Effect of common building materials in narrow shaped X-ray fields transmission

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Abstract. Diagnostic and interventional radiology, are an essential part of present day medical practice. Advances in X-ray imaging technology, together with developments in digital imaging have had a significant impact on the practice of radiology. This includes improvement in image quality, reduction in dose and a broader range of available applications resulting to better patient diagnosis and treatment. X-rays have the potential for damaging healthy cells and tissues, therefore all medical procedures employing X-ray equipment must be carefully managed. In all facilities and for all equipment types, procedures must be in place in order to ensure that exposures to patients, staff and the public are kept as low as reasonably achievable. Commonly used construction materials such as, ceramic tiles and plasterboards can provide a certain degree of protection against X-radiation. In this study, the secondary radiation transmission through common building materials is investigated, in the case of narrow shaped X-ray fields. Double plasterboard and double reinforced in thickness ceramic tile provided better radiation protection results.

1. Introduction

Diagnostic X-rays account for the major portion of man-made radiation exposure to the general population. Although individual doses associated with conventional radiography are usually low, examinations involving computed tomography and international radiography can be significantly higher. However, with well-designed, installed and maintained X-ray equipment, and through use of proper procedures by trained operators, unnecessary exposure to patients can be reduced significantly, with no degradation in the medical information derived. To the extent that patient exposure is reduced, there is, in general, a decrease in the exposure to the equipment operators and other health care personnel [1-3]. In some cases a judicious use of common building materials or a careful selection of location and orientation of the X-ray unit may eliminate the need for additional shielding without compromising the X-ray safety of the installation [4]. In this study the secondary radiation transmission through common building materials, such as single ceramic tile, double reinforced ceramic tile, single plasterboard and double plasterboard, for a narrow shaped X-ray field, is investigated [5,6]. As far as we know from current literature, this kind of combined study has not been performed previously. The presented results may be of use in panoramic radiography applications or other narrow field imaging techniques.

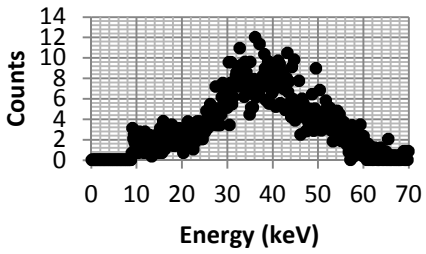
2. Materials and Methods

A conventional radiographic system (Philips Optimus 80) was used, installed at the Department of Radiology, Sismanoglio General Hospital of Athens, Greece. It was equipped with a three phase high voltage generator, a diagnostic X-ray tube with two focal spots, a tube voltage ranging from 40 to 150 kVp, a tube current ranging from 1 to 660 mA and an exposure time ranging from 0.001 to 16 s. The

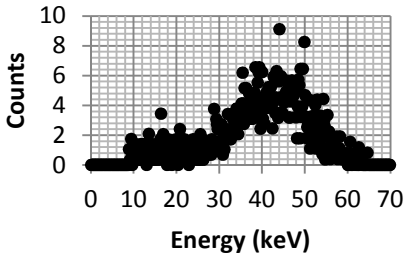
Half Value Layer (HVL) was measured 2.1 mm Al at 70 kVp and the tube current was 10 mA. In order to simulate the human head, a cylindrical phantom from plexiglas, with a diameter of 16 cm and a height of 15 cm was used. The phantom was placed on the radiographic table and the distance between the phantom and the tube focus was 83 cm. The distance between the central point of phantom and the point of measuring secondary radiation was 50 cm. The measuring instruments were placed in a special radio protective apparatus and the materials studied were positioned at its input. The materials used as barriers, for the secondary X-ray transmission, were: (a) Single ceramic tile with thickness of 0.7 cm, (b) double reinforced ceramic tile with thickness of 1.8 cm, (c) single plasterboard [7] (or gypsumboard wall) with thickness of 1.3 cm and (d) double plasterboard with thickness of 2.6 cm. All thicknesses were measured with a Vernier caliper with reading error 0.05 mm. The X-ray field used was 16 cm x 2 cm, which is utilized for panoramic or other specific applications. An Amptek XR-100 CdTe spectrometer was used for measuring secondary X-rays energy distribution. The correction of the spectrometer with respect to the energy per X-ray bin was equal to (1/5.89) keV. In addition, the quantum efficiency response (QE) of the CdTe, obtained from the manufacturer data sheet, was equal to [8-10]:

$$Q(E) = 0.000002 * E^3 - 0.0001 * E^2 + 0.008 * E + 1.0362 \qquad (1)$$

where E is the X-ray energy. In X-ray spectrum measurements, the tube voltage was kept constant at 70 kVp and the tube load at 32 mAs. The ionization chamber used for measuring the secondary radiation was a calibrated 451P-DE-SI model of Fluke Biomedical. In this study, the irradiation time was kept at 2000 ms, so as to account for the response time of the instrument [11-13]. The secondary radiation dose rate (μSv/hr) was measured at a fixed location, with or without the barrier material studied. Before the measurements, a complete quality control program was performed on the radiographic unit to assess its reproducibility and accuracy.



a)



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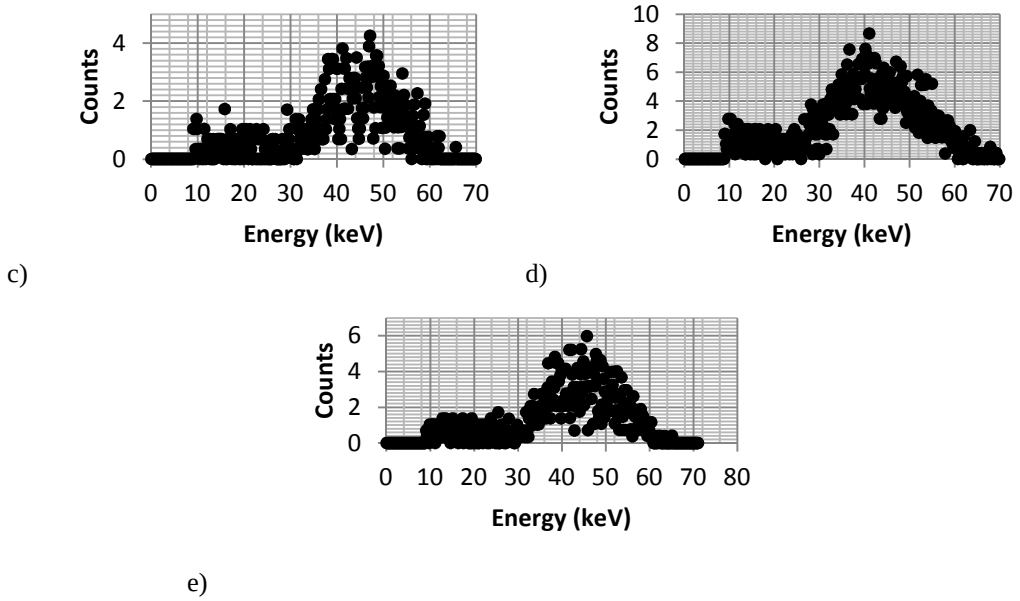

Figure 1. Secondary X-ray energy distribution at 70 kVp, for: a) Without material, b) Single ceramic tile, c) Double reinforced ceramic tile, d) Single plasterboard, e) Double plasterboard.

3. Results and Discussion

The accuracy of the X-ray tube voltage was 1.3 %, and its reproducibility was 1.9 %. The measurements were performed with the PTW-Freiburg T43014 [14-15], Diavolt Universal kVp-Dose-time meter placed at a distance of 1.0 m from the focal spot on the upper surface of the cylindrical phantom.

In Figure 1, the secondary X-ray energy distributions at 70 kVp for all materials studied are presented. All materials slightly increase the average value of energy spectrum, as also presented in the third column at Table 1. Due to the directivity of the scatter radiation, the spectrometer alignment with respect to the incident X-rays and the hole diameter, the spectrometer was able to detect only a portion of the secondary X-rays, scattered at an angle of 90 degrees with respect to the primary X-rays.

Table 1. Secondary radiation dose rate, transmission and average energy for all materials studied.

	Secondary radiation dose rate (μSv/hr)	Transmission %	Average value of energy (keV)
Without material	500.0	-	37.3
Double plasterboard	150.0	30.0	41.5
Double reinforced in thickness ceramic tile	150.0	30.0	41.6
Single ceramic tile	200.4	40.1	39.6
Single plasterboard	300.0	60.0	40.0

In Table 1, the secondary radiation dose rate (μSv/hr), as well as the corresponding transmission, and the corresponding average spectrum energy are presented. Double plasterboard and double reinforced in thickness ceramic tile provided better radiation protection results. In both these cases the average secondary radiation energy value was higher, due to the beam hardening effect at these

materials, as they have higher density. According to the above results, common building materials, such as the materials studied, may be of value for shielding purposes, especially in cases of low workload and spaces with small occupancy factor.

4. Conclusion

For narrow shaped X-ray fields, such as 16 cm x 2 cm, common building materials, such as single ceramic tile, double reinforced ceramic tile, single plasterboard and double plasterboard and the combination of them, may be of value for shielding purposes, especially in cases of low workload and spaces with small occupancy factor. From the above materials studied, the double plasterboard and the double reinforced in thickness ceramic tile provided better radiation protection with low cost, for narrow X-ray fields and for low energies.

References

[1] NCRP 2004 *Structural Shielding Design for Medical X-Ray Imaging Facilities - Report No. 147*

[2] Environmental Health Directorate Health Canada 1999 *Radiation Protection in Dentistry - Recommended Safety Procedures for the Use of Dental X-Ray Equipment - Safety code 30*

[3] Environmental Health Directorate Health Canada 1991 *Radiation Protection in Veterinary Medicine - Recommended Safety Procedures for Installation and Use of Veterinary X-Ray Equipment - Safety code 28*

[4] Petrantonaki M, Kappas C, Efstathopoulos E, Theodorakos Y and Panayiotakis G 1999 Calculating shielding requirements in diagnostic X-ray departments. *Br. J. Radiol*. **72** 179-185

[5] Edward R, Herbert W 1966 Experimental study of the photon energy spectrum of primary diagnostic X-rays *Phys. Med. Biol* **2** 225-238

[6] Archer B R, Thornby J I, Bushong S C 1983 Diagnostic X-ray Shielding Based in an Empirical Model of Photon Attenuation *Health Phys*. **5** 507-17

[7] See http://www.isolgomma.com/eng/

[8] Martini N, Koukou V, Michail C, Sotiropoulou P, Kalyvas N, Kandarakis I, Nikiforidis G, Fountos G 2015 Pencil beam spectral measurements of Ce, Ho, Yb, and Ba powders for potential use in medical applications *Journal of Spectroscopy* 563763

[9] Vlachos I, Tsantilas X, Kalyvas N, Delis H, Kandarakis I, Panayiotakis G 2015 Measuring scatter radiation in diagnostic X rays for radiation protection purposes *Rad. Prot. Dosim.* doi:10.1093/rpd/ncv093

[10] See http://www.amptek.com/

[11] Health Physics Society, http://www.hps.org/publicinformation/

[12] Economides S, Hourdakis C, Kalyvas N, Kalathaki M, Simantirakis G, Tritakis P, Manousaridis G, Vogiatzi S, Kipouros P, Boziari A, Kamenopoulou V 2007 Performance of medical radiographic X-ray systems in Greece for the time period 1998-2004 *Phys. Medica* **23** 107-114

[13] See http://www.flukebiomedical.com/

[14] See http://www.ptw.de/

[15] Tsalafoutas I 2006 Excessive leakage radiation measured on two mobile X-ray units due to the methodology used by the manufacturer to calculate and specify the required tube shielding *Br. J. Radiol.* **79** 162–164