

Důležitost kvantifikace radiačního rizika a jeho komunikace s obyvatelstvem týkajících se ochrany před dopady radioaktivních odpadů

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Souhrn

Článek se zabývá zajištěním dostatečné ochrany obyvatelstva před potenciálně nepříznivými účinky radioaktivních odpadů. To zahrnuje také zaměstnance specializovaných pracovišť zapojených do nakládání s takovými odpady, kde je třeba pozornost sběru, zpracování, fixaci, skladování a přepravě radioaktivního odpadu, stejně jako nároky na dočasná či trvalá uložiska těchto odpadů. Během celého tohoto procesu mohou být osoby, které manipulují s odpadem nebo se zdržují v jeho blízkosti, vystaveny ionizujícímu záření. Je to způsobeno jak vnějším ozářením, tak i radioaktivní kontaminací okolního prostředí. Všechny operace s radioaktivním odpadem musí splňovat platnou národní legislativu a mezinárodní normy. Komunikace potenciálních rizik pro veřejnost hraje důležitou roli při zajištění ochrany osob, zejména těch, které nemají žádné nebo omezené znalosti základní radiační ochrany. Bez dostatečné informovanosti populace mohou být dopady v této oblasti buď podceňovány, nebo zbytečně přehnané, což může vyvolat nežádoucí paniku nebo chaos.

Klíčová slova: kvantifikace rizika, komunikace rizika, ionizující záření, radionuklidy, radioaktivní odpady, uložiska, ochrana osob.

The importance of radiation risk quantification and its communication with the population regarding protection against the impacts of radioactive waste

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Summary

The paper concerns the provision of adequate protection for the population against the potentially adverse effects of radioactive wastes. This also includes employees of specialised workplaces involved in the management of such wastes, where the collection, treatment, fixation, storage and transport of radioactive wastes, as well as temporary or permanent storage facilities must be considered. Throughout this process, persons handling or in contact with waste can be exposed to ionising radiation. It is mainly due to external exposure, but in some cases, the surrounding environment may be contaminated, leading to internal exposure as well. All radioactive waste operations must comply with applicable national legislation and international standards. Communication of potential risks to the public plays an important role in ensuring the protection of persons, especially those with no or limited knowledge of basic radiation protection. Without sufficient information of the population, the impacts in this field may be underestimated or overestimated, leading to unnecessary panic or chaos.

Keywords: risk quantification, risk communication, ionising radiation, radionuclides, radioactive waste, repositories, protection of persons.

1. Introduction

Any close contact with radioactive materials, inhalation of contaminated air, or ingestion of contaminated food may result in radiation exposure for the persons involved. Work involving any radiation sources or substances containing radioactive materials should be carried out in accordance with strict safety and security requirements consistent with national and international standards. Under normal conditions, the main aim of radiation protection is to minimise the impact of radiation on exposed persons' health. In this case, the exposure must not exceed the regulatory dose limits.

The other target of radiation protection is to prevent any accident which may lead to overexposure. If such a situation occurs, all possible measures should be taken to minimise the impact of radiation exposure and return the situation back to normal, controllable conditions.

These constraints should also apply to handling radioactive waste, which includes any materials (solid, liquid, or gas) containing radionuclides, for which no further use is foreseen, and that are produced by nuclear power generation, nuclear facilities decommissioning, spent fuel processing, uranium mining, medical treatments, industrial processes, or research. Here, personnel in contact with such waste may be exposed, but the exposure is monitored and kept below relevant dose limits. During the whole process, some radioactivity may be released into the external environment, normally in a controlled manner, which may slightly contaminate the surrounding areas and, in this way, contribute to additional population exposure. In rare extreme cases, an accident or, in principle, also a terrorist attack, involving excessive release of radioactivity from waste, may occur. In such an emergency, appropriate actions by local radiation workers and, if necessary, by outside specialists trained to handle such situations should be taken.

The radiation situation should be monitored and evaluated continuously to ensure compliance with regulatory requirements, which are expressed in specific quantities and units [1,2]. Radiation exposure quantification is important for monitoring, assessing, and reporting on the radiation situation related to the waste itself and to possible radioactive contamination of the environment. The radiation protection quantities and units are also very important for communicating radiation risk to the public, who should be appropriately informed to protect themselves and cooperate with the radiation workers and emergency units involved. The quantification of radiation risk and its effective communication are cornerstones of radiological protection, particularly when managing the long-term hazards associated with radioactive waste.

2. Radiation risk quantification

Risks of exposure to radioactive waste arise from radiation emitted by radionuclides present in the waste. These exposures may result in health effects, including both stochastic (probabilistic) effects at low doses and deterministic (tissue reactions) effects at doses above a certain threshold level.

In general, in the case of CBRN (Chemical, Biological, Radiological, Nuclear) agents, the risk due to radiation emitted by radionuclides is much better known and quantified than it is in the case of C or B components. This is mainly because great attention was paid in the past to radioactive and nuclear sources, reflecting the interest in this area, which was influenced mainly by events and applications of the relevant technologies. To determine the radiation-related health effects, significant epidemiological studies have been carried out, particularly in the following groups of people [2,3]:

- a) Survivors of the atomic bombing of Hiroshima and Nagasaki in Japan towards the end of the 2nd World War;
- b) Patients exposed to radiation for the purposes of diagnosis and therapy;
- c) Occupationally exposed individuals (e.g. the uranium miners' cohort);
- d) People living in the vicinity of nuclear facilities where accidents have happened;
- e) People living in the vicinity of damaged nuclear power plants (especially accidents in Chernobyl and Fukushima) and individuals deployed in clean-up operations; and
- f) Individuals affected by above-ground nuclear weapon tests.

The health risk from the above-mentioned events, in addition to some deaths due to very high exposure, primarily included the initiation of such diseases as cancer and hereditary radiation damage.

In quantifying radiation risks and health effects, it is important to distinguish between external and internal radiation, as well as between the quantities and units used to assess stochastic and deterministic effects.

The main currently used quantities for assessing the stochastic effects of external radiation are shown in Fig. 1 [5]. More details can be found in the respective literature and publications (for example, [6,7]). The unit for dose equivalent related quantities is Sv (sievert), while for the dose it is Gy (gray).

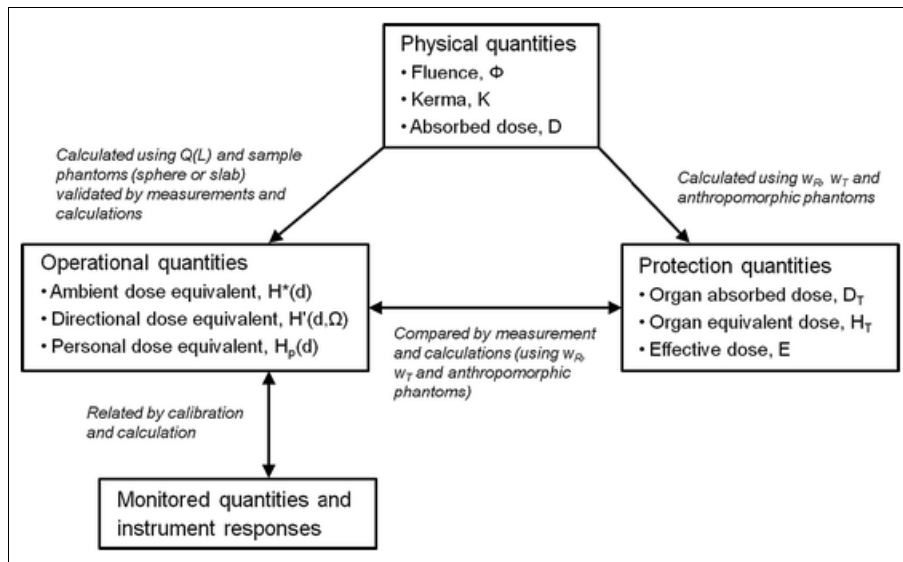


Fig. 1. Physical quantities, protection quantities and operational quantities used for the assessment of external exposure.

While quantities for the reflection of stochastic effects are well elaborated and available in a few modifications, deterministic effects are not. The quantity for these effects is *RBE-weighted dose*, defined as the dose multiplied by RBE (Relative Biological Effectiveness). The unit of this quantity is Gy-Eq (gray-equivalent). We should be aware that the unit Sv cannot be used for deterministic effects and is limited to an effective dose below 1 Sv.

Another problem in radiation protection is evaluating internal exposure, which requires accounting for the radionuclide's half-life.

Radiation monitoring in radiation protection is the systematic measurement of radiation doses or contamination to assess and control exposure for people and the environment. It involves using devices such as personal dosimeters (film badges, thermoluminescent dosimeters - TLDs) and area monitors to ensure exposure stays within safe regulatory limits, as recommended by the ICRP and IAEA.

According to the regulatory authorities, the radiation levels in terms of basic dosimetry quantities should be measured using appropriate dosimeters and monitors. There are three main types of radiation monitoring:

- 1) **Personnel Monitoring:** Evaluates radiation doses received by individuals working with radiation sources. It typically involves wearing personal dosimeters, such as film badges, TLDs, or pocket dosimeters, to track cumulative exposure, especially for staff in the medical or nuclear sectors.
- 2) **Area Monitoring:** Assesses radiation levels at specific locations in the vicinity of a radiation source to confirm the adequacy of protection measures.
- 3) **Environmental Monitoring:** Measures radioactivity in the environment to ensure compliance with standards and protect the public.

In some cases, including the evaluation and monitoring of the exposure to the public coming from releases of radionuclides from radioactive wastes, many places have to be monitored to get the results, based on which one can map the movement of radioactive substances and thus assess the exposure to persons affected Fig. 2 [8].

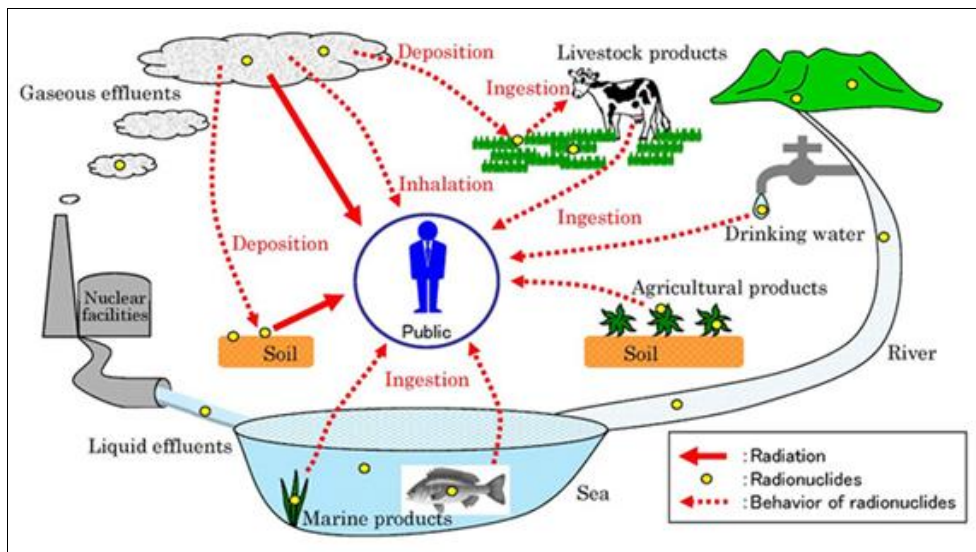


Fig. 2. Pathways illustrating the movement of radionuclides released from such radioactive sources as radioactive waste or nuclear power plants.

3. Radiation risk communication

Every day, radiation health physicists, technicians, and physicians are expected to communicate effectively with concerned people who may be affected by radiation exposure, yet they are usually not adequately trained in how to do so and what to expect in terms of possible consequences. Radiation professionals can use their knowledge and expertise in radiation science while adapting their instruction, presentations, and communication styles to meet the needs and the background of each audience: from scientists to concerned citizens, from doctors to first responders, and beyond.

Much radiation communication with the public occurs because someone is concerned about their own or a loved one's health. Only occasionally do people want to know their personal risk from a specific exposure. The desire for personalised information isn't swayed by the fact that the risk estimate is based on population statistics and, at low doses, on the linear non-threshold model. Our ability to communicate radiation risk is further hampered by the fact that individuals in a high-stress situation typically have difficulty hearing and remembering information and tend to focus on negative news. This may be different for the patients undergoing radio diagnostic examinations or radiotherapy treatments, who usually trust the medical doctor and ask no questions.

In general, because the ability to absorb information is hindered in high-stress situations, it becomes crucial to communicate thoughtfully so that the information is received as intended. In the same way that medical treatment is tailored to a patient, information needs to be tailored to the recipient as well. Before one starts communicating. A simple way to improve radiation communication is to take an active interest in the person on the receiving end. To facilitate the whole process, it is important: (1) to understand how your audience prefers to get their information, (2) to identify your intended outcome, and (3) to decide on the communication techniques that will be most effective.

Efficient radiation risk communication requires clear, honest, and timely information that addresses public fear and uncertainty while explaining technical data in understandable terms. It bridges scientific expertise and societal needs, often utilising analogies (e.g., medical imaging vs natural background) to build trust, reduce anxiety, and promote protective actions.

In the communication process, it may be useful and helpful if the speakers contribute to the discussion of radiation exposure from all important sources, many of which cannot be controlled (e.g., cosmic radiation, natural radioactivity, etc.). One must also stress the real development in this field, where population radiation exposures are rising due to the expansion of its ever-growing applications, especially in medicine. This is illustrated in Fig. 3 [9], which reflects the rise in radiation exposure in the USA. However, similar situations are, or can be expected, in most industrialised countries.

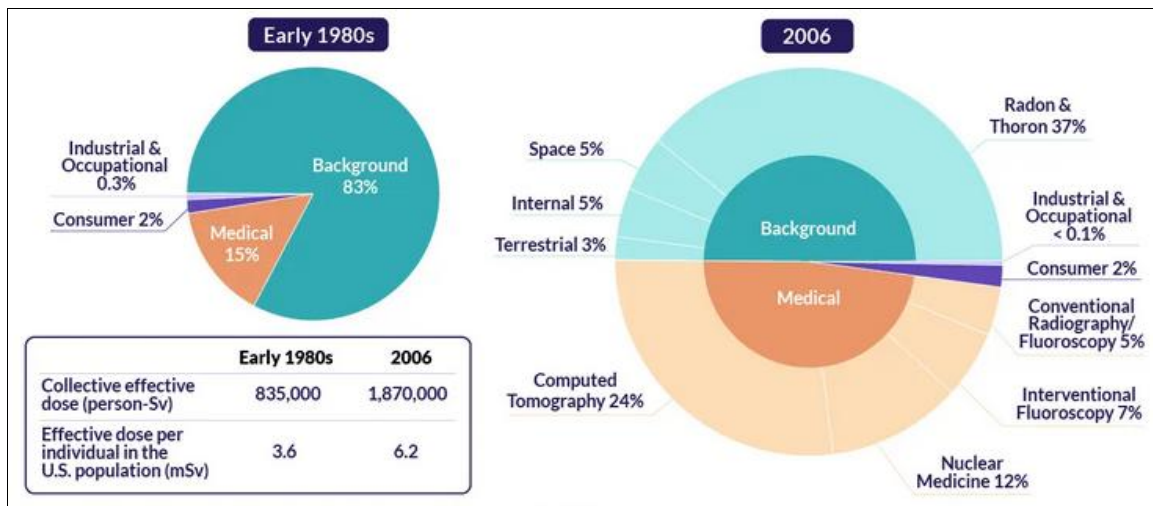


Fig. 3. The rise of population exposure in the USA in the period of 1980-2006.

In communication with the lay public, it is usually not possible to use specialised terminology, including definitions of quantities and units, but it is sufficient to depict the situation adequately by providing an appropriate example of the contribution to exposure from different sources. They may be compared as percentages, as in the picture above.

Sometimes we may even use special units used in radiation protection, but it is not necessary to bother the population with physical or biological details. It would be enough to compare the contributions to exposure from different sources in the relevant units. The most important thing is that people can compare exposure from different sources and thus recognise which of these sources are more dangerous than others. This can also be applied to the information about exposure potentially originating from radioactive waste.

Another good example of how to present and interpret exposure from other source types is the overview of the contribution to population doses from cosmic radiation (Fig. 4).



Fig. 4. Annual doses at various levels from cosmic radiation [9].

4. Conclusion

Radioactive waste management and radiation protection aim to protect people and the environment from ionising radiation by ensuring the safe handling, processing, and disposal of radiation sources and radioactive materials that are no longer in use. Waste should be separated by level and parameters of radioactivity, stored for decay, and handled in accordance with ALARA (As Low As Reasonably Achievable) principles. In environmental remediation (e.g., decontamination of land) in contaminated areas, the generation of radioactive waste that must be managed appropriately under radiological protection is inevitable and should be regarded as integral to this process.

Key issues in establishing a framework for radiological protection in radioactive waste management under existing exposure conditions are discussed, with reference to related ICRP recommendations. Radioactive waste arises from many useful applications of radioactive substances in medicine, industry, and research. Moreover, radioactive waste also arises during the dismantling (decommissioning) of nuclear power plants that are no longer in use. They must be treated appropriately, and all radioactive and nuclear materials must be disposed of in accordance with the relevant safety and security requirements.

Všechny země, které produkují vysokoaktivní odpady a vyhořelé jaderné palivo, se o tyto materiály musí postarat samy. Hlubinné úložiště je celosvětově považováno za nejbezpečnější způsob, jak zneškodnit vysokoaktivní odpady a vyhořelé jaderné palivo. Také Česká republika směřuje k jeho výstavbě.

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