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Radiation Protection Applications in Radiographers and Space- A Short Review

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Abstract

Radiation protection knowledge among radiographers is important to protect themselves from the biological effects of radiation exposure. Therefore, it has become a vital factor in radiation. The emphasis of this study lies in the radiation protection knowledge specifically among the groups of radiographers. Detailed information has been acquired by the author about the radiation protection program, personal protective equipment and its specification, concepts about dose limitations, radiation dosimeters, techniques of monitoring either in working place or self-monitoring, principles of ALARA, sealed and unsealed materials and the concepts of shielding in this study. When a spacecraft is in orbit, it will encounter a variety of space radiation environments, including those containing electrons, protons, heavy ions, and gamma rays. This will cause a variety of space radiation effects, including single event effects, total ionizing dose effects, displacement damage effects, surface charging and discharging effects, and effects related to internal charging. Therefore, the spacecraft should be provided with radiation shielding. Prior to discussing mass shielding, protection, and radiation hardening functional materials, it is first necessary to establish the protective principle and validity from space settings on spacecraft.

Keywords: Radiation Protection, Radiographers, Space, PPE, Radiation

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1. Introduction

Ionizing radiation has brought a lot of benefits to the public. Almost half of the cancerous cases are treated by radiation. However, radiation has its own risks also. DNA of healthy cells can be destroyed when exposed to radiation. Radiation might also cause deterministic and stochastic effects not only to the patients but also to the radiology workers. Therefore, radiation protection has become an important concept in the study of radiation. For the group of radiographers, their primary focus of work is radiation protection. The goal of radiation protection is to reduce the negative impacts of radiation [1]. The goals of radiation protection are to prevent deterministic consequences by maintaining doses underneath the appropriate threshold and to limit the chance of stochastic effects to the greatest extent possible [1]. Occupationally exposed personnel must have a basic knowledge and comprehension of the hazards caused by radiation exposure, as well as the procedures for mitigating these risks [2]. Due to excessive exposure to ionizing radiation and a lack of information about radiation safety precautions, radiographers in the early days typically passed away from cancer [3]. Radiology staff behavior is often influenced by their level of awareness of Radiation Protection (RP), and a lack of knowledge on this problem will lead to dangerous behaviors that have negative health impacts. As a result, radiographers' knowledge, attitude, and behavior about radiation hazards are crucial to RP [4]. In this paper, we will focus on radiation protection knowledge especially for the radiographers. The International Space Station (ISS) is now hosting manned space expeditions, which wl soon include missions to the Moon and beyond. Space radiation, which is made up of highly charged particles and can have severe radiation consequences, is exposed to space crew members. Because the International Space Station (ISS) is in low-Earth orbit (LEO), the geomagnetic field partially protects the crew from solar energetic particles (SEPs) and galactic cosmic rays (GCRs). Beyond LEO, magnetic shielding is essentially nonexistent, making the radiation environment hostile. Due to the lengthy flight times on the proposed Lunar Orbital Platform Gateway and upcoming trips to Mars and deep space, space personnel will be exposed to substantially greater space radiation levels. Based on the assumption of a 180-day one-way duration, similar flight conditions, and similar shielding asfor the Mars Science Lab (MSL) cruise, with additional highly variable contributions from SEP events, it is anticipated that the cumulative dose equivalent in free space for a round-trip trip to Mars will be 660 mSv from GCRs.

As human operations are expanded into deep space, radiation shielding is one of the radiation defenses under consideration. Human health risks during space activities have been described by the US National Aeronautics and Space Administration (NASA). Radiation dangers are increased by protons and high atomic number, high energy (HZE) particles from He to Fe nuclei in GCRs. Even though HZE particle contributions to the GCR composition are minimal, the HZE particles significantly contribute to the radiation dosage due to high linear energy transfer (LET), leading to severe biological impacts. In manned flights on the space shuttle, the Mir station, the ISS, and the Apollo era, dosimetry in the space environment has been conducted. Compared to personnel on missions in LEO, crews on the Lunar Orbital Platform Gateway will experience significantly greater radiation dose rates [5].

2. Radiation protection program

Radiation protection program (RPP) should be organized by the employer in every workplace in order to increase the radiation protection knowledge among radiographers. One of the most critical roles of a radiation protection program play is to prepare radiation employees in safe work practices. Employers should offer radiation workers information and training so that the workers who may be subjected to ionizing radiation risks realize how to utilize all radiation-producing equipment or radiation materials in the workplace securely [6]. The radiation protection program for radiation workers should cover issues such as the requirement for local regulations and guidelines to be followed, arrangements for the providing of personal protective equipment, a program for radiation protection education and training, arrangements for individual monitoring, and techniques for regularly reviewing and monitoring the radiation protection program's performance [7].

3. Personal protective equipment (PPE)

A radiographer should know that excessive exposure can be reduced by using personal protective equipment (PPE) properly and following the rules for radiation protection [3]. The most common Personal Protection Equipment (PPE) which is used in radiation rooms are made from lead. Example of others PPE are lead apron, lead gloves. The high energy radiation such as gamma rays can be stopped by substances which are thick and dense shielding such as lead and concrete. Workers' training must highlight the significance of appropriately fitting and using personal protection every time. Radiographers must choose the PPE which is fitted to themselves. Workers must be provided the training, instructions, and knowledge about the unique risks of the job, as well as the repercussions of unprotected exposure. Their training should cover where, when, and how to procure, fit, utilize, and clean protective equipment. They must also be able to identify malfunctioning equipment and problems that may come from its use. PPE such as aprons, gloves and sleeves used incorrectly might increase personal radiation exposure. For example, they should be kept flat or on circular hangers. It is because cracks and damage in the shielding are caused by folding or creasing which may result in recurrent radiation exposure to the same region of the body even it is just a slightly damage and they have the potential to diminish the level of protection [2].

Yanjie Zhao et.al (2020) has suggested that personal protection equipment must be worn in a certain sequence [8]. Every radiographer must be familiar with the proper methods and procedures for wearing personal protective equipment when conducting every radiation treatment to the patients. The procedures of taking on the PPE is as follows, firstly, the radiologic technologist must wash their hands, then they wear on the first surgical cap, the respirator, followed by the second surgical cap, and then isolation gowns, then the first surgical gloves, first shoe covers, protective glass, disposable gowns, second surgical gloves, second shoe covers, second surgical mask, and finally they must check the outfit for tightness. All these procedures are done in a clean room [8]. After exiting the contaminated area and entering the possibly contaminated region, medical staff should clean their hands before removing the surgical mask, outer shoe covers, outer gloves, disposable gowns, and protective eyewear in the right order. When medical staff go into the second buffer rooms, they should remove their inner shoe coverings, isolation gown, inner gloves, and outer cap. Similarly, the radiation worker must undertake hand hygiene before entering the first buffer room. They then go to the first buffer room, remove the respirator mask, inner cap, and lastly a surgical mask. It is important to note that the radiation worker cannot touch the front of the respirator when discarding it. Lastly, they do personalized cleansing in the clean room, disinfecting the external auditory canal with 75% alcohol, the nasal cavity with iodine, the mouth with normal saline, and taking a complete shower for less than 30 minutes after returning to the home [8].

4. Dose Limitation

Dose limits are established to shield the employees from either the deterministic effects or stochastic effects of ionising radiation. They are calibrated to strike a balance between the risks of exposure and the advantages of employing ionising radiation [9]. Therefore, a radiographer should know the dose limit for each categories of radiation workers and always monitoring themselves. If the dosage report shows that the employee received a dose that exceeded the dose limit, his employer is required to send him for a medical checkup, which involves a thorough blood examination. In addition, the individual will be suspended from radiation employment for an extended length of time [10]. However, for a female employee becomes pregnant, she should tell her employer so that her working circumstances can be amended as needed.

5. Radiation dosimeters

The radiographers should always wear their own personnel dosimeter so that they can monitor their radiation exposure levels or absorbed radiation from time to time. Besides that, radiation dosimeters are also used to monitor the safety level of radiation in their working environment. Some of the examples of radiation dosimeter that has been used are handheld survey meters [11]. Handheld survey metres are the most common and well-known tools to determine ionising radiation. These metres are primarily required to accurately assess radiation exposure rates, dosage rates, and levels of radioactive contamination. Some of the common examples of handheld survey meters are Geiger Muller Counter, proportional detectors, or scintillation detectors.

Each type of equipment has distinct features, and a radiation specialist should be contacted by every radiation worker to determine the optimum portable survey device for the application [5]. The most common radiation dosimeter that has been used for radiographers for the purpose of self-monitoring when exposed to radiation is the pocket ionization chamber. A portable ionization chamber can assist them in reading in the field in real time, allowing the user to prevent from potentially harmful doses [11]. Noted that a radiation dosimeter or badge does not offer protection while measuring and detecting radiation exposure. Radiation monitoring is used to verify that dosage restrictions are not exceeded. Workplace radiation monitoring is required to guarantee excellent practice and to enhance through corrective actions when concerns are found [6]. Besides that, others common types of personnel radiation dosimeters that radiographers often use are film badge, Thermoluminescent Dosimeter (TLD) and pen dosimeter. Unfortunately, the film badge and TLD are now outdated and will be phased down in the future and replaced by Optically Stimulated Luminescent Dosimeter (OSLD) and Radiophotoluminescent Dosimeter (RPL). RPL promises the best dosage measuring equipment in comparison to TLD and OSL. It is because the luminescence signal has no attenuation after reading, therefore RPL may be reviewed out several times for a single exposure [13].

Whole Body Counting is a type of device which used to measure radioactive elements in the body with the technology of a spectrum analyser and a counter directly. This device is extremely sensitive and capable of measuring weak transmitted gamma radiation from radionuclides accumulated in a specific bodily organ. Chair type and shielded room type are the two most frequent categories of whole-body counting systems [14]. The chair type features a chair form with three detectors placed at different locations. The detector's placements will enable for the most accurate detection of radioactive deposits in three separate vital organs, including the lung, thyroid, and stomach. Besides that, this system includes enough thickness of the shielding material on the detector and the patient to reduce contamination from background radiation [14]. The shielded room type, as the name indicates, is a room that is protected on all sides, resulting in a low background counting environment. The chamber is outfitted with a gamma spectrometry instrument, as well as gamma analysis software. The radiation worker must be present in the room when the measurement of radiation contamination is being taken. The radionuclide concentration measured in parts of the body will next be translated to radiation dosage by using the method of mathematical model of humans, followed by the same data analysis as in the bioassay approach [14].

6. Techniques of monitoring

It is important for all the radiographers to have knowledge about the techniques of radiation area monitoring. Radiological monitoring is classified into three categories which are area monitoring, workplace monitoring and personnel monitoring [14]. Techniques of area monitoring can be categorized as two different categories which are active monitoring and passive monitoring. Active monitoring involves utilizing portable radiation detector such as survey meter while passive monitoring involves the use of an integrated dosimeter, such as film or TLD badges, that is placed in a strategic area [15]. The legislation requires that any workplace that contains radioactive sources or irradiating devices be checked on a regular basis to guarantee that the working surroundings are safe for every radiation worker. Area monitoring is necessary to properly classify operating areas. The classification of locations is critical because the areas will be segregated into three distinct groups: clean areas, supervised areas, and regulated areas. Different areas need various administrative controls. For example, the clean area is open to the public, but the monitored and controlled areas are confined to radiation workers only [14]. In area monitoring, there are mainly two kinds of measuring methodologies utilized in radioactive contamination which are direct and indirect method. However, these approaches differ depending on whether they will be for surface or environmental radiation pollution. Surface contamination monitoring can be done either directly using monitoring instruments or indirectly by collecting smeared samples from contaminated surfaces and then measuring them with a monitoring apparatus. A direct technique involves gently moving the mobile contamination monitor across the probable contaminated region. The probe of the monitoring instrument should be positioned as near to the surface being inspected as feasible while not touching it. Instruments should be correctly calibrated so that actual readings represent the real degree of contamination. Any radioactive elements discharged into the environment will be measured to verify that the amount emitted is below the permitted level for environmental contamination. Airborne radiation pollution is measured indirectly using an air sampler and a filter device [15].

Bioassay method is a type of internal exposure monitoring technique [16]. It is an indirect approach for measuring the absorption of alpha, beta, and low energy gamma emitters. Samples such as urine, sweat, or blood have been collected and analyzed to get the necessary data. After they have collected the data, it will be transformed to radiation dosage using a mathematical model of a human person. These specimens are gathered throughout a period to provide a more precise measurement [14]. Apart from that, bioassay method is performed by using the radioisotopes to monitor the interested organs. For example, tritium, which is a type of hydrogen isotope is utilized in urine analysis while radioactive 125-iodine will be ingested for thyroid scanning [16]. In urine testing, and urine sample is analyzed on a liquid scintillation counter which can reveal whether the radioactive substances has been absorbed by the radiation worker. Beta emitters are eliminated nearly completely in the urine if the worker has been contaminated whereas it may be eliminated just partially. In the case of thyroid scanning, when radioactive iodine enters the body, it will search for the thyroid gland and accumulates there. A thyroid count is often performed by positioning a scintillation detector in front of the thyroid gland for some time, with the resulting count showing whether the radioactive iodine is presence or absence [17].

7. Principles of as low as reasonably achievable (ALARA)

As Low as Reasonably Achievable (ALARA) principles can be achieved in three different aspects which are, Time, Distance, and Shielding. "Time" basically denotes the duration spent close to a radioactive source.

Reduced exposure duration decreases the dosage correspondingly. When the duration spent in a specific radiation field is twice, so does the worker's dosage. As a result, in order to decrease radiation dosage, the duration spent in the radiation field must be restricted [1]. The term "distance" indicates the proximity of a radiation worker to a radioactive source [18]. With the inverse square law, the absorbed radiation dose is inversely proportional to the square of the separation distance. In general, doubling the distance will reduce the radiation exposure by a factor of four [1]. Barriers that can absorbed radiation must be placed between the radiation worker and the radioactive sources for the purpose of shielding and protecting [18]. The amount of radiation that gets through decreases exponentially as the barrier thickness increases [1]. Shielding with lead or lead similar components for x-rays and gamma rays is an efficient approach to limit radiation exposure [19].

Every radiation staff must know how to apply the ALARA principles in their working place. The staff at a radiology department should be instructed in what to do in case of an emergency, receive frequent refresher training, and be familiar with the written procedures for their work with radiation and the operation of the devices they use, including the safety features. More training should be provided when new medical imaging technology is implemented in the radiology department. However, Paul A. Oakley suggested that the ALARA principle is not suitable for all conditions. Since there is currently no reliable evidence supporting the use of LNT in the low-dose range, hence using dose as a proxy for risk in radiological imaging is inappropriate, and thus the ALARA concept is outmoded [20]. As a radiographer, one should know how to handle and store the sealed and unsealed radioactive materials to prevent radiation contamination. They must be taught and aware about how to operate it safely and securely in compliance with any regulatory standards. When it is used incorrectly or intentionally, such radioactive materials can inflict bodily harm or death [11].

A sealed radioactive source is a solid radioactive substance that has been permanently sealed in a capsule. An open source is a type of source which can cause leakage and spread pollution. It can either be in solid, liquid, or gaseous form [21]. Leak testing for sealed radioactive materials should be carried out every 12 months. If radiation workers should alert to the Radiation Protection Officer immediately if there is any leakage [22]. Every radiographer should keep the unsealed radioactive materials properly in lead lined containers [23]. Besides that, these radioactive materials should all be labelled well with a “Radioactive” warning sign [11]. The term "half value layer (HVL)" refers to the thickness of shielding material that decreases the radiation rate to half of what it was before [24]. Thickness plays an important role in shielding concept. Therefore, it is important as it is used to calculate the thickness of the shielding materials that are needed so that it plays a protective role that has the efficiency to stop the radiation.

$$\boldsymbol{No\ of\ HVL, 2^n = \frac{Dose\ rate\ before\ shielding}{Dose\ rate\ after\ shielding}}$$

where n refers to the half-value layer. The most efficient shielding material is lead which can block and absorb high energy radiation. Because of its attenuating characteristics, lead has been widely regarded as "the element of choice" for radiation shielding. Lead is a malleable and corrosion-resistant metal. Because of its high density at 11.34 grammes per cubic centimeters, lead is an efficient X-ray and gamma-ray radiation barrier [25]. Shielding is important for every radiation worker to protect themselves from radiation contamination and exposure. They should stand behind the shielding barriers which are made from shielding material when conducting radiation treatment for patients.

8. Space radiation environment

Between low orbits and higher altitudes like the geostationary orbit, the nature of this environment is very different. We focus our discussion on energetic charged particles from solar particle events, galactic cosmic radiation, and particles trapped in radiation belts when it comes to radiation. According to the particle's energy, nature, and satellite orbit, the degradations will vary from the point of view of consequences. The effects of space radiation on materials and electronic components have been the subject of extensive research for many years. For examples, the deterioration of electronics, photonics, thermal control coatings, and material erosion are cumulative impacts. Transient effects include noise in photonics and detectors, as well as single event effects in electronic circuits. Lastly, discharges of static electricity [25]. The problem of radiation-induced biological consequences caused by high energy radiation is amplified by man's expanding presence in space. The biological impacts of radiation might be of two different kinds. Impacts that are not random, such as cell alteration or destruction. The strength of the symptoms and the rate at which they manifest both rise in direct proportion to radiation exposure (Stassinopoulos & Raymond, 1988). Stochastic effects linked to cellular changes, whose likelihood of developing over time rises in direct proportion to radiation exposure. Cancers and genetic impacts are two examples [26].

8. Space radiation protection materials

Quality shielding protective materials, electrostatic protection materials, and anti-radiation functional materials make up space radiation protection materials. The fundamental radiation protection strategy now employed for astronauts in space is mass shielding. As charged particles go through the substance, their energy gradually decreases until they eventually stop after capturing enough electrons. The incident particles will be blocked in the material when the thickness of the shielding material is larger than the range of a charged particle in the material [27]. Therefore, depending on the type of particle, a material of a specific thickness can reduce the energy penetrating the particle and protect the particle radiation of a certain energy range. However, the secondary radiation and the increased weight of the spacecraft make the thickening of the shielding material problematic in various ways. The best shielding material in theory is liquid hydrogen, although there are still many issues with actual use. Water, which is far better than aluminum but not as effective as liquid hydrogen, is the favored shielding material.

The highest possible number of electrons per unit mass, the largest nuclear reactioncross section per unit mass, and the least number of secondary particles are requirements for high-performance shielding materials [28]. The development of novel radiation-protection materials and techniques has received significant financial and human resources investment from the United States. Polyethylene is a better radiation shielding material, according to NASA studies. As a result, the United States offers a polyethylene sleeping bag in the astronaut rest area, which can offer some radiation protection for astronauts while they sleep. High-energy charged particles, especially heavy ions, can be efficiently protected by utilizing materials made of high-quality elements, and a lot of bremsstrahlung radiation will also be produced. The efficacy of the unit mass thickness material's shielding increases with a decrease in atomic number when considering the protection provided by the Galaxy's cosmic rays. So, an efficient technique to passively protect against space radiation is to build with low atomic number and high atomic number elements in combination [29]. Isolation can cause severe psychosocial adaptation problems, which might result in neurobehavioral issues. Many ground-based platforms, such the Antarctica-based Concordia facility and the ongoing Mars500 isolation experiments in Russia, are utilized to research these issues and create solutions.

The issue of autonomous medical care (AMC), or the capacity to manage illnesses or accidents in total isolation, arises when people are isolated. This is categorically a Category 1 danger for the Mars expedition. Most autonomous medical care AMC risk mitigation strategies are technological, or they rely on the advancement of telemedicine and portable medical equipment. There are dangers associated with radiation exposure from space. Both acute for example short-term danger of radiation illness and late (cancer) impacts are possible due to the complex nature of the space radiation environment. When personnel are unable to achieve suitable protection during strong solar particle occurrences (SPE), acute radiation syndrome (ARS) can result. Chronic exposure to galactic cosmic radiation (GCR), which differs significantly from the natural background radiationon Earth in terms of both quality and quantity, is linked to late radiation morbidity [30]. Liquid hydrogen performs best as a shield material in space since it is the lightest substance available. Because it is a low temperature liquid, hydrogen is not a useful material for a shield. The design of space shields may be significantly impacted by hydrogen storage in lithium hydride or graphite nanofibers. Polyethylene seems to be a good compromise so far. In the crew sleeping quarters on the ISS, aluminum panels with lighter polyethyleneslabs have been employed by NASA. The dose measurements were in line with the anticipated 20% radiation decrease in the protected area. Water is a natural light barrier and is available in large quantities on the ISS and other spacecraft with life support systems. Stacks of moist cleaning cloths and towels can be used to create a "protective curtain" [31].

9. Conclusions

The present study was designed to determine the radiation protection knowledge among radiographers. Generally, it can be concluded that the radiation protection system among the radiographers can be summarized in several concepts which are PPE, principles of ALARA and techniques of self-monitoring and working place monitoring by using radiation dosimeters. These concepts are important to them to protect them from the radiation contamination. The current findings highlight the importance of radiation protection safety measurements to the radiographers in order to reduce the related hazards. Medical imaging is rapidly evolving nowadays. As a result, radiation protection systems must stay abreast to the latest technologies and be upgraded as needed. The security and dependability of spacecraft in orbit are seriously threatened by space radiation. The goal of those who work in aerospace science and technology is to increase a spacecraft's radiation resistance through structural design and material choice. Since the combined impacts of primary and secondary radiation must be considered during mass shielding, the quality-restraining effects of aerospace loads must also be considered. As a result, one crucial area for spacecraft protective material development is the creation of composite materials made of low- and high-atomic-number elements that reduce spacecraft mass while increasing radiation resistance. The use of nanotechnology in materials for spacecraft radiation shielding is another area of active research [32].

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