SHIELDING CALCULATIONS AS A REGULATORY TOOL IN DIAGNOSTIC RADIOLOGY

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Abstract

The initial safety assessment is the primary tool for determining the protection measures that should be put in place, and all the parameters that have a bearing on radiation protection and source safety should be considered. Subsequent safety assessments are undertaken to confirm that safety measures continue to meet the standards. The safety assessment should be submitted with the licence application to the regulatory authority. The regulatory authority shall establish a process for dealing with applications and shall provide guidance to the operator on developing and presenting safety assessments. Also, it shall establish a process for dealing with applications in accordance with clearly defined procedures without undue delay. A reliable shielding calculation as a major part of safety assessment is likely to be an effective tool that provides a common platform for both the licensee, who must demonstrate safety measures, and for the regulator, who is responsible for ensuring compliance with regulatory requirements. The weekly shielding design goals for controlled and uncontrolled areas which are used in performing shielding calculations can also be used as regulatory dose level, It is also recommended to use the concept of dose constraint as shielding design goals for the purpose of optimization of safety and protection for workers and public. Reliability of the submission and time for processing the licensing by regulator are very important; therefore, the need for a simple and reliable tool to handle this issue more effectively and reliably regardless of the level of experience. The Federal Authority for Nuclear Regulation (FANR) in the United Arab Emirates developed software for shielding calculations and intends to make it available for applicants and licensees. This software will serve as guidance for the regulator when conducting a review or assessment based on the inherent report generated by software codes that confirm the adequacy of the safety measures and assess the potential consequences of changes in the operating variables, as well as the ability to modify input such as regulatory measurements during inspections. The FANR considers this software to be an adequate tool to bring the licensee and the regulator onto a common platform for effective performance of the regulatory reviewer and reliable commitment of the licensee as well being a cost-effective and time-saving tool.

1. BACKGROUND

Safety assessment is a prime responsibility of registrants or licensees and should be carried out for the sources for which they are responsible. The initial safety assessment is the primary tool for determining the protection measures that should be put in place. Subsequent safety assessments are undertaken to confirm that safety measures continue to meet the standards set, and to indicate the need for improvement where necessary [1].

The International Basic Safety Standards (BSS) requires the legal person who is applying for authorization from a regulatory body to "make an assessment of the nature, magnitude and likelihood of the exposures attributed to the radiation source and take all necessary steps for the protection and safety of both workers and the public". Also, this required safety assessment shall be made and submitted to the regulatory body as part of the application for licensing to allow the regulatory body to specify this document as part of the process for review of an application. Usually, the safety assessment should be carried out before the source is received at the site or brought into routine operation, to give sufficient time for the necessary protection and safety measures to be put into place. The safety assessment shall include a systematic critical review of the nature and magnitude of exposures in normal operation, the limits and technical conditions for operation of the radiation source, the ways in which changes in the environment could affect protection or safety, the protection and safety implications of any proposed modifications. Also, safety assessment should take into account that the prime consideration is that a safety assessment should be suitable and sufficient to identify adequately the protection and safety technical measures that are planned or are built into the installation to keep individual doses low and should be considered for normal operation [4].

The BSS requires that the regulatory body shall establish a process for dealing with applications, such as application for the issuing of an authorization. In addition, the regulatory body shall provide guidance to the operator on developing and presenting safety assessments or any other required safety related information. Prior to the granting of any licensing, the applicant shall be required to submit a detailed demonstration of safety, which shall be reviewed and assessed by the regulatory body in accordance with clearly defined procedures, and the regulatory body shall establish a process for dealing with applications [2].

2. SHIELDING CALCULATION AND SAFETY ASSESSMENT

The BSS lays down the requirements for protection of workers and the general public against the dangers of ionizing radiation. It encapsulates the principles of Justification, Optimization and Dose Limitation articulated by the ICRP and develops them into a regulatory system that can control the practices involving ionizing radiation. Regulatory requirements require that the licensee ensures that he has commissioned equipment for medical radiological procedures, prior to its being used on patients. An assessment of the facility at the various points will identify gross breaches of the shielding recommendations. As it is not possible in practice to measure the shielding at every point of every boundary, the process relies on the professional integrity of all parties involved to ensure that the shielding is as required. For this reason it is important to retain written confirmation or any other demonstration criteria of the shielding installed from the various parties involved. The BSS requires that a safety assessment be provided when applying for a Licence or an amendment to an existing Licence. Eventually, this safety assessment is aimed at identifying protective measures needed to restrict exposures to ionizing radiation arising from routine operation of the practice and from reasonably foreseeable accidents resulting from the practice.

Usually, radiation shielding shall be designed by a qualified expert during early planning stages to ensure that the required degree of protection is achieved. All pertinent information regarding the proposed radiation source and its use, type of building construction, and type and nature of occupancy of nearby areas should be provided. It may also be necessary for the pertinent regulatory authority to review the shielding design or existing facility prior to construction or operating, as appropriate.

3. METHODOLOGY AND DISCUSSION

Structural radiation protection for diagnostic X ray facilities is most commonly performed following the recommendations of National Council on Radiation Protection and Measurements Report No. 49 [6] and recently Report No. 147 [7]. In medical X ray imaging applications, the radiation consists of primary and secondary radiation. Primary and secondary radiation exposure to individuals depends primarily on the amount of radiation produced by the source, the distance between the exposed person and the source of the radiation, the amount of time that an individual spends in the irradiation area, the amount of protective shielding between the individual and the radiation source. Shielding planning for a medical X ray employs the knowledge of basic planning, the ALARA principle, and shielding principles.

The concepts of shielding calculation depend on shielding design goals (P), distance (d) to occupied areas, the occupancy factor (T) for an area that is defined as the average fraction of time that the maximally exposed individual is present, workload and its distribution (W), and use factor (U). The weekly shielding design goals for controlled and uncontrolled areas are 0.1 and 0.02 mGy per week, respectively [6]. It is also most likely to use the concept of dose constraint in radiation installations as shielding design goals for purpose of optimization of safety and protection for workers and public.

The most common period of time for which the workload and workload distribution is specified is one week. However, NCRP report (6) defines the normalized workload $Wnorm$ as the average workload per patient and this may include multiple exposures depending on the type of radiographic

examination and clinical goal. The total workload in this case is the product of $Wnorm$ and number of patients (N) to limit workload calculation by N variant:

..... $W_{tot} = NW_{norm}$ ....(1)

According to NCRP [6], the clinical workload distributions are specified for a given type of radiological installation as Rad Room (all barriers), Fluoroscopic Tube, Cardiac Angiography, Peripheral Angiography), dedicated Chest Radiographic, and Mammographic, where the distribution of workload as a function of kVp is much more important than the magnitude of the workload[1]. Eventually, the amount of workload is expressed only by the number of patients who are exposed weekly in X ray installation and average un-attenuated air kerma (K^{-1}) per patient at 1 m.

The general shielding concepts use the general transmission function for broad beam and transmission curves to estimate the thickness of shielding materials required either for primary beam or secondary radiation, as follows:

$$B(x) = \frac{P}{T} \times \frac{d^2}{NK^{-1}} \quad (2)$$

where $B(x)$ is transmission value, and the required thickness can be obtaining from transmission curves used shielding materials for primary and secondary radiation.

NCRP report No. 147 [7] also provides the algebraic solution for shielding thickness $x_{barrier}$ for primary barriers by using a given tabulated fitting factors $\alpha, \beta, and\ \gamma$ as follows:

$$x_{barrier} = \frac{1}{\alpha\gamma} ln \left[\frac{\left(\frac{NTUK^{-1}}{Pd^2}\right)^{\gamma} + \frac{\beta}{\alpha}}{1 + \frac{\beta}{\alpha}} \right] \quad (3)$$

As well, the algebraic solution for shielding thickness $x_{barrier}$ for secondary barriers by using a given tabulated fitting factors $\alpha, \beta, and\ \gamma$ is provided as follows:

$$x_{barrier} = \frac{1}{\alpha\gamma} ln \left[\frac{\left(\frac{NTK^{-1}}{Pd^2}\right)^{\gamma} + \frac{\beta}{\alpha}}{1 + \frac{\beta}{\alpha}} \right] \quad (4)$$

It is noticed that the required factors for performing shielding calculation are maintained easily whether for tabulated data such as workload and related un-attenuated air kerma for specific type of installation, or for easily measurable such as distance, occupancy factor, use factor, or from given data such as weekly shielding design goals as related to dose limit or dose constraint. Therefore, these approaches are minimizing the personal and individual interface significantly.

4. CONCLUSION

The effective and efficient use of shielding materials and development of optimal design requires a qualified expert either for performing or for evaluation and reviewing. However, the Federal Authority for Nuclear Regulation (FANR) in United Arab Emirates developed a software for performing shielding calculations for imaging medical facilities based on NCRP report No.147 algebraic computation Model. The software enables user to enter the related parameters via simple user interface (Fig. 1) and performs the shielding calculation and provides the user with result with ability to document the calculation in form of calculation report to be used as part of submission to regulatory authority in content and terminology understandable from all parties. The software serves

[1] Traditional shielding methods have assumed that a conservatively high total workload per week is performed at a single high operating potential.

as guidance for the regulator when conducting a review or assessment based on the inherent report generated by software codes and assesses the potential consequences of changes in the operating variables as well as the ability to modify input such as regulatory measurements during inspections.

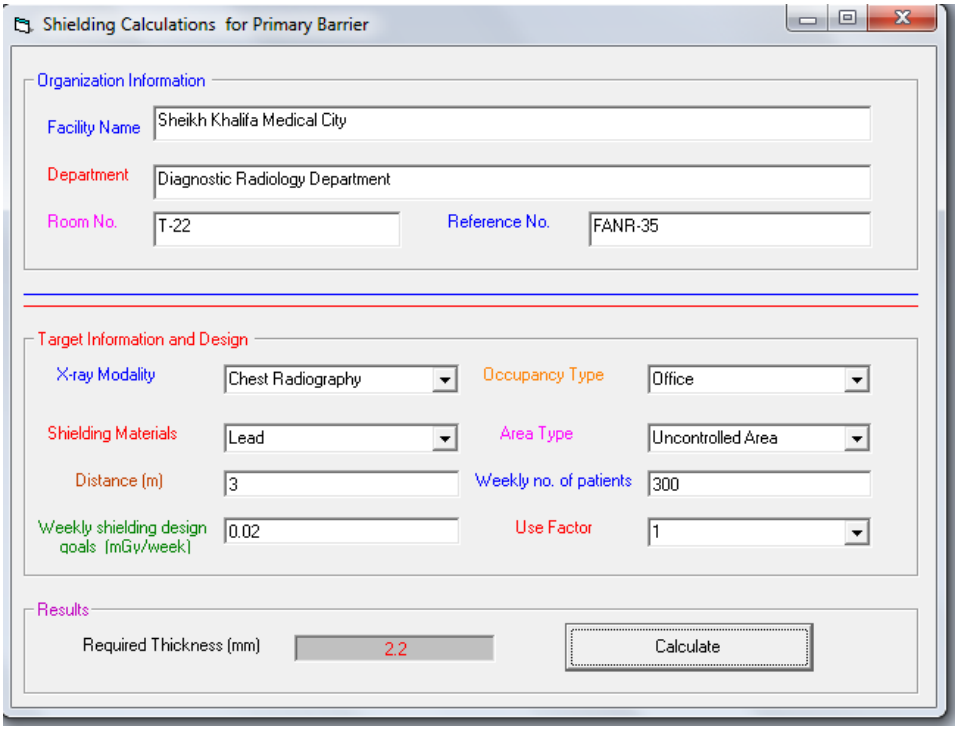

FIG. 1..User interface for primary barrier shielding calculation for medical radiology modalities showing related parameters required for performing calculations.

Finally, the software could be an adequate tool for bringing the licensee and the regulator onto a common platform for effective performance of the regulatory reviewer and reliable commitment of the licensee, as well being a cost-effective and time-saving tool.

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