Public Health England

Protecting and improving the nation's health

Risks from land contaminated with radioactivity

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Introduction

In some parts of the UK land has been contaminated with radioactivity, mainly from historical industrial activities (Oatway, 2020). To manage the risks posed by such land, the UK government introduced legislation in 2006. The objective of this legislation, collectively known as the radioactive contaminated land regime, is to provide a system for the identification and remediation of land where levels of radioactivity in that land, above that which is present naturally, is causing unacceptable risks.

Effective communication of the risks posed by radioactive contamination of land is important to ensure that appropriate decisions are made with regards to managing those risks, and that those decisions are accepted by all stakeholders. To help with that process, this document provides information to put the risks from radiation in general, and from radioactivity in or under land in particular, into perspective. The information in this document is aimed at all stakeholders who may be affected by land which is contaminated with radioactivity.

The risk to health from radiation

When ionising (high energy) radiation passes through the tissues of a living organism some of its energy is lost. The amount of energy deposited in tissues is known as the "absorbed dose" and is given in units of the gray (Gy). Any energy deposited by the radiation as it passes through a tissue has the potential to cause damage to cells that make up that tissue, including to the DNA within those cells.

At high levels of absorbed dose, the damage caused to cells may be sufficient to kill those cells. When a substantial amount of cell death occurs the ability of the associated tissue to function properly may be impaired. At very high doses, the damage caused may lead to the death of the person. For damage to a tissue to occur, the dose received must be higher than the threshold dose for that tissue. Studies have shown that no significant damage to any tissue in the human body occurs when the absorbed dose is below 0.1 Gy.

If the radiation dose received is below the threshold for severe tissue damage then cells are not killed but they may still show signs of being damaged by the radiation. Of particular importance is damage to the DNA within cells. Although cells do have a very effective mechanism for repairing DNA, mutations affecting the DNA can set the cell on a path towards uncontrolled proliferation that may lead to cancer. However, radiation is not the only mechanism that can damage DNA and cause cancer to develop. Damage to DNA can occur spontaneously, from exposure to certain chemicals or from exposure to some infections. Exposure to radiation therefore only results in an increase in the frequency of normal or spontaneous mutations rather than the production of unique mutations.

As the processes of cell damage by radiation and the effectiveness of subsequent cell repair are both random, the health effects from exposure to low levels of radiation are referred to as “stochastic effects”. This is because, even if the magnitude of the dose received is known, it is impossible to predict precisely if or when any health effect, like cancer, may arise.

The effect of ionising radiation exposure on the long-term risk of developing cancer has been studied for many years. The main studies to date have focussed on the atomic bomb survivors in Hiroshima and Nagasaki, on people exposed to ionising radiation for medical reasons, and on those who have received a radiation dose due to their occupation. Based on the results of those studies it is assumed that there is a linear relationship between the level of dose received and the probability that cancer will develop. This is known as the linear no-threshold (LNT) hypothesis. A consequence of the LNT hypothesis is that any level of radiation exposure has an associated risk of developing cancer; the system of radiation protection and the related regulations are based on this assumption.

Different types of radiation, such as alpha and beta particles and gamma rays, deposit energy at different rates as they pass through a tissue, which in turn affects the potential for each type of radiation to cause damage. The quantity used to describe the absorbed dose weighted by harmfulness of the radiation is called the “equivalent dose” and has the unit of the sievert (Sv). In addition, as each tissue is made up of different types of cells, each tissue has a different level of sensitivity to radiation. The quantity used to describe the absorbed dose weighted by both radiation harmfulness and tissue sensitivity is called the “effective dose” whose unit is also the sievert (Sv).

The effective dose is not a quantity which can be measured directly. Instead, it is a quantity that is used to give a broad indication of the detriment to health from stochastic effects due to being exposed to radiation regardless of the energy and type of radiation involved. Another advantage of expressing the radiological impact in terms of effective dose is that the effects of exposure from different pathways, for example the ingestion or inhalation of radioactivity or irradiation from a source of radioactivity located outside of the body, can be summed together.

As well as the possibility of causing cancer in the exposed individual, mutations to genetic material could potentially be passed on to future generations. However, as there is no direct evidence of radiation-induced heritable effects in humans, this genetic risk is judged to be considerably lower than the risk of the exposed individual developing cancer (ICRP, 2007). Heritable effects are therefore not discussed further.

The risk to health from land contaminated with radioactivity

The system of radiological protection, which provides the framework for the radioactive contaminated land regime, aims to prevent serious injury by keeping doses below thresholds where severe tissue damage occurs whilst limiting the risk of stochastic effects (ICRP, 2007). The guiding principles of the system of radiological protection are justification and optimisation. With respect to land contaminated with radioactivity, the principle of justification recognises that any remediation may bring about a reduction in dose and other harmful impacts, including anxiety and blight, but may incur costs and other adverse effects including to the environment and to those involved in the remediation. For remediation of land contaminated with radioactivity to be justified, any action taken must do more good than harm.

Once it has been decided that remediation should be undertaken, a process of optimisation ensures that that the form, scale and duration of any remedial work maximises the benefit gained against any detriment caused. This process ensures that for the prevailing conditions, including those associated with economic and social factors, doses are as low as are reasonably achievable (ALARA).

Land can be determined as being contaminated if the whole body effective dose to someone using that land, from the contaminating radioactivity, exceeds 3 mSv per year[1]. To put this dose into context, the annual average effective dose to someone living in the UK from exposure to all sources of radiation, including naturally occurring sources of radiation, is estimated to be about 2.7 mSv (Oatway et al, 2016). Someone who is exposed to a dose at which land could be designated as being radioactively contaminated would therefore receive about double the average annual dose received by someone living in the UK. Table 1 provides a summary of typical doses received by people in the UK from different sources of radiation.

In England and Wales, land can also be legally designated as being contaminated if the estimated equivalent dose to the lens of the eye or to the skin of an exposed individual is greater than 15 mSv or 50 mSv per year respectively. Specific dose criteria for the lens of the eye and the skin are used to prevent the occurrence of damage to those organs as they are thought to be the organs most at risk from

[1] This criterion assumes exposure to a homogeneous source of radioactive contamination. Where the contamination is heterogenous, or where exposure to the contamination is not certain to occur, other criteria exist that require accounting for the probability that lasting exposure will occur.

exposure to radionuclides in land. For comparison, regulation for controlling the dose to those who work with radiation, for example medical staff, limits exposure to the lens of the eye or to the skin to an equivalent dose of 20 mSv per year and 500 mSv per year respectively.

Table 1 Typical dose from exposure to different sources of radiation

Source of exposure	Effective dose
Dose from a single dental x-ray	0.005 mSv
Dose from a single transatlantic flight	0.04 mSv
CT scan of the head	1.4 mSv
Average annual dose from naturally occurring radiation in the UK	2.3 mSv
Average annual dose from all sources of radiation in the UK	2.7 mSv
Annual dose used to define radioactive contaminated land	**3 mSv**
Average annual dose from all sources of radiation in the USA	6.2 mSv
CT scan of the chest	6.6 mSv
CT scan of the whole spine	10 mSv

The concept of risk

The International Commission on Radiation Protection (ICRP) has derived a nominal risk factor, based on epidemiological data, that relates the magnitude of the effective dose received to the risk that a stochastic health effect may arise (ICRP, 2007). This factor can be used to estimate the probability of developing cancer from exposure to a certain level of radiation. It should be borne in mind that this is a statistical relationship and does not necessarily apply to any specific individual.

The Health and Safety Executive (HSE) has defined levels of risk of death that they consider to be “acceptable”, “tolerable” and “unacceptable” (HSE, 2001). Unacceptable risks are those that the HSE would aim to prevent occurring regardless of the benefits that incurring such a risk might bring. At the other end of the scale, acceptable risks are those that people would generally regard as insignificant or trivial in their daily lives and are typical of the risk from activities that are inherently not very hazardous or from hazardous activities that can be, and are, readily controlled to produce very low risks. Although acceptable risks are very low, duty holders are expected by HSE to reduce those risks further wherever it is reasonably practical to do so or where the law requires it. Between those risks considered to be acceptable and unacceptable are those that the HSE considered to be tolerable. Tolerable risks are those the HSE expects measures to be employed to reduce those risks further whilst recognising that excessive regulation is unlikely to be warranted.

The HSE believes that an individual risk of death of one in a million per annum corresponds to a very low level of risk that could be used as a guideline for the boundary between broadly acceptable and tolerable levels of risk. For the boundary between tolerable and unacceptable risk of death, the HSE suggest a value of 1 in 10,000 per annum for members of the public who have a risk imposed on them. This is shown schematically in Figure 1. For comparison, an annual effective dose of 3 mSv corresponds to a risk of fatal cancer developing of about 1 in 6000 per annum; this level of risk lies within the unacceptable region of the HSE tolerability of risk framework and hence the source of that exposure, in this case radioactive contamination of the ground, is subject to regulatory control. Where contamination of the environment results in annual doses below 3 mSv, the associated risks will lie within the tolerable region of the risk framework; management of those risks is therefore less stringent although the use of simple and inexpensive measures to reduce those risks further will always be encouraged.

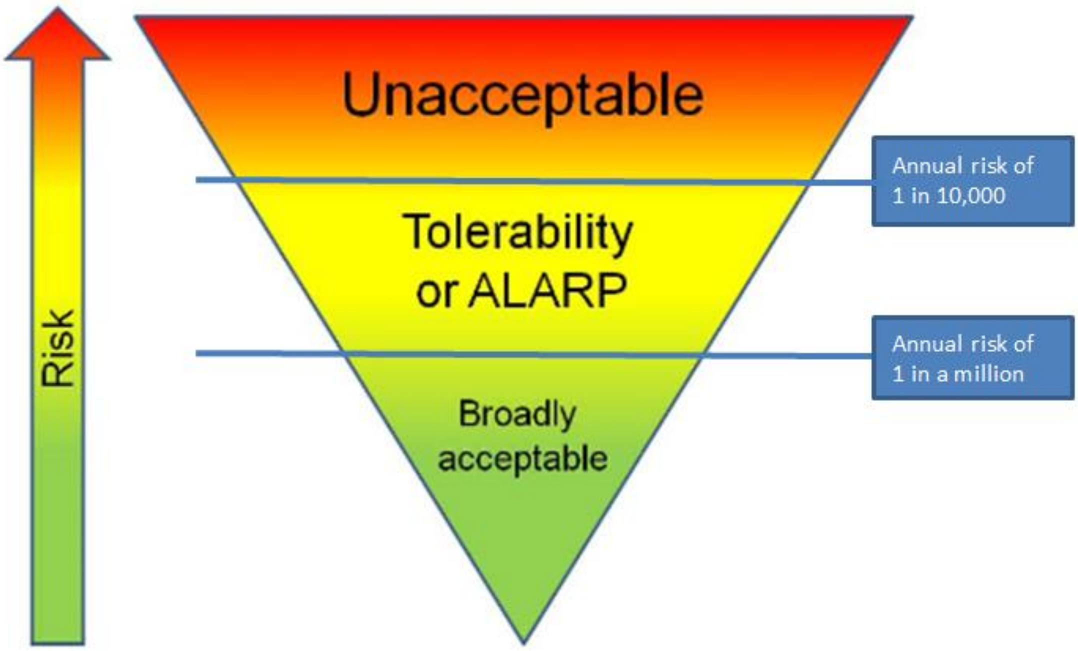

Figure 1 The HSE tolerability of risk framework for members of the public

Whilst risk to health can be expressed as a numerical quantity, how individuals view risk can vary considerably due to different perceptions and experiences. For example, the risks to health arising from exposure to materials that cannot be seen, and exposures over which a person has little or no control, are usually perceived to be higher than the numerical risk estimated using a quantitative assessment. Particularly with regards to radiation, members of the public may have an elevated impression of how significant the risks to health are such that, to some people, any radiation in the environment poses an unacceptable risk to health. This view is likely to be exaggerated when vulnerable groups, such as children, are exposed.

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About Public Health England

Public Health England exists to protect and improve the nation's health and wellbeing, and reduce health inequalities. It does this through world-class science, knowledge and intelligence, advocacy, partnerships and the delivery of specialist public health services. PHE is an operationally autonomous executive agency of the Department of Health and Social Care.

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