1. Write a note on Personal radiation dosimeters

A personal radiation dosimeter is a device worn by individuals to measure and record the cumulative dose of external ionizing radiation they are exposed to over a period of time. These devices are essential for workers in environments such as nuclear facilities, medical imaging departments, and research laboratories. The primary goal of a personal dosimeter is to monitor exposure to ensure it remains within safe limits.

Personal dosimeters are classified into two main categories namely, (a) passive dosimeters and (b) active (or electronic) dosimeters.

(a) Passive Dosimeters:

These devices passively store information about radiation exposure, which is then processed and analyzed in a laboratory at regular intervals. Based on the principle involved, passive dosimeters are divided into, (i) Thermoluminescent Dosimeters, (ii) Optically Stimulated Luminescence Dosimeters and (iii) Film Badges.

(i) Thermoluminescent Dosimeters: They contain a sensitive crystalline material that stores energy from radiation exposure. When heated, the material emits light that is proportional to the absorbed dose. Thermoluminescent Dosimeters are sensitive and widely used, but the reading process typically erases the stored information.

(ii) Optically Stimulated Luminescence Dosimeters: Optically Stimulated Luminescence Dosimeters use a layer of aluminum oxide that, when stimulated by a laser or LED light in a lab setting, emits light proportional to the radiation dose. A key advantage of these kind is that they can be re-read multiple times for verification or audits, as only a fraction of the signal is depleted during each reading.

(iii) Film Badges: Film Badges use a piece of photographic film which darkens in proportion to the radiation exposure. The film is developed in a lab to determine the dose.

(b) Active Dosimeters (Electronic Personal Dosimeters - EPDs)

EPDs are battery-operated electronic devices that provide immediate, real-time feedback on both cumulative dose and current dose rate via a digital display. EPDs produce audible, visual, and vibrating alarms that alert the user if the dose or dose rate thresholds are exceeded. They are useful in high-dose areas or emergency response situations where real-time monitoring is critical.

When not in use, dosimeters should be stored in a safe, low-background radiation area, away from heat and direct sunlight, to prevent false readings.

2. What are radioactive tracers? Explain any three applications of them.

Radioactive tracers are substances with a radioactive atom used to track movement in biological, chemical, or industrial systems, revealing chemical reactions and locations via the radiation they emit. They are used in medical imaging (PET/SPECT scans for tumors), environmental studies (tracing pollutants), and industry (leak detection, process optimization).

A radioactive compound is introduced into a living organism and the radio-isotope provides a means to construct an image showing the way in which that compound and its reaction products are distributed around the organism.

The principle behind the use of radioactive tracers is that an atom in a chemical compound is replaced by another atom, of the same chemical element. The substituting atom, however, is a radioactive isotope. This process is often called radioactive labeling. When a labeled chemical compound undergoes chemical reactions one or more of the products will contain the radioactive label. Analysis of what happens to the radioactive isotope provides detailed information on the mechanism of the chemical reaction.

The advantage of the technique is due to the fact that radioactive decay is much more energetic than chemical reactions. Therefore, the radioactive isotope can be present in low concentration and its presence detected by sensitive radiation detectors such as Geiger counters and scintillation counters.

Applications:

1. Medical diagnosis: A radiotracer bound to a biologically active molecule, is injected into the body. Areas with high metabolic activity (like tumors) absorb more of the tracer. They are used to detects cancers, heart conditions, and brain disorders by creating images that show the regions the tracer accumulates, highlighting abnormal tissues or damaged organs.
2. Environmental Monitoring: A tracer is introduced into water systems (rivers, groundwater) or soil. It helps to determine water flow rates, to map underground aquifers, and track the movement of pollutants or contaminants through the environment, aiding in environmental cleanup.
3. Industrial Process Optimization (Leak Detection/Flow Studies): A tracer is added to a fluid (oil, gas, chemicals) in a pipeline or vessel, or used in manufacturing. It detects leaks in pipes, measures flow rates in complex systems, and optimizes mixing in chemical reactors, saving costs and improving efficiency.

3. Explain the principle and procedure of Proton Therapy.

Proton therapy is an advanced and highly precise radiation treatment for tumors. Compared with other methods, it focuses more energy on the tumor itself with less radiation to surrounding healthy tissue. Proton beam therapy works by disrupting the tumor's DNA and destroying tumor cells.

Principle: Proton therapy is based on the Bragg Peak. In this therapy, protons deposit most energy precisely at the tumor's end, sparing healthy tissue beyond. Protons are accelerated using a cyclotron or a synchrotron. These high energy protons are guided with magnets. The tumour is precisely scanned using a fine pencil of proton beam thereby destroying cancer cells. In this therapy, the side effects are fewer, especially for children and complex tumors.

Protons are positively charged particles. When protons travel through tissue, they lose energy. It is so adjusted that a highly concentrated energy is released at a specific and controllable depth right at the tumor. The energy within the proton beam can be adjusted based on the depth of the tumor, so that different amounts of radiation can be delivered to different parts of the tumor. The radiation from protons damages the DNA of the tumor, making the tumor unable to repair itself or grow new cells. The protons stop after the peak and virtually no radiation exits the tumor. This avoids damage to the surrounding healthy organs which is crucial for sparing growth and development in patients.

To produce protons, hydrogen gas is ionized and the hydrogen nucleus is a proton. This ionised hydrogen is accelerated to high speeds up to 60% light speed in a cyclotron or synchrotron. The accelerated protons are steered by magnets to the treatment room. Scanners shape the beam to match the tumor's 3D size and depth, creating a "spread-out Bragg peak".

Patient held with cushions lies still on a treatment table and imaging (CT/X-ray) ensures precise positioning. A large, rotating gantry moves the patient, directing the focused proton beam from multiple angles to cover the entire tumour.

The actual dose delivery is only in minutes but total time of setting up and treatment is about an hour. The patient won't feel the radiation. The patient can leave immediately as the patient is not radioactive.

The advantages are of high accuracy, minimizing damage to adjacent tissues like the brain, heart, or eyes.

The side effects are also low as early long-term toxicity are reduced. The proton therapy is ideal for pediatric cancers, brain tumors, head/neck cancers, and re-irradiation. Some side effects include sore, reddened skin in the area where the proton beam entered the body. Hair loss in the treatment area. Tiredness or low energy. Depending on the area treated, a patient may get headaches and problems with eating and digestion.

4. Write a note on Radiation safety.

Ionizing radiation is widely used in industry and medicine, and can present a significant health hazard by causing microscopic damage to living tissue. There are two main categories of ionizing radiation health effects. At high exposures, it can cause "tissue" effects, also called "deterministic" effects due to the certainty of them happening, conventionally indicated by the unit gray and resulting in acute radiation syndrome. For low level exposures there can be statistically elevated risks of radiation- induced cancer, called "stochastic effects" due to the uncertainty of them happening, and conventionally indicated by the unit sievert.

In the medical field, ionizing radiation has become an inescapable tool used for the diagnosis and treatment of a variety of medical conditions. Ionizing radiation (X- rays, gamma rays, alpha/beta particles) can destabilize molecules in cells, potentially causing tissue damage or cancer. Radiation safety ensures the benefits of radiation in medicine (imaging, therapy) and industry outweigh these risks, protecting patients, workers, and the public. The fundamental goal is to keep all radiation doses as low as possible, even if considered safe at higher levels.

Radiation safety is nothing but minimizing exposure to ionizing radiation. This is achieved by following to the 'As Low As Reasonably Achievable (ALARA)' principle.

Reducing the duration of exposure to radiation, staying away from radiation source and, using radiation shielding like lead aprons and concrete to protect individuals and the environment from harmful effects like cell damage, are some of the ways to radiation safety. This involves careful facility design, personal protective equipment, monitoring devices, and strict protocols for medical, industrial, and research applications.

Shorter the time of exposure ensures lower dosage of radiation. The intensity of radiation intensity drops significantly with distance as inverse square law. Therefore, staying away from radiation sources reduces the harmful effects. Materials like lead are good absorbers of radiation. Placing materials like lead between the source of gamma rays or X-rays help reducing the effect of radiation on living beings. Plastic is a good absorber of beta particles.

Personal Protective Equipment comprises of Leaded aprons (circumferential preferred), thyroid shields, and specialized clothing for staff; protective gowns for patients. Monitoring devices are film badges and thermoluminescent dosimeters to measure exposure for workers. The rooms are shielded with leaded acrylic or concrete, mobile rolling shields for interventional settings.

Some procedural controls are also formulated to reduce radiation exposure. Some of them are strict protocols, minimizing radioactive waste, avoiding mouth pipetting, and protecting skin integrity.