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Radiation Protection and Decommissioning of Nuclear Facility- A Short Review

Khairunnisa Rosda, Nor Azwani Ridzuan, Siti Amira Othman*

Faculty of Applied Sciences and Technology "Universiti Tun Hussein Onn Malaysia", 84600, Pagoh, Johor, Malaysia

Abstract

A recommended practice for protecting workers from ionizing radiation is creating and implementing a radiation protection program. A qualified professional such as a healthphysicist, often known as a radiation safety officer, typically oversees a radiation protection program (RSO). Ionizing radiation has been used in many industries these days including the medical field, food production, engineering, and manufacturing. Radiation protection is used to protect from ionizing radiation being exposed to humans, surroundings, or workplaces. Thisreview will discuss (a) as low as reasonably achievable (ALARA), (b) radiation protection dosimetry, and (c) survey area monitoring. One of the radiation protections that should be doneis using the principle of ALARA. The principle of ALARA is to make sure the patients and medical staff receive as low as possible radiation exposure while making the treatment successful. Nuclear facilities such as power plant or research reactor that generate electricity by using the process of nuclear fission. While nuclear decommissioning is the process from decommissioning and removal of nuclear material to environmentally sound site recovery. This entire complex process, which involves repairing radioactively contaminated plant systems and their structures and removing radioactive fuel, typically takes 20 to 30 years.

Keywords: Radiation Protection, Decommissioning, Nuclear, Nuclear Reactor, Radiation

Full length article **Corresponding Author*, e-mail: sitiamira@uthm.edu.my

1. Introduction

Any process in which energy is emitted by one body and moves across a medium or through space before being absorbed by another body is referred to as radiation. Ionizing and non-ionizing radiations are two categories that can be used to categorize radiation based on theimpact they have on the matter. Examples of ionizing radiation are x-ray, gamma, and cosmic rays while non-ionizing radiations are microwaves, visible light, and radio waves. Ionizing radiation has many benefits to humans as it could be used in medical treatment and research. Though, ionizing radiation has detrimental effects on the human body that worsen as its use rises. Skin burns or radiation syndrome can occur when the ionizing radiation exposed exceeds the accepted limit. Ionizing radiation at low doses can cause long-term effects like cancer. Humans must consequently use radiation protection to shield themselves from radiation exposure and its harmful effects [1]. Patients, doctors, and employees in several departments, including radiology, interventional cardiology, and surgery, are concerned about radiation safety [2]. Radiation protection seeks to minimize the negative effects of ionizing radiation by reducing unneeded radiation exposure [3].

Since the early 1900s ionizing radiation has been used as medical treatment to treat and diagnose people. It directs an x-ray beam to a specific area of the body to produce a computerized image of the structures there, including the bones, tissues, and organs. X-rays stand out from lower energy photons because of their ability to ionize atoms and destroy chemical bonds [4]. Free radicals are created because of this ionization, chemically active substances that may inadvertently harm DNA [5]. By that, the medical staffand patients that receive the treatment can be exposed to ionizing radiation either by scattered radiation or direct exposure. Therefore, to prevent exposure to ionizing radiation, radiation protection is crucial for both employees and patients. Therefore, even at low doses, humans need to be protected from radiation because it can eventually lead to cancer and other negative effects. The radiation protection should include As Low as Reasonably Achievable (ALARA), radiation dosimetry, and survey area monitoring and radiological control. World Nuclear Association (2022) explained briefly that decommissioning term meaning includesradioactivity clean-up and dismantling process of the plant.

The process started with a declaration of permanent closure for any operations, followed with defueling and coolant removal. After waste successfully removed and decontamination done, license termination must be approved and verified [6]. Although there are actually no technical limits to nuclear reactor units, nuclear plantsmost commonly get decommissioned and demolishes once reach their end of their designed life which about 30–40 years. This is purposely to make the site available for other uses and activities.Most newer plants today are designed for a 40-to-60-year operating life which is a few years longer than the older ones. The European Commission (2021) explained that following the Chernobyl disaster in 1986 has made similar nuclear reactors or any that are first generation Soviet-designed reactors consideredas unsafe as existing nuclear reactors in Europe. Two reactor units which has same design as Chernobyl in Ignalina, Lithuania undergo decommissioning. From the year 2016 to 2020, over 98% of the spent fuel elements were removed from the reactor building and transported to dedicated long-term storage facilities [7]. To shut down a nuclear plant, Nuclear Energy Institute, NIE (2016) stated that the reactor unit must be permanently in stable uncritical condition, and all heat generated must discharged safely.

The Nuclear Regulatory Commission (NRC) formed regulations and guidance pointing out the requirements and process flows that associated companies must followin order to ensure that decommissioning is safe and environmentally sound. Some steps in the process such as decontaminating the facility, dismantling the unit’s structure as well as storing all used nuclear fuels are vital. This is because to ensure there are reduction with the residual radioactivity, contaminated materials are well removed to suitable disposal facilities and other used materials disposed to consolidated storage area. Then, the property was released for other purposes [8]. There are three generally accepted approaches to decommissioning: immediate dismantling, deferred dismantling and entombment. A suitable flow of operations, protective system and equipment are important to ensure radiation protection among the workers. Relatedly, in order to avoid radiological consequences, continuous monitoring of the radiological situation. Some significant impacts of decommissioning process are caused by the handling, storage and disposal of low and intermediate level radioactive waste. The evidence presented is one of the first to be compiled on the approach to nuclear plant decommissioning and provides useful insights. While the conclusions are supported by more comprehensive research, caution is clearly warranted in applying the general principles drawn from the three cases.

2. As low as reasonably achievable (ALARA)

The principle of ALARA in medical imaging is to reduce the radiation exposure of medical staff and patient as low as possible with successful treatment [9]. At least as far back as the Manhattan Project, the fundamental idea embodied in the ALARA principle can be found [10]. This idea is used in radiologic practice to minimize radiation exposure and its associated dose. The ALARA concept should serve as a reference for the selection of technical radiography and fluoroscopic exposure parameters for all patient imaging procedures for the radiographer and the radiologist. The ALARA has three basic radiation protection concepts including time, distance, andshielding. Time simply refers to the time that the radiographer or employees spent near the radiation exposure source. Stay away from dangerous regions including radioactive areas and areas with airborne radiation. To minimize exposure, the radiographer should minimize the time and complete their job as soon as possible and quickly leave that area. Over the period of exposure, radiation exposure can increase [11]. For example, the radiographer should check the X-ray in the proper spot at the appropriate time without a fuzzy image. Reducing the time near exposure can reduce the radiation exposure as well as reduce the radiation dose. Other than that, doubling the distance from the radiation area can reduce exposure. Theamount of radiation exposure is inversely related to the square of the distance, not to the distance from the radiation source [12]. This means that increasing the range from the source ofradiation by two can only cut the exposure to radiation by one-fourth, not by half [11]. Increasingthe distance also will decrease the radiation dose. This approach can be compared to a fire thatis raging; the closer we are to it, the more heat we experience, and the farther away, the less heat we feel. By maximizing your distance from the x-ray source, you can decrease your dose and will avoid picking a strong dose in your hand.

Lastly, shielding is also one of the basic principles of radiation protection in ALARA. The best way to protect humans from radiation exposure is by using lead or lead equivalent. Gamma rays and neutrons are shielded from entry by barriers made of lead, concrete, or water.There are many types of shielding that the medical staff use to protect themselves from radiation exposure such as lead aprons, lead glasses, and thyroid shields. Putting shielding between humans and radiation can help reduce and eliminate radiation exposure and radiationdose. The type of radiation the source is producing determines the type of shielding that will be most effective. The radiation shielding equipment costs a lot of money, and using them might be uncomfortable. However, a doctor can be shielded from radiation exposure when using these instruments [11]. The ALARA has three basic radiation protection concepts including time, distance, and shielding. Medical practitioners must be informed about the levels of exposure and risks associated with the diagnostic procedures they must defend using radiation dosimetry, which is required to assist X-ray imaging equipment operators in determining if their operations are optimized [1]. Survey area monitoring function to document every radiation exposure level, radiation exposure to the worker, and contamination of radioactive material. Radiation protection can shield people from radiation exposure and is particularly beneficial in loweringradiation exposure to the body.

3. Radiation Protection Dosimetry

Medical X-ray imaging is a crucial diagnostic tool for a variety of injuries and disorders,and it is increasingly utilized to direct minimally invasive psychotherapy that provides better and more rapid options than traditional surgery for the diagnosis of urgent medical conditions. X-ray imaging has become one of the important and giving benefits to patients in treating injuries or diagnosing diseases of patients. Radiation dosimetry is necessary to help X-ray imaging equipment operators decide whether their operations are optimized and to advise medical professionals about the levels of exposure and dangers associated with the diagnostic procedures they must defend [1].

An individual's exposure to external radiation dose is measured using radiationdosimeters. An individual is often given a dosimeter to monitor exactly the amount of radiation. Thermoluminescent dosimeters (TLD), optically stimulated luminescent dosimeters (OSL), and film badges are examples of badge-type dosimeters. These dosimeters are normally worn for a specified period—usually weekly or monthly being processed at a professional laboratory.Other than that, there is also an electronic person dosimetry (EPD) type for a person to use to measure their radiation dose and a pocket ion chamber (PIC) provides a measurement of cumulative radiation dose. In conjunction with manufacturers of digital radiography systems, the International Electrotechnical Commission and the American Society of Physicists in Medicine establishedand created a new exposure index for digital X-ray imaging systems [13]. The index has since become an international standard. The exposure index dose is not the specific dose required fora patient and medical staff but it is the estimated dose for patients and the medical staff depending on the typical radiation treatment. Other than that, there are many ways to study theradiation dose that is exposed to the patients and one of them is an effective dose. Effective dose is an estimation of the exposure to the entire body.

The integral dose is also a different measurement that depends on the patient's features, the area exposed to radiation, and the number of X-rays the patient has absorbed. Moreover, organ dose depends on the procedure's location and the closeness of organs nearby and in the X-ray field [14]. For radiographic treatment of the chest, teeth, and limbs, the effective dose range is 0.02 mSv. The radiography treatment dose range for joints, the head, and the neck is 0.02 mSv–0.2 mSv. For radiographic treatment of the abdomen, pelvis, and spine, the effective dose rangeis 0.2 mSv-2.0 mSv. For computed tomography, the effective dose range is 2 mSv–20 mSv [15]. As a result, one goal of radiation protection dosimetry in medical diagnostics is to give medical professionals an estimation of the degree of risk involved with the doses of radiation that their patients have received. Therefore, the second goal of radiation protection dosimetry in radiology is to offer a realistic approach that will enable imaging X-ray services to measure the doses they are employing and analyze them to good practice evaluated on a national or international scale. The main goal of radiation dosimetry determining the average dose rate fromX-ray exams supplied to human tissues and organs known to be vulnerable to radiation-inducedcancer or genetic damage.

3. Survey area monitoring

Survey area monitoring is another radiation protection that needs to be done for low doses of ionizing radiation. Survey area monitoring function to document every radiation exposure level, radiation exposure to the worker, and contamination of radioactive material.There are certain methods and procedures for survey area monitoring. The steps in area monitoring are first the worker should establish a layout plan by referring to the plot plan of the area that needs to be monitored. The area of monitoring can be done passively or actively. Active monitoring uses a mobile or portable radiation detector, such as a survey meter, whereas passive monitoring uses an integrated dosimeter, such as film or TLD badges, installed at a strategic location. In addition, workplace monitoring should concentrate on the quantities to be monitored, the frequency of the measurements, and the timing and location of the measurements. Finally, the monitoring of the workplace should concentrate on the reference levels and the necessary steps when they surpass the maximum level. In areas where radioactive contamination is likely to occur, contamination monitoring is another crucial step in radiation protection. It entails monitoring for environmental contamination, airborne contamination in workplaces, surface contamination in workplaces, and contamination of personnel. The type of radiation involved in the contamination determines the detector that is utilized but the G-M detector has an advantage over other detectors in terms of being more sensitive, but it falls short in terms of response time.Every monitoring could be done by direct monitoring or indirect monitoring. Monitoring for surface contamination can be done directly with a monitoring tool or indirectly using a smear sample that was taken from the contaminated surface and then quantified with the tool. Direct monitoring is carried out by slowly moving the device of monitoring and shouldbe brought as close as possible to the surface that is being monitored. The efficiency of the contaminant is measured using the indirect monitoring technique of a smear sample. Monitoring environmental contamination is to guarantee that any emission of radioactive material into the environment is within the permitted limit, it will be monitored. Monitoring for contamination serves to make sure that radioactive contamination levels stay within permissible ranges. Personnel who operate with open or unsealed radioactive sources or in locations where contamination is known to be present must undergo monitoring for internalcontamination.

4. Decommissioning approach

Immediate dismantling, deferred dismantling and entombment are three commonly used approach of decommissioning. Each of them needs early and clear decisions about the timing of the closure of facilities and intended future use of the site. Besides, they also require enough funding, trained personnel, regulatory supervision and waste management and disposal facilities [16].

4.1. Immediate Dismantling or Early Site Release (DECON)

This option is a phase that allows the facility to be removed from regulatory control to safe storage before dismantling relatively soon after shutting down of regulated activities [17]. It involves draining systems down, deactivating unrequired electrical systems, legacy wastes removal, security systems adjusting and environmental surveillance. Only then, the site is available for any re-use activities. DECON lowered the radiation level in the plant and reducesthe potential exposure to workers during subsequent decommissioning operations [18].

4.2. Safe Enclosure or deferred dismantling (SAFSTOR)

This approach holds the final removal of controls for a longer time commonly between 40 to 60 years. Until the dismantling and decontamination process happens, the facility is placed into a safe storage to ensure all residual radioactivity has decayed. Difference between DECON and SAFSTOR is that SAFSTOR might unpredictably able to increase the cost proportional to risks in this case.

For example, the reactor left intact but in a safe state, highlyradioactive components such as used fuel need to be removed and placed in on-site storage while the surveillance and monitoring continue. On the other hand, this process allows decay of radioactivity and dismantling of the plant in future years exactly like the DECON [18].

4.3. Entombment (ENTOMB)

For this option, the facility placed into a condition that allow the remaining on-site radioactive material to remain there without ever removing it completely. Most of the times it involves decreasing size area where the radioactive material is located and then permanently close the facility on site into a state where the remaining radioactive material is on-site without ever removing it [18]. The implementation phase is the actual hands-on operations fordecommissioning as it also involves removal, packaging, transportation and storage or disposalof systems and structures to meet objectives [17]. In addition, license termination is the last phase for final demolition of the structure and restoration of the site of the nuclear power plant**.** This step is important to ensure the license has been terminated and all radioactive substances above acceptable levels have been removed. Fromthese three approaches, SAFSTOR allows significant reduction in residual radioactivity on site and lowered radiation hazard during the eventual dismantling [18].

4.4. Challenges in Decommissioning of Nuclear Facilities

Radiation protection during decommissioning is somewhat similar to radiation protection during shutdown. In any situation, activities involving high doses and open workplaces must take into account the risk of contamination or contamination with radioactive material. Several researchers mentioned in their study of how due to these, appropriate flow of operations, protective system and equipment are important to ensure radiation protection among the workers.Relatedly, to avoid radiological consequences, continuous monitoring of the radiation situation not only at a high level, but also work activities for individual, radiation protection mustbe incorporated early in the decommissioning plan ensuring a high level of training. radiation protection for all involved, managing and maintaining work orders, properly directing staff, ensuring ongoing work control, managing the complexity of activities. Underlaying, managing and optimizing materials Supervising nuclear installations and supervising operations [19].

5. Impacts of Nuclear Facilities Decommissioning

Several researchers write about the fact that decommissioning of nuclear power plants was performed very infrequently, and based onthis fact, the ongoing nuclear power plant Examine Germany's Lubmin on the environmental impact of decommissioning. Methodological aspects such as transferability to other decommissioning projects and assumptions about the plant's useful life will be discussed. The results show that the environmental impact is mainly due to the need for on-site energy to remove components and circumferential work. Other significant impacts are caused by thehandling, storage, and disposal of low and intermediate level radioactive waste. Recycling of conventional non- radioactive metal waste can significantly reduce the process, depending on the recycling rate.

6. Conclusions

In conclusion, the low doses of ionizing radiation have given many benefits to humanscompared to the cons. Low doses of ionizing radiation also have been used in medical treatmentfor many years and have thrived year after year. However, a small amount of this low dose ofradiation's negative effects cannot be tolerated. Human radiation exposure will eventually lead to many other diseases, including cancer. Therefore, radiation protection cannot be disregardedor undervalued. Radiation protection can shield people from radiation exposure and is particularly beneficial in lowering radiation exposure to the body. There are many ways to protect the surroundings and humans from being exposed to radiation. From all journals and researches reviewed associated with decommissioning of nuclear facilities activity, the nuclear industry shown that with technology, resources and expertise, the industry can successfully decommission commercial nuclear reactors. Besides, commercial reactor operators have sufficient funds to decommission the nuclear plant. The disposal process is done ina safe and environmentally friendly manner. The decommissioning of a nuclear power plant will have relevant impacts on environment. Dose monitoring on the human body and at workplace as well as site entry and exit screening are vital to protect both workers and the public societythroughout the whole decommissioning process.

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