DANISH HEALTH AUTHORITY
Radiation Protection

Radiation

– A part of your everyday life

Information about ionising radiation

Radiation – a part of your everyday life
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Translated from Stråling – en del af din hverdag.
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What is radiation?

Radiation is transfer of energy. Radiation can be generated naturally or artificially. Some types of radiation – such as heat and visible light – can be detected by our senses. But most types of radiation cannot be sensed, including X-rays and radiation from radioactive substances.

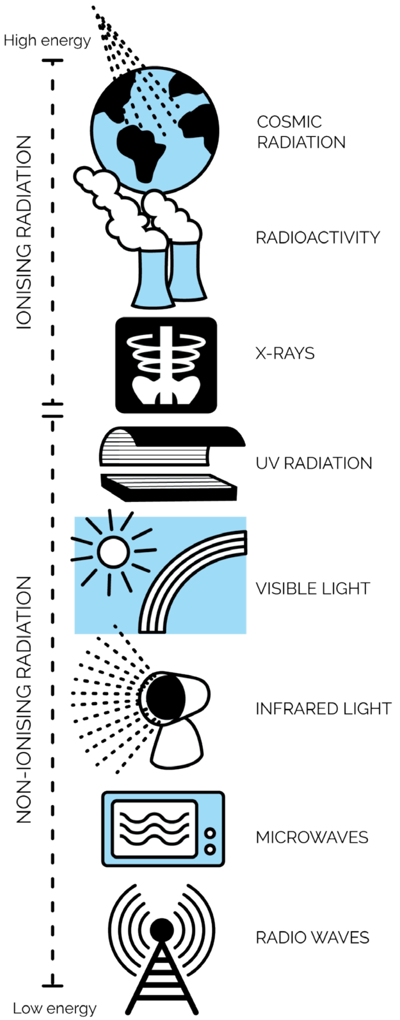
As shown in Figure 1, radiation energy varies according to type. The higher the energy, the more the radiation can affect the material it collides with. Some types of radiation are so energetic that they can detach electrons from atoms and molecules, thus causing chemical changes in them. If this happens inside a living cell, it can cause damage, for instance to the cell's DNA. Radiation with these properties is called ionising radiation.

Cosmic radiation from outer space, X-rays and the radiation given off by radioactive substances are all ionising radiation.

Visible light and radiation from mobile phones, microwave ovens and the like are not energetic enough for their radiation to detach electrons from atoms and molecules. These types of radiation are called non-ionising radiation.

This publication deals only with ionising radiation, which will be referred to as "radiation".

Figure 1. Examples of ionising and non-ionising radiation



How does radiation affect the human body?

People are exposed to radiation constantly. When cells in the body are exposed to radiation, energy is transferred to those cells, which results in cell damage. Cell damage happens constantly, but the body is very effective at repairing it. Some damage, however, is not repaired. This may result in permanent cell changes or cell death. These two types of harm to the body is referred to as late effects and acute effects.

Units

The biological effect of exposure to radiation (dose) is expressed in units called sieverts (Sv). The doses people are exposed to are usually very small, and are stated in units called millisieverts (mSv).

Late effects

Late effects are cancer or next-generation genetic effects. Even very small doses can cause late effects. They are the result of changes in the cells' DNA.

Cancer may occur in the organs that were exposed to radiation. Cancers such as leukaemia and lung cancer may be caused by bone marrow and lung tissue exposure, respectively. The cancer may take many years to develop.

Animal studies show that irradiation of the genitals not only carries a risk of genital cancer, but also of genetic effects in offspring. This has never been demonstrated in humans, but it is assumed that genital irradiation carries a very small risk of hereditary genetic effects.

Cancer risk

If 100,000 individuals each are exposed to a dose of 1 mSv, approx. five of them are statistically expected to develop cancer in later life.

However, approx. 30,000 of these individuals will develop cancer from other causes. This means that an additional dose of 1 mSv per person in that group statistically increases the cancer incidence from 30,000 to 30,005.

Acute effects

Acute effects are organ or tissue failure as a result of cell death. The dose has to exceed a certain limit over a short range of time for it to cause acute effects. Acute effects result from the body's inability to regenerate cells in time to replace those that die. An example of an acute effect is a radiation burn. Very large doses may cause symptoms such as nausea, vomiting and gastrointestinal bleeding, and in the worst case may be fatal.

Where does radiation come from?

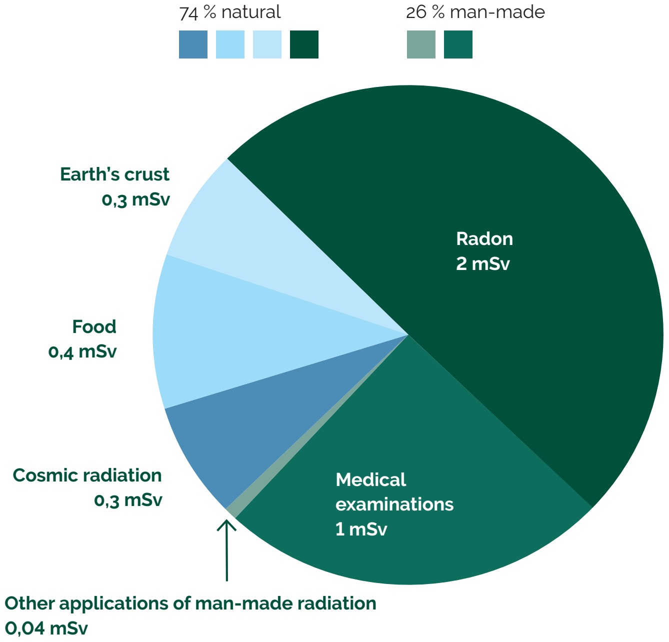
At a dose of 4 Sv over a short range of time the risk of dying from exposure is about 50%. A dose of more than 10 Sv is almost always fatal.

Doses causing severe acute effects or death are very rare. Examples of serious accidents causing such high doses are the Chernobyl nuclear accident (1986), the radiological accident in Goiania (1987) and the radiological accident in Yanango (1999). Further information can be found at www.iaea.org.

Where does radiation come from?

Around 74% of the radiation that residents of Denmark are exposed to is of natural origin, and 26% is man-made. Figure 2 shows the average doses a resident of Denmark receives annually from natural and man-made radiation.

Figure 2. Average annual dose to a resident of Denmark



Doses from natural radiation come from:

- Radon, a radioactive gas formed in the earth's crust. On average, a resident of Denmark receives an annual dose of about 2 mSv from radon.
- Content of other radioactive substances in the earth's crust. On average, a resident of Denmark receives an annual dose of about 0.3 mSv from radioactive substances in the earth's crust other than radon.
- Content of radioactive substances in food. On average, a resident of Denmark receives an annual dose of about 0.4 mSv from food.
- Cosmic radiation from the Sun and our galaxy. On average, a resident of Denmark receives an annual dose of about 0.3 mSv from cosmic radiation.

Doses from man-made radiation come from:

- The use of X-rays and radioactive substances for medical examinations. On average, a resident of Denmark receives an annual dose of about 1 mSv from medical examinations.
- Other applications of man-made radiation. On average, a resident of Denmark receives an annual dose of about 0.04 mSv from other applications of man-made radiation.

On average, a resident of Denmark receives an annual dose of 4 mSv from natural and man-made radiation.

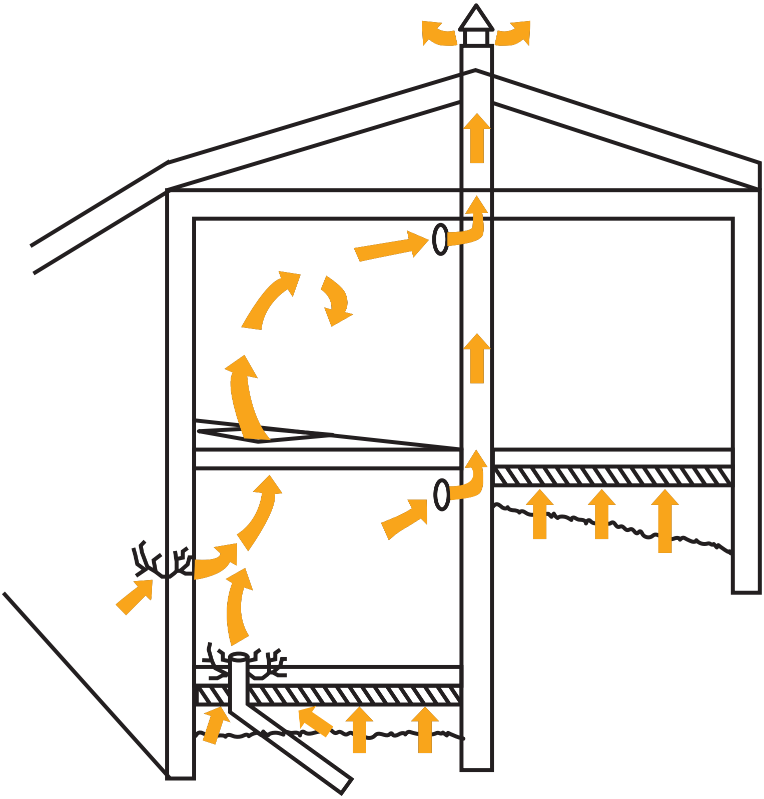
The following chapters describe in more detail what the sources of natural and man-made radiation are, and how residents of Denmark are exposed to these sources.

Radon

Radon is a radioactive gas formed in the earth's crust. Radon seeps into the air from the earth's crust. As it emits radiation, radon converts into other radioactive substances. When these substances are inhaled in the air we breathe, they settle in the lung tissue, and this increases the risk of developing lung cancer. Radon causes an estimated 9% of all lung cancers in Denmark, or 300 cases of lung cancer annually. Lung cancer typically takes 10-40 years to develop. The risk of lung cancer from radon is about 25 times higher for smokers than for non-smokers.

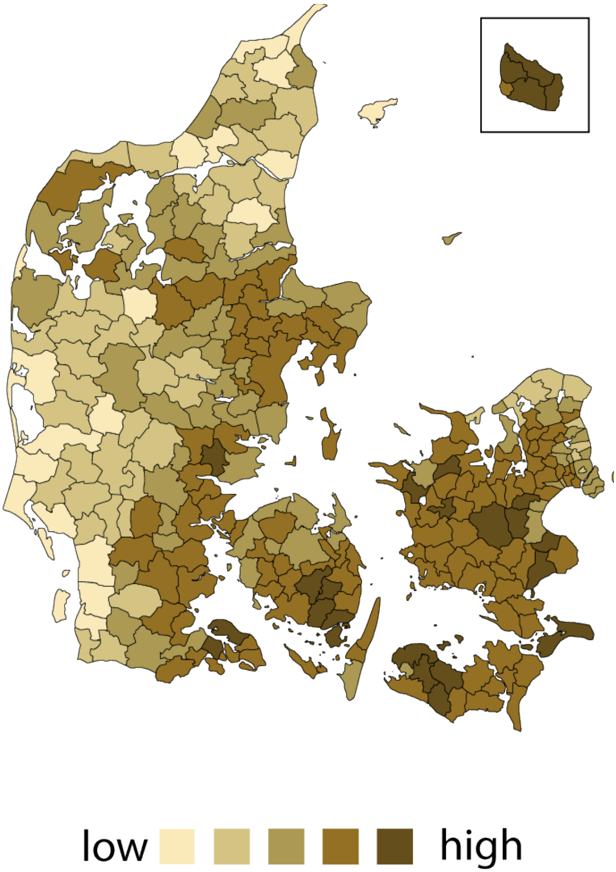
Radon is concentrated in buildings, which it penetrates through cracks in foundations and other underfloor structures. The radon level is usually highest at basement and groundfloor level where there is direct contact between the flooring and the ground, which means that it is generally higher in single-family houses and terraced houses than in blocks of flats.

Figure 3. Radon can penetrate buildings through cracks in foundations and through ducts



The radon level is location-dependent because different parts of Denmark have very varying levels of ground radon. Figure 4 shows the estimated radon level in single-family houses in Denmark, by municipality. The radon level is lowest in tracts of sandy ground, such as in West and North Jutland. The highest levels are found on the rocky island of Bornholm.

Figure 4. Estimated radon level in Denmark by municipality. The colour-shading shows the concentration of homes with above-average radon content



More information about radon

The Radon Guide provides information about radon, on measuring radon levels, and on how to prevent radon in homes. The Radon Guide is available in Danish at www.sis.dk or www.radonguiden.dk.

Owing to geological factors and differences in housing construction, air change, etc., the annual dose from radon to residents of Denmark ranges from about 0.5 to 8 mSv per person, and in some cases higher.

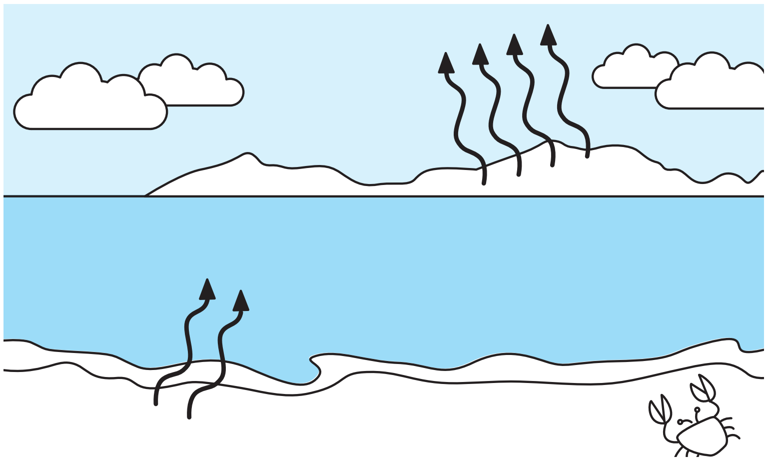
On average, a resident of Denmark receives 2 mSv annually from radon.

5. The earth's crust

The earth's crust contains small amounts of radioactive substances other than radon. These radioactive substances were present when Earth was formed, and they continue to expose people to radiation.

The content of radioactive substances depends on the composition of the earth's crust. The concentration of radioactive substances is greater in rocky areas than in sandy areas, for example. This means that residents of the rocky island of Bornholm are exposed to more radiation from the earth's crust than residents of West Jutland, where the ground is mainly sand.

Figure 5. The level of exposure depends on the composition of the earth's crust



Brick, concrete and other building materials are made of raw materials from the earth's crust and therefore also contain radioactive substances. This means that buildings, roads, etc. also contribute to the population's exposure.

The content of radioactive substances in the earth's crust is low and only exposes the population to low doses. However, the extraction of raw materials, such as coal and oil, may result in a concentration of radioactive substances. This may result in the exposure of workers in such industries.

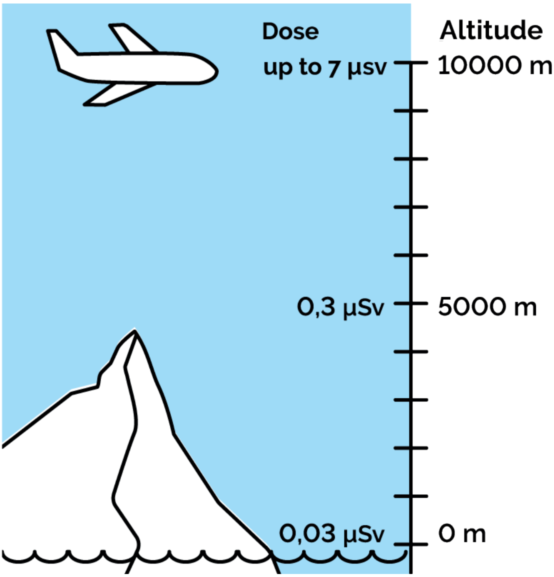
On average, a resident of Denmark receives 0,3 mSv annually from the earth's crust.

Cosmic radiation

Cosmic radiation is highly penetrative radiation emitted mainly by the sun and our galaxy. The earth's atmosphere weakens cosmic radiation. Figure 6 shows how cosmic radiation depends on altitude (elevation above sea level). The cosmic radiation around the highest Alpine mountain peaks, at an altitude of about 5,000 metres, is about 10 times higher than at sea level. In Denmark, which has very small differences in elevation, the cosmic radiation is virtually the same everywhere.

The magnetic field of the earth deflects cosmic radiation, making it less intense at the equator than at the poles. The intensity of cosmic radiation depends on sunspot activity. The greater the sunspot activity, the more intense the cosmic radiation.

Figure 6. Doses from 1 hour at different altitudes
(1 µSv = 0,001 mSv)



Exposure during flights

At flight levels of 10 to 12 km, the intensity of cosmic radiation may be several hundred times greater than at sea level. Table 1 shows typical doses for flight routes. Note that the dose is higher for routes near the poles than routes close to the equator.

Table 1. Typical doses for flights from Copenhagen

Flight route	Flight time (hours)	Typical dose (mSv)
Copenhagen - London	2	0,01
Copenhagen – New York*	7	0,05
Copenhagen – Cairo**	5	0,02
Copenhagen – Tokyo*	12	0,06
Copenhagen– Bangkok**	11	0,04

** Transpolar route*
***Equatorial route*

Air passengers and crews can only reduce their exposure to cosmic radiation by reducing their number of flights and by avoiding routes in proximity to the poles.

On average, a resident of Denmark receives 0.3 mSv annually from cosmic radiation.

Food

Food has a natural content of radioactive substances. The nutrients and water absorbed by plants from the soil and atmosphere contain small amounts of radioactive substances, which pass through the food chain and become part of the human diet. Drinking water also contains small amounts of radioactive substances. From the food we eat, the substances are absorbed in the body, and after a while excreted by natural metabolic processes.

Figure 7. Food contain small amounts of radioactive substances

Some ordinary foods and beverages may have a higher content of naturally-occurring radioactive substances than others. This applies to dried fruit and nuts, certain spices, oats, bananas, meat, fish, tea and coffee, for example. The doses from intake of these foods are extremely low, and from a radiation protection point of view there is no reason to avoid them.

Accidents at nuclear power plants have resulted in dispersion of radioactive substances in the local food chain. These accidents have not resulted in an increase in the dose that residents of Denmark receive from foods.

Cigarettes and other tobacco products contain small amounts of radioactive substances. The radioactive substances are absorbed by the tobacco plants during cultivation. When tobacco is smoked, the radioactive substances settle in the lungs, where they irradiate the lung tissue and increase the risk of lung cancer.

Figure 8. Radioactive substances in tobacco increase the harmful effects of smoking

On average, a resident of Denmark receives 0.4 mSv annually from foods.

The shelf life of foods can be extended by irradiating them. The foods do not become radioactive from this treatment, and intake of irradiated foods does therefore not result in doses to the population. Apart from dried herbs and spices, the sale of irradiated foods is banned in Denmark. If foods have been irradiated or contain irradiated ingredients, this must be stated in the informative labelling.

Medical examinations

X-rays have been used for more than a century for medical examinations, and radioactive substances are also used extensively for this purpose. The use of radiation is indispensable for examining teeth, infections, fractures, cancer, etc.

In Denmark, around 8 million X-ray examinations are done every year. Half of these are dental X-ray examinations. Table 2 shows examples of typical X-ray examinations and the associated doses. There is a large variation in the dose from different types of examinations. The dose from a CT scan, for example, is about 1,000 times greater than the dose from a routine X-ray examination at the dentist's.

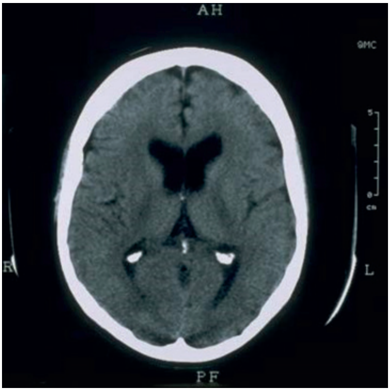
Table 2. Examples of the radiation dose from X-ray examinations

X-ray examinations	Typical dose (mSv)
Teeth, arm, leg	0,01
Lungs	0,1
Mammography	0,5
Full-body, CT scan	10

Conventional X-ray examinations produce shadow images, as shown in Figure 9. A CT scan, which is an advanced form of X-ray examination, produces more detailed images of the body's internal organs. CT scanning was introduced in the 1970s. Since then, CT scanning has increased substantially, and now accounts for 70% of the total dose from X-ray examinations.

Figure 9. X-ray image of an upper-arm fracture

Figure 10. Brain CT- Scan



Radioactive substances are used for nuclear medicine examinations of organ function and in cancer diagnostics. In 2021, 186,000 such examinations were carried out. Table 3 shows examples of nuclear medicine examinations and the associated doses.

Table 3. Examples of doses from nuclear medicine examinations

Nuclear medicine examinations	Typical dose (mSv)
Kidney	1
Bone	4
Lung (with CT)	4.5
Tumor-scan (PET-skan with CT)	18

PET scanning is a technique in nuclear medicine used primarily in cancer examinations. Additionally, PET scans can be used to examine other organs such as bones and the heart.

The patient is infused with a radioactive substance which binds to cancerous tissue. The site and spread of the cancer in the body is then determined by a scan. A PET scan can detect cancer at a very early stage.

Today, nuclear medicine scans are often combined with a CT scan to obtain more detailed images of the body.

Figure 11. PET-CT-scanner,

The doses from medical examinations are very unevenly distributed in the population, so the average dose to a resident of Denmark represents substantial variation.

On average, a resident of Denmark receives 1 mSv annually from medical examinations.

X-rays and radioactive substances are also used for treating disease – especially cancer. The dose to patients from radiation therapy is normally far greater than that from medical examinations, and it is distributed across relatively few patients. The number of therapeutic doses is not included when determining the annual average dose to residents of Denmark.

Other applications of man-made radiation

In addition to medical uses, X-rays and radioactive substances are used for many other beneficial purposes in society. In a few cases, this results in exposure of large groups in the population. In the vast majority of cases, only people whose occupation involves exposure receive doses from these applications.

The population is exposed to radiation, for example, when X-rays are used for baggage control in airports and from the use of certain types of smoke alarms and lighting fixtures containing radioactive substances. The dose from these applications accounts for far below 1% of the average annual dose received by a resident of Denmark from natural radiation and from medical examinations.

In certain professions, X-rays and radioactive substances are used extensively. Radiation is used, for example, for sterilising medical equipment, inspecting welding seams, determining the thickness of various products, localising leaks in pipes, veterinary radiology and for research. Usually, only people in occupations involving these procedures receive doses from these applications of radiation. The staff at hospitals and clinics also receive doses in the course of their work to diagnose and treat patients.

Figure 12. Baggage control scanners

Denmark does not generate energy from nuclear power, but a number of our neighbouring countries have nuclear power plants. Under normal circumstances, nuclear power plant operation causes negligible exposure of the global population. However, accidents at nuclear power plants may have serious consequences for people and the natural environment locally, and they may result in the dispersion of radioactive substances globally. Following the accidents at the nuclear power plants in Chernobyl in 1986 and Fukushima in 2011, it was possible to trace very small amounts of radioactive substances leaked from these sites in Denmark. The contamination from Chernobyl was responsible for a dose several hundred times lower than the average dose received by a resident of Denmark annually from natural and man-made radiation. The radioactive fallout from the nuclear test programmes in the 1950s and 1960s is responsible for a dose of the same level. The exposure from Fukushima is about 100 times lower.

On average, a resident of Denmark receives 0.04 mSv annually from other forms of man-made radiation.

Authorities and legislation

The Danish Health Authority is the national radiation protection authority. The regulatory work is carried out by the Radiation Protection unit in the Danish Health Authority (SIS). The objectives of the Danish Health Authority, Radiation Protection are to ensure that workers, patients and the population as a whole, as well as animals and the environment, are protected against the harmful effects of ionising radiation.

Figure 13. The Danish Health Authority is the official body responsible for radiation protection in Denmark

The principles of radiation protection are:

- Radiation must only be used when justified. This means that the socially beneficial effects of using radiation for a specific purpose must outweigh the unwanted effects of exposure.
- All doses must be kept as low as reasonably achievable.

- No individual must be exposed to doses exceeding the official dose limits. Table 4 shows the annual dose limits for people whose occupation involves exposure and for the rest of the population. The dose limits do not include the annual average of 4 mSv, which a resident of Denmark receives from natural radiation and medical examinations. For medical examinations and treatment, there are no dose limits for the patients. In such cases, the beneficial effects of radiation for patients shall outweigh any unwanted effects.

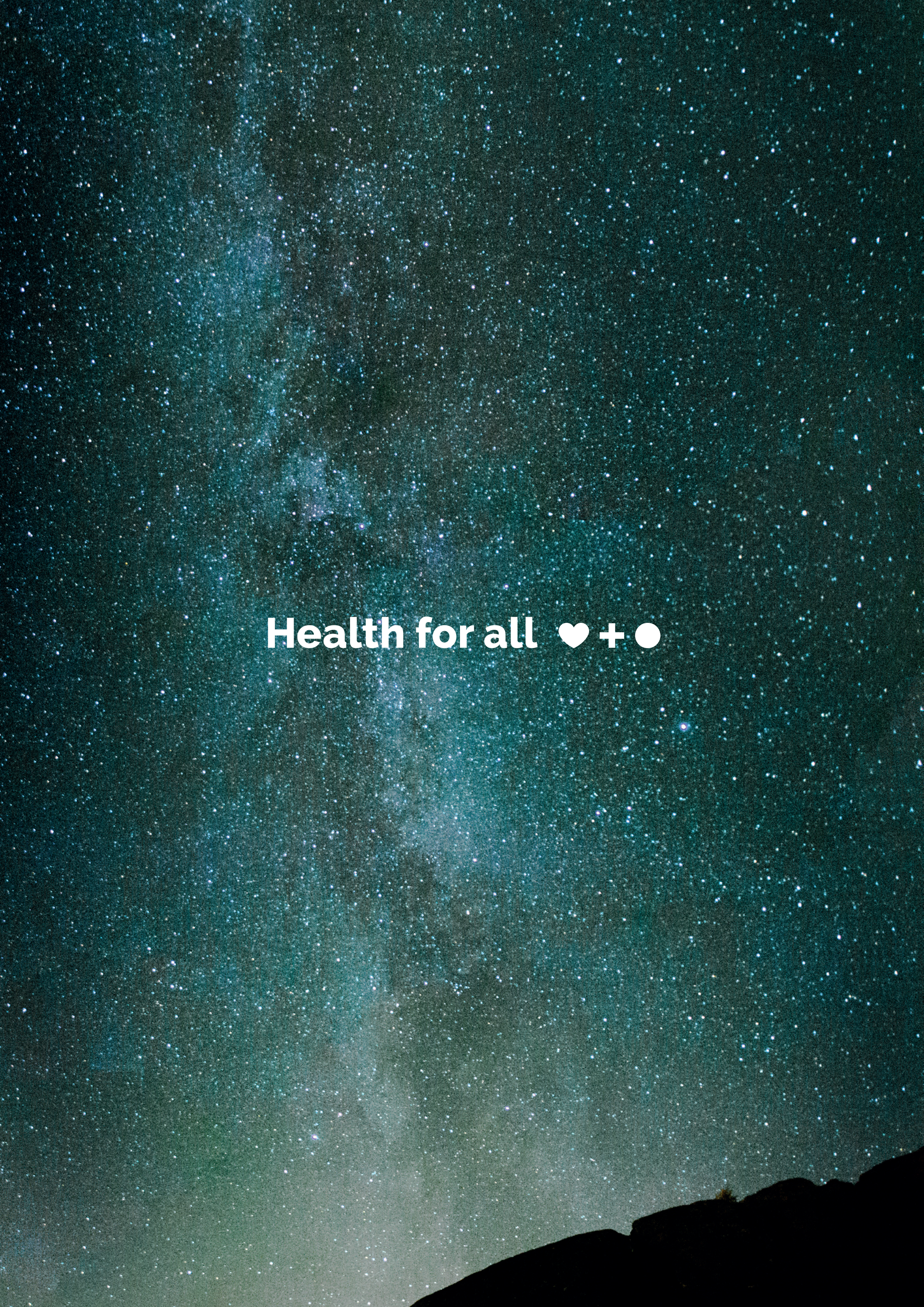
Table 4. Annual dose limits

	Doselimit (mSv/year)
Occupationally-exposed person	20
Resident of Denmark	1

Use of radiation sources generally requires a licence from the Danish Health Authority and, in the majority of cases, radiation sources and facilities must be registered with the Danish Health Authority.

Devices or objects containing radioactive substances must meet fixed radiation protection requirements and must be approved by the Danish Health Authority, Radiation Protection before they can be marketed to consumers in Denmark. This applies, for example, to certain types of smoke detectors and special light sources. Toys, personal adornments, cosmetics, foodstuffs, and feedstuffs containing radioactive substances are prohibited in Denmark. It is prohibited to purchase – either over the internet or abroad – consumer products containing radioactive substances that are not approved by the Danish Health Authority, Radiation Protection.

The Danish Health Authority, Radiation Protection website - www.sis.dk - provides more information about the Danish Health Authority, Radiation Protection and legislation concerning ionising radiation.


Health for all