Optically stimulated luminescence dosimeters

OSLDs offer advantages that include the ability to be re-read and a high sensitivity (low minimum measurable dose), and they have become popular because of these favorable properties. OSLDs operate much like TLDs; their major difference is that luminescence is produced by a light beam, rather than by heat. Currently, TLDs and OSLDs were the only types of passive dosimeters. Figure 2. displays an example of an OSLD.

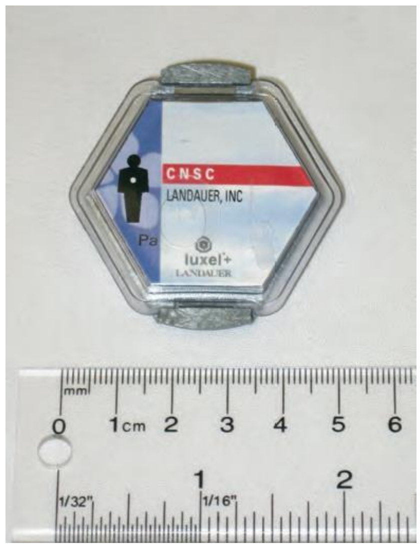

FIGURE 2. **A whole-body optically stimulated luminescence dosimeter.**

Direct reading dosimeters (DRD)

DRDs are active dosimeters since they display doses and dose rates while they are being used. Many direct reading dosimeters have alarmed that sound at preset doses and dose rates. The most used types display dose readings electronically and are composed of either a diode or a GM detector.

For many years, DRDs have been used as dose control devices, particularly in the nuclear power industry. A dose control device provides real-time estimates of doses or dose rates and is used in work planning and execution. DRDs are not typically used to measure doses of record, but sometimes are used for this purpose under defined circumstances.

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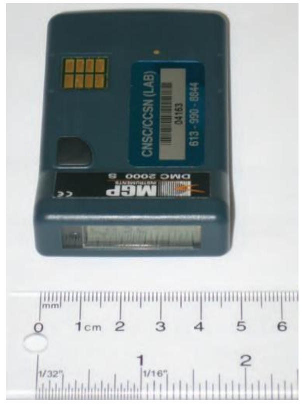

FIGURE 3. **A direct reading dosimeter.**

Dosimeter placement

The recommended placement of a dosimeter is on the trunk of the body, between the waist and neck. This positioning provides a good estimate of effective dose in situations where the body is uniformly exposed to radiation. In the preceding examples of non-uniform exposure where both the whole body and the extremities are exposed to radiation, the dose from external sources of radiation may be measured with:

1. A whole-body dosimeter worn on the trunk (to measure the effective dose as well as the equivalent dose to the skin of the body).

2. Extremity dosimeters worn on the hands and/or feet (to measure the equivalent doses to the extremities).

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Dosimetry for neutron radiation

About neutron radiation

When neutrons are produced, they usually have a wide distribution of energies called an energy spectrum, which varies with the nature of the source. The type of reaction that a neutron undergoes depends very strongly on its energy. *Many factors (such the nature of the source; the thickness, shape and composition of shielding material; or the geometry of the work environment), can alter the energy spectrum that comes into contact with a worker's body*. This makes neutron dosimetry very challenging.

About dosimeters for measuring neutron radiation

Measurement techniques for determining doses due to beta and photon radiation are generally inappropriate for measuring neutron radiation. Since neutrons interact differently in matter than photon and beta radiation, neutron detectors have different physical principles than instruments for detecting photon and beta radiation. Two types of neutron dosimeters are personal neutron dosimeters (of which the most popular is the solid-state nuclear track detector) and portable neutron survey meters.

Solid-state nuclear track detectors

A solid-state nuclear track detector uses a material called CR–39 plastic (composed of allyl diglycol carbonate). CR–39 technology is based on the reaction of neutrons with material in the detector. The reaction produces charged particles, such as protons, at the site of interaction. The protons produce tracks in the dosimeter that are later made visible through a chemical etching process. After etching, the tracks are viewed, and the number of tracks is related to the dose.

Portable neutron survey meters

Portable neutron survey meters are based on a design that allows them to respond to neutrons with a wide range of energies. When used, portable neutron survey meters are usually placed in an area in the work environment where radiation readings are highest. By integrating the dose rate over the period of time that workers spend in that location, doses can be estimated and assigned to each worker.

With this measurement method, the neutron survey meter's highest measured dose rate is used. This ensures that resulting assigned doses remain conservative. Figure 4 shows a typical portable neutron survey meter.

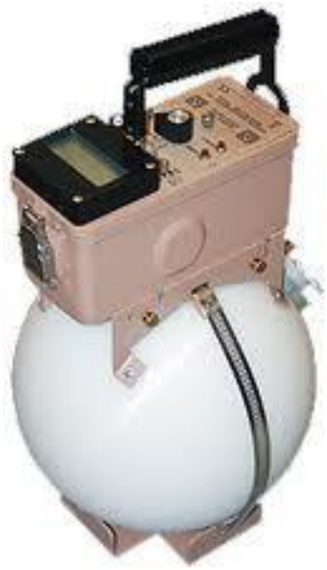

FIGURE 4. A portable neutron survey meter.

INTERNAL DOSIMETRY

Internal dosimetry is the measurement of doses due to nuclear substances that have entered the body by way of ingestion, inhalation, or other means.

Internal dosimetry involves two steps:

1. The level of radiation inside a person's body is estimated using one of three methods:

A. *in-vivo* bioassay (direct measurement of radioactivity in the body)

B. *in-vitro* bioassay (measurement of radioactivity in a person's urine or feces)

C. measurement of radioactivity in workplace air.

2. The resulting internal radiation dose is calculated.

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In-vivo bioassay (direct measurement of radioactivity in the body)

In-vivo bioassay involves the measurement of nuclear substances within the body. This measurement method uses external instruments that detect the radiation emitted by these substances.

To detect radiation emitted by nuclear substances within the body, these substances must emit radiation with sufficient range to escape from the body. In-vivo bioassay is therefore appropriate for measuring gamma radiation – since this type of radiation typically has sufficient range to be detected outside the body, even when it originated inside the person.

In-vivo bioassay measures gamma radiation using a detector positioned near the person. The most common types of detectors used in this manner are whole-body counters, lung counters, and thyroid counters. These devices are calibrated to identify and determine the amount of gamma-emitting nuclear substances within the body. The following text discusses these three types of detectors.

Whole-body counters

A whole-body counter is a device used to measure radioactivity within the human body. This instrument is intended to detect the presence of nuclear substances in a person's body and identify the type and amount of nuclear substances detected.

A self-serve whole-body counter is activated by workers themselves as they swipe their identity cards in a reader. This allows worker information (for example, name, employee number, and date and time of the count) to be stored in a database.

A self-serve whole-body counter offers the advantage of rapid worker monitoring. Workers simply stand in the device, which contains some lead shielding to reduce background radiation, while they are counted for a short period of time; for example, 90 seconds. If no activity is detected, the results are recorded, and no dose is assigned; this is the case for most workers counted.

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However, if the counter does detect activity on the worker, it prompts the user to conduct a longer count (for example, five minutes) and the facility's radiation protection staff are notified for potential follow-up.

Monitoring frequency depends on the potential for exposure, the nature of the work performed and the associated radiological hazard. As the potential for nuclear substances to be taken into the body increases, monitoring is carried out more often. For example, a nuclear power facility's worker who handles nuclear fuel and may be exposed to fission and activation products (such as cobalt-60) are monitored monthly, or more frequently, depending on the task performed. Other workers whose tasks are less likely to result in exposure to fission and activation products may be subject to whole-body counting less often, such as quarterly or annually.

Lung counters

A lung counter is a device used to monitor the inhalation of airborne contaminants, such as uranium oxides or insoluble transuranic-like plutonium.

Many alpha-emitting radioactive airborne contaminants deposited primarily in the respiratory tract emit relatively low-energy gamma radiation. Measurements taken with a lung counter typically require longer counting than those with a whole-body counter. This is due to the difficulty in distinguishing the airborne contaminants' gamma radiation from background radiation for two reasons: first, the gamma radiation's energy is significantly reduced by tissue overlying the lungs, and second, a significant proportion of background radiation also consists of low-energy gamma radiation. A lung counter is typically used over a period of about 30 minutes to detect doses of a few millisieverts.

Thyroid counters

A thyroid counter consists of an appropriately calibrated detector that is placed in front of the thyroid gland, which is located in the neck. Thyroid counters are used in workplaces where radioactive iodine presents an internal hazard. When taken into the body, radioactive iodine deposits principally in the thyroid gland.

In-vitro bioassay (measurement of radioactivity in substances excreted by the body)

In-vitro bioassay is used to determine the presence of nuclear substances or to estimate their amount in urine, feces or other biological materials removed from the body. Shorter-range radiations, namely alpha (α) and beta (β), are generally less penetrating than photon radiation (gamma radiation and X-rays), and therefore cannot be detected from outside the body. They can be detected, however, in material excreted from the body. The purpose of in-vitro bioassay is to determine the quantity of nuclear substances excreted from the body, in order to estimate the quantity present within the body. The most common type of *in-vitro* bioassay is the measurement of tritium in urine. Another *in-vitro* bioassay method involves the analysis of urine and feces for the presence of other nuclear substances. The following text discusses these two *in-vitro* bioassay methods.

Measurement of tritium in urine

Tritium emits low-energy beta radiation. Due to this radiation's short range of travel (up to 0.006 mm) in tissue, it cannot reach the skin's outer surface from within the body. Therefore, beta radiation emitted by tritium atoms inside the body cannot be detected from outside the body and requires *in-vitro* bioassay.

Internal exposure to tritium originates almost exclusively from tritiated water. When tritiated water is taken into a worker's body, it is retained by the body, and then distributed and excreted following the same pattern as regular water.

Monitoring programs require potentially exposed workers to submit urine samples on a routine basis (for example, every two weeks and after leaving areas with elevated levels of tritium). A small amount of sample, typically 1 mL, is mixed with a compound that emits light when radiation interacts with it. The compound, called a scintillation cocktail, is mixed with a urine sample in a vial. The mixture is then analyzed using a liquid scintillation analyzer, which measures the amount of tritium in the sample.

Measurement of radon decay products in workplace air

Sometimes, neither in-vivo bioassay nor in-vitro bioassay can be used to monitor workers for the intake of nuclear substances. This is the case with short-lived nuclear substances, such as radon decay products.

Since radon decay products have such short half-lives, they decay quickly and before their activity could be measured via bioassay methods. Radiation from radon decay products must therefore be measured in workplace air. An instrument which is used to estimate individual exposures to radon progeny is called a personal alpha dosimeter (PAD). One example of a workplace where a PAD is required is a uranium mine, where workers may inhale radon decay products and uranium ore dust.

A PAD consists of a battery-operated air pump and a filter. The following basic overview presents how the device works.

- Air is drawn through the dosimeter, which is worn by a worker on his or her belt.
- The filter captures radon decay products. As the products decay, they emit alpha particles, some of which interact with a cellulose film placed a few centimetres from the filter. These interactions cause microscopic damage (tracks) to the film.
- The cellulose film is etched and the number of tracks is counted using a microscope.
- A calibration factor is used to convert the number of tracks into an air concentration of radon decay products.
- The worker’s exposure is calculated by taking the concentration of radon decay products in air and the worker’s exposure time into account (accurate records of time spent by workers in the workplace are necessary).

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