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IONIZING RADIATION, HEALTH EFFECTS AND PROTECTIVE MEASURES

KEY FACTS

- Ionizing radiation is a type of energy released by atoms in the form of electromagnetic waves or particles.
- People are exposed on a daily basis to natural sources of ionizing radiation, as well as human-made ionizing radiation sources.
- Ionizing radiation has many beneficial applications, including uses in medicine, industry, agriculture and research. As the use of ionizing radiation increases, so does the potential for health hazards if not properly used or contained.
- Acute health effects such as skin burns or acute radiation syndrome can occur when radiation doses exceed certain levels. Low doses of ionizing radiation can increase the risk of longer term effects such as cancer.

WHAT IS IONIZING RADIATION?

Ionizing radiation is a type of energy released by atoms that travels in the form of electromagnetic waves (gamma or X-rays) or particles (neutrons, beta or alpha). The spontaneous disintegration of atoms is called radioactivity, and the excess energy emitted is a form of ionizing radiation. Unstable elements which disintegrate and emit ionizing radiation are called radionuclides.

All radionuclides are uniquely identified by the type of radiation they emit, the energy of the radiation, and their half-life. The activity — used as a measure of the amount of a radionuclide present — is expressed in a unit called the becquerel (Bq): one becquerel is one disintegration per second. The half-life is the time required for the activity of a radionuclide to decrease by decay to half of its initial value. Half-lives for radionuclides range from tiny fractions of a second to millions of years (e.g. iodine-131 has a half-life of 8 days).

RADIATION SOURCES

People are exposed to natural radiation on a daily basis. Natural radiation comes from many sources including more than 60 naturally-occurring radioactive materials found in soil, water and air. Radon, a naturally-occurring radioactive gas, emanates from rock and soil and is the main source of natural radiation. Every day, people inhale and ingest radionuclides from air, food and water.
People are also exposed to natural radiation from cosmic rays, particularly at high altitude. On average, 80% of the annual dose that a person receives from background radiation is due to these naturally occurring terrestrial and cosmic radiation sources. Background radiation levels vary due to geological differences; exposure in certain areas can be more than 200 times higher than the global average.

Human exposure to radiation also comes from man-made sources ranging from nuclear power generation to medical uses of radiation diagnosis or treatment. Today, the most common man-made sources of ionizing radiation are X-ray machines and other medical devices.

**TYPES OF EXPOSURE**

Radiation exposure may be internal or external, and can be incurred by various exposure pathways.

*Internal exposure* to ionizing radiation occurs when a radionuclide is inhaled, ingested or otherwise enters into the bloodstream (e.g. injection, wounds). Internal exposure stops when the radionuclide is eliminated from the body, either spontaneously (e.g. through excreta) or as a result of a treatment.

*External contamination* may occur when airborne radioactive material (dust, liquid, aerosols) is deposited on skin or clothes. This type of radioactive material can often be removed from the body by simple washing.

Exposure to ionizing radiation can also result from *external irradiation* (e.g. medical radiation exposure to X-rays). External irradiation stops when the radiation source is shielded or when the person moves outside the radiation field.

**HEALTH EFFECTS OF IONIZING RADIATION**

Radiation damage to tissue and/or organs depends on the dose of radiation received, or the *absorbed dose* which is expressed in a unit called the gray (Gy). The damage producing potential of an absorbed dose depends on the type of radiation and the sensitivity of different tissues and organs.

To put all ionizing radiation on common ground with regard to potential for causing harm, a radiation weighted dose called the *effective dose* is introduced, the sievert (Sv). The Sv takes into account the type of radiation and sensitivity of tissues and organs. The Sv is a very large unit so it is more practical to use smaller units such as millisieverts (mSv) or microsieverts (μSv). There are one thousand μSv in one mSv, and one thousand mSv in one Sv. In addition to the amount of radiation (dose), it is often useful to express the rate at which this dose is delivered (*dose rate*) e.g. μSv/hour or mSv/year.

Beyond certain thresholds, radiation can impair the functioning of tissues and/or organs and can produce *acute effects* such as skin redness, hair loss, radiation burns, or acute radiation syndrome. These effects are more severe at higher doses and higher dose rates. For instance, the dose threshold for acute radiation syndrome is about 1 Sv (1000 mSv).

If the dose is low or delivered over a long period of time (low dose rate), there is greater likelihood for damaged cells to successfully repair themselves. However, *long-term effects* may still occur if the cell damage is repaired but incorporates errors, transforming an irradiated cell that still retains its capacity for cell division. This transformation may lead to cancer after years or even decades have passed. Effects of this type will not always occur, but their likelihood is
proportional to the radiation dose. This risk is higher for children and adolescents, as they are significantly more sensitive to radiation exposure than adults.

Epidemiological studies on populations exposed to radiation (atomic bomb survivors, radiotherapy patients, occupationally exposed cohorts) showed a significant increase of cancer risk at doses above 100 mSv.

Prenatal exposure to ionizing radiation may induce brain damage in foetuses following an acute dose exceeding 100 mSv between weeks 8-15 of pregnancy and 200 mSv between weeks 16-25 of pregnancy. Before week 8 or after week 25 of pregnancy human studies have not shown radiation risk to fetal brain development. Fetal exposure to radiation can increase the risk of cancer in childhood. Studies have shown this effect with doses above 100 mSv.

**RADIATION EXPOSURE IN NUCLEAR EMERGENCIES**

Radioactive material may be released into the environment during an emergency in a nuclear power plant (NPP). The radionuclides of greatest concern to human health are iodine and caesium.

Occupational exposure, either internally or externally, of rescuers, first responders, and NPP workers is likely to occur during the emergency response. It may result in radiation doses high enough to cause acute effects such as skin burns or acute radiation syndrome.

Those living in closer vicinity to a NPP can be externally exposed to radionuclides present in a radioactive cloud or deposited on the ground. They can also be externally contaminated by radioactive particles deposited on skin or clothes. Internal exposure may take place if radionuclides are inhaled, ingested, or enter an open wound.

The general population is not likely to be exposed to doses high enough to cause acute effects, but they may be exposed to low doses which could result in increased risk of long-term effects like cancer. Consumption of contaminated food and/or water contributes to overall radiation exposure.

If radioactive iodine is released into the environment and enters the body through inhalation or ingestion, it will concentrate in the thyroid gland increasing the risk of thyroid cancer. The risk of thyroid cancer is higher in children than adults, particularly those under 5 years, and those whose diets are generally deficient in iodine.

**PROTECTIVE HEALTH ACTIONS IN NUCLEAR EMERGENCIES**

During nuclear emergencies, public health protective actions may be implemented to prevent radiation exposure and associated health risks.

In the early phase of an emergency (within the first few hours/days), urgent protective actions may be implemented to prevent radiation exposure, taking into account projected doses that people may received in the short-term (e.g. effective dose within 2-7 days, thyroid dose within one week). Decisions are based on NPP conditions, amount of radioactivity actually or potentially released into the atmosphere, prevailing meteorological conditions (e.g. wind speed and direction, precipitation), and other factors. The potential urgent actions which might be announced by local authorities include evacuation, sheltering indoors, and the administration of non-radioactive iodine.

Evacuation is the urgent removal of populations within a radius around the event site. It is most effective when used as a precautionary action before an airborne release takes place. Sheltering
indoors (e.g. homes, schools, office buildings) can also significantly reduce exposure to the radioactive material released and dispersed.

The administration of non-radioactive iodine can prevent the uptake of radioactive iodine by the thyroid gland. When potassium iodide (KI) pills are taken before or shortly after exposure, they saturate the thyroid gland to reduce the dose and risk of thyroid cancer. KI pills do not protect against external radiation, or against any other radioactive substances apart from radioactive iodine.

Potassium iodide pills should be taken only when instructed by competent authorities. It is important to follow dosage recommendations, especially for children. Pregnant women should take KI pills when instructed by competent authorities to protect their thyroid and the thyroid of the fetus. When instructed, breastfeeding woman should also take KI pills to protect themselves, and give KI to the breastfed baby following recommended dosages.

Food, water and agricultural countermeasures may be implemented to reduce radiation exposure during the early phase of an emergency (e.g. restricting consumption of water, and locally produced food and dairy products).

Mental health support for the early management of acute stress after a nuclear event can speed recovery and prevent long-term consequences such as post-traumatic stress disorder or other persistent mental health disorders. Reactions may be intense and prolonged with profound emotional impact, particularly in children.

As environmental and human monitoring data increases, other protective actions may be implemented, including relocation of people to temporary housing or in some cases, permanent resettlement. These protective actions are implemented taking into account the doses that a population may receive over the long-term (e.g. effective dose during one year). Food and water monitoring programs should be established to inform longer term decisions on food restriction, water consumption, and the control of internationally traded foodstuffs.

The recovery phase may extend for a considerable period. Cessation of protective measures should be linked to environmental, food and human health monitoring and based on a risk-benefit analysis. Appropriate long-term follow-up programmes should be established to assess public health consequences and the need for any subsequent actions.

**WHO'S RESPONSE**

In accordance with its Constitution and the International Health Regulations (2005), WHO is mandated to assess public health risks and provide technical consultation and assistance in association with public health events, including those associated with radiation events. In doing so, WHO is working with independent experts and other UN agencies.

WHO's work is supported by a global network comprising more than 40 specialized institutions in radiation emergency medicine. The network, the Radiation Emergency Medical Preparedness and Assistance Network (REMPAN), provides technical assistance for radiation emergency preparedness and response.
Technical background information

- Food safety in nuclear emergencies: http://www.who.int/foodsafety/en/