 1975). Jointly sponsored by the IAEA, ILO and WHO.
 - : *Manual on radiation protection in hospitals and general practice*, Vol. 3: X-ray diagnosis (Geneva, 1975). Jointly sponsored by the IAEA, ILO and WHO.
 - : *Manual on radiation protection in hospitals and general practice*, Vol. 4: Radiation protection in dentistry (Geneva, 1977). Jointly sponsored by the IAEA, ILO and WHO.
 - : *Manual on radiation protection in hospitals and general practice*, Vol. 5: Personnel monitoring services (Geneva, 1980). Jointly sponsored by the IAEA, ILO and WHO.

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