TRAINING IN EXTERNAL DOSIMETRY CALCULATIONS WITH COMPUTATIONAL CODES

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ABSTRACT

A typical radiological protection education program should include: radiation physics, biological effects of ionising radiation, detection and measuring of ionising radiation, radiation dosimetry, and regulations. Theoretical learning is required in all these subjects, but only two of them involve practical learning: detection and measuring of ionising radiation, and radiation dosimetry. For the practical learning of detection and measuring of ionising radiation, one should have access to different equipment, such as sources and detectors. This equipment may be expensive or difficult of obtaining it, because of regulations. Thus, students might not practice frequently with them. In contrast, practical learning of dosimetry calculation only requires a computer, because radiation dosimetry calculation is based on the calculation of the flux distribution and the dose-to-flux conversion factors. On the one hand, dose-to-flux conversion factors are obtained from databases, such as that of the National Institute of Standards and Technology. However, the flux distribution calculation could be a difficult task, because one should solve the transport equation. Although there are some practical approaches that calculate easily the flux distribution, like the isotropic point source approach, this calculation might be also a hard task for complex geometries. Fortunately, there a lot of codes that can calculate the flux distribution with different methods. The state of the art of these codes are those based on Monte Carlo method. However, these codes are not user-friendly and may require high computational times. On the other hand, there are several user-friendly codes based on the isotropic point source approach, which can calculate faster the flux distribution, even for complex geometries. These codes are accurate enough for obtaining an approximate flux distribution and calculate an appropriate shielding. In this work, the authors describe the use and applications of two codes of this kind: MicroShield and EasyQAD. In particular, several examples will be given in the full paper, such as the dosimetry calculation due to radioactive wastes and shielding calculation.

1. Introduction

A typical radiological protection education program should include: radiation physics, biological effects of ionising radiation, detection and measuring of ionising radiation, radiation dosimetry, and regulations. Theoretical learning is required in all these subjects, but only two of them involve practical learning: detection and measuring of ionising radiation, and radiation dosimetry.

For the practical learning of detection and measuring of ionising radiation, one should have access to different equipment, such as sources and detectors. This equipment may be expensive or difficult of obtaining it, because of regulations. Thus, students might not practice frequently with them.

Radiation dosimetry requires various specifications of the radiation field at the point of interest and deals with methods for a quantitative determination of energy deposited in a given medium by directly or indirectly ionizing radiations [1]. This energy deposited as radiation interacts with atoms of the material, is responsible for the effects that radiation causes in matter, for instance, a rise in temperature, or chemical or physical changes in the material properties [2]. Several quantities related to the radiation field and this energy have been used for quantifying the effects of radiation with matter. Nowadays, one uses the absorbed dose for quantifying the effects of ionising radiation with matter.

Absorbed dose calculation is based on the calculation of the flux distribution and the dose-to-flux conversion factors. On the one hand, dose-to-flux conversion factors are obtained from databases, such as that of the National Institute of Standards and Technology. On the other hand, one can calculate the flux distribution calculation by solving the transport equation. This calculation might be a hard and complex task, but there are several codes that can calculate the flux distribution with different methods.

The state of the art of these codes are those based on Monte Carlo method, such as: MCNP [3], PENELOPE [4], GEANT [5], etc. However, these codes are not user-friendly and may require high computational times. On the other hand, there are several user-friendly codes based on the isotropic point source approach, which can calculate faster the flux distribution, even for complex geometries. These codes are accurate enough for obtaining an approximate flux distribution and calculate an appropriate shielding.

Summarising, practical learning of dosimetry is accessible to students, because it only requires a computer. In this work, the authors describe the use and applications of two codes for calculating the external dose: MicroShield [6] and EasyQAD [7], which are based on the isotropic point source approach. The outline of this paper is as follows. Sections 2 and 3 describes the codes MicroShield and EasyQAD respectively. Section 4 describes the learning method. Section 5 summarises the conclusions.

2. MicroShield

MicroShield [6] is a comprehensive photon/gamma ray shielding and dose assessment program that is widely used for designing shields, estimating source strength from radiation measurements, minimizing exposure to people, and teaching shielding principles.

It is fully interactive and utilizes extensive input error checking. Integrated tools provide graphing of results, material and source file creation, source inference with decay (dose-to-Ci calculations accounting for decay and daughter buildup), projection of exposure rate versus time as a result of decay, access to material and nuclide data, and decay heat calculations.

MicroShield can define sixteen different geometries, such as: point, lines, disks, cylinders, rectangular volumes, etc. It also contains updated library data (radionuclides, attenuation, buildup, and dose conversion), which reflect standard data from ICRP 38 and 107 as well as ANSI/ANS standards and RSICC publications including (ICRP) Publication 116 absorbed dose rates and dose conversion factors from ANSI/ANS-6.1.1-1977. In addition, it includes custom materials based on ANSI/ANS-6.4.2-2006.

3. EasyQAD

EASYQAD [7] was built at Hanyang University, Seoul, Korea as a visualization code system based on the commonly used QAD-CGGP-A point-kernel code in order to perform conveniently gamma and neutron shielding calculations. Its Graphical User Interfaces (GUI) were constructed by MATLAB GUI and compiled in C++ programming language by using MATLAB Compiler Toolbox to form a stand-alone code system that can be run on Windows XP or Windows 7 environment without any MATLAB installation.

Its user-friendly interfaces allow complex items to be easily defined and presented without expert knowledge or special training. One enters geometrical, chemical and nuclear properties through templates and computer aided sequences to build the view to be measured. In these sequences the operator enters the dimensions of 3D-shapes, their chemical compositions, their densities, the type of radioactive sources, the locations of the sources, the type and positions of detectors.

It also contains a material library including about 180 materials, but the user can also build a complete new material and store in this library. Multi-group energy and source spectrum can be defined in which gamma spectrum energy can be determined from the selection of energy gap, minimum energy and the number of energy groups. It is also possible to load the spectrum data from available files. Finally, one can calculate the dose for multiple points at the same time using point, line and grid detectors.

4. Methods

The methodology is focused on the use of two different dose calculation software (MicroShield and EasyQAD) to solve two simple problems. In the first problem, one should obtain the maximum number of trips that a truck driver can make, with a cargo of Cs-137 and without exceeding the dose limit of 1 mSv per year. In the second problem, one calculates the optimal containment for a Co-60 and I-131 source and the thickness of the room wall where the source will be stored to protect people working in the contiguous rooms.

Firstly, a brief theory lesson is given. The purpose of this is to explain basic concepts of dosimetry, such as radiation interaction with the matter (photo electric, Compton and pair production), the concept of mass coefficient, mass thickness, half value-layer or build-up factor. In addition, the instructors explains the basic law of attenuation:

$$I(x) = I_0 \cdot e^{-\mu \cdot x}$$

Where I is the radiation intensity in the point considered, I_0 is initial intensity and μ is a proportionality constant called attenuation coefficient with L^{-1} dimension, and this coefficient depends on the material considered and the incident photon energy.

Secondly, the instructors highlight the three criteria to take into account considering the ALARA (As Low As Reasonably Achievable) concept. These three criteria (Distance, time and shielding) are clearly applied in the problems.

4.1 Driver Truck Problem

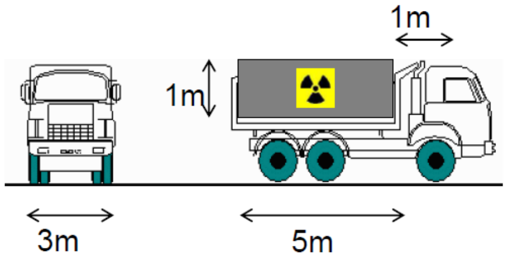

Fig 1. Dimensions used in the Driver Truck Problem.

Problem: *A truck whose dimensions are 5 meters long by 3 meters wide and with a height of 1 meter, has to transport 2000 Tm of radioactive ashes (Cs-137) of 100 Bq / cm3. Taking into account that the truck driver is located 1 meter, obtain with MicroShield and EasyQAD the equivalent dose rate in mSv / h (Deep dose parallel) with and without Buildup. It is known that each trip lasts 2 hours and that the maximum allowable dose is 1 mSv. Calculate how many trips you can make and the dose you receive, considering the dose rate with and without Buildup*.

In this exercise, the instructors point out four special issues. First, the source calculation from the radioactive isotope Cs-137. Second, the difference between the dose calculation with and without build-up factor. Third, dose limit depending on the category of the worker. Fourth, time limit, so the driver does not exceed the dose limit. This time limit is expressed in terms of number of trips.

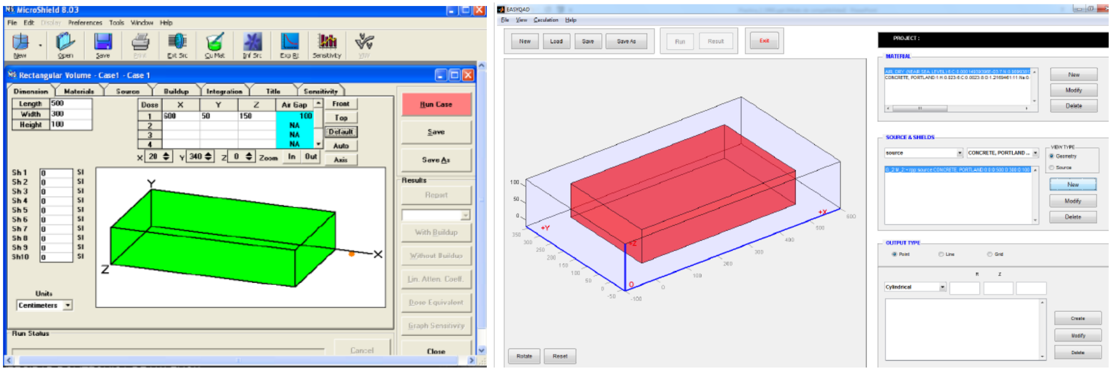

Fig 2. Screen captures of MicroShield (on the left) and EasyQAD (on the right) for the Driver Truck Problem

4.2 Drum problem

Problem: *A cylindrical Pb drum with a thickness of 0.1cm, 1 meter in diameter and 1.5 meters in height is used to store Co-60 and I-131 from medical applications that have been previously compacted into concrete. The activities of each nuclide are: 50 Bq / cm3 for Co-60 and 100 Bq / cm3 for I-131. The drum is stored temporarily in a room of the hospital, one meter away from a concrete wall that separates this room from a visitor's room. Considering that there is a person working in the visitor's room, one meter away from the wall, one should obtain with EasyQAD and Microshield the dose rate in mSv / h with and without Buildup. Considering that the annual work hours for this person are 1900, determine if they will exceed the annual limit,* *which is 1 mSv (consider the dose rate with Buildup). Determine the minimum thickness of the wall so that the annual limit is not exceeded.*

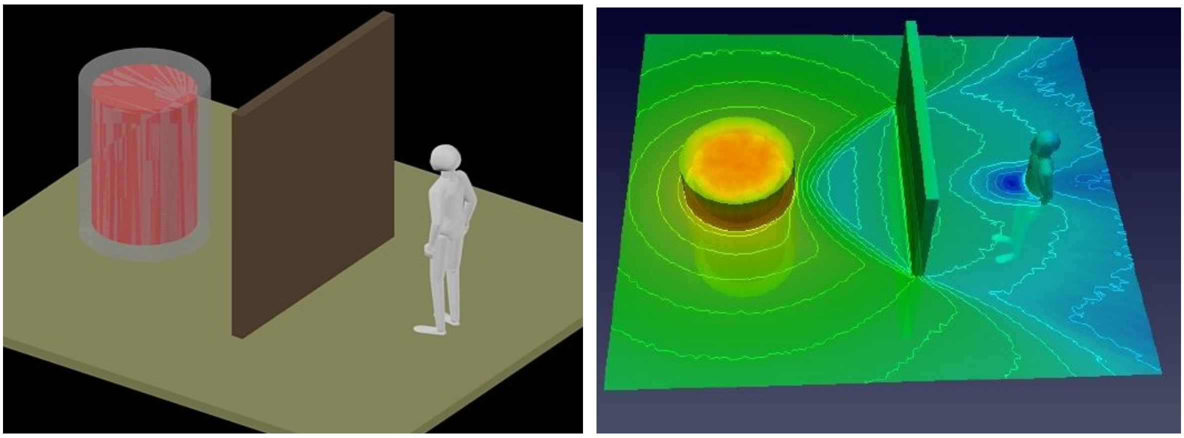

Fig 3. Geometric Example of the problem

The main objective of this problem is to provide a real calculation of a shielding, third ALARA criterion. As in the previous exercise, the instructors highlight several issues. First, the source calculation from radioactive isotopes Co-60 and I-131. Second, the difference between the dose calculation with and without build-up factor. Third, the attenuation of radiation due to thickness and different materials (lead and concrete). Forth, dose limit depending on the category of the worker. Fifth, increasing the shielding, so the worker does not exceed the dose limit.

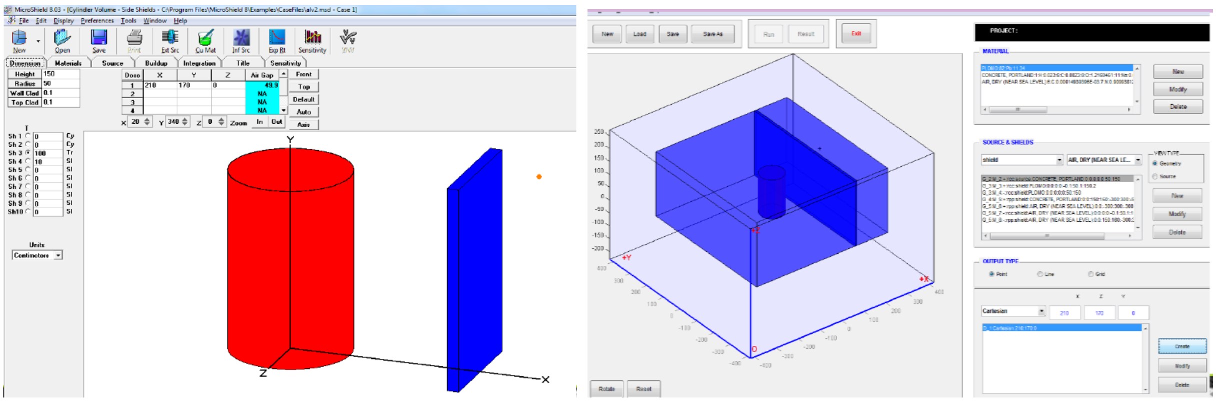

Fig 4. Screen captures of MicroShield (on the left) and EasyQAD (on the right) for the Drum Problem

An analysis of the wall thickness is required, so that the worker does not exceed the annual dose limit. The results are displayed as a flux-thickness curve that simplifies the determination of the optimal thickness. MicroShield can automatically obtains this curve without changing the input, but EasyQAD needs to change the input for each thickness.

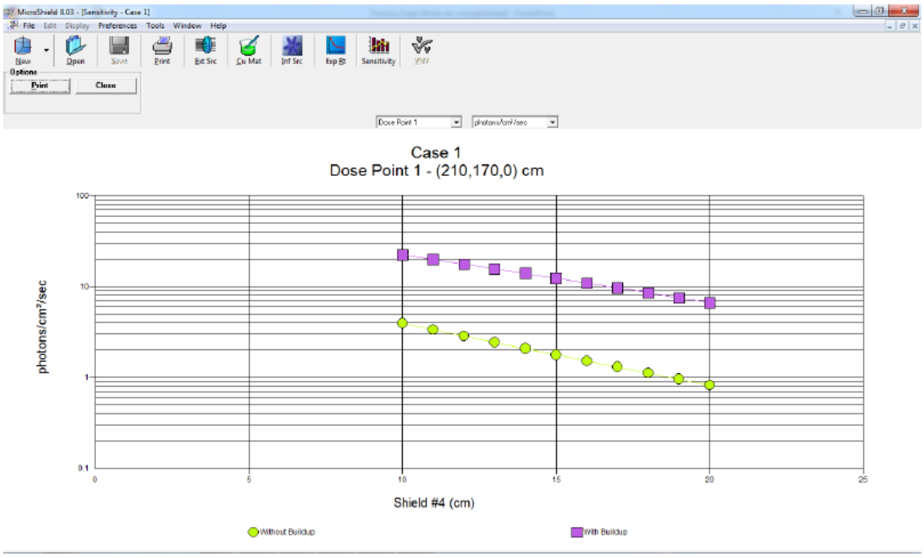

Fig 5. Graph sensitivity (Microshield).

5. Conclusions

This work emphasises two advantages of the training of external dosimetry calculation. First, it only requires a computer and software. Second, it includes both theoretical and practical learning.

Exact external dosimetry calculation might be a hard task, because one should solve the transport equation to determine the flux. However, there are several codes than can calculate the external dose with simplified methods, like those based on the isotropic point source approach.

In this work, the authors used two codes for dose and shielding calculations: MicroShield and EasyQAD. These codes are based on the point source approach, but the results obtained with them are accepted by the Spanish Nuclear Safety Council (CSN).

These codes are a good educational and training tool for practical lessons, without needing expensive devices or large facilities. Their use is very easy and an exhaustive knowledge about the different options of the programs is not necessary to perform real simulations.

Realistic problems were solved in the practical sessions. The practical sessions allow apply the theory to practical learning, which is more dynamic and entertaining than the theoretical learning.

Learners can compare both codes, which is useful for checking that the models and the simulations are correctly executed.

6. References

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