Course title: Atomic and Nuclear Physics

Week # 16

Main Topics: Pregnant patients, radio therapy and contamination monitoring

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Lecture Learning Outcomes:

At the end of the lecture, you will be able to:

(i) Understand the precautionary measures for pregnant patients

(ii) Explain different aspects of radio therapy

(iii) Solved problems related to radiation contamination

Vulnerability to Radiation exposure

The effects of radiation is not same for all human beings of different ages. Childhood is considered most vulnerable periods in which exposure to environmental stresses including radiation can eternally change the body structure, physiology, and metabolism to a greater extent. Exposure to high levels of radiation during pregnancy can potentially harm early life.

The effects of radiation on a developing fetus depend on several factors, such as the type of radiation, the dose, the gestational age at exposure, and the specific organs that are affected. Even though inevitable in certain cases it may turn out necessary to get exposed to ionizing radiation, including X-rays, CT scans, and certain medical treatments involving nuclear medicines and isotopes which can pose risks to the fetus.

The expected adverse effects include increased risk of malformations, growth retardations and other developmental disabilities and elevated risk of cancer. Introduction of high doses of radiation during specific phases of pregnancy can increase the risk of congenital birth defects, such as abnormalities in the brain, spinal cord, heart, or other organs.

Ionising radiation exposure during pregnancy might lead to retardation of fetus growth, where the biological systems do not develop at the expected rate. Intellectual or developmental disabilities due to exposure to high doses of radiation to the developing brain at early pregnancy may potentially lead to intellectual or developmental disabilities. I has been scientifically suggested that exposure to high radiation during pregnancy may increase the risk of childhood cancers in the offspring.

It's important to note that the risk of harm to the fetus depends on the dose of radiation received, the gestational age at exposure, and the specific organs exposed. Low doses of radiation from routine diagnostic imaging, like X-rays or CT scans performed with proper shielding and safety measures, usually don't cause significant harm to the fetus.

Medical professionals take precautions to minimize radiation exposure during pregnancy by avoiding unnecessary procedures or using alternative imaging methods that don't involve radiation when possible. Pregnant women should always inform their healthcare providers about their pregnancy before undergoing any medical procedures involving radiation to ensure appropriate steps are taken to minimize risk.

At the same time, even if radiation exposure during pregnancy is potentially harmful to the developing fetus, the risks can be minimized by using appropriate shielding and following medical guidelines to reduce or avoid exposure.

In general, radiology techniques such as X-ray imaging is used to detect and diagnose diseases and injuries to decide the forms of medical treatment. X-rays take in ionizing radiation that can impart energy into human cells and cause changes in vital tissue. It is necessary to minimize accompanying risk to the patient. Only way to reduce the risk is by limiting the radiation exposure to the minimum required to create the clinical images needed to answer the medical question.

Dose limits do not apply for radiation exposure of patients, since the decision to apply radiation is justified depending upon the individual patient situation and need. When it has been decided that a medical procedure is justified, the procedure should be optimized. This means that the conditions should achieve the clinical purpose with the appropriate dose. Dose limits are determined only for the staff and not for patients.

Radiology facilities to follow procedures to determine the pregnancy status of female patients of reproductive age before any radiological procedure. This is to evaluate the quantum of significant dose to the embryo or fetus. One approach widely accepted approach is the 'ten day rule,' which states that "whenever possible, one should confine the radiological examination of the lower abdomen and pelvis to the 10-day interval following the onset of menstruation."

Radiotherapy

Radiotherapy is one of the major forms of cancer treatment. Radiotherapy uses ionizing radiation from suitable radionuclides to destroy cancer cells and limit cell growth in the cancer site. Radiotherapy is applied with utmost care by a team of experienced and qualified experts in radiation oncology, medical physics and radiation therapy technology.

Radiotherapy can be delivered externally or internally. In external beam radiotherapy, radiation beams originating externally from a radionuclide applied to the specific tissues of patient. These beams are usually created through the use of a linear accelerator or a cobalt unit.

Internal delivery of radiation uses a technique called brachytherapy. In this treatment method, small and encapsulated radioactive sources are placed directly into or near the volume to be treated. Brachytherapy allows a high radiation dose to be delivered locally to a tumour with a sharp dose fall-off outside the tumour. Use of this treatment modality is generally limited to small, well-localized tumours. Endovascular brachytherapy, is used for prevention of restenosis in arteries following coronary arterial angioplasty.

The real position of the radioactive source inside the patient should be verified by real-time fluoroscopy during the procedure. Any inconsistency between the planned and the actual location that cannot be rectified by further source movement. In such cases the only choice is to pull the source back into the delivery device.

Radiation contamination monitoring

Radiation contamination monitoring involves the systematic and continuous assessment of areas, objects, or individuals for the presence of radioactive substances. It's a critical process used in various fields such as nuclear power plants, medical facilities, environmental monitoring, and emergency response situations to ensure safety and prevent exposure to harmful levels of radiation.

Purpose of Radiation Contamination Monitoring

1. The primary aim of contamination monitoring is safety assurance. Therefore, the goal is to safeguard individuals and the environment from the harmful effects of radiation exposure.
2. All the monitoring programs have to ensure compliance with regulatory standards and limits for radiation exposure in different settings framed for the safety

Methods and Techniques of monitoring

1. Radiation Detection Instruments are the major components of monitoring. Various instruments are used to detect and measure radiation levels, such as Geiger counters, scintillation detectors, and dosimeters. These devices can measure different types of radiation, including alpha, beta, gamma, and neutron radiation.

2. Monitoring Equipment are fixed in monitoring stations, handheld devices, and portable detectors are utilized to assess radiation levels in specific areas or on surfaces.
3. In addition to direct assessment, sampling and analysis of different components which have direct bearing with probable contamination are to be investigated. Radiation contamination monitoring may involve taking samples of air, water, soil, or surfaces to analyse for the presence of radioactive materials. Laboratory testing is often conducted to identify and quantify specific radioactive isotopes.

Areas of Application

Contamination monitoring has to be carried out in specific locations were there is greater probability of radiation contamination.

1. Nuclear Facilities are to be continuously monitored. Regular monitoring is essential in nuclear power plants, research reactors, and facilities handling radioactive materials to prevent leaks, spills, or accidents that could lead to contamination.
2. Medical Settings were nuclear medicine or diagnostic tools used are to be under the umbrella of regular monitoring. Hospitals and clinics monitor radiation levels to ensure safe use of medical imaging equipment like X-ray machines, CT scanners, and radiation therapy devices.
3. Above all environmental monitoring is unavoidable as the flora fauna are the chains in cycling contaminants in the biosphere. Monitoring is performed in environmental settings to assess radiation levels in air, water, soil, and food to protect public health and ecosystems.

Emergency Response

1. Radiation Emergencies can occur any time. In case of accidents, spills, or incidents involving radioactive materials, rapid monitoring helps assess the extent of contamination and aids in emergency response and cleanup efforts.
2. Decontamination is the vital exercise when there is contamination. Monitoring guides decontamination efforts by identifying contaminated areas or objects that need remediation.

Regulatory Compliance:

1. Following the standards and guidelines prescribed by the competent authorities are to be followed. Adherence to national and international regulations and guidelines that dictate safe levels of radiation exposure.
2. Record Keeping is a vital part of regulatory compliance. Detailed records of monitoring activities, results, and corrective actions taken are maintained for regulatory compliance and future reference.

Training and Preparedness

1. Personnel Training in regular intervals are needed to update and equip the response team. Individuals involved in radiation monitoring require proper training in the use of detection equipment, safety protocols, and interpretation of results.
2. Emergency Preparedness is another aspect to reduce impact of any contingency. Establishing protocols and procedures for immediate response in case of unexpected radiation events or contamination incidents.

Radiation contamination monitoring is a crucial aspect of ensuring public safety, environmental protection, and regulatory compliance in various industries dealing with radioactive materials. Regular monitoring, proper equipment, adherence to safety protocols, and effective emergency response plans are essential components in managing and mitigating the risks associated with radiation contamination. For monitoring radiation contamination, the most necessary instruments used to detect and quantify are discussed here.

Four basic types of radiation measuring instrument are used:

1. Dose rate meters used to measure the external radiation exposure.
2. Dosimeters which indicate the cumulative external exposure.
3. Surface contamination meters which indicate the potential internal expo□sure when a radioactive substance is distributed over a surface.
4. Airborne contamination meters and gas monitors which indicate the internal exposure when a radioactive substance is distributed within an atmosphere

Before attempting to make a radiation measurement it is essential for the user to be fully familiar with the features and controls of the instrument.

While performing external exposure measurements, following procedure can then be used.

1. Check the test or calibration certificate. Confirm that the last formal test date, test conditions and result are satisfactory. Check the last routine test result.
2. Assess the radiation to be measured. Judge whether the instrument is suitable to obtain the measurement required.
3. Set the instrument's parameters. Test the battery, adjust the detector voltage and set the zero as necessary.
4. Obtain the measurement. On multirange instruments, start on the maximum and then switch successively to lower ranges until an appro□priate reading is obtained. Check the range setting and note the reading. Repeat the measurement with and without a buildup cap or with a beta/gamma shutter open and closed. Check the stability of the readings for different orientations of the instrument.
5. Assess the result. Decide whether there are any factors which have influenced the result such as: small beam size; a non-isotropic or pulsing radiation field; temperature, humidity or air pressure effects; or interference from radiofrequency or magnetic fields.
6. Apply correction factors. Multiply the reading by any relevant correction or calibration factors.
7. Record the result. Decide whether the result is reasonable by compari□son with previous measurements or calculations. Keep a written record of the conclusions.

References:

1. David Donaire-Gonzalez et al., (2019) Personal assessment of the external exposome during pregnancy and childhood in Europe. *Environmental Research*, 19, 95-104.

2. International Atomic Energy Agency (IAEA), Radiation protection of pregnant women in radiology. Pregnant women | IAEA

3. International Commission on Radiological Protection (ICRP), https://www.icrp.org/

4. United states Nuclear regulatory commission (USNRC), Exposure (radiation) | NRC.gov

5. World Health Organisation Radiation and health (who.int)

6. Workplace monitoring for radiation and contamination. https://www-pub.iaea.org/MTCD/Publications/PDF/PRTM-1r1_web.pdf