Use of computational modeling to geometry optimization in mass coefficient attenuation calculation

C. M. Barbosa[1,3]; C. Raitz[2]; R. S. F. Dam[1,3];
W. L. Salgado[1,3]; C. M. Salgado[1];
I. C. B. Lima[3]; D. Braz[3].
E-mail: caroline.mattos@coppe.ufrj.br;
craitzj@hotmail.com; rdam@coppe.ufrj.br;
william.otero@coppe.ufrj.br;otero@ien.gov.br;
inaya@coppe.ufrj.br

[1]DIRA, IEN; [2]SEINS, IEN; [3]PEN, COPPE, UFRJ

Keywords: gamma ray, MCNP, mass attenuation coefficient

This report presents a study of different models to simulate mass attenuation coefficient (μ_m) experiments using the Monte Carlo method. The μ_m is a property of materials that quantifies the amount of radiation reaching a detector per unit length per unit density. It can be used to infer the density, type of material, fluid flow regimes, etc. [1]. The MCNPX code [2] was used to simulate each configuration. In this study, the experimental apparatus was modeled using a isotropic point source, a cylindrical shaped sample with height of 5 cm, and a 2 × 2″ NaI(Tl) detector. The study considered the use of lead collimators and virtual collimation [2]. Three radioactive sources were considered, with energies of 59.54 keV (^{241}Am), 81 keV and 356 keV (^{133}Ba) and 662 keV (^{137}Cs). The materials chosen for the samples were aluminum (an element), water (a compound), and seawater (a mixture), with densities 2.6989, 0.9982, and 1.0233 g/cm³, respectively. The composition and density of each material was obtained from the Compendium of Materials [3]. In the MCNPX code, the F8 Tally was used for pulse height distribution (PHD). The peak values corresponding to each source, obtained from the PHDs, were used in the calculation of the mass attenuation coefficients μ_m. All the coefficients were compared with reference ones obtained from the NIST XCOM database [4].

Results for the cases considering a geometry with an isotropic source and lead collimators, are shown in Table 1. Table 2 shows the results for the second geometry, composed of a divergent source (virtual collimation), without lead collimators. Both geometries yield results close to the reference ones, as can be seen from the relative error. All simulations used 10^8 events. However, statistics have improved by an order of magnitude when using virtual collimation, since no gamma photon was lost within the lead collimators. For seawater, the distance errors were larger than for the element and compound materials. This is due to the greater complexity of seawater composition. It is good to remember that, for mixtures, the values provided by XCOM are also estimative.

Table 1. Simulation of isotropic source and lead collimators.

Aluminum			
Energy [keV]	**μ [cm²/g]**	**XCOM μ**	**Δμ**
59.54	0.27388	0.28080	2%
81	0.19391	0.19960	3%
356	0.09650	0.09730	1%
662	0.07681	0.7466	-3%
Water			
Energy [keV]	**μ [cm²/g]**	**XCOM μ**	**Δμ**
59.54	0.20336	0.20666	2%
81	0.17999	0.18290	2%
356	0.11032	0.11110	1%
662	0.09860	0.08574	-15%
Seawater			
Energy [keV]	**μ [cm²/g]**	**XCOM μ**	**Δμ**
59.54	0.20308	0.21220	4%
81	0.17015	0.18470	8%
356	0.10078	0.11070	9%
662	0.08923	0.08536	-5%

Table 2. Simulation of the divergent source (virtual collimation).

Aluminum			
Energy [keV]	**μ [cm²/g]**	**XCOM μ**	**Δμ**
59.54	0.27947	0.28080	0.5%
81	0.19840	0.19960	0.6%
356	0.09668	0.09730	0.6%
662	0.07618	0.7466	0.6%
Water			
Energy [keV]	**μ [cm²/g]**	**XCOM μ**	**Δμ**
59.54	0.20534	0.20666	0.6%
81	0.18176	0.18290	0.6%
356	0.11061	0.11110	0.4%
662	0.08535	0.08574	0.5%
Seawater			
Energy [keV]	**μ [cm²/g]**	**XCOM μ**	**Δμ**
59.54	0.20529	0.21220	3%
81	0.17230	0.18470	7%
356	0.10026	0.11070	9%
662	0.08536	0.08536	10%

The objective of this study is to optimize the simulations. The results indicate that it is possible to replace lead collimators by a virtual collimation, improving the statistics of the simulation. The next steps are to apply the virtual collimation to simulations with higher number of events, a more complex geometry and materials with different densities and thicknesses.

References

[1] SALGADO, C. M. "Identificação de regimes de fluxo e predição de frações de volume em sistemas multifásicos usando técnica nuclear e rede neural artificial". PhD Thesis, (2010).

[2] PELOWITZ, D. B. et al. "MCNPX user's manual version 2.5. 0." Los Alamos National Laboratory, v. 76, p. 473, (2005).

[3] MCCONN, R. J. et al. "Compendium of material composition data for radiation transport modeling". Pacific Northwest National Lab. (PNNL), Richland, WA (United States), (2011).

[4] BERGER, M.J. et al., "NIST standard reference database 8 (XGAM", http://physics.nist.gob.br, (1990).