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Radiological Analyses of Intermediate and Low Level Supercompacted Waste Drums by VQAD Code

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ABSTRACT

In order to increase the possibilities of the QAD-CGGP code, as well as to make the code more user friendly, modifications of the code have been performed. A general multi-source option has been introduced into the code and a user friendly environment has been created through a Graphical User Interface. The improved version of the code has been used to calculate gamma dose rates of a single supercompacted waste drum and a pair of supercompacted waste drums. The results of the calculation were compared with the standard QAD-CGGP results.

1 INTRODUCTION

QAD-CGGP [1] is a member of a well-known family of point-kernel codes, developed by Los Alamos Scientific Laboratory, and is routinely used for engineering calculations of gamma ray penetration through various shield configurations. The original QAD-CGGP code assumes a single body geometrical source and the buildup factor calculation is limited to a single layer shield. In order to increase the possibilities of the QAD-CGGP code by widening the code's application field, a number of modifications have been performed in the past. Uniform multi-source option and shielding multi-layer option have been introduced into the code [2, 3].

To finalize modifications of the code, we have decided to introduce a general multi-source option and to create a Graphical User Interface (GUI) as a response to modern software design guidelines. GUI provides a visual, user friendly environment for QAD input and output creation and analyses.

Testing of the Visual QAD-CGGP (VQAD) code has been conducted on intermediate and low level supercompacted waste drums. Radiation dose rate calculations have been performed for a single supercompacted waste drum as well as for a pair of supercompacted waste drums. NPP Krško waste characterization has been taken as a reference one.

2 GENERAL MULTI-SOURCE OPTION

QAD-CGGP code treats a single source volume by a number of point isotropic sources and computes the line of sight distance from each of them to the detector. Based on path lengths through different material regions from source to detector, both material and geometry attenuation ate determined, as well as buildup factor value for the particular source. At the detector position contributions from all the source points are summed up to give scalar flux of the uncollided beams for every energy group. Using buildup and flux-dose rate conversion factors, dose rate at the detector position are calculated.

The introduction of a general multi-source option into the code implies that the user can specify arbitrary number of sources, each one with different geometrical shape and source specification, i.e. different source spectrum. A "source loop" has been added to the code that passes through each source, treating it as a single one, while all the others are treated as barriers, and adds its contribution to the total sum.

On one side, the introduction of general multi-source option into the code increases the applicability of the code, but on the other side it also increases time and effort needed for input creation. The complexity of the output makes the result analyses and error tracking very difficult.

Negative aspects (input and output complexity) of the latest code modifications as well as the modification performed in the past [2, 3] can be annulled through the usage of Graphical User Interface.

3 GRAPHICAL USER INTERFACE

Modern software design guidelines require from the code to be equipped with a Graphical User Interface (GUI) that creates a user friendly environment and makes the interaction with the code in the input and output form effortless.

The existing QAD-CGGP code accepts the input in a particular sequence and in the rigid format. Preparation of an input file is therefore time consuming and requires detailed knowledge of the program. Analyses of the output are also rather difficult due to the lack of graphical representation of the results.

An effort has been done in the past to create a GUI for QAD-CGGP code [4]. However, the mentioned GUI is not free of charge, it is limited to input preparation and the interaction between GUI created in Visual Basic 6 and the executable version of QAD-CGGP program created in FORTRAN is conducted through the SHELL command. In our experience [5] such an approach results in system dependant rather unstable code.

New Graphical User Interface has been developed in Visual Basic 6 (VB6). The existing QAD-CGGP FORTRAN source code has been recompiled using Microsoft Fortran Power Station 4.0. Source code has been changed in a way that all program lines dealing with input and output have been removed. The remaining calculational core of the code has been rearranged and Dynamic Link Library (DLL) *QAD_subroutines.dll* has been created. *QAD_subroutines.dll* is composed of a number of QAD subroutines, like *source, length, kernel*, etc. Apart from being a user friendly environment, new VB6 GUI also acts as a main program controlling the execution of calculational subroutines that are a part of the *QAD_subroutines.dll*. FORTRAN and VB6 have a good one to one matching of types, for example VB6 **double** corresponds to FORTRAN **double precision** and VB6 **long** corresponds to FORTRAN's **integer**. Also, VB6 stores its arrays using the same convention as FORTRAN. Therefore, the interaction of VB6 and DLL is more straightforward, faster and stable than the interaction of VB6 and the executable version of the FORTRAN code through SHELL command. Since the original QAD-CGGP source code has been subjected to major changes and a GUI has been added, we felt justified to treat the newly created program as a new version of QAD and we named it Visual QAD (VQAD). The structure of the VQAD program is depicted in Figure 1.

VQAD is designed and tested for operation under Windows 98, Windows 2000 and Windows XP operating systems, and cannot be run under DOS operating system.

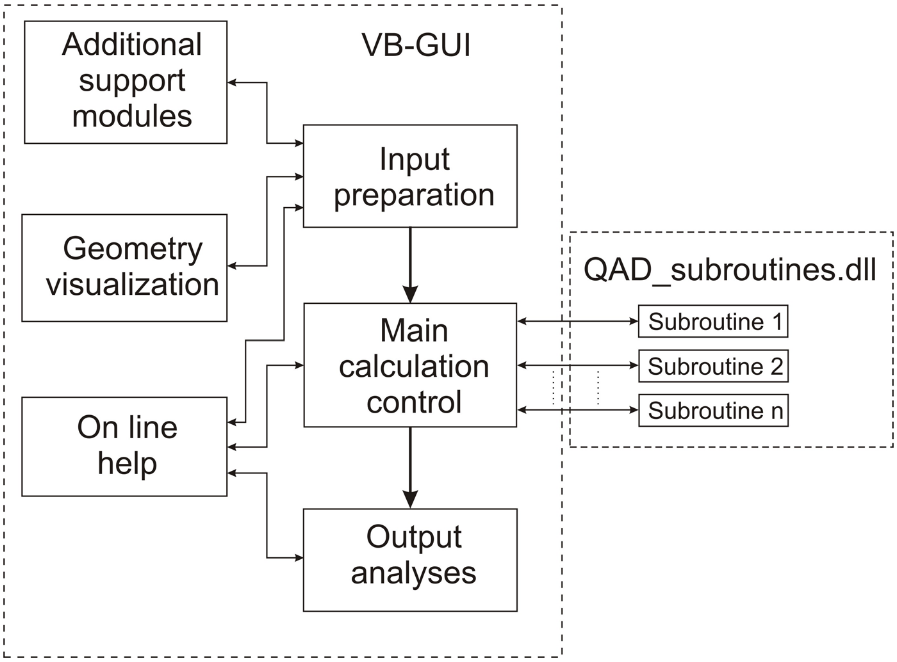

Figure 1 The structure of the VQAD program

VQAD provides novices and experience users help in preparation of the input parameters as well as easier and more efficient access to the results:

- on line context sensitive help with detailed description of the item in question, can be accessed by pressing “F1” button on the keyboard,
- on line graphical representation of the problem geometry,
- additional tables containing flux to dose rate conversion factors and atomic numbers and densities of the elements can be accessed anywhere from the program,
- graphical representation of the results.

4 TESTING VQAD PROGRAM

VQAD code has been used to calculate gamma dose rates in two shielding problems. Both of the problems have been conceived to provide simple but effective way to test and validate VQAD program.

The problems are based on the actual situation that occurred in the NPP Krško. Due to the lack of space necessary for storage of drums filled with low and intermediate radioactive waste, two supercompaction campaigns were carried out in NPP Krško, the first one during the years 1988 & 1989, and the second one during the years 1994 & 1995. The output of the second campaign was a number of compacted waste drums (*pellets*) that were placed in a Tube Type Containers (TTCs). The details on the actual number of drums placed in a single TTC (it can vary from 5 to 8), dimensions and construction materials of the TTC, as well as the isotopic contents of each drum, are NPP Krško propriety information, and therefore we designed our testing problems assuming the necessary parameters. Nevertheless, designed problems are sufficient for VQAD testing and validation.

Vertical cross section of the assumed model for the first test case, a single TTC filled with 5 compacted waste drums, is depicted in Figure 2.

The inner diameter of the TTC was set to 64 cm, while the outer diameter was assumed to be 64.4 cm, i.e. the thickness of the TTC wall was set to 2 mm. The assumed height of the TTC was 270 cm (the height of each pellet was 54 cm), and the material of the TTC was carbon steel. The isotopic inventory of five pellets that were placed inside the TTC and are of interest for VQAD testing (gamma emitters) consists of Co^{60}, Cs^{134} and Cs^{137}. The gamma spectra of each pellet used in the calculation are given in Table 1. The detector location was set at 1 m distance from the outer border of the TTC at 135 cm height.

Table 1 Gamma spectra of the pellets used for filling the first TTC

	Gamma spectra [photons/s]					
Energy [MeV]	**Pellet 1**	**Pellet 2**	**Pellet 3**	**Pellet 4**	**Pellet 5**	**Total**
0.569	7.49E+04	2.77E+04	6.35E+04	2.80E+04	8.00E+04	2.74E+05
0.604	4.75E+05	1.76E+05	4.03E+05	1.77E+05	5.08E+05	1.74E+06
0.662	9.09E+07	3.46E+07	7.63E+07	3.66E+07	9.14E+07	3.30E+08
0.795	4.17E+05	1.54E+05	3.53E+05	1.55E+05	4.45E+05	1.52E+06
1.173	3.61E+06	1.56E+06	8.67E+06	9.11E+05	3.42E+06	1.82E+07
1.333	3.61E+06	1.56E+06	8.67E+06	9.11E+05	3.42E+06	1.82E+07

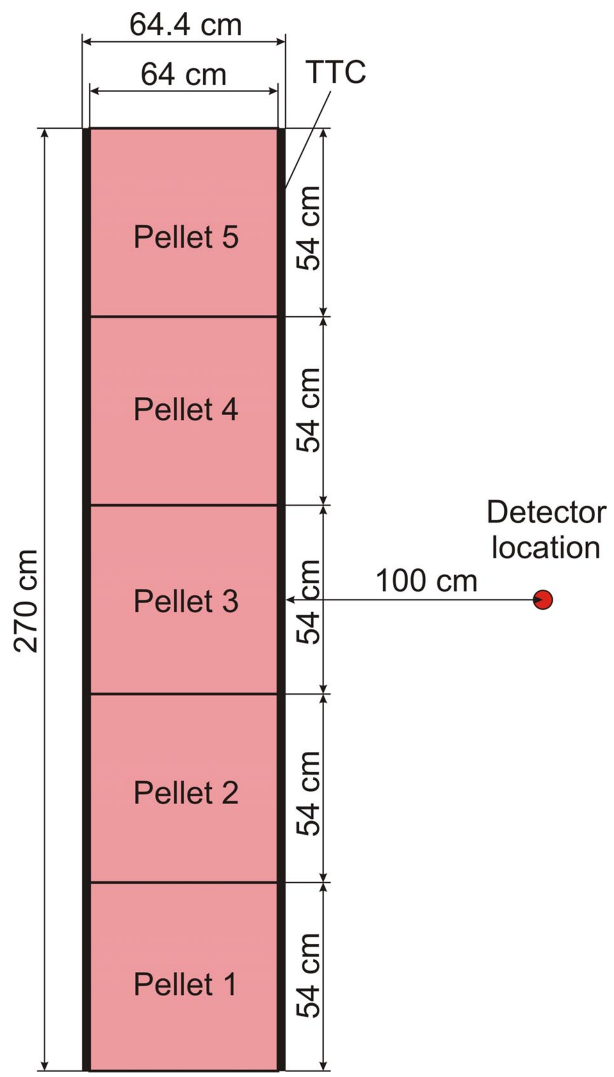

Figure 2 Vertical cross section of the VQAD first test case model

In the second test case, two TTCs were placed next to each other. The first TTC was the one from the first test case, while the other was filled with 6 pellets (the height of each pellet was 45 cm). The gamma spectra of each pellet used for filling the second TTC are given in

Table 2. The detector has been placed at 1 m distance from both TTCs at 135 cm height. The horizontal cross section of the second test case model is depicted in Figure 3.

In both test cases the density of the pellet material has been neglected. Although that assumption is a cause of a major error in actual dose rate calculations, it is not off a concern for VQAD testing procedure.

The results of the calculations were compared with the standard QAD-CGGP results.

Table 2 Gamma spectra of the pellets used for filling the second TTC

	Gamma spectra [photons/s]						
Energy [MeV]	**Pellet 1**	**Pellet 2**	**Pellet 3**	**Pellet 4**	**Pellet 5**	**Pellet 6**	**Total**
0.569	2.79E+03	3.07E+03	4.35E+04	1.24E+03	4.06E+03	5.25E+03	5.99E+04
0.604	1.77E+04	1.95E+04	2.76E+05	7.85E+03	2.57E+04	3.33E+04	3.80E+05
0.662	3.95E+06	4.56E+06	5.40E+07	3.16E+06	6.57E+06	7.15E+06	7.94E+07
0.795	1.55E+04	1.71E+04	2.42E+05	6.88E+03	2.26E+04	2.92E+04	3.33E+05
1.173	1.61E+05	2.18E+05	4.32E+06	8.79E+05	2.27E+06	2.99E+06	1.08E+07
1.333	1.61E+05	2.18E+05	4.32E+06	8.79E+05	2.27E+06	2.99E+06	1.08E+07

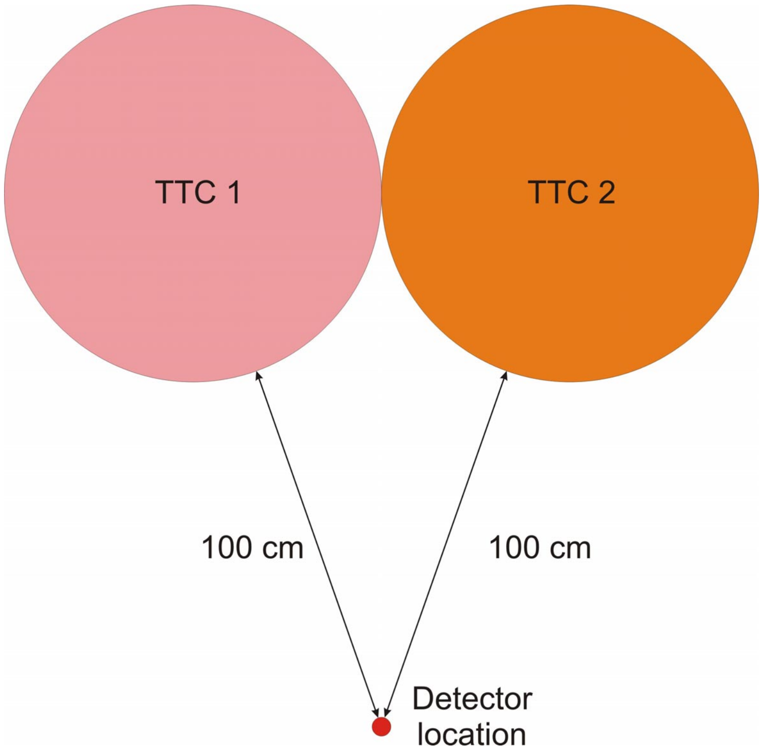

Figure 3 Horizontal cross section of the VQAD second test case model

4.1 First test case (1 TTC) results

In the first test case, dose rate has been calculated for a single TTC and one detector location at 1 m distance from the outer boundary of the TTC at the middle of its height. The result of the VQAD program was $1.8675 \cdot 10^{-2}$ mSv/hr. The result obtained by manual superposition of each pellet contribution to the total dose rate at detector location, when dealing with old QAD-CGGP was similar $1.8674 \cdot 10^{-2}$ mSv/hr The result obtained by old QAD-CGGP when homogenization of all five TTC's source spectra has been conducted was $1.9451 \cdot 10^{-2}$ mSv/hr.

4.2 Second test case (2 TTCs) results

In the second test case, dose rate has been calculated for a pair of TTCs and one detector location at 1 m distance from each TTC outer boundary at the middle of their height. The result of the VQAD program was $2.5028 \cdot 10^{-2}$ mSv/hr. The result obtained by manual superposition of each pellet contribution to the total dose rate at detector location, when dealing with old QAD-CGGP was similar $2.5030 \cdot 10^{-2}$ mSv/hr The result obtained by old QAD-CGGP when homogenization has been performed for every TTC separately and the results of two independent calculations have been summed manually was $2.4858 \cdot 10^{-2}$ mSv/hr. When geometry and source homogenization of both TTCs into a single formation (a volumetrically equal rectangular parallelepiped of the same height as two TTCs, 270 cm, and with the base 128×50 cm) has been conducted, the resulting dose rate was $2.6051 \cdot 10^{-2}$ mSv/hr.

5 CONCLUSION

Creation of the new program, Visual QAD, by merging Graphical User Interface created in Visual Basic 6 and enriched with additional support modules and geometry visualization module with FORTRAN Dynamic Link Library, QAD_subroutines.dll, has been successful. VQAD provides means for novices, as well as experienced users, for fast and reliable model description, i.e. input preparation and output analyses.

The comparison of the results obtained by VQAD code and the results of the manual superposition of QAD-CGGP results, shows minor discrepancies that emerge from round off errors. When test cases where subjected to homogenization procedure additional error has been introduced. Therefore, it can be concluded that incorporation of the general multi-source option into QAD has been successful and that the results are better than the ones obtained by homogenization procedures.

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