Chapter 2
Health and Safety

Radiation is an emotive subject – and often misunderstood. People are right to be wary of radiation, but that doesn't mean that a factory containing properly maintained and well-managed x-ray equipment should be less safe than any other working environment. This chapter covers health and safety issues, and puts permitted radiation limits in the context of everyday exposure.

2.1 Radiation Basics

Energy from a source is generally referred to as radiation. Different forms of radiation have been harnessed to develop equipment that we now take for granted in everyday life. There are basically two main sources of radiation, natural and manmade. Examples of radiation include heat or light from the sun, microwaves from an oven, x-rays from an x-ray tube and gamma rays from radioactive elements.

The electromagnetic spectrum (Figure 2.1) is a continuum of electromagnetic radiation arranged according to its frequency and wavelength, from radio waves (which have a long wavelength) through the visible light spectrum, to gamma rays (which have a short wavelength).

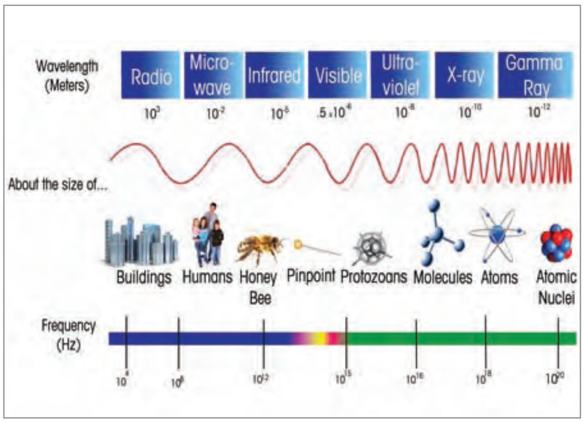

Figure 2.1

2.1.1 Ionising Radiation

Ions are atoms with too few or too many electrons. Ionising radiation is radiation that has enough energy to force electrons out of atoms to create ions. X-rays are a form of ionising radiation within the electromagnetic spectrum. They have the ability to penetrate synthetic and biological matter.

Other forms of ionising radiation include alpha particles, beta particles and gamma rays, all of which are emitted by radioactive materials or sources. Since radioactive materials are not used in x-ray inspection systems, their effects and applications are not covered by this guide.

2.1.2 Background Radiation

Background radiation includes natural and artificial sources. Humans have always been exposed to radiation from the environment in which they live. Natural sources account for approximately 84% of the total radiation that we receive (Figure 2.2).

Radon Gas

Radon gas is produced by the decay of radium-226, which is present wherever uranium is found. It seeps out of uranium-containing soils and rocks, typically granite. Radon is often the single largest contributor to an individual's background radiation dose. The proportion is typically around 50%, but it varies widely from location to location.

Cosmic Radiation

The earth and all living things on it are exposed to radiation from outside the solar system. Some of this radiation is filtered out by the earth's atmosphere.

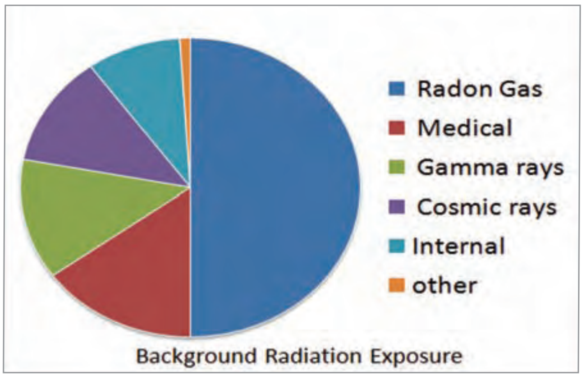

Figure 2.2

Internal Radiation

This type of exposure arises when a person inhales or ingests radioactive material, normally in the form of a very fine dust. The various organs of the body then receive a radiation dose emitted by the radioactive material.

Medical Radiation

The main source of artificial radiation, contributing 15% of all background radiation exposure, is from medical x-rays (chest and dental x-rays).

2.1.3 Radiation Dose, Quantities and Units

From the point of view of occupational exposure, the accrued radiation dose is the most important measure. Occupational exposure limits are given in terms of the permitted maximum dose.

The unit of radiation dose is the sievert (Sv). As occupational exposure levels are normally low, smaller units – millisievert (mSv: a thousandth of a sievert) or microsievert (µSv: a millionth of a sievert) – are more commonly used.

The radiation dose rate measures the rate at which radiation is absorbed over time. This is expressed in µSv/h.
Dose Rate = Dose (µSv) ÷ Time (hours)

2.2 Putting Radiation Quantities into Context

To understand radiation levels, let's look at and compare dose rates from some natural and artificial sources of radiation that we are exposed to in day-to-day life. (Figures 2.3 to 2.5)

Figure 2.3
Eat a jar of mussels every week for one year = 250 µSv/year

Figure 2.4
Frequent fliers = 200 µSv/year; Airline pilots and air crew = 2000 µSv/year

Figure 2.5
Maximum permitted leakage levels from an x-ray system = 1 µSv/hour (ROW regulations), 5 µSv/hour (US regulations)

Each member of the world population is exposed, on average, to 2400 µSv a year of ionising radiation from natural sources. This typically far exceeds the radiation exposure received from a properly installed and maintained x-ray inspection system.

2.3 Food Irradiation

The irradiation of food does not cause it to become radioactive, just as a person does not become radioactive after having a chest x-ray.

Food irradiation, which is regulated by the FDA and WHO (World Health Organisation), involves exposing food to a radiant source, such as x-rays. The benefits include extended shelf-life, improved product quality (because ripening is delayed) and reduction in the number of micro-organisms present. A WHO study in 1997 confirmed that food radiation levels up to 10 kGy (10,000 GRAY – a GRAY is a unit of radiation absorbed dose) did not affect its safety or nutritional value.

The FDA doesn't regard a dose below 1 kGy as an irradiation process. For example, to kill salmonella in fresh chicken requires a dose of up to 4.5 kGy, which is about 7 million times more radiation than a single chest x-ray. The radiation dose received by objects scanned by an x-ray inspection system is typically 200 µGRAY or less – a level that is too low to affect the safety or nutritional value of food. Organic food producers and others who may be concerned about the implications of irradiation will be reassured to know that this low-level dose is less than background radiation. It has absolutely no effect on the food product.

In the UK, the Food Standards Agency (FSA) recently completed an independent nationwide report on radioactivity in food. The survey measured radioactivity from different parts of the food chain, including levels applicable to people who live close to nuclear sites and eat local food. It combined the data with possible exposure from other authorised radioactive discharges. The report found that the total dose in the UK is under the EU annual dose limit for members of the public of 1 millisievert for all exposures to radiation.

2.4 Working with X-ray Inspection Systems

X-ray radiation has practical uses in medicine, research, and product inspection applications. If used improperly, it also presents a health hazard to humans.

People tend to assume that any dose of radiation, no matter how small, is a health risk. However, there is no scientific evidence of any health risk at doses below 20,000 µSv a year, which is the limit set for occupational radiation exposure to adults working with radioactive material.

Modern x-ray systems for food and pharmaceutical applications do not contain sources of live radiation such as uranium. They provide a safe working environment for the operators. Provided safety guidelines are followed, there are no restrictions for anyone, including pregnant women and young adults operating this type of equipment.

The x-rays within an x-ray inspection system are electrically generated, which means they can be turned on and off. This differs from radiation sources such as uranium, which naturally emit radiation in the form of alpha, beta or gamma rays. These sources can only be made safe by containment.

2.4.1 Protection Principles

To protect the user from the effects of radiation, x-ray inspection systems are safe by design. The risk of being exposed to radiation can be controlled through the following protection principles: time, distance and shielding. X-ray systems for the food and pharmaceutical industries are classified as cabinet systems, meaning that the x-ray generator is always installed in an enclosure.

Time

For people who are exposed to radiation that is additional to natural background radiation, limiting or minimising exposure time will reduce the dose. The dose rate is directly proportional to the amount of time spent in a given location.

Dose rate (µSv/Hour) = Dose ÷ Time

Distance

The intensity of radiation from an x-ray source decreases in proportion to the inverse of the square of the distance from it. This principle is commonly known as the Inverse Square Law. Dose Rate is proportional to 1 ÷ $(\text{Distance})^2$.

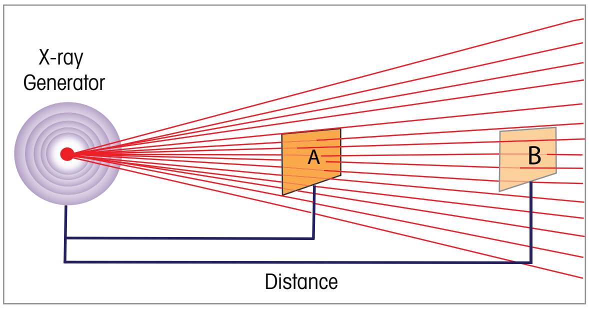

Figure 2.6

For example (Figure 2.6), if the radiation dose rate measured at A (one metre from the x-ray source) is assigned a value of 1 ($1 \div 1^2$); at B (two metres from the source) it will be 0.25 ($1 \div 2^2$), i.e. a quarter of the dose rate at A.

Shielding

As already discussed in Chapter 1, x-rays are absorbed when they pass through a material. The most efficient absorbers of x-rays are highly dense materials (Figure 2.7). That is why x-ray machines tend to be made from stainless steel, while the design of some x-ray generators incorporates lead or copper for additional containment of the x-rays.

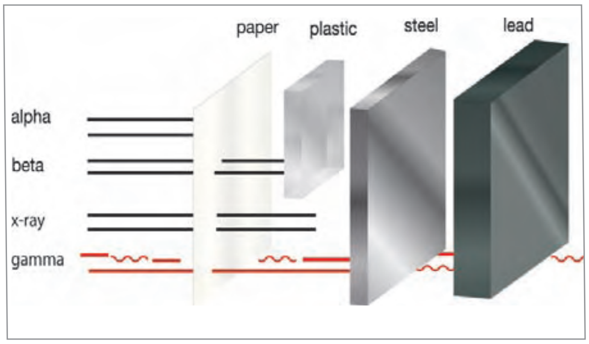

Figure 2.7

2.4.2 X-ray Inspection System Safety

When using x-rays for product inspection, the x-ray system must be built to comply with safety standards such as the Ionising Radiation Regulations 1999 and the American Standard 1020.40 CFR. Meeting safety standards ensures that all personnel and production staff are safe when operating the machine – providing everyone follows the safety procedures. For this reason, x-ray inspection systems should be built utilising the following safety requirements:

- All systems should be fully CE certified
- Must adhere to local rules and regulations – for example, in the UK all systems should comply with Ionising Radiation Regulations 1999
- Maximum allowable radiation leakage levels should not exceed 1 µSv/hour (ROW regulations), 5 µSv/hour (US regulations)
- All systems are subject to a final critical radiation survey once installed and a certificate is issued
- As a minimum, Category 3 (or higher) safety interlocks should be used on all potential access points to the primary x-ray beam, to prevent accidental exposure

2.5 References

Links to various sources and types of information are included below for reference:

The Health Protection Agency – Radiation Safety in the UK

http://www.hpa.org.uk/radiation

Food Standards Agency Report

http://www.food.gov.uk/news/newsarchive/dec/radio

FDA – Main Regulatory Body for the United States

http://www.fda.gov/cdrh/radhealth/

World Health Organisation (WHO)

http://www.who.int/foodsafety/publications/fs_management/irradiation/en/

FAO/WHO Food Standards

http://www.codexalimentarius.net

Health & Safety Executive UK – Safety advice on working with ionising radiation

http://www.hse.gov.uk

Soil Association

http://www.soilassociation.org

Contact your local Mettler-Toledo office for your local radiation safety body

http://www.mt.com/pi