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The Application of a Graded Approach in the Management System Requirements to Radiation Protection for Nuclear Facility

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ABSTRACT

A graded approach meets requirements for all phases of a nuclear facility's lifespan, including site selection, evaluation, design, construction, commissioning, operation, and de commissioning. The management system requirements application should be assessed for each process's system, product item, components, structure, activities, services, or controls. The International Atomic Energy Agency (IAEA) incorporates the principle of a graded approach as a fundamental element to ensure safety at nuclear sites. This study utilizes a graded method to implement management system requirements for radiation protection. The present study identifies examples of the aspects that must be taken into consideration during grading. The requirements of management system are largely relevant to the regulation of the working environment, human resource management, strategic planning, and the performance monitoring and evaluation. This paper illustrates the implementation of an organized methodology in applying radiation protection requirements. It includes various examples such as the categorization of work areas and subsequent classification of zones within each area, controlling access to these areas, establishing local regulations and overseeing work activities, monitoring both the workplace and individuals, planning and obtaining work permits, as well as providing appropriate protective clothing and equipment. This paper is clear on importance of applying the principle of graded approach to enhance the safety of the facility, by introducing some common practical examples. The paper ensuring the importance familiar of the staff about The characteristics of (facility/activity) to prepare a references documents for the operational procedures according to the safety significance and complexity, considering The potential impacts of the facility, human life and health and the environment, the required corrective actions for any possible consequences of an unanticipated event or an activity improperly carried out, with certain level of control, according to the resources available, and the associated risks. Moreover, Case study for both of (external/internal) doses of the facility staff is introduced as a practical case for optimization using the graded approach.

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Introduction

The management system evaluates and confirms the safety of the facility, which includes regular safety assessments conducted by the regulatory body. The assessment is based on various sources of data, including the SAR, the radiation protection program, operational limits and conditions, operating procedures, the emergency plan, and training documentation. It also takes into account modifications to SSCs and their cumulative effects, procedures change, measures for radiation protection, standards and regulations, aging effects, lessons learned and operating experience from similar facilities, technical developments, re-evaluation of the site, planning for emergency, and physical protection. Evaluating the implementation of management system criteria for radiation protection in nuclear facilities reduces overall expenses while enhancing radiation safety through risk control. Hence, a graded approach functions as a primary tool for maximizing regulatory resources, controls, and checks. It includes components such as personal qualifications and training, procedure types and formats, verification, inspection, testing, materials, records, and supplier performance. This applies to both the primary systems and the secondary systems. Ensure the inclusion of a radiation protection system as a key objective. Hence, we regard the Radiation Protection Program (RPP) as a system that is classified or evaluated based on a set of levels or grades. This article will include an overview of the program's subjects. The graded method refers to the process of verifying the safety of a nuclear facility by analyzing, documenting, and taking the appropriate actions following the regulatory framework (IAEA GSR Part 3, 2011).

It is common inside the radiation facilities there in clear categorization for the risks. To optimum the radiation protection program inside the radiation facility the main point is to have a definite categorization for the sources and hence have to have a corresponding resource. If you have not, this will affect bad in the future, because you can not to perform the required corrective actions at the correct time effectively. Also, the traditional radiation protection point of view focus on the limits, but the graded approach depends on the dose constrain and ALARA principles, to reduce the individual doses and collective doses, to remain As Low As Reasonably Achievable, even if the work load increased. Facing the (event/accident) require to use the specific (PPE/instruments) to reduce these doses with the lowest cost. The study aims to optimize the radiation tasks, resources, by categorize the radiation activities, grading process, ensuring the flexibility, by provides a framework for regulators to adapt safety requirements to the specific circumstances of each situation, in addition to guarantee the continuous improvement; with including a feedback loop to drive continuous improvement in safety and risk management. These gabs need to be covered according to the introduced the graded approach implemented.

Research reactors are considered an exceptional case in this context. Nuclear facilities, in general, are proportional to Egyptian Law no. 7 (2010) and Executive ordinance of the Law no. 7 (2010):

1) The comparative significance of safety, protection, and security
2) The potential hazard magnitude.
3) The facility life cycle stage; and at last:
4) The distinctive characteristics of a facility.

A graded approach for a control system refers to a systematic methodology in which the level of control measures, conditions, and requirements is adjusted based on the probability and potential impact of a loss of control. Various sorts of control can be implemented in a system (IAEA SSG-22S, 2012):

1) A nuclear facility is governed by a regulatory framework.
2) The nuclear facility operator employs a management system.
3) A nuclear facility incorporates a control or safety system.
4) Or all of them

This study aiming to establish a graded method to implement management system requirements for radiation protection in the radiation facilities; with introducing examples of some aspects, to grade the requirements of management system regulations for the working environment, human resource management, strategic planning, and the performance monitoring and evaluation; to apply the highest quality with lowest risks and of course minimizing the collective doses for the facility staff, with reasonable cost, according to the ALARA principle. This is mean deep meaning of the radiation protection philosophy.

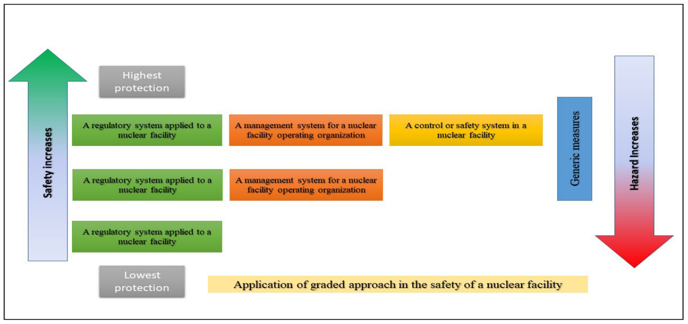

Figure 1: Graded approach application and the safety of the facility.

Place of the work

This study is performed depending on the gained experience from the extensive work inside the Egyptian Testing and Research Second Reactor (ETRR-2) complex, inside (EAEA) Inshas site.

Justification of study

This study serves as a practical application of the requirements of the national regulatory authority, which are consistent with the requirements of the International Atomic Energy Agency for reference radiation facilities. The Egyptian Nuclear and Radiological Regulatory Authority (ENRRA), is the national body responsible for the regulation, licensing, and oversight of nuclear and radiological activities in the country. (ENRRA), supported by the Egyptian government, is responsible for ensuring the protection of the occupational, facility, public and the environment; from harm of the ionizing radiation.

ENRRA operates with the full support of the Egyptian government and is tasked with ensuring the safety and security of all nuclear and radiation applications, protecting people and the environment from radiation hazards. Its key responsibilities include:

- Developing and enforcing regulations and standards for nuclear and radiological safety.
- Reviewing and assessing license applications for facilities and activities involving radiation sources and nuclear materials.
- Conducting inspections to ensure compliance with safety requirements.
- Coordinating with international bodies like the International Atomic Energy Agency (IAEA) on safety protocols and agreements.

Implementing a graded approach effectively maximizes benefits and minimizes risks and, consequently, harms to the lowest possible level. The results of the study are effective for those concerned with radiological investigations, and hence it could be used as a guideline for both of radiation sources and facilities.

***The grading concept general considerations*:**

A graded approach should be employed to determine the level of detail and its extents of the safety assessment conducted for a specific facility or activity in a given state. This method should be in line with the potential radiation hazards related to the facility or activity. A graded approach is suitable for every phase of a nuclear facility's life cycle. The nuclear facility maintains any grading that has been carried out during its entire lifespan. The assessment of safety functions and operational limits and conditions (OLC) for a nuclear facility ensures the prevention of undue radiation exposure to the environment, the public, and workers. If the management system effectively categorizes its requirements, a system of varying levels of stringency can be applied to facilities and activities (IAEA, GSR part 2, 2016). Activities are graded according to safety analyses, regulatory requirements, and engineering judgment. The safety study has verified that the required structures, systems, and components, along with the actions taken by operators, are successful in maintaining releases and hazards at acceptable levels. Regulatory requirements refer to the prescribed methods of control and inspections conducted by the regulatory authority. The regulatory standards outline the precise criteria of the facility, as well as the responsibilities of the inspector in granting or renewing the license for said institution. Engineering judgment considers the safety functions of classified structures, systems, and components (SSCs), as well as the potential repercussions if these functions are not carried out. Furthermore, it suggests that the verdict has been recorded. Additional elements that should be taken into account when determining a grade include the intricacy and advancement of the technology, the level of experience in operating the activities, and the phase in the facility's lifespan. A graded approach refers to the requirements of management system for a product, service, activity, system, item, structure, component, or process control. It considers factors such as relative importance, variability, complexity, maturity, and potential impact on safety, health, environment, quality, security, and economic aspects. Implementing a graded approach enables customization of controls, measures, training, certification, inspections, and procedure specifics based on the level of hazard or significance for environmental, health, quality, safety, security, and economic factors. When assessing these factors, it is important to analyze the system as a whole. Working with radioactive sources and/or radiation sources at authorized nuclear facilities can result in random or predictable health consequences. Hence, it is vital to categorize the establishments and their origins, enforce suitable strategies, endeavor to entirely avert predictable health consequences, and reduce uncertain impacts to the furthest extent (IAEA SAFETY ASSESSMENT, 2008 & IAEA TECDOC Series No. 1740, 2014). Efficient attainment of this goal can be accomplished by a systematic method that takes into account the many aspects of each-facility, as seen in Table 1 (IAEA-TECDOC-1344, 2003).

The use of the graded method will ensure the efficient allocation of appropriate resources (such as time, money, staff, etc.) following specified requirements. The graded approach is a method used to establish the required amount and type of controls needed to ensure protection or safety for a certain product, object, system, structure, component, service, activity, or control.

1) The scope and magnitude of planning and analysis.
2) Identify the kind and extent of testing, inspection, and verification.
3) The operations, documents, and records need to be subjected to a thorough examination and given official authorization.
4) The documents and records are described in detail;

5) The qualifications and training accessible to persons are assessed in terms of their type and level; Suppliers are evaluated based on their type and level (IAEA Safety Standards Series No. NS-G-4.6, 2008).

A graded approach is relevant to every phase of a nuclear facility's life cycle, encompassing the site selection stages, design, construction, commissioning, operation, and decommissioning, as well as any associated operations. The IAEA safety standards series, specifically Safety Guide No. GS-G-3.5 (IAEA GS-G-3.5, 2009), offers assistance in establishing a systematic method for evaluating the implementation the requirements of management system. Throughout the lifespan of a facility, any land leveling activities should be carried out in a manner that guarantees the preservation of safety measures, avoids any violations of the facility's license and operational limits and conditions (OLC), and prevents any adverse impacts on the facility's personnel safety and the general public, or even the environment.

A hierarchical strategy is required for the implementation of international radiation protection requirements in scheduled exposure situations within the management system of nuclear sites. This strategy should align with the practice characteristics or the origin within a practice, as well as the exposures probability and its values. The term (hazard and or risk) includes any situation may cause harm to people, facilities, or the environment. The graded approach is taken into account Quantitative considerations to assess the magnitude of this term.

Table 1. Possible health effects according to handled radiation sources categorization

Source Category	Source Description	Possible Health Effects
1	Extremely dangerous	Permanent injury to fatal in a few minutes to an hour
2	Very dangerous	Permanent injury to fatal in hours to days
3	Dangerous	Permanent injury, but unlikely to be fatal in a period of days to weeks
4	Unlikely to be dangerous	Temporary injury is possible in many weeks of exposure
5	Most unlikely to be dangerous	No one could be permanently injured by this source.

Table 2. Graded approach vs. Application for authorization

Type of Control	Risk level	Practice Complexity
Notification, or Authorization by Registration	Low	Simple
Authorization by Licensing	High	Complex

This study outlines various grading methodologies for fulfilling the reference criteria. Grading should generally comply with radiation protection regulations to ensure the safety of the facility, its employees, the public, and the environment against the detrimental impacts of ionizing radiation. This encompasses nuclear plants at various levels, ranging from low to medium to high. This paper focuses on the topic of radiation protection and provides a graded approach to the requirements of management system for radiation protection in nuclear facilities. The study proposes a grading methodology and identifies the factors to consider when grading the application of RPP; by providing a brief explanation of the approach through an application exercise.

Theoretical aspects and standards

Process for grading

The grading method can be implemented by designing a grading procedure that encompasses the following steps, as depicted in Figure 1.

1) Evaluate the importance of all process including the product, service, activity, and process control using the established criteria for grading.
2) If relevant, determine the categorization based on certain criteria.
3) Conduct an initial evaluation to determine the appropriate grade based on the assessment.
4) The grading method can be established by constructing a grading process that consists of the steps, as depicted in Figure 1.
5) There are additional costs associated with renewing and developing.
6) Throughout the process of assigning grades, regular checks are carried out at different stages, starting from the beginning until the final grade is determined.
7) Make sure that the appropriate controls are implemented for each grade level;

Application of grading to radiation protection

The national regulatory body (ENRRA), supported by the Egyptian government, is responsible for ensuring the protection of occupational, facilities, the public, and the environment; where licensed operators of radiation and nuclear substances are located. Therefore, it is established certain requirements for safety and security controls of any radiation sources (Egyptian Law no. 7, 2010 & Executive ordinance of the Law no. 7, 2010). Following the graded approach in regulation; the sources are notified, registered, or licensed in the records of (ENRRA) as mentioned in Table (2). While the facilities must be licensed and categorized according to the license type and its category, the regulatory requirements are defined to ensure the control of potential and confirmed risks in these facilities.

The radiation protection requirements at nuclear facilities are established as follows:

1. Radiation exposures at the nuclear facility are subject to dose constraints which are set/approved by the regulatory body or another competent authority. The radiation protection aims to ensure the justification of all operational states and keep any resultant exposure as low as reasonably achievable, taking into account social and economic factors; according to the ALARA principle. Radiological risk can be assessed by different tools; such as the risk analysis matrix (see Fig. 2). The graded approach could be applied according to the categorization of sources and practices; according to the associated Radiological risk as mentioned in Table 3.
2. A radiation protection program developed by the operating organization considering the regulatory requirements. This program includes a statement of policy from the operating organization that illustrates the objective of radiation protection and the operating organization's commitment to the principle of protection optimization. The program of radiation protection is subject to the requirements of Radiation Protection and Safety of Radiation Sources at the International Safety Standards and is subject to the approval of the regulatory body (GSR Part 1, IAEA, 2010; GSR Part 3, 2011; GSR part 1 (rev. 1) & IAEA, 2016).

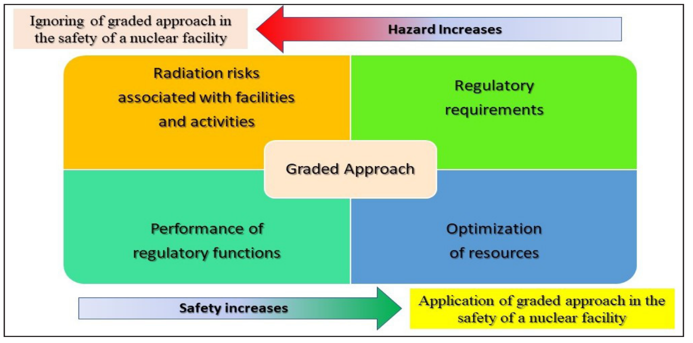

Figure 2: Graded approach dominant parameters.

Table 3. Graded approach versus radiological risk

Likelihood	Consequence				
	Negligible	**Minor**	**Moderate**	**Major**	**Extreme**
Almost certain	M	VH	VH	E	E
Likely	M	H	VH	VH	E
Possible	L	M	H	VH	VH
Unlikely	L	M	M	H	VH
Rare	L	L	L	M	H

Radiation Protection Program (RPP)

A radiation protection program needs to consider the graded approach and can be simple or complex depending on the activities and responsibilities of the organization. The organization of radiological protection, including the functions, responsibilities, qualifications, and line of communication of the radiological protection personnel. Provisions for adequate training in practices for radiation protection keep a high level of the safety of the facility. The operating organization policy includes radiation protection objectives and commitment to the radiological protection principles, in particular the optimization principle. The RPP is subject to the occupational radiation protection requirements and in particular includes the necessary measures for controlling (GSR Part 1, IAEA, 2010).

Control of occupational exposure

The application of graded approach means the safety requirements is commensurate with the practice or source characteristics and with the exposure's probability and magnitude. It works to categorize the potential hazards to developing methods for different risky practices, to ensure regulating safety. Measures for controlling are compliance with applicable regulations. For control of occupational

(IAEA, GSG-7, 2018) exposure to meet the relevant regulatory body requirements; the radiation doses measurement and its assessments should be kept for all workers who may occupationally exposed to significant radiation levels.

Results of Practical Applications

Applications of a graded approach in ETRR-2 Complex facilities

The Egyptian Atomic Energy Authority (EAEA) owns the (ETRR-2) complex. This complex consists of the Egyptian Testing and Research Second Reactor (ETRR-2) nuclear facility, the Fuel Manufacture pilot plant (FMPP), and the Radioisotope Production plant (RPF). The ETRR-2 is a multipurpose reactor, 22 MW, open pool-type reactor with a maximum thermal neutron flux of 3.7x 1014 n cm-2 s-1. Radioisotopes such as (Ir-192 wire and needle, Co-60, I-131, I-125, Mo-99, Tc-99m, etc.) are produced in the reactor. Neutron activation analysis (NAA), neutron transmutation doping (NTD) of silicon ingots, neutron radiography, irradiated gemstones, education for university students, research for scientists, and training for new operators are applications and services introduced by the (ETRR-2) multipurpose reactor .Additionally, the reactor features unique hot cells, Impact testing, tensile strength tests, and other material characterization techniques can be used to irradiated materials.

The FMPP plant produces the fuel elements for the reactor, and the RPF plant produces radioisotopes for medicinal and industrial use. The RPF produces Mo-99, I-131, I-125, Cr-51, and Ir-192 radioisotopes, in addition to (Mo-99/Tc-99m) generators. The three installations were designed, provided, constructed, and commissioned through international cooperation with INVAP- Argentina (INVAP-EAEA, 2003). For grading of management system requirements, some typical methodologies are applied in radiation protection program, quality assurance and activities quality control, radioactive materials safe transport, components classification, radioactive waste classification. The following part illustrates the application of radiation protection as one of the typical graded approach applications.

Application of grading to radiation protection of ETRR-2 complex facilities

This work applies a graded approach to implement the requirements of management system for radiation protection of ETRR-2 Complex facilities. Identification of the considered factors examples as a part of grading. The requirements of management system are primarily related to environment working control, human resources, planning, and monitoring and measurements. The study provides of graded approach examples in the application of the radiation protection requirements such as; the working areas classification and access control, zones classification in a controlled area for each facility, local rules and working supervision, the workplace and individuals monitoring, work planning and work permits, and finally; protective equipment and protective clothing.

I. Classification of working areas and access control

A graded approach is applied to different requirements of working area classification and access control which are designating and delineating controlled areas, access control, and authorized personnel.

The controlled areas are designated and delineated by physical controls which are considered in the design and applicable during operation. To apply a graded approach ,the controlled area is divided into different zones according to the radiation and/or contamination levels for normal operation and operational accidents. Occupational protection and safety measures are established, including; areas appropriate local rules, instructions, and procedures also the use of work permits. Specific protective measures and safety provisions are required for each area as normal exposures controlling/preventing the contamination spread during normal working conditions; and restrict the extent of potential exposures or preventing it as possible. Examples of a graded approach in delineating-controlled areas are physical barriers, a warning symbol, a color scheme, and signs indicating their nature.

Access control is a system that aims to control access to the controlled areas for 24 hours which is achieved by three main categories namely; source control, physical control, and administrative control. The graded approach is applied for access control to different areas through administrative procedures, such as the use of work permits, and by physical barriers, which may include locks or interlocks. Moreover, personnel may use special access cards with definite permission till finished the tasks, under Radiation Protection Officer(RPO) supervision and Radiation Protection Manager (RPM)advice. The degree of restriction is commensurate with the expected exposures probability and its values, and the personnel shall check for potential contamination leaving the area's barrier.

The achievement of source control requirements may include material selection by investigating the impurities in raw materials, source the highest quality to reduce corrosion, minimization of radioactive waste (RAW), etc. While physical control requirements are considered in shielding, ventilation, distance time, decay interval, decontamination, and Personal Protective Equipment (PPE) use. Finally, administrative control which is defined in local rules and procedures that considered as an essential part of the RPP to ensure the requirements for:

1. Working area classification and access control.
2. Workplace monitoring program: External radiation, surface, and airborne contamination.

3. Work permit approval: (Operation, Maintenance, Radiological implication assessment).

Graded approach requirements are applied to the authorized personnel to enter controlled areas. For any reasons such as maintenance, repairs, taking samples, safeguard, etc., one or more persons need to enter the controlled areas, besides the needed operators, authorized personnel will be present all the time during operations. Before the entering of personnel to this area the workers are equipped with suitable clothing and tools. The licensees shall plan the work and verify the existing radiation field. The RPM gives the work plan permit; the personnel shall be able to enter into the cells or perform tasks with appropriate PPE. All tasks that involve high risk shall be programmed with enough time ahead between the RPF supervisor and the RPM.

II. Classification of zones in controlled areas for nuclear facility

Radiation zones are divided in the potential exposure's probability and its values, and the protection requirements and safety procedures, nature and its extension. Regarding safety, the most significant features of the facility are the prevention of spills, multiple containment features, and zoning. According to graded approach requirements, the building must be designed based on the zoning into three areas per potential radiological exposure and contamination risks.

R1 zone; where access is normally prohibited, due to high levels of dose rate, airborne, and/ or contamination, but may be permitted under certain conditions, such as radioactive solid waste storage and hot cells during times of annual maintenance or emergencies.R2 zone; where the work is compliant with the dose limits application for external exposure may be ensured only by working time restriction, as highly active tools decontamination room. All other areas within the controlled area; except the R1 zone and R2 zone are implied in the R3 zone, which is recognized by dealing with very small quantities of open radioactive materials used or when only the highly active materials are ensured under enough control when are handled. A contamination zone is considered when the contamination level exceeds than the planned at the specified area. In a graded approach, some special protective necessary measures are applied; due to potential or actual air contamination or wide surface contamination over the specified level. Subdivision may be considered based on the levels of necessary precautions in different areas of this zone. The most likely zone is that neighbors to the decontamination glove box, during irradiated targets loading, or (RAW) reception or transfer, and/or zone that surrounds hot cells during final target preparation.

III. Local rules and work supervision

Local rules are flexible and updated according to new conditions and/or staff behavior changes. Requirements of local rules include:

a) Access and exit procedures at controlled areas.
b) Dosimetry requirements for recording and investigations if any alarms are initiated.
c) Requirements for PPE – in routine work and emergencies; to ensure adequate safety levels and minimize the risks.
d) Investigation and action levels for dose rates, and airborne contamination; to keep under control.
e) Taken actions in the event of different alarms.
f) Update written operation procedures to be followed if any failures happen.
g) Commitment to radiation worker's training, re-training, and performing drills periodically; in different conditions.

Work supervisors are trained in applicable radiation protection requirements according to the international standard (GSR Part 3, 2011); and the ability of the application of local rules to the work they supervise. The supervisors have accurate information about any work they supervise to keep all doses and risks as low as reasonably achievable and prevent overexposure for all workers. They are observing the rules, written procedures, protective measures, and safety provisions to ensure adequate levels of protection and safety for workers. In addition, the supervisors have a responsibility to keep records for all investigation levels and take urgent actions when required.

IV. Dose assessment and the workplace and individuals monitoring Dose assessment aims to:

- Introduce the information provision of about the workplace conditions
- Suggest new means of measures and protection compatible with operational changes to improve radiological working conditions;
- Actual exposure estimates; to demonstrate compliance with, Egyptian Nuclear and Radiological Regulatory Authority (ENRRA),the national regulatory body requirements;
- Evaluate the operating procedures to develop; aiming to reduce all types of radiation exposure;
- Ensure confirmation of good working practices;
- Increase workers awareness to understanding the exposure situation (how, when and where) in order to motivate them exposure reduction;
- Evaluate the doses in the accidental exposure's situation; to reduce in the future.

The workplace monitoring is performed utilizing an appropriate combination of fixed radiation monitors and air contamination devices through periodic monitoring and sampling by well trained personnel. The nature of the prevailing radiation conditions is reflected by the monitors' location selection and the also sampling frequency. To full fill a workplace monitoring requirement in control area, taking into consideration the graded approach, specific types of workplace monitoring must be performed such as dose rate monitoring, monitoring of airborne radio nuclides and gaseous effluent through appropriate filters. Workplace monitoring during the production process and at entrance and exit of containers to transport radioactive material are taking into consideration. Also dose rate and contamination monitoring of the radioisotopes that leave the facility using SWEEP-TESTS are important. Finally different waste types produced should be monitored through and a contamination and dose rate measurements. Generally having information of workplace monitoring in all locations via special software of fixed area monitoring system is important for individual monitoring. In individuals monitoring, dose assessment is done for the workers who work inside the controlled areas, both external and internal exposures are considered .For grading the individuals monitoring, persons who work under conditions in the hot corridor where internal exposures may occur are monitored with Thyroid Iodine Monitor (TIM) and Whole-Body Counter (WBC) and using other in vivo and/or in vitro measurements. While for suspected significantly non-uniform external exposure of any individual, additional dosimeters should be worn as wrist gamma dosimeters, ring dosimeters, digital dosimeters, and additional TLDs in different parts of the body. Accurate estimations of dose are applicable before starting the risky tasks, suitable alternative arrangements are provided for new one. Individual monitoring is done with comparable measure means, passive and active dosimeters are used at the same time for graded approach at some tasks. The instruments used for individual monitoring are accurate and reliable and tested, verified, and calibrated periodically.

V. Work planning and work permits

Planning and permission are very important at the radiation and nuclear installations. Any error performed during the task may lead to dangerous results, hence, catastrophic consequences. This requires careful planning and scheduling of the tasks. The work planning is ensuring the availability of personnel, tools, equipment instructions, and materials are when needed and achieved (ALARA principal). One of the most important means of achieving protection optimization is the advance work planning. This pre-planning aims to establish Procedures for general arrangements to perform different types of tasks at the facility. Work planning leads to restricting exposures, helps in collective dose reduction, and facilitates dose assessments. Also, it encourages the official documentation to comply with ENRRA requirements.

For applying the graded approach requirements in work planning, such parameters should be taking into consideration:

a. Any similar previously completed work information;
b. Working start time, estimated duration, and the involved human resources;
c. Estimated doses maps;
d. The facility's state;
e. Other area' sactivities that may cause work conflicts;
f. Operational preparation and assistance;
g. The used protective clothing and tools;
h. Ensuring supervisory control and co-ordination by good communication;
i. Waste arising safe handling;
j. Safety conventional.

The RPM should address optimization and identify responsibilities in preparing a work plan. He should ensure following written procedures and using safe work method statements. In General, enforcing radiation work permits is helpful in work planning to address all hazards.

A radiation work permit (RWP) should be designed for tasks requiring radiation protection procedures. Information and instructions to be considered as part of the grading and to be provided in the (RWP) could include for instance:

a. A detailed working area dose rate map and the possible hot spots, produced from a survey made before the work or otherwise estimated;
b. An estimated contamination levels and its possibility changing during the task performance;
c. The estimation of the individual and collective exposure for each work step;
d. Any additional dosimeters specification to be used by the workers;
e. Protective equipment specification that may be used in different work phases;
f. Any restrictions for time or dose;
g. Instructions for RPO contact.

VI. Protective clothing and protective equipment

Some instances of graded techniques for protective gear requirements should be taken into consideration.

1. The working environment and current radiation levels are taken into consideration while choosing the kind of protective apparel.

2. To provide suitable protection from contamination without negatively impacting manual tasks, double strong latex gloves, or more, are utilized in addition to long gloves.
3. For some tasks, extra coveralls may be needed in addition to standard ones.
4. During decontamination, waterproof boots are worn when the floor is damp.
5. In an emergency, standard or ventilated sturdy plastic suits may be utilized.
6. The kind of protective gear chosen shouldn›t increase the amount of external dosage received while working by lengthening the working hours.
7. If excessive exposure is anticipated, half or full lead suits are worn.
8. Aprons have been worn, if contamination is most likely increase.
9. Lead glasses and/or lead necks are employed for specific jobs.
10. The protocols for donning masks, disposable normal and long latex gloves, disposable overalls, disposable footwear covers (overshoes), work pants, overcoats, and shirts are adhered to.
11. The type of working environment determines the need for additional personal protective equipment (PPE).

In situations where airborne contamination or loose surface contamination is present or could be created during operation, respirators are worn carefully as protective gear to prevent intakes. The type of airborne and the potential for leaking into the eyes are taken into consideration while assessing respirators. Half masks and full-face masks are the two varieties. Activated carbon cartridges and absolute filters are included with both of them. They are worn in areas where fine or suspended dust contamination may exist. The mask needs to offer protection from the particular radio nuclides of concern, such as I-131. Additional equipment includes remote handling tools, portable shields, portable ventilation devices with local exhaust filters, and special

In certain situations, additional equipment is used to reduce doses, such as portable ventilation units with local exhaust filters, portable shields, remote handling tools, specialized monitoring and communications equipment, temporary containers for solid radioactive waste, and containers for radioactive liquids.

According to the grading approach, changing areas must be designed to accommodate the kind of protective gear and apparel being used because they are meant to stop the spread of contamination by dividing a space into a clean side and a potentially contaminated side. Additionally, practical training gives students firsthand experience and helps them familiarize themselves with the features and procedures of the facility. To determine and attain the necessary work competency for relevant RPF employees, training is analyzed, designed, developed, implemented, and evaluated. Operators receive formal training that includes technology topics up to the level required for their operational responsibility. The instruction aids in the development of a comprehensive theoretical and practical understanding of plant systems, including their layout, operation, and function. Retraining is ongoing.

Case study

The graded approach application in one of the distinguished radiation facilities was conducted on external and internal doses of 20 persons from the occupational during the (I-131) production in this facility. A whole-body counter (WBC), from type ACCUSCAN II (Canberra, USA) was used to assess the internal dose, while the (TLD) results by Harshaw TLD™ model 6600 plus automated reader instrument, of the same persons, were used with the effective doses. Both of them are listed below and presented graphically in Figures (3 and 4).

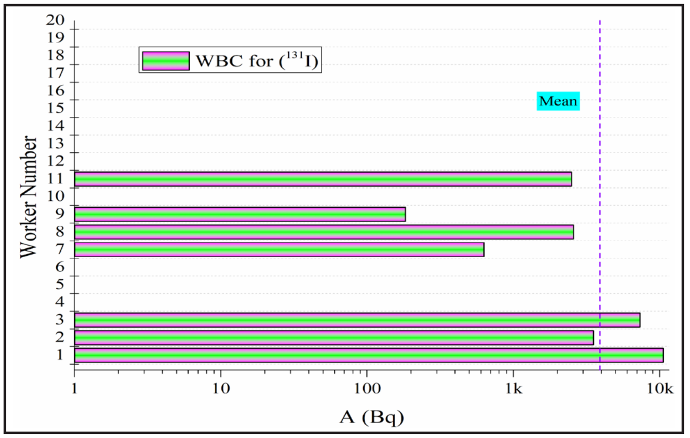

Figure 3: Workers number and intake Activity of I-131, according to the whole-body counter results.

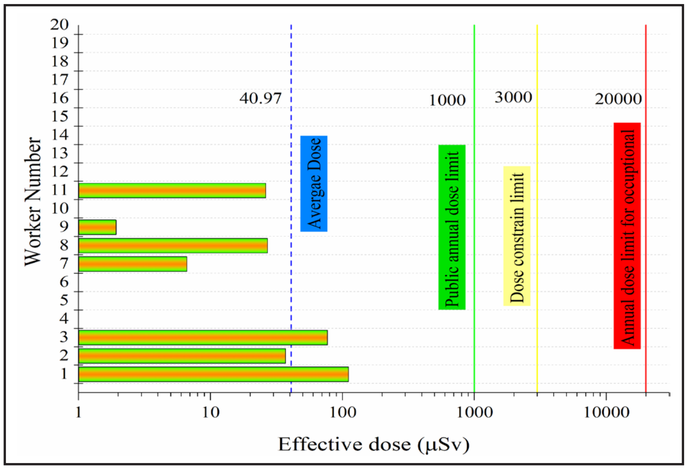

Figure 4: The whole-body counter results of the effective dose for the same occupational works.

Fig.3 shows that only seven persons i.e., 35% have been detected to have activity of I-131 and thirteen i.e., 65% have a very low activity for (I-131) which is below detection limits. Moreover, Fig. 3 indicates that the workers in the production of I-131 in the facility had an average activity of 3902.14 Bq for I-131during 6 months of continuous production. Considering the short half-life ($T_{1/2}$) of (I-131) and low energy of the emitted gamma and beta radiation, it is expected the hazard from this internal contamination is low. This can be confirmed by the results illustrated in Fig. 4. Fig. 4 shows the WBC results for the total effective dose for the occupational works in this facility from having a maximum value of 111.10 μSv and a minimum of 1.92 μSv with an average value of 40.97 μSv for the 20 workers. Furthermore, Fig. 4 compares the total effective dose for the workers by different limits such as public 1000 μSv, dose constrain 3000 μSv, and occupational levels 20,000 μSv. The mentioned values have decreased over time; with the acquisition of experience in different situations in radioisotope production, where the internal contamination values become under the detection limits; while the external exposures decrease with each quarter compared to the previous one; which confirms the implementation of an effective program applying the graded approach. This result confirms that the applied RPP is effective in protecting the facility staff.

The risk limits (dose constraints/dose limits) are performed by the operator and reviewed by the regulator as one of the main keys to review the safety assessment before issue the license. this limit is a sum for (external and internal) doses.

Comparison of the applicable graded approach with the similar facilities:

Unfortunately, there is no published paper in this field typically, but it is sure the graded approach comparison in radiation facilities must focused on the facility state: construction, pre-commissioning, hot- commissioning, operation and decommissioning. This paper is Fouse only on the operation stage, which – for all facilities – consider the elements of risk analysis, safety analysis, safety assessments, radiation protection program (area classification, PPE, instruments, written procedures, occupational and public doses, …..). the current study followed the (ENRRA) requirement, which is covered by the (IAEA) requirements. This are the basis for any proposed comparisons in the future .Apply the graded approach in radiation facilities aims to ensure adequate protection without imposing an unnecessary burden where safety measures and the regulatory requirements are proportional to the magnitude of the potential radiation risks. The regulatory process has the procedure to achieve this goad, by document development, safety review & assessment, licensing/consenting, regulatory inspections and regulatory enforcement. The rule (operator/regulator) graded approach effectively is the main key for optimization.

Relevant update documents list:

1) IAEA Safety Standards Series: GSR Part 1 (Rev. 1) - Governmental, Legal and Regulatory Framework for Safety (2016).
2) IAEA Publication: Application of a Graded Approach in Regulating the Safety of Radiation Sources (Undated, published circa 2021/2022).
3) IAEA SAFETY STANDARDS, Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors, DS511, DRAFT SPECIFIC SAFETY GUIDE, A revision of Safety Guide SSG-22, 2020.
4) Commission staff working paper, impact assessment, accompanying the document, COUNCIL DIRECTIVE, laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation, 2011.
5) IAEA safety standards series no. ssg-22 use of a graded approach in the application of the safety requirements for research reactors specific safety guide international atomic energy agency Vienna, 2012.
6) IAEA TECDOC Series No. 2082: Use of a Graded Approach in the Application of Systematic Approach to Training for Facilities and Activities (2025).
7) CNSC Regulatory Document REGDOC-1.6.2: Radiation Protection Programs for Nuclear Substance and Radiation Device Licensees (2021).
8) ONR (UK) Guidance on the Ionizing Radiations Regulations 2017 (IRR17).

Conclusion

A graded approach is key to protecting the health and safety of occupational workers, facilities, the public, and the environment. A graded approach is used for all regulatory processes and different regulatory procedures for different facilities and activities. Prior radiological evaluation and safety assessment can be ensured by the use of a graded approach that the RPP is well adapted to the planned situation. The current paper is clear, explaining and supporting this applicable graded approach to (radiation/nuclear) facilities.

The introduced case study clears these main points, that cleared the internal contamination values become under the detection limits; while the external exposures decrease with each quarter compared to the previous one; which confirms the implementation of an effective program applying the graded approach.

Referring to different radiation risks inside nuclear facilities; it is necessary to apply a certain level of control by using a graded approach. The philosophy of a graded approach relies on using the resources and regulatory requirements that correspond with the associated risks; to ensure effective regulatory control of different facilities and activities with radiation sources. Hence; applying a graded approach enhances the safety of the facility. To apply the graded approach professionally, you must understand and mitigate risks to control planned, existing, and emergency exposure situations. Finally, the goal to apply the graded approach in radiation facilities is to ensure adequate protection without imposing an unnecessary burden where safety measures and the regulatory requirements are proportional to the magnitude of the potential radiation risks.

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