EVALUATION OF TRANSMITTED ESPECTRA OF MEGAVOLTAGE X RAYS THROUGH CONCRETE USING MONTE CARLO SIMULATION

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Abstract. *With the improvement of technology in radiotherapic centers, medical linear accelerators are largely replacing Cobalt-60 teletherapy units. In most of the cases, the same room that, before, was used to place a ^{60}Co teletherapy unit is reused to install, in replacement, a linear accelerator. When the room physical space can not be changed, high – density concrete is employed to provide shielding against the primary, scatter and leakage radiation. This work presents a study based on Monte Carlo simulations of transmission of some clinical photon spectra (of 10, 15 and 25MV accelerators) through concrete of two different densities. Concrete walls of thickness 1.0, 1.5 and 2.0m were irradiated with 30 cm x 30 cm primary beam spectra. The results show that the thickness of the barrier decreases up to approximately 35%, when barite (high – density concrete) is used instead of ordinary concrete. The average energies of primary and transmitted beam spectra were also calculated.*

Keywords*: Concrete Barrier, MONTE CARLO simulation, Radiotherapy, Linear Accelerators, High-density concrete.*

1. INTRODUCTION

In megavoltage radiotherapy rooms, ordinary concrete is usually used due to its low construction costs, although higher density concrete are sometimes used, as well. The use of high-density concrete decreases the required thickness of the concrete barrier. A disadvantage is its high cost. The NCRP Report No. 151 provides values of structural shielding design and evaluation for Megavoltage x – and – gamma – ray Radiotherapy facilities. This work presents a study based on Monte Carlo simulations of transmission of some clinical photon spectra (of 10, 15 and 25MV accelerators) through concrete of two different densities.

2. METHODOLOGY

The Monte Carlo simulation code, MCNPX, was employed to perform the simulations. A parallel photon beam of 30cm x 30cm field size was normally incident on a concrete barrier. The irradiation geometry is shown in Figure 1. Concrete of two different densities was assumed: 2.35 and 3.35 g/cm³. The shielding effect of concrete depends on its density and composition. Table 1 provides the concrete compositions. The density of ordinary concrete considered by NCRP Report No.151 is 2.35 g/cm³, and the definition of high – density concrete (or heavy concrete) is any concrete with density of > 2.35 g/cm³. The barite (heavy concrete) was chosen in the Compendium of Material Composition Data for Radiation Transport Modeling. The megavoltage X-ray spectra (10, 15 and 25 MV) from Rogers et al. (2001) were used as an input data for the simulation. The F2 tally, which gives the fluence averaged across a surface, was used to obtain the transmitted photon spectra. The thickness of the barrier varies from 0.5 to 2.0 m. The number of histories simulated was large enough to keep the standard deviation below a few percent.

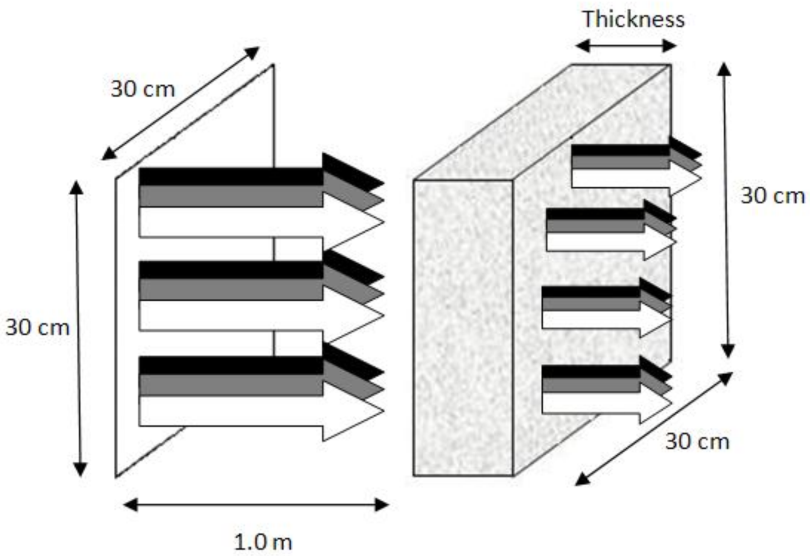


Figure 1. Irradiation geometry for expanded and aligned field.

Table 1. Density and elemental composition assumed for concrete.

	Ordinary Concrete	Barite Concrete
Density (g.cm^{-3})	2.35	3.35
H	0.0056	0.003585
O	0.4983	0.311622
Na	0.0171	-
Mg	0.0024	0.001195
Al	0.0456	0.004183
Si	0.3158	0.010457
S	0.0012	0.107858
K	0.0192	-
Ca	0.0826	0.050194
Fe	0.0122	0.047505
Ba	-	0.463400

The average photon energy ($\bar{E}$), for each spectrum, was calculated as shown in equation 1.

$$\bar{E} = \frac{\sum_{i=1}^{N} E_i \phi(E_i)}{\sum_{i=1}^{N} \phi(E_i)} \tag{1}$$

where E_i is the transmitted photon energy of the *i*th energy interval; $\phi(E_i)$ is the corresponding average fluence obtained by MCNP calculations and *N* is the number of energy intervals of the spectrum.

3. RESULTS AND DISCUSSION

The Figure 2 (a), (b) and (c) shows the transmitted spectra for 10, 15 and 25MV respectively, through concrete barriers that varies from 0.5 to 2.0 m. The incident beam spectra are also shown. The dot line represents ordinary concrete and the continuous one, barite. As expected, the transmitted spectra are hardened after traversing larger concrete thicknesses.

Table 2 provides the average photon energy for each transmitted spectrum, when ordinary concrete is used. In addition, Table 3 shows the average photon energy for transmitted spectra when barite is considered.

Figure 2 (a) shows the transmitted spectra for the 10MV beam. The average energies are 3.42, 3.65 and 3.71MeV for 1.0, 1.5 and 2.0m of ordinary concrete barrier, respectively. As expected, the transmitted spectra are hardened after traversing larger concrete thicknesses. For barite barriers, the average energies values are almost constant and lower than the values presented for ordinary concrete.

Figure 2 (b) shows the transmitted spectra for the 15MV beam. The average energies for 1.0, 1.5 and 2.0m thick ordinary concrete barriers are 3.96, 4.24 and 4.27MeV, respectively. The results are consistent with the expected. Analyzing the average energies calculated values for the transmitted spectra through barite, it can be noticed a reduction of approximately 50% in the average energies values.

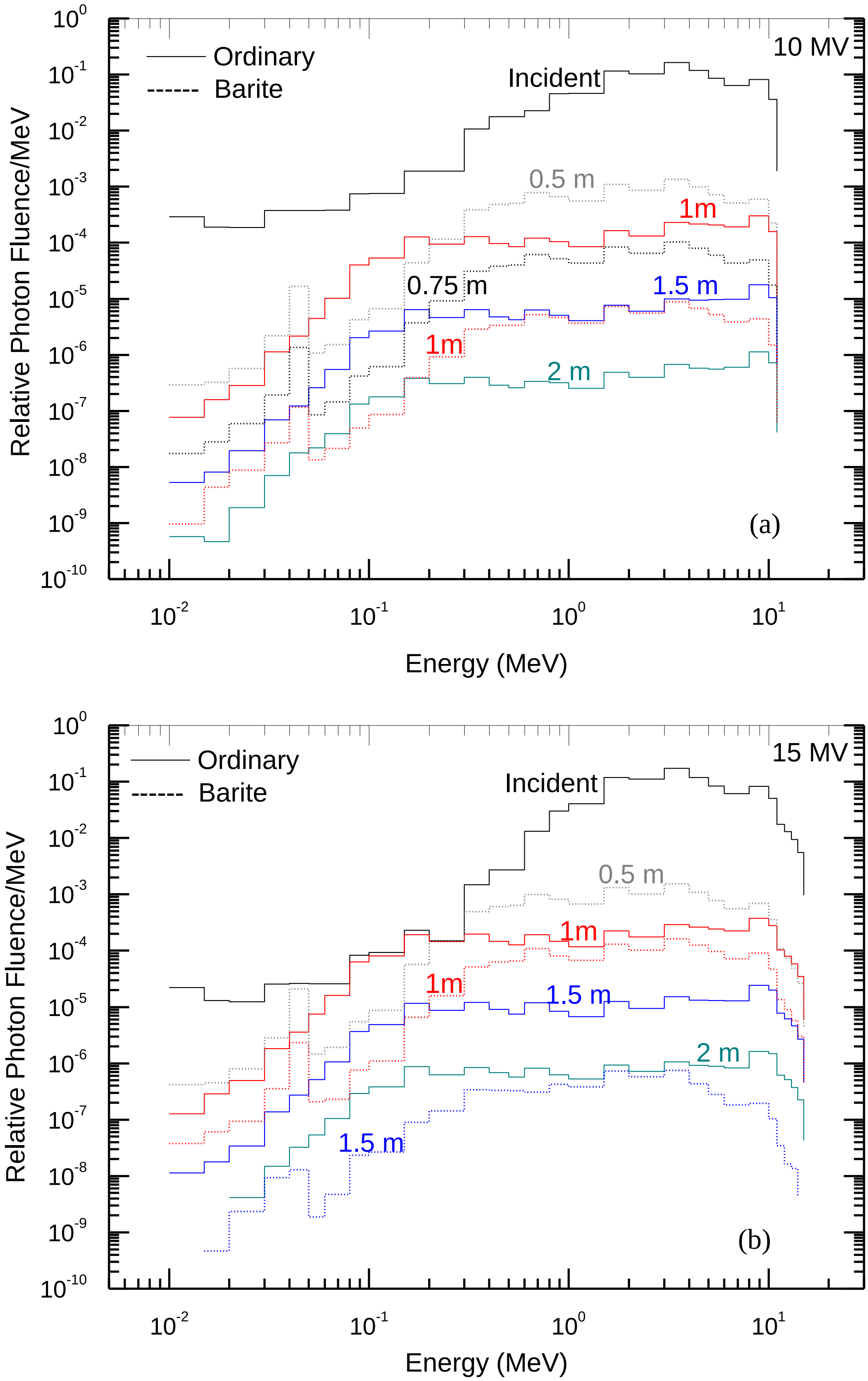
Figure 2 (c) shows the transmitted spectra for the 25MV beam. The average energies are 5.00, 5.10 and 5.02MeV for ordinary concrete barriers of 1.0, 1.5 and 2.0m thickness, respectively. Increasing the thickness of the barite concrete barrier, the transmitted photon spectra average energies decreases.

Table 2. Average photons energies for transmitted spectra through ordinary concrete barriers.

Photon Energy (MeV)	**Concrete Thickness (m)**	$\bar{E}$ **(MeV)**
Varian (10 MeV)	1.0	3.42
	1.5	3.65
	2.0	3.71
Varian (15 MeV)	1.0	3.96
	1.5	4.24
	2.0	4.27
Elekta (25 MeV)	1.0	5.00
	1.5	5.10
	2.0	5.02

Table 3. Average photons energies for transmitted spectra through barite barriers.

Photon Energy (MeV)	**Concrete Thickness (m)**	$\bar{E}$ **(MeV)**
Varian (10 MeV)	0.5	2.75
	1.0	2.79
	1.5	2.79
Varian (15 MeV)	0.5	2.91
	1.0	3.15
	1.5	2.35
Elekta (25 MeV)	0.5	3.30
	1.0	2.96
	1.5	2.41


Relative Photon Fluence/MeV
Energy (MeV)
Ordinary
Barite
10 MV
Incident
0.5 m
1m
0.75 m
1.5 m
1m
2 m
(a)
Relative Photon Fluence/MeV
Energy (MeV)
Ordinary
Barite
15 MV
Incident
0.5 m
1m
1m
1.5 m
2 m
1.5 m
(b)

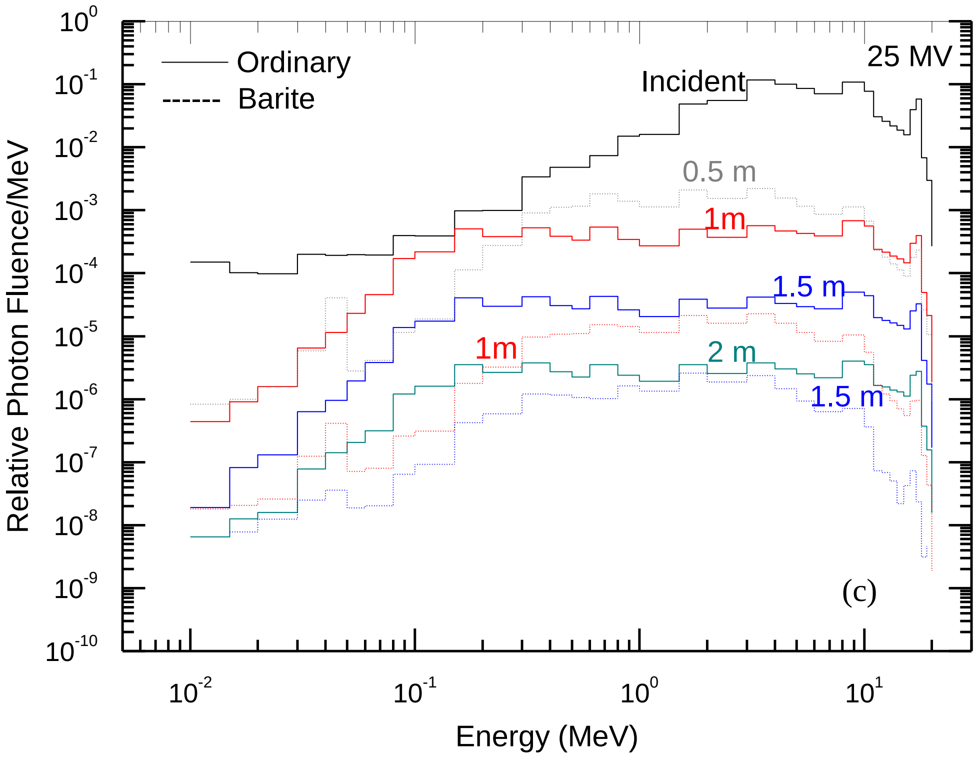


Figure 2. Transmission of primary spectra of (a) 10MV, (b) 15MV and (c) 25MV through concrete barriers.

4. CONCLUSIONS

Comparing the transmitted megavoltage x ray spectrum for 10 MV through both concretes densities (ordinary and barite), it's shown that 1m of barite slabs attenuates more than 1.5m thick wall of ordinary concrete. That indicates a decrease of approximately 33% in the barrier thickness.

For 15 and 25 MV transmitted spectra, the concrete wall reduction is about 25% when barite (with 1m of thickness) is used instead of ordinary concrete (with 1.5m thick wall).

The results show that the use of high-density concrete decreases the required thickness of the concrete barrier. The replacement of ordinary concrete for barite is a very important and useful option when a high-energy medical accelerator is to be fitted into a teletherapy unit treatment room that previously works with an accelerator with lower energy, and there is no physical space to enlarge the walls of the room using ordinary concrete.

5. AKNOWLEGEMENTS

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