Attenuation characteristics of materials used in radiation protection as radiation shielding

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Abstract: Crystal glass has been widely used as shielding material in gamma radiation sources as well as x-ray generating equipment to replace the plumbiferous glass, in order to minimize exposure to individuals. In this work, ten plates of crystal glass, with dimensions of 20cm x 20cm and range of thicknesses from 0.5 to 2.0 cm, and barite concrete were irradiated with potential constants of 60kV, 80kV, 110kV, 150kV and gamma radiation of ^{60}Co. The curves of attenuation and of transmission were obtained for crystal glass, barite plaster and barite concrete (mGy/mA.min) at 1 meter as a function of thickness.

Keywords: Crystal glass, barite concrete, Curves of attenuation, radiation shielding.

1. INTRODUCTION

Crystal glass and the barite plaster and barite concrete has been largely used as shielding material in installations housing gamma radiation sources as well as x-ray generating equipment , in order to minimize exposure to individuals [1,2].

The knowledge of the physical characteristics of crystal glass and the barite such as density, the degree of radiation attenuation and composition, granulometry, plasticity, density, resistance to compression and the degree of radiation attenuation for the different types of barite plaster and barite concrete commercially available in Brazil respectively are very important when dealing with shielding calculations for both medical and industrial installations [3].

This work was carried out aiming to determine the transmission and attenuation factors as well as the thickness equivalent of a half value layer and deci value layer for different x-ray energies and gamma radiation of ^{60}Co[4,5].

2. MATERIALS AND METHODS

In this work, plates of crystal glass, with dimensions of 20cm x 20cm and range of thicknesses from 0.5 to 2.0 cm, were used. The plates were x-ray irradiated with potential constants of 60kV, 80kV, 110kV, 150kV and gamma radiation of ^{60}Co. Barite plaster and barite concrete were also evaluated. The samples were prepared in rectangular plate format with dimensions of 30cm x 30cm with thicknesses varying from 1cm to 8cm and exposed to x-ray beams generated by the voltages and ^{60}Co, with constant current of 10mA in a secondary laboratory, with a Pantak 250 type x-ray apparatus [6, 7, 8].

The rate of kerma in air was measured with farmer type dosimeter and ionization chamber of 0.6cc at a distance of 1 meter from the source of radiation. The thickness above 20cm were obtained by modifying the components in the conglomeration (Trace I, II and III – one part of cement two parts of fine sand +1.35 part of water + three parts of $BaSO_4$) [9].

3. RESULTS AND DISCUSSION

The chemical composition of the crystal glass, the barite plaster and barite concrete are indicated in the Table 1. Table 2 illustrates the irradiation conditions for the materials studied in this research.

Tabela 1. – Chemical analysis for different shielding materials.

Chemical Composition	Cristal Glass (%) ρ =2.08 g/cm^3	white barite Trace I(%) ρ =2.67 g/cm^3	white barite Trace II(%) ρ =2.46 g/cm^3	white barite Trace III(%) ρ =2.70 g/cm^3
SiO_2	83.68	54.56	33.93	38.10
CaO	11.15	11.78	11.65	7.33
CO_2	-	8.70	39.11	35.20
BaO	-	10.13	5.49	7.88
SO_3	-	6.53	3.70	5.38
MgO	3.44	-	-	0.86
Al_2O_3	1.09	5.30	3.84	3.36
K_2O	0.59	0.94	0.68	0.56
SrO	0.02	0.10	0.05	0.07
Fe_2O_3	-	1.00	0.72	0.60
P_2O_5	-	0.76	0.66	0.48
Pm_2O_3	-	0.16	0.12	0.14

Tabela 2. – Quality specification of the x- ray and ^{60}Co.

ISO quality 4037-1	Effective energy(keV)	Voltage (kV)	Inherent filtration (mmAl)	Additional filtration(mmCu)	1ª CSR (mmCu)	2ª CSR (mmCu)
W60	45	60	3.912	0.297	0.18	0.21
W80	57	80	3.912	0.507	0.35	0.44
W110	79	110	3.912	1.988	0.96	1.11
W150	104	150	3.912	1.030	1.86	2.10
^{60}Co	1250	-	-	-	-	-

The attenuation of the radiation beam as well as the values of HVL and TVL are shown in table 3, 4, and 5 as a function of thickness for different compositions of barite plaster – concrete (Trace III). These values can be used to determine the thickness of wall coverings facing the primary and secondary beams in order to conform to the desired level of radiation in a radiodiagnostic installation [10, 11].

As the radiation shielding depends on the material's density, it is interesting to plot linear attenuation coefficients as a function of density. The methods of radiation attenuation depend on the energy and the type of radiation. Selection of concrete or lead in γ-ray shielding usually depends on radiation energy and cost of shielding material. According of the NCRP [4], concrete wall thickness for 100kVp x-ray shielding is 80 fold, and its weight is 17 fold which is similar to lead shielding, but the concrete wall thickness for 1 MeV γ-ray shielding is only 6 fold and its weight is 25% which higher than lead wall; therefore the cost will be much lower with concrete than lead shielding.

Tabela 3. – Quality specification of the x- ray and ^{60}Co

Voltage (kV)	Result						Literature[3]			Result	
	Barite Plaster						Concrete			Cristal Glass	
	HVL (cm)			TVL (cm)			Voltage (kV)	HVL (cm)	TVL (cm)	HVL (cm)	TVL (cm)
	I	II	III	I	II	III	2.35 g/cm^3			ρ =2.08 g/cm^3	
60	0.36	0.35	0.35	1.20	1.20	1.20	50	0.43	1.50	0.79	2.50
80	0.61	0.60	0.57	2.00	2.00	1.90	70	0.84	2.80	1.20	3.90
110	0.93	0.94	0.86	3.10	3.10	2.90	100	1.60	5.30	1.30	4.10
150	1.50	1.50	1.40	5.00	5.10	4.60	150	2.24	7.40	1.80	6.10
^{60}Co	6.70	6.90	5.90	22.30	22.90	19.80	^{60}Co	6.90	20.60	5.60	18.70

Tabela 4. – Attenuation values and transmission of radiation into the concrete of barite (Trace III), when irradiated with ^{60}Co as a function thickness.

Thickness (cm)	Attenuation (mGy/h)	δ (Standard deviation)	Transmission factor
0.00	3.78E+00	7.46E-03	1.00E+00
3.00	2.68E+00	5.12E-03	7.07E-01
4.00	2.36E+00	3.60E-03	6.24E-01
5.00	2.13E+00	3.44E-03	5.63E-01
7.00	1.68E+00	3.26E-03	4.43E-01
8.00	1.52E+00	4.49E-03	4.02E-01

Tabela 5. – Attenuation values and transmission of radiation into the crystal glass, when irradiated with ^{60}Co as a function thickness.

Thickness (cm)	Attenuation (mGy/h)	δ (Standard deviation)	Transmission factor
0.00	3.76E+00	6.18E-03	1.00E+00
1.00	3.30E+00	3.57E-03	8.78E-01
2.00	2.91E+00	4.75E-03	7.73E-01
3.00	2.55E+00	2.04E-03	6.79E-01
4.00	2.32E+00	4.31E-03	6.17E-01
5.00	2.04E+00	3.42E-03	5.42E-01
6.00	1.81E+00	3.93E-03	4.80E-01
7.00	1.59E+00	4.40E-03	4.22E-01

4 CONCLUSIONS

According to the results presented in the work, it can be concluded that the attenuation and transmission values, and thicknesses of the semi and deci-reduced layers are rare for the barite plaster, barite concrete and crystal glass types of materials studied, although their use permits the dimensioning of the armor covering for external x radiation with precision and safety without elevating the cost of protection.

Knowledge of the attenuation characteristics of crystal glass and barite is important both from the point of view of a planning of a radiation protection, such as the feasibility and design, as from the point of view of the implementation of projects on shielding of radioactive facilities. Attenuations obtained in this research for the materials and white barite crystal glass showed characteristics similar to those obtained in the literature[3] for other materials.

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