

Facts about Radiation Risk Related to Bioengineering: Awareness of the Public by Passing on Relevant Information

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Abstract The paper deals with the radiation risk in perspective with the other risks we encounter in our everyday lives. It emphasizes the health impact associated with bioengineering imaging techniques based on the use radiation generators or radiopharmaceuticals. Some aspects, important for the realistic perception of the actual and realistic magnitude of radiation hazards, which are usually largely exaggerated by the public, are discussed. In addition, some facts based on a comparison of different risks in order to neutralize possible psychological impact caused by radiophobia are also outlined.

Keywords Radiation Exposure, Risk, Bioengineering, Population Protection

1. Introduction

The use of ionizing radiation (further only radiation) in medicine, and specifically in bioengineering, has steadily been increasing, and thus resulting in a considerable escalation of radiation exposure to members of the public. The average population exposure from numerous applications of radiation and nuclear based technologies is mainly due to the radiation imaging associated with examinations of patients aimed at obtaining appropriate diagnostic information. The contribution from other radiation/nuclear applications in industry and other areas, including the operation of nuclear power plants, under normal conditions is by far lower than that attributed to the medical use of radiation and radionuclides.

However, the public perceives nuclear energy as something too dangerous and characterized by very high risks. This is why in many countries there are groups, and even political parties, which are ready to fight against nuclear installations, unaware of or ignoring the fact that it is the medical field that is largely responsible for their radiation

exposures, and these have to be strictly controlled and optimized.

2. Radiation Exposures from Various Sources and Activities

Mankind has continuously been exposed to natural radiation, which includes the contribution from solar and cosmic radiation, radiation emitted from the earth's crust, radon, and internal radiation from radionuclides present in certain concentrations in the foods we eat and the water we drink. In fact, radiation and radioactivity are essential aspects of our normal life, where all radiation exposure due to man-made sources should be regularly monitored and regulated in such a way that their detrimental impacts are kept to the very minimum, but, at the same time allowing these applications since in many cases they are extremely beneficial.

Following the discovery of X-rays, radioactivity and other radiation sources such as accelerators and nuclear reactors, their applications added some exposure not only to personnel and patients but also to the general population. By and large, the highest contribution from these man-made sources is due to the medical field, where radiation and radionuclides are widely used, especially in medical imaging as one of the main modalities of bioengineering techniques.

The radionuclides present in our environment can cause both internal and external exposure. Internal exposure is received as a result of the intake of radionuclides where the major routes for members of the public are the ingestion and inhalation of the radionuclides present in some concentration in the food chain. Consequently, ingestion includes the intake of the radionuclides present in drinking water and milk, and the consumption of food products. Inhalation is mainly associated with the intake of radionuclides through breathing radioactive materials which are usually deposited on dust particles and are present in aerosols.

Under normal conditions, one encounters rather relatively low exposures where only stochastic biological effects are expected. The effective dose has been introduced to quantify these effects, which are manifested by the occurrence of additional cancer cases among exposed persons. This quantity is defined as follows

$$E = \sum_T w_T \sum_R w_R D_{R,T}$$

where $D_{T,R}$ is the average dose from radiation R in the tissue or organ T and w_R and w_T are the radiation weighting and tissue weighting factor, respectively [1,2].

The effective dose includes the contributions from both external radiation and internal exposures. The unit of the effective dose is *sievert* (Sv), which is the measure of the probability of developing cancer with the risk corresponding to $5.5 \times 10^{-5} \text{ mSv}^{-1}$ [3]. Such a risk may be very low for an individual but cannot be neglected for larger numbers of exposed persons. This can be illustrated by about 55 additional cancer cases among 1 million persons who have received an effective dose of 1 mSv each.

To put it in perspective, in a group of 1 million persons exposed to 1 mSv there will be more than 200,000 cases of cancer anyway, since the spontaneous cancer rate in the population is usually higher than 20-25%. This means that at least 1 person out of 4 will sooner or later develop cancer due to many other pollutants or factors other than radiation itself.

It has to be emphasized that the effective dose can only be used for low level exposures. On the other hand, as long as the exposure exceeds a certain threshold (relatively high doses), the occurrence of deterministic effects is observed, where all exposed persons will be affected with the probability of 100%. This cannot happen in normal or planned situations but rather in the case of incidents, accidents or radiological terrorist attacks. The assessment of the exposure in such emergency situations is usually expressed in terms of the absorbed dose in *grays* (Gy) where a whole-body dose of around 4 Gy is associated with the death of 50% of persons exposed.

As has already been mentioned, we are all exposed to a certain radiation background which in the Czech Republic amounts to about 3.5 mSv per year. The individual components of natural and man-made radiation exposure are illustrated in Fig. 1 (based on the assessment of the National Radiation Protection Institute [4]).

The public has to be able to distinguish between the two types of exposures discussed above, the impact of which is characterized by different quantities: the effective dose (in Sv) and the absorbed dose (in Gy). Any use of radiation or nuclear technologies is subject to the control by the pertinent national regulatory authorities, which usually follow relevant international standards developed by such expert bodies as the International Commission for Radiological Protection (ICRP) [5] and the International Atomic Energy Agency (IAEA) [6]. Their recommendations are accepted worldwide and serve as a basis for national radiation protection regulations. In the Czech Republic, the State Office for

Nuclear Safety (SONS) [7] is responsible for both radiation protection and nuclear safety. The SONS regularly informs the public about the radiation situation in the country, including incidents or any unusual radiation situations.

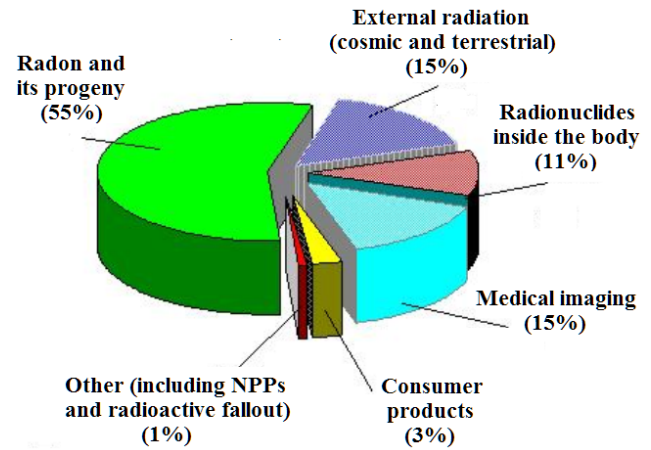


Figure 1. The assessment of the annual average population exposure in the Czech Republic in terms of the effective dose (external radiation components: cosmic radiation 7%, and radiation from soil, rock and building materials 8%, NPPs – nuclear power plants).

3. Radiation Risk vs. other Risks

The radiation risk is only one of many phenomena which can affect our life in terms of its shortening. Table 1 illustrates some comparison between the risk due to radiation exposure and some common types of risks related to other routine activities.

Table 1. Estimated Days of Life Expectancy Lost from Various Risk Factors (Based on [8-10]).

Industry type or activity	Estimated days of life expectancy lost
20 cigarettes a day	2,400 d
Overweight by 20%	1,000 d
Mining and quarrying	200 d
Construction	300 d
Agriculture	250 d
Motor vehicle accidents	200 d
Home accidents	90 d
All industries	60 d
Radiation – 3.5 mSv/y for 30 y	50 d
Radiation – 1 mSv/y for 70 y	35 d
Medical radiation (average)	6 d

It is obvious that the risk caused by radiation exposure is highly overestimated by members of the public, and this overestimation may result in a negative perception of anything related to atomic or nuclear physics, which may lead even to some psychological implications. This is why it is important to talk to the public and explain the real magnitude of exposure to radiation by carefully chosen means of communication so that the population will understand the real danger from radiation rather than to identify it as something extremely hazardous, as is usually portrayed by the mass media.

One has to realize that the average effective dose to the population from major sources of exposure is going up rapidly and in some developed countries this exposure is approaching the exposure due to natural sources. This trend is caused mainly by the very intensive use of radiation imaging techniques which may not always be fully justified. It is no secret that many radiation protection specialists consider more than 30% of medical imaging procedures as unnecessary or not absolutely justified[11]. The population is for the most part unaware of the medically oriented exposures, some of which are characterized by rather high effective doses (even exceeding 20 mSv per examination) but the public usually shows much greater concern when it comes to the impact of the use of nuclear energy, where the exposure under normal circumstances is trivial (less than 10 μ Sv per year).

The perception of the risk due to the medical use of radiation is completely different when comparing it with what the population thinks about the possible impact of nuclear power plants. On the other hand, some patients insist on being examined by CT and other high-dose radiation diagnostic modalities because they feel that they receive better treatment and it is good for them.

Of course, as everywhere, accidents have happened and obviously (with a certain rate) will happen in the future. With respect to the medical use of radiation, patients know very little about the possible severe harm resulting from the violation of safety rules, software flaws, faulty programming, and inadequate staffing and their qualifications and training. Medical accidents in terms of overexposures are especially serious in radiotherapy, where every year several patients are exposed unintentionally to fatal doses. Even in medical imaging involving radiation, there have been accidents resulting in some severe health detriments due to overexposure[12].

4. Preparation of the Public to Understand Protection Measures Aimed at Minimizing Radiation Risk

It is well known that a successful campaign to educate the population about radiological risk must begin with scientifically credible and easily understandable explanations of potential hazards arising from radiation exposure and radioactive contamination. One has to transfer to the public the message that radiation is invisible and odorless and can only be detected using specialized equipment which is used by professionals to keep exposure as low as reasonably achievable (the so-called ALARA radiation protection principle) and in any case below dose limits or reference levels established by relevant national regulatory bodies.

People have to distinguish between normal situations where the radiation exposure is in the range of several mSv and emergency events when the exposure may be much higher due to direct external exposure or internal radioactive

contamination. Basically, external exposure here means that a person has come close enough to a radioactive source or material to have received a possibly harmful dose of radiation, but the exposure affects only the person exposed and does not present any threat to anyone else.

On the other hand, radioactive contamination means that the radioactive material (typically in the form of dust) is still present on the person's skin or clothing, in body orifices (ears, nose, and mouth) or wounds, or internally (via damaged skin, inhalation, or ingestion). In this case persons around and especially those in close contact are also exposed to some radiation levels (for example, patients going through therapy treatment using radiopharmaceuticals).

Basic knowledge about protection against external and internal exposures is especially important in the event of any radiological accident or the use of a radiological dispersive device (dirty bomb). The external radiation dose can be reduced by lessening the time a person was in the presence of radioactive material (twice as long = double the dose), the distance from the source (the dose drops sharply with the distance: double the distance = reduction of the dose by 25%), and the shielding (with more and denser layers of material reducing the dose progressively due to the penetration of radiation). Protection against internal exposure relies primarily on the prevention of radioactive material entering the body through the use of some effective simple means such as respirators or even ordinary pieces of cloth that can filter the air before it enters the nose or mouth.

The public should be aware of some previous radiation and nuclear emergencies in order to learn lessons from past events. A good scenario in case of an accident involving the spreading of a powerful radioactive source may resemble the situation following the radiological event in Goiania, Brazil, in 1987 [13]. The accident was caused by a discarded radiotherapy Cs-137 source and resulted in 4 deaths, more than 200 individuals heavily contaminated and about 5,000 individuals who developed psychosomatic symptoms that mimicked symptoms characterized by radiological exposure.

There have even been some other more serious nuclear accidents, namely at the Chernobyl NPP in 1986 and recently at the Fukushima NPP complex in 2011. Each of those or similar radiation/nuclear disasters have been scientifically evaluated and, as a result, much stricter safety and security standards have been adopted worldwide.

At the same time, however, the public should trust the relevant regulatory authorities and be convinced that they do whatever is possible under the circumstances to mitigate the consequences of any radiological emergency.

5. Conclusion

It is evident that, in addition to the requirements regarding a high level of education and training of the personnel handling radiation sources and operating nuclear installations, the public should also be informed about and familiar with the basic aspects of radiation protection in

order to assess and perceive the associated risk realistically and in a context with other risks encountered in our everyday life or at work. Communication with the public is an essential part of the activities of regulatory authorities and other institutions engaged in providing information, education and training related to the field of radiation and nuclear safety and security. It is important to familiarize the public with the difference between natural background radiation exposure and the exposure due to man-made radiation sources used in medicine and industry. It is also equally vital to assist the public in understanding the difference between a normal (planned) situation, where the risk is normally trivial, and a relatively very rare emergency situation, which may result in visible and distinguishable health effects requiring immediate response. Experience clearly shows that an informed public behaves more rationally and is better prepared to cooperate with emergency and rescue workers in the event of any situation where high radiation exposure or severe radioactive contamination of the environment may occur. The experience from the Chernobyl and Fukushima nuclear accidents revealed that concern over radiation exposure may cause severe psychological trauma and distress, the impact of which is lower in properly informed persons than in those who do not know anything about radiation and its biological effects.

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