Guide to Radiation

in Namibia's Uranium Exploration & Mining Sectors

This booklet is intended to be a first guide on radiation-related issues for individuals active in the Namibian uranium exploration and mining sectors. It was prepared by Dr Gunhild von Oertzen and Dr Detlof von Oertzen of VO Consulting.
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Radiation

Radiation is travelling energy.

Radiation occurs in the form of electromagnetic waves, for example:

Increasing wavelength

Increasing energy

Radio waves are low energy electromagnetic waves and have a wavelength of between a metre to a kilometre.

Microwaves have enough energy to be used to cook food. Their wavelength is between a centimetre and a millimetre.

Infrared radiation, for example from a fire, is felt as heat and has a wavelength of about a tenth to a thousandth of a millimetre.

Visible light has a wavelength the size of bacteria, or about a ten-thousandth of a millimetre.

Ultraviolet light, for example from the sun or from artificial sources, has sufficient energy to damage the skin when applied for too long. It has a wavelength of about a hundred-thousandth of a millimetre.

X-rays are high-energy penetrating electromagnetic waves which are used in medical and security applications. Their wavelength is a millionth to a hundred millionth of a millimetre.

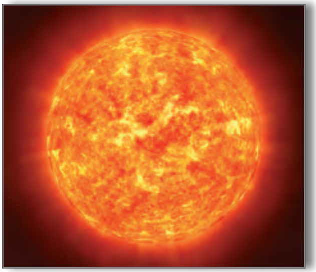
Gamma rays are very high in energy and originate from radioactive materials. Their wavelength is about a thousandth of a millionth of a millimetre.

A different form of radiation is made up of high energy subatomic particles which are emitted by radioactive materials. These are called **alpha and beta radiation**, see page 8.

Natural Background Radiation

Background radiation is present wherever we are, that is why we call it 'natural background radiation'.

Natural background radiation comes from:



cosmic radiation from the Sun and other objects in the universe,

terrestrial radiation from the soil, from rocks and ores, and from groundwater,

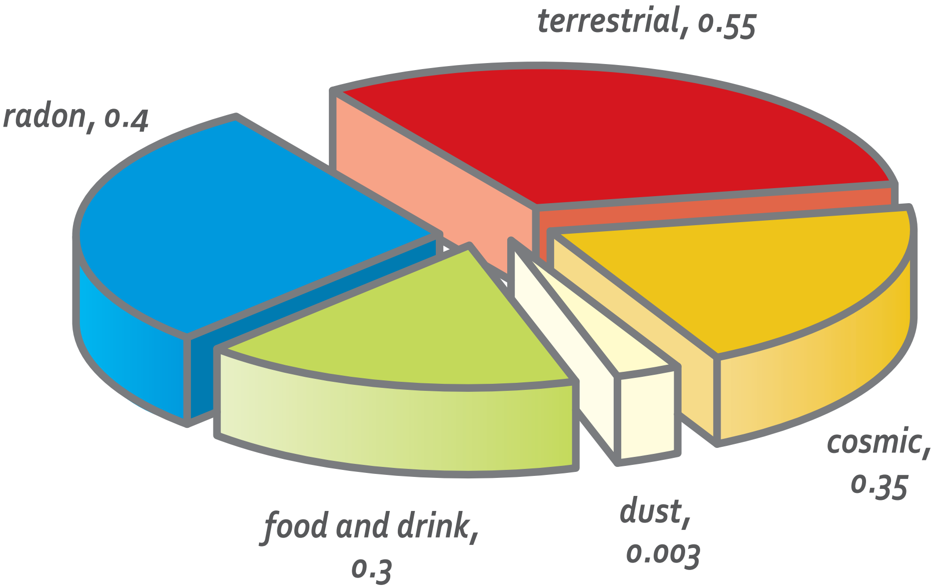
food and water we consume, and

dust and radon gas, mixed with the air we breathe.

Background Radiation in the Erongo Region

The natural background radiation in the Erongo Region is about 1.6 mSv per year.

Natural background radiation in Erongo Region, in mSv per year



Man-Made Sources of Radiation

By far the largest portion of man-made sources of radiation is from smoking.



Many materials used in everyday life contain small amounts of radioactive materials. These give rise to (normally very small) additional radiation exposures. Examples are burnt mantles used in gas lanterns (thorium), smoke detectors (americium), ornamental glasses (uranium), ceramics and porcelain dentures (uranium) and salt replacements (potassium).

In the United States, the average exposure from consumer products is estimated to be 0.06 mSv per year. In Namibia, this exposure is not known but is probably lower as consumption is lower.

Smoking leads to high internal radiation exposure: **smoking 1 pack of cigarettes a day can lead to annual exposures of 10 mSv or more.**

Other man-made exposures are from medical exposures, frequent flying (exposure to cosmic radiation) and from security x-rays.



Radioactivity

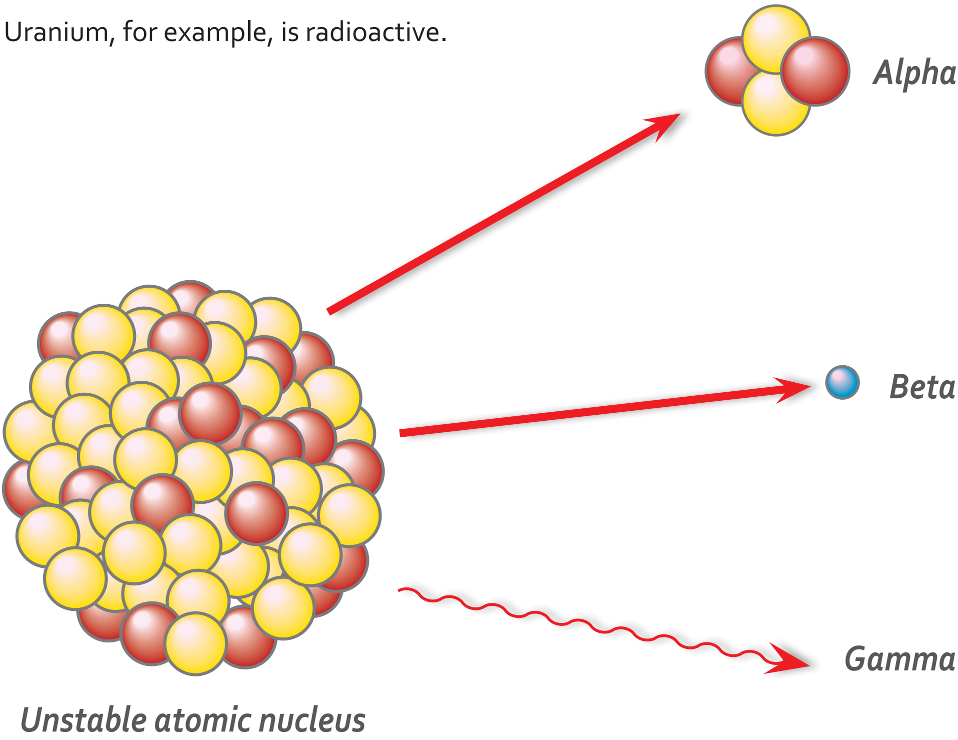
Radioactivity is the decay of an atomic nucleus.

In nature, not all atoms are stable.

If the nucleus of an atom is unstable, it decays, and in the process gives off radiation.

Elements which have unstable atoms are called radioactive.

Uranium, for example, is radioactive.



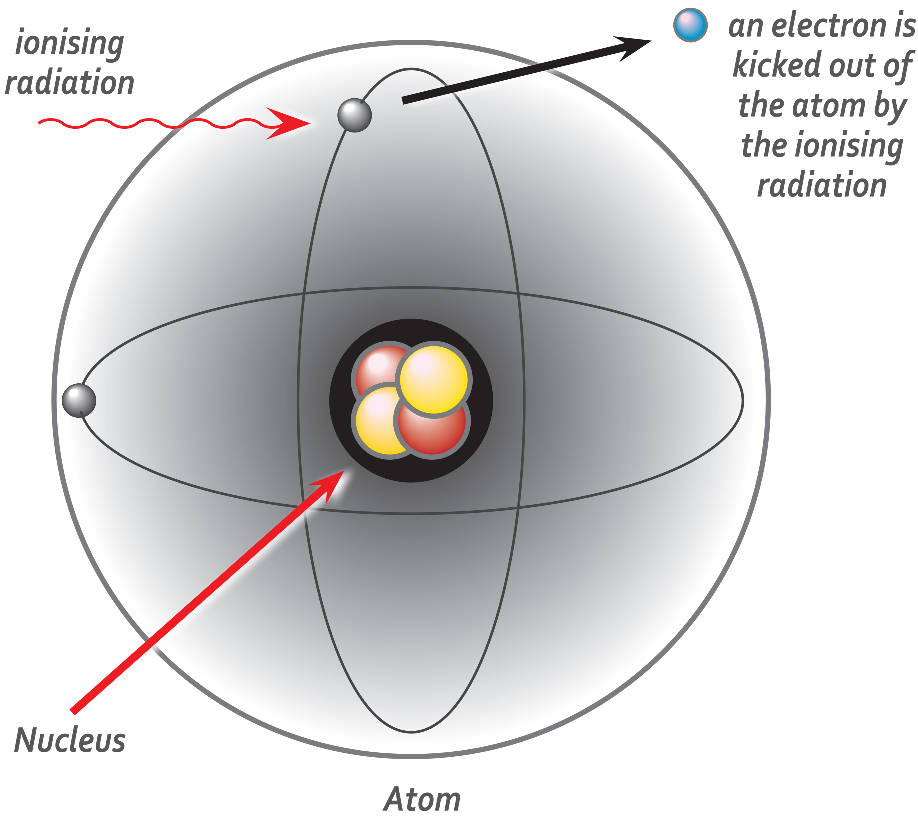
Ionising Radiation

Ionising radiation is high-energy radiation that can be harmful.

The various types of radiation found in nature have different energies.

If radiation has enough energy, it can damage atoms by stripping electrons off them.

This type of radiation is called ionising radiation, and is harmful because it can damage human tissue.



Three Types of Radiation

A radioactive nucleus can emit three types of ionising radiation, called alpha (α), beta (β) or gamma (γ) rays.

Name	Description	Largest hazard
Alpha α	Alpha particles are like helium nuclei and consist of 2 protons and 2 neutrons. They are doubly charged and travel only a few cm in air. They can be stopped by a sheet of paper or the human skin. They can be harmful when they are in the body.	internally, i.e. when getting into the body, for example when breathed in or when contained in food
Beta β	Beta particles are much lighter than alpha particles, and less charged (they are basically electrons). They travel up to a metre in air and penetrate 1-2 cm of human tissue. They can be stopped by a sheet of aluminium foil. Internally, they are much less hazardous than alpha particles.	externally
Gamma γ	Gamma rays are similar to x-rays – they are highly penetrating radiation. Gamma rays are stopped by thick layers of concrete or lead.	externally

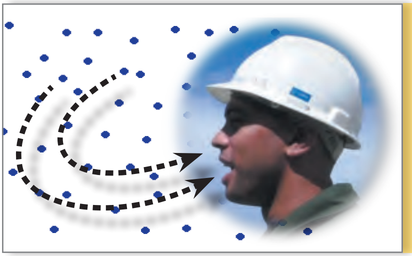
α 3 cm in air
0.05 mm in solids

β 5 mm in water
a few cm in solids,
up to 1 m in air

γ no maximum range
attenuation depends on material

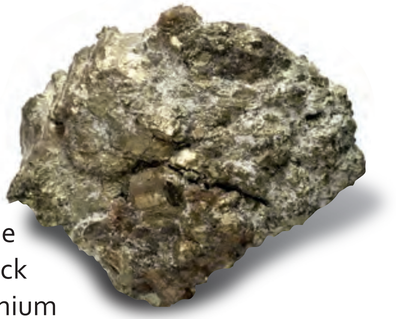
Exposure Pathways

Exposure to radiation can be internal or external.

	Type of exposure	Description
	External (direct)	Gamma irradiation, typically from ores, waste rocks, drill cores, and in the yellowcake processing area.
	Internal (inhalation)	Inhalation of fine ore dust or uranium dust in the air leads to internal exposure to alpha radiation.
	Internal (inhalation)	Inhalation of radon gas, which is a radioactive gas from the uranium decay chain. The accumulation of radon gas and its decay products can be prevented with good ventilation.
	Internal (ingestion)	Eating food contaminated by radioactive materials, swallowing uranium or uranium ore dust, or drinking contaminated water.

Uranium

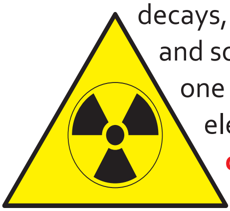
Uranium is a very dense radioactive metal.



Uranium is a very dense material, and almost as dense as gold or tungsten. One litre of uranium metal weighs 19 kilograms, compared to 1 litre of water which weighs 1 kilogram.

In metallic form, uranium is a silver-grey metal. In the ore, it occurs in oxidised form and is dark grey to black in colour. Some uranium compounds such as ammonium di-uranate are yellow, which is why it is called yellowcake.

Three isotopes of uranium occur in nature: U-238, U-235 and U-234. Here, isotope means that there are three types of uranium atoms which have a different number of neutrons but the same number of protons (92) in their nucleus.



All three uranium isotopes are radioactive, although only weakly. When U-238 decays, it forms thorium, which in turn decays into protactinium, and so on. In this way, a so-called decay chain is formed, with one element decaying into the next one until eventually a stable element (lead) is reached. The first member of the **decay chain** (for example U-238) is called the **parent** while the decay products are called the **daughters** or **progeny**.

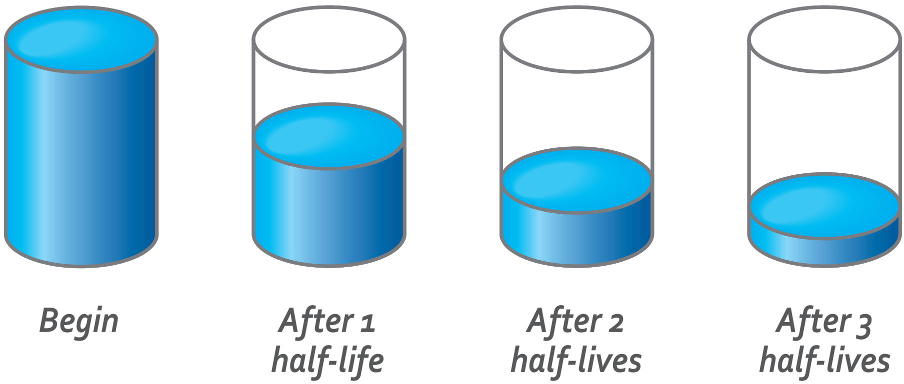
The uranium isotope U-235 is not only radioactive, but it is also **fissile**. This means that if activated by neutrons, U-235 can sustain a chain reaction whereby the uranium atom breaks into fragments and releases large amounts of energy. This energy can be used to generate electricity, and is the reason why uranium is used as a fuel in nuclear power reactors.

Half-life

The half-life is a measure of how radioactive a substance is.

The half-life is the amount of time it takes for half of a given substance to undergo radioactive decay. An element with a long half-life decays slowly, which means it is weakly radioactive. In contrast, a short half-life means that the element decays quickly, which makes it strongly radioactive.

During each half-life period, one-half of the material remaining decays. For example, let us begin with a full bucket of uranium. Then, after 1 half-life, there is half of the bucket of uranium left. After 2 half-lives, only a quarter of the bucket of uranium remains, and after 3 half-lives, an eighth of the bucket of uranium is left over, and so it continues.



The half-life of U-238 is about 4.5 billion years, or 4,500,000,000 years.

The half-life of radon (a decay product of uranium) is only 3.8 days. The decay products of radon have very short half-lives, such as Polonium-218 (3 minutes), Polonium-214 (0.0001 second) or Bismuth-214 (20 minutes).

The half-life of U-235 is 700 million years.

Measuring Radioactivity

Radioactivity is measured in Becquerel (Bq).

Radioactivity is measured in decays per second, or disintegrations per second. This is also sometimes called 'counts per second'.

The unit in which disintegrations per second are measured is called the Becquerel (Bq). Sometimes we also use the kilo-Becquerel (kBq), which is one thousand Becquerel, i.e. 1,000 Bq = 1 kBq.

Granite has a (radio-)activity of 1-2 Bq per gram.

Common soils have about 1 Bq per gram.

Some phosphate fertilizers have about 5 Bq per gram.

Pure uranium oxide (yellowcake) has an activity of 20 kBq per gram.

Measuring Exposure to Radiation

Exposure to radiation is measured in Sievert (Sv).

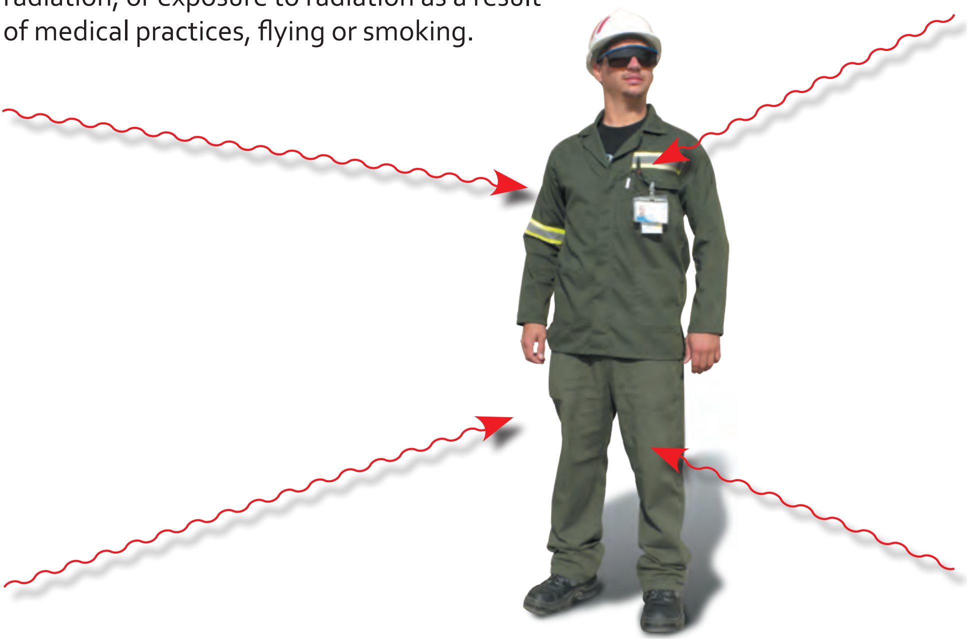
Human exposure to radiation is measured in Sievert (Sv), and indicates the **biological effect** that the ionising radiation has on the body. The unit takes into consideration the different effects that alpha, beta and gamma radiation have on human tissue.

Often, the milli-Sievert (mSv) is used, which is a thousandth of a Sievert.

International and Namibian legal standards recommend an exposure dose limit of **20 mSv per year** for workers, when averaged over five consecutive years.

For members of the public, the annual exposure dose limit is 1 mSv.

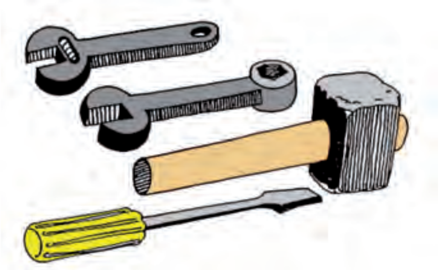
The given exposure limits do not include the exposure to natural background radiation, or exposure to radiation as a result of medical practices, flying or smoking.



Contamination

Contaminated equipment must be cleaned or remain in the contaminated area.

Work areas with a lot of ore dust or where uranium is concentrated can be contaminated with radioactive materials. It is important that such contamination is not introduced to clean areas, so as to keep the exposure to ionising radiation as low as possible.



Therefore, keep contaminated tools and equipment in the work area where they were contaminated, and **clean the tools after using them.**

Tools and equipment are only allowed off site if all contamination is removed. Ask your radiation safety officer to issue a radiation clearance before relocating tools and equipment.

Personal protective equipment (PPE) including shoes and overalls must be cleaned on site to prevent the spread of contamination to other areas.

Pay attention to what PPE is required in your particular work area!

Contaminated waste must be disposed of only in the waste bins provided for contaminated waste.

Do not mix contaminated and uncontaminated waste – this will spread contamination!

Exposure Controls – External Radiation

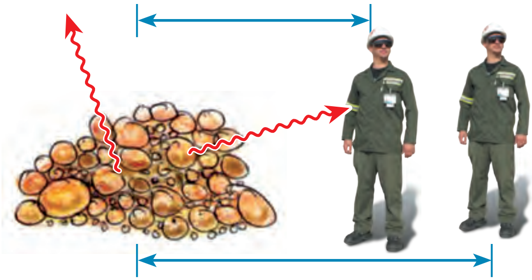
Minimise your exposure to external radiation by paying attention to "time, distance and shielding".

Time

Keep the time you spend in radiation areas to a minimum!

Distance

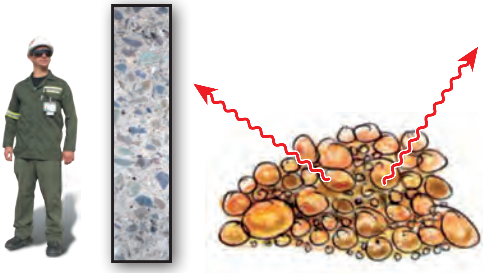
Shorter distance – larger exposure



Longer distance – smaller exposure

Increase the distance between you and a radiation source to as much as possible!

Shielding



Concrete, lead and other dense materials provide good shielding.

Put as much shielding as possible between yourself and the source of radiation!

Exposure Controls – Internal Radiation

Minimise your exposure to internal radiation by wearing a dust mask, and ensuring that work areas are always well ventilated.

Use suitable respiratory protection when working in areas that are classified as respirator areas.

Reduce internal exposure from the inhalation of dust by wearing a dust mask, this is particularly important if you work under dusty conditions.

Radon is a radioactive gas which is formed as part of the uranium decay chain.

When radon decays, it forms solids which can settle in your lungs and expose you to alpha radiation.

Reduce internal exposure from the inhalation of radon and its decay products by ensuring that your work area is always well ventilated.

Hygiene

Good hygiene is essential to limit the ingestion of radioactive materials.

Prevent the accidental swallowing of uranium or ore dust – this is most easily done when you keep yourself and your tools clean at all times.

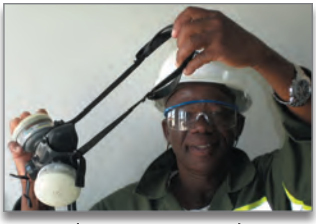
Remember the following:

Clean your hands before eating, smoking and drinking!

Only eat in clean areas, and store your food in a clean container!

Do not take any PPE home, as this stops the risk of spreading contamination beyond your work area and the mine site.

After work, clean yourself thoroughly. Your partner will like it too!



Make sure your dust mask or respirator fits tightly.

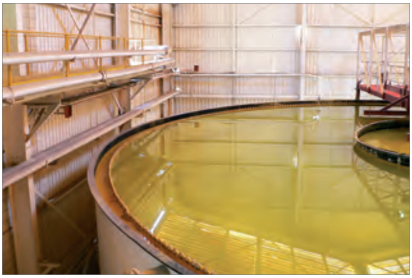
When you have to wear a respirator, beards are not permitted!

Personal Protective Equipment–PPE

Personal protective equipment, or PPE for short, helps reduce the exposure to radiation, and keeps you safe, so wear it.

Protective glasses and dust masks in dusty working conditions

Respirators in areas with uranium dust



Overalls for protection against external contamination

Gloves to minimise direct contact with hazardous substances

Safety shoes or gum boots, and hard hats to protect you

Exposure of Workers

The annual occupational exposure of designated radiation workers in Namibia may reach about 5 mSv per year (mSv/a). The average exposure of most other workers in the Namibian exploration and mining sectors is less than 5 mSv per year.

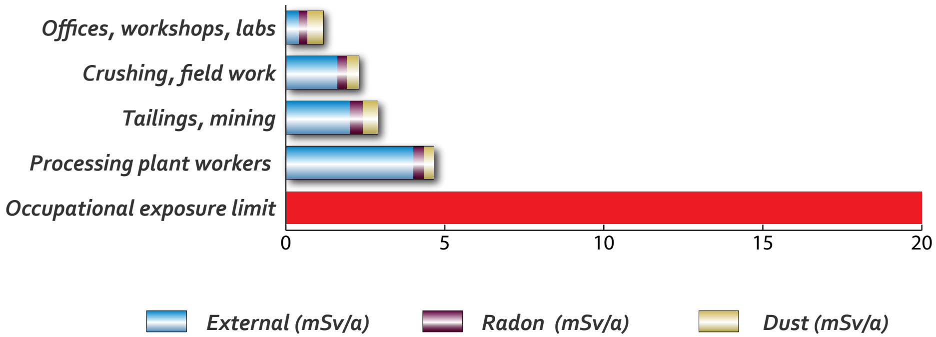
Ore grades in Namibian uranium mines are normally low.

The average occupational exposure of Namibian mine workers is therefore usually low when compared to the Namibian occupational dose limit.

Work areas which need regular monitoring and exposure controls are those where workers are exposed to concentrated uranium or high-grade ores, such as where yellowcake is prepared, and in dusty work areas such as crushers and open pits.

The graph below shows some typical annual exposures for exposure groups found at a Namibian uranium mine. The total exposure dose is the sum of the external exposure to radiation, and the internal radiation due to the inhalation of radon and dust.

Typical radiation doses of select uranium mine workers



The Namibian occupational dose limit of 20 mSv per year is shown as a red bar.

Pregnant Workers

A pregnant worker has to be protected from the effects of radiation just like a member of the public, because she is carrying a member of the public (baby) inside her. The annual average exposure dose therefore needs to be limited to 1 mSv per year.

It must be known as soon as possible if a lady worker is pregnant. This will assist the worker and her supervisor to effectively protect the unborn baby.

International and Namibian radiation protection standards for members of the public prescribe an exposure dose limit of 1 mSv per year for pregnant workers.

Worker: annual exposure dose limit of 20 mSv

Baby: annual exposure dose limit of 1 mSv

Inform your supervisor as soon as you become pregnant, it's for your child's and your own well-being!

Notes


KOMATSU