ORIGINAL ARTICLE

SHIELDING EFFICIENCY OF LEAD AND CONCRETE: A COMPARATIVE STUDY

*C. C. Nzotta and E. Udeh

Department of Radiography/Radiological Sciences, Faculty of Health Sciences and Technology, College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria.

Eemail: nzottac@yahoo.com

Lead is the most common shield against x-rays because of its high density, ease of installation and low cost. Though there had been an unguided choice of shielding materials by radiation producers and users particularly in Radiology. There has not been sufficient data and bases for comparing the shielding efficiency of lead and concrete as obtained in various local environments. This is a comparison of the shielding efficiency of lead and concrete to x-rays of diagnostic energy range (40kVp – 125kVp). This comparison is done with radiation from mobile x-ray unit of kV_{max} – 110, mAS_{max} – 100 and total filtration 2.5mmAL. At a fixed FFD of 100cm a uniform x-ray machine setting is used to expose 1.00mm slices of lead using RAD ALERT dosimeter, the HVL of the lead is determined for various KV settings of the machine. This is repeated for different slabs of 15mm thick concrete. The results show that the HVL of lead for this energy range 40 – 125kv is 0.055mm – 0.192mm far less than that of concrete 19.6 – 66.3mm at the same energy range. Also the total linear attenuation coefficient of lead is 0.75 – 1.26/mm and 0.010 – 0.035/mm for concrete at this energy range. The total mass attenuation coefficient for lead is 0.66 – 1.12mm^2/g. This is greater than that of concrete 0.043 – 0.152mm^2/g at this energy range.

1. Introduction

The shielding facilities in rooms where ionizing radiation is used or produced is designed in such a way that all possible orientations of the primary beam from the source, persons outside the room or behind the protective screen are not exposed to doses in excess of the levels specified in table 1 [1].

The assessment of dose includes the contributions from primary beam, scattered and leakage radiation. Shields used for primary beam are primary shields while secondary shields are used for scattered and leakage radiation. The factor that must be considered in determining primary shielding material requirement is exposure. This is evaluated using the half value layer measurement or by the product of the distance of the shield from the source, the occupancy factor, the use factor, the workload and the conversion of work load into Rontgens [2].

$$E = \text{ÕËWUT x } 1/d^2$$

where E is weekly exposure reaching the point in question (R/WK), E is R/mA. Min./wk).
U is the use factor, T is the occupancy factor (no limits) and
d is the distance in meters from the x-ray tube to the point in question].

The effectiveness of a shield increases with density.

Table 1: Categories of Persons exposed to Radiation

	Category of personnel	*Design level (mSv/YR)*
1.	Exposed workers	5.0
2.	Other workers in the hospital	0.5
3.	In patients [excluding radiation associated with their treatment]	1.0
4.	Visitors to - Radiotherapy / nuclear medicine - Diagnostic x-ray units	 0.5 0.05
5.	All others	0.05

Lead is the most common shield against x-rays because of its high density (11340kg/m^3), ease of installation and low cost [3]. Though there had been an unguided choice of shielding materials (especially for the cubicles and walls of x-ray rooms). There has not been sufficient data and bases for comparing the shielding efficiency of lead and concrete as obtained in our local government. This work is a comparison of the shielding efficiency of lead and concrete to x-rays of diagnostic energy range (40kVp - 125kVp).

Diagnostic application of x-ray contributes more to the radiation exposure to man than any other application [4].

Heavy metals like lead, tungsten, molybdenum with high absorption coefficient for x-rays are used as shields [5].

Shielding can increase the dose rate [6] if the electrons from a high beta source e.g. ^{32}P strike a lead surface, x-ray photons will be generated. It is best to cover any high z material such as lead or tungsten with a low material such as Aluminum, wood, plastic etc. This effect can be significant if a person wearing lead gloves picks up a beta from a strong beta source.

Gamma rays that require 1cm of lead to reduce their intensity by 50% will also have their intensity reduced to half by 9cm of packed soil, 6cm of concrete, 2cm of depleted uranium and 150m of air [7].

The implication is that other materials could be used as shield so long as they have sufficient thickness. A high density glass as screen protects television viewers from the effect of the radiation.

2. Materials and Methods

1. A mobile x-ray machine at the department of radiography Nnamdi Azikiwe University Nnewi campus with the following specifications was used. Kv_{max} – 110, mAs_{max} – 10, filtration 2.5mmAL.
2. 25 sheets of lead material each 30mmsq and thickness 1.0mm.
3. Slabs of concrete of 15mm thickness.
4. RadAlert 100, Dosimeter. Nuclear radiation monitor
5. Lead Apron and gloves.

The x-ray machine setting for the readings is the same for both the lead and concrete measurements. The FFD is 100cm and mAs is 30. The slabs of concrete and slices of lead sheets were placed erect along the primary beam pathway. The central ray was directed to the center of the shields so as to cover the sensitive area of RADALERT to avoid oblique rays. The meter measured the energy of the entrance surface beam and the energy of the various exit beam from the various inter position of 1mm slide of lead sheets until the exit energy is exactly half of the energy of the entrance surface beam at that kilo voltage setting. The thickness of lead that produced this is noted as the HVL for that kilo voltage. This is repeated for different KV settings for different superimpositions of concrete of 15mm thickness. Steps were taken to avoid error due to parallax on the kV and mAs meters of the x-ray machine.

The line voltage drop was adequately compensated for before each exposure. Care was taken to avoid air gap between the slabs and slices. Thick concrete slabs were used to absorb oblique rays all around the slices.

3. Results and Discussion

The results obtained from the readings and measurements are presented below (table 2).

The HVLs of lead and concrete at kvp of 40 – 80 were calculated using the corresponding equation of each of the transmission curves. The values obtained are compared on table 3.

The total linear and total mass attenuation coefficients of lead and concrete were calculated using equation (9) and (10) respectively. The values are as shown below (table 4).

In the choice of shielding materials, the energy of the radiation is put into consideration. From the data and the results of the measurements, the half value layer of lead 0.055 – 0.192mm for x-ray of energy 40kV – 80kV is far less than that of concrete 19.6 – 66.3mm at the same energy range. Also the total linear attenuation coefficient of lead 0.75 – 1.26/mm for x-rays of 40kV – 80kV is far greater

Table 2: Exposure Reduction for Lead and Concrete at Different Kvp and Thickness

	Concrete		*Lead*	
Kvp	***Thickness (mm)***	***Exposure (mR)***	***Thickness (mm)***	***Exposure (mR)***
40	0	0.042	0	0.042
	15	0.032	1	0.014
	30	0.017	2	
	45	0.014		
	60	0.011		
45	0	0.082	0	0.082
	15	0.044	1	0.014
	30	0.016	2	
	45	0.010		
	60			
50	0	1.624	0	1.642
	15	1.004	1	0.022
	30	0.303	2	0.020
	45	0.095	3	0.017
	60	0.044	4	
	75	0.017		
55	0	2.306	0	2.306
	15	1.277	1	0.034
	30	0.612	2	0.032
	45	0.158	3	0.031
	60	0.070	4	
	75	0.017		
60	0	2.403	0	2.403
	15	0.947	1	0.046
	30	0.749	2	0.047
	45	0.644	3	0.047
	60	0.272	4	
	75	0.151		
65	0	2.575	0	2.575
	15	2.091	1	0.104
	30	1.514	2	0.099
	45	0.973	3	0.065
	60	0.628	4	0.111
	75	0.273	5	0.040
70	0	2.806	0	2.806
	15	2.149	1	0.236
	30	1.613	2	0.196
	45	1.233	3	0.122
	60	0.697	4	0.208
	75	0.207	5	0.075
75	0	2.849	0	2.849
	15	2.133	1	0.383
	30	1.760	2	0.300
	45	1.247	3	0.195
	60	1.038	4	0.362
	75	0.749	5	0.178
80	0	2.861	0	2.861
	15	2.343	1	0.559
	30	2.110	2	0.345
	45	1.867	3	0.321
	60	1.503	4	0.552
	75	1.317	5	0.251

than that of concrete 0.010 – 0.035/mm. The total mass attenuation coefficients of lead 0.66 – 1.12mm^2/g for x-rays of 40kV – 80kV was found to be greater than that of concrete 0.043 – 0.152mm^2/g.

Table 3: HVLs of lead and concrete

Energy (kvps)	Exposure (mR)	Half value (mR)	HVL (mm)	
			Concrete	Lead
40	0.042	0.021	19.6	0.55
45	0.082	0.041	21.0	0.60
50	1.624	0.812	23.0	0.65
55	2.306	1.153	24.0	0.70
60	2.403	1.201	26.2	0.79
65	2.575	1.287	38.9	0.74
70	2.806	1.403	39.3	0.81
75	2.849	1.424	44.9	0.86
80	2.861	1.430	66.3	0.92

Table 4: Total linear and mass attenuation coefficients of lead and concrete.

Energy (kvp)	***m(/mm)***		***m/p (mm^2/g)***	
	Concrete	***Lead***	***Concrete***	***Lead***
40	0.035	1.26	0.152	1.12
45	0.033	1.16	0.143	1.03
50	0.030	1.07	0.130	0.95
55	0.029	1.00	0.126	0.89
60	0.026	0.99	0.113	0.88
65	0.018	0.93	0.078	0.82
70	0.018	0.85	0.078	0.75
75	0.015	0.81	0.065	0.72
80	0.010	0.75	0.043	0.66

4. Conclusion

Shielding efficiency is a measure of attenuation coefficients. The data collected and results of the measurements show that lead is a more efficient radiation shield than concrete within the x-ray diagnostic energy range.

References

[1] Nuclear Energy Board, 1988, *The design of diagnostic Medical facilities using ionizing radiation*. Dublin.

[2] Lea and Febiger, 1990, *Christensen's Physics of Radiology*, 4th edition, 379 – 382.

[3] Curtins F.J., 2008, Clemson Shielding Theory notes Clemson EXE693, Project on plane wave shielding effectiveness calculator. http://www.cvcl.clemson.edu/emc/calculators/SE_calculator/index.

[4] Nzotta C.C., Akhigbe A.O. Akpa T.C., Nwoke A.N.K., 2007, Scattered Radiation from Diagnostic X-ray Units in Lagos Metropolis, *Nigerian Journal of Medical Imaging and Radiation Therapy*. **1**, 4 1-44.

[5] Barkova V.G., Kisolev A.V., Chudacv V. Ya, 2006, *Proceedings of RUPAC* Article on Evaluation of Efficiency of Concrete.

[6] National Centre for environmental health/radiation studies branch 2002, *Acute Radiation Syndrom Report*. 04 – 09.

[7] United Nations Scientific Committee on Effects of Atomic Radiation 1993 *Annex E: Medical radiation exposures – sources and effects of ionizing rays*, New York, USA: UN Publication.