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Analysis of Gamma Shielding Evaluation Codes Based on Point Kernel Methodology

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1. Introduction

Workers in nuclear power plants are exposed to many types of radiation source in various situations. In order to reduce exposure to workers, an estimated radiation dose evaluation of workers should be performed prior to establishing an optimized work plan. Therefore, the point kernel methodology, which can calculate the radiation dose by various types of sources. It can be applied to assess the worker's dose estimation.

The point kernel methodology is a methodology that divides an arbitrary type of source into a constant cell and then evaluates the radiation dose by assuming each cell as a point source. The radiation dose of workers is calculated by summing the dose evaluation results of the point sources for each cell. The point kernel methodology requires less computational time than other methodologies, although they lack accuracy for sources of complex geometry when evaluating radiation dose. Therefore, the point kernel methodology is considered the optimal methodology for evaluating radiation dose by performing iterative calculations. Currently, the previous developed gamma shielding evaluation code has many codes that consider the point kernel methodology. Each code has a different method of dividing sources and the dose evaluation method accordingly is also different.

Therefore, gamma shielding evaluation code analysis based on various point kernel methodologies should need for external exposure dose evaluation of workers. In this study, the gamma shielding evaluation code based on the point kernel methodology was analyzed.

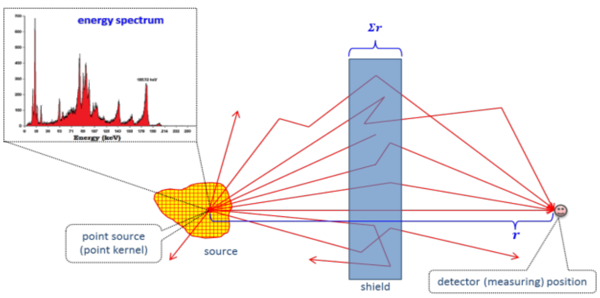

Fig 1. Point kernel method

2. Material and method

In this study, 1) QAD-CGPIC, 2) IGSHIELD, 3) Gmsh codes were investigated as gamma shielding evaluation codes for point kernel methodology. Each code was developed as QAD-CGPIC, IGSHIELD, Gmsh to implement more complex geometric sources based on the QAD code developed earlier. Each code was developed to support 3D implementation on the user interface as it became possible to support complex geometric sources. Finally, these codes were developed to estimate more accurate radiation dose.

3. Results

3.1 QAD-CGPIC Code

The QAD-CGPIC code is an improved version of the QAD code, which evaluates doses by applying a point kernel methodology developed by the Safety Research Institute, AERB in 2001 to calculate fast neutron and gamma shielding through various shielding configurations [1,2]. Based on the QAD code, QAD-CGPIC had been improved to select gamma ray build-up factor suitable for more complex geometry implementations and dose rate calculations. The QAD-CGPIC code is characterized by having a user-friendly interface. It inputs geometry interactively and implemented in 3D along the X, Y, and Z axes. Although the QAD-CGPIC code can have a relatively diverse shield configuration, it cannot handle a thickness greater than 40 mfp (mean free path). The characteristics of the QAD-CGPIC code are presented in Table 1.

Table 1 : Characteristics of QAD-CGPIC code

Categories	Specifics
Code language	• Visual Basic and Fortran
Build-up factor	• Select Geometric Progression build-up factor or Carpo's build-up factor
Characteristics	• Handles off centered multiple identical sources
	• Axis of cylindrical sources can be parallel to any of the axes.
	• Provides plots of buildup factors (ANSI-1990) and material cross sections
	• Interactive input of geometry with 3D view
	• Unable to handle thickness greater than 40 mfp

3.2 IGSHIELD Code

The IGSHIELD code is a gamma ray shielding evaluation code developed by Subbaigh and Sangapani in 2008 [3]. It applies a point kernel methodology based on the QAD-CGPIC (QAD-CGGP) code. The

IGSHIELD codes had been improved to support more complex shielding configurations than previously developed codes. It has a user-friendly and interactive interface for gamma ray shielding. It has a characteristic that a user who immediately displays the shape of the source as a 3D display can perform the necessary modifications. The IGSHIELD code cannot be implemented for some 3D display irregular types of sources. The characteristics of the IGSHIELD code are shown in Table 2.

Table 2 : Characteristics of IGSHIELD code

Categories	Specifics
Code language	• Visual Basic and Fortran
Build-up factor	• Select Geometric Progression build-up factor or Carpo's build-up factor
Characteristics	• Process various multi-source shapes such as points, lines, planes, and other bulk sources in a single operation
	• System geometry is immediately displayed on a 3D display for the user to make the necessary modifications
	• Unable to process some 3D irregular shapes of sources

3.3 Gmsh Code

The Gmsh code is a gamma ray shielding code developed by Manoj Kumar Hansda, Shaji Mammento in 2021 for the implement of irregular 3D type sources that cannot be processed in the QAD, IGSHIELD codes [4]. It provides an effective graphical user interface and implements box, cylinder, cone, torus, wedge and complex 3D models. It has the characteristic of using a tetrahedral mesh-based geometry in that it is possible to implement an irregular shape of a source. However, computational time can increase depending on complex geometry. The characteristics of the Gmsh code are shown in Table 3.

Table 3: Characteristics of Gmsh code

Categories	Specifics
Code language	• Python-2.7
Build-up factor	• Geometric Progression Build-up factor
Characteristics	• Ability to handle any type of complex source geometries and irregular source shapes
	• Handling discrete distributed photon energy sources
	• Modeling any kind of regular and irregular complex multilayered shield geometries
	• Having provision to export the output results into ParaView, an open source data analysis and visualization software, for quick visualization and analyzing of the results
	• Increased computation time due to complex geometry

4. Conclusion

This study investigated the code for dose evaluation by applying the point kernel methodology. 1) QAD, 2) IGSHIELD, 3) Gmsh codes were investigated as the code for calculating gamma shielding evaluation based on point kernel methodology. Each code has been gradually improved to support various shielding configurations. As each code was improved, dose evaluation for a complex type of source became possible. Based on the codes investigated, this study can be used to perform dose evaluation to reduce exposure of workers in nuclear power plants with various types of sources.

ACKNOWLEDGMENTS

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