Nasibeh Bagheri / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 4, Jul-Aug 2013, pp.965-969

Comparing the Effect of Different Metal Plates and Lead Apron for Reducing the Dose Rate from Cs-137 and Ba-133 Gamma Ray

Nasibeh Bagheri
Physics Department, Payam Noor University, Fariman, Iran

Abstract

The lead aprons are used as the standard radiation attenuating shields for nuclear medicine workers. Unfortunately, a lead apron is relatively heavy and leads to musculoskeletal complaints for users at overtime. In this study, the Monte Carlo code MCNP4C was applied to assesses the effect of 0.5 mm lead and different kinds of metal plates and appointed equivalent dose rate. Two radiation sources namely Cs-137 and Ba-133 were used that emit gamma rays of 140 keV and 511keV energy respectively. In this work, eight different plates made of Pb, Pb–Sb and combination of six other metals employed as radiation shield in form of 0.5 mm thickness sheets with dimension of 50 cm ×50 cm. The distance of radioactive sources from the detector was 30 cm. This study showed that light weight aprons containing 0.5 mm Bi, or combination of metals such as Bi-Pb or Bi-Sb-W alloys decrease weight of apron 10, 26 and 5 percent respectively, and all of them have same attenuation compared with pure lead. Results compared using "t test" statistical analysis. This research shows that Bi, Bi-W-Sb and Bi-Pb alloys, as radiation shields, are more suitable than lead. This is due to having same radiation attenuation as lead, but lighter weight.

Key words: Nuclear medicine- lead apron - equivalent dose rate.

I. INTRODUCTION

Radiation shielding garments are commonly used in hospitals, clinics and dental offices to protect patients and medical workers from unintentional direct and secondary radiation When radiation passes into an absorbing medium such as human body, some of the energy in the beam is transferred to that medium. Radiation passing through body tissues may produce biological damage, so medical personnel, as well as patients; routinely wear radiation shielding garments (typically aprons) to be protect from direct and secondary exposure to radiation [1]. Within a Nuclear Medicine department, the dispensing and injection of radiopharmaceuticals is often thought to be the major contributor of Nuclear Medicine technologists (NMTs) dose [2].

The largest fraction of the total radiation dose received by NMTs has been found to be from interacting with the post-injection patients [3]. Although lead is effective in reducing x-radiation, it has the drawback of being heavy. Worn occupationally over a number of years, the weight can have a detrimental effect on the health of the wearer, particularly spinal problems. If not addressed, this can become an occupational health and safety issue [4]. Radiation protective apparel is available in thicknesses ranging from 0.25 mm to 1 mm lead-equivalent thickness. In most countries, regulations require a thickness of at least 0.5 mm lead-equivalent be used [5]. The weight of a one-piece 0.5 mm lead equivalent apron can be 8.45 kg and they are cumbersome to move about in. It has been estimated that wearing a 6.8 kg lead apron can result in pressures of 21 kg per cm^2 of intervertebral disc [6] and their use over long periods has induced significantly higher levels of back pain for wearers [7]. The protective lead apparel is recommended for pregnant workers (usually in the form of a lap apron) to restrict the fetal dose to less than the recommended limit of 1 mSv per year [8], but its weight may pose additional health and safety issues [9]. Another reason for the limited use of lead aprons by NMTs may be the common misunderstanding among that their use will actually increase their absorbed dose by converting higher energy photons, commonly employed in Nuclear Medicine, to lower energy photons which are more readily absorbed in the body. However, while there may be a shift to lower energies, there will also be an accompanying reduction in the amount of radiation incident on the wearer, thus increasing overall protection [10].

II. MATERIALS AND METHODS

In this work, the Monte Carlo code MCNP4C was used to compare the effect of different metal plates and lead used in nuclear medicine technicians apron for reducing the equivalent dose rate against radiation from photons of energies of 140 and 511 keV.

Benchmark of simulating program performed at secondary standard dosimetery laboratory (SSDL), Karaj, Iran. For this purpose two radiopharmaceuticals, Cs-137 and Ba-133. different metal plates and a RADOS detector were used. Sources were placed at a distance of 30 cm from the detector (Figure 1,a). Distance adjusted by two removable and fix laser sets .the sources activity measured by curry meter(model rams88) that are used for measuring gamma and beta radiation with ±% 5 > precision, The RDS-110 is a microprocessor based multi-purpose survey meter designed for monitoring gamma, x-ray and beta radiation that was adhesive to the phantom exactly. the radiation is detected by one halogen quenched, energy compensated gm tube, which combined with the microprocessor technology and backed up by an advanced counting algorithm, gives a reliable response even in low background radiation fields. The detector turned on after adjusting the distance and irradiated for 15 min and the results be recorded. The metal sheets were placed between the detector and the radioactive sources and measurement repeated as mentioned above (Figure 1,b). This was done for different thicknesses of sheet metal. The calibration factor of system (c.f.=1.6) and measured background radiation taken into account in the final dose calculation .the device measuring Precision was ±% 20**.**

For more confidence analytical method used to calculate the dose reduction beyond the metal shields. The analytical equations in health physics were used in this phase that followed in below

$$\dot{D} = \frac{\Gamma \times A}{d^2} \quad \text{(a)}$$

$\dot{D}$ is the equivalent dose rate in units of Rem per hour (Rem/h) **Γ** is the specific gamma ray dose constant in units of (Rem.m^2/Ci.h)

A is the activity of point source (Ci)

d is the distance from point source of radionuclide in units of meter

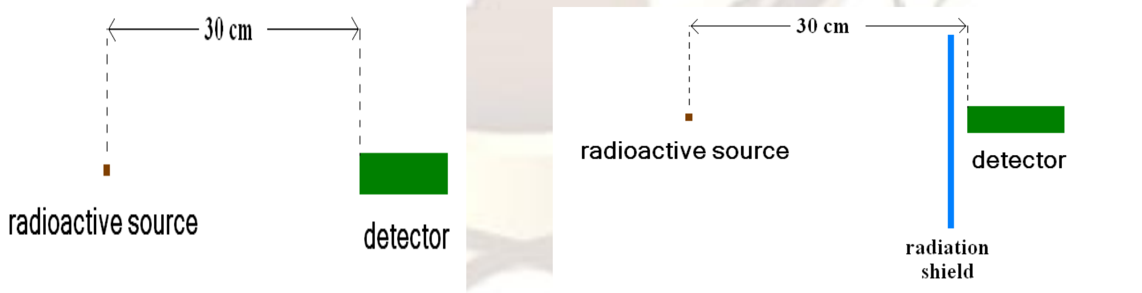
Under conditions of good geometry, the attenuation of a gamma beam is given therefore by where

$$I = I_\circ e^{-\mu t} \quad \text{(b)}$$

I is the gamma radiation intensity transmitted through an absorber of thickness d, $I_\circ$ is the gamma radiation intensity at zero absorber thickness, it is the absorber thickness, μ slope of the absorption curve – the attenuation coefficient after benchmarking and proving the performance of the simulation program , different kinds of material and sources used to calculate the dose reduction. The mount carlo simulation used for different thicknesses of several metal sheets which used in above. The performance and comparison of results proved simulation accuracy.

Eight materials were investigated in this study pure Pb , one Pb–Sb, and six non-Pb metals as shield for estimating equivalent dose rate. All metal were provided as thin sheets ranging in thickness 0.5 mm. For all these materials, the thin sheets were cut into squares approximately 50 cm×50 cm. The tissue-equivalent phantom was an ICRU sphere with 30 cm diameters that containing oxygen with %76.2, nitrogen % 2.6 ,carbon %11.1, and hydrogen %10.1 weight percentage.all sources were placed at a distance of 30 cm from phantom.Energy deposition for photons computed with the *F8 tally.

A total of two sets were measured for this part of the experiment as in thicknesses 0.5 mm. the first set recorded one without shielding, one with the lead apron and different metal plates such as bismuth, tin, tungsten, antimony,..., The simulation results is in units MeV that was considered for a particle .whereas sources had isotropic and uniform distribution in all directions so as to calculate the total flux volume of the detector with an defined activity in units of μSv/h.



(a) (b)

Figure 1. Schematic of the dose measurement method used for gamma rays (a) without and (b) with a shield

III. RESULTS

Tables 1 and 2 showed the equivalent dose rate results of the with and without of variation shields in different thicknesses in each phase of the study after correction for calibration factors and background radiation for Cs-137 and Ba-133 respectively, then a comparison of dose savings of lead and other sheets. This value of table includes measurements and comparisons of between the three phases: calculation, simulation and measurement ±standard deviation. This calculation displayed in chart (f.g2and3)

equivalent dose rate (µSv/h) / Shield	simulation	Calculation	measurement ±SD
No shield	6.00	5.60	5.00
Pb=1mm	5.30	5.10	**4.70**
Pb=2mm	4.70	4.60	4.6
Fe=1mm	5. 90	5.50	4.80
Zn=0.5mm	5.90	5.80	4.80
Alloy:Pb,Zn,Fe	4.90	5.00	4.65

Table1. lists and compares the equivalent dose rate in calculation, simulation and measurement for deferent shielding with Cs-137

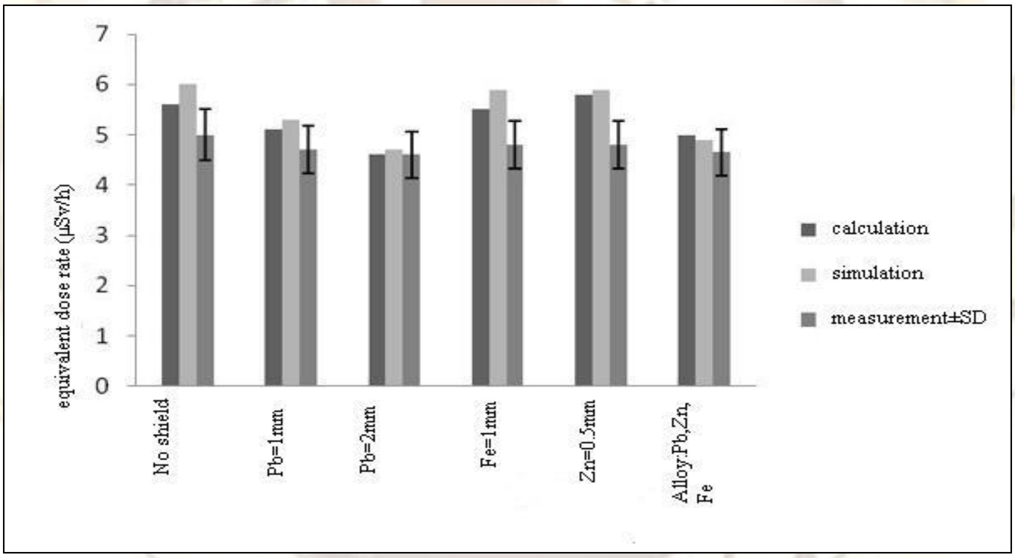


Figure2. The equivalent dose rate in calculation, simulation and measurement for deferent shielding with Cs-137

equivalent dose rate (µSv/h) / Shield	simulation	Calculation	measurement ±SD
No shield	3.00	3.60	3.10
Pb=1mm	1.80	2.30	1.90
Pb=2mm	1.2	1.40	1.50
Fe=1mm	2.70	2.70	2.50
Zn=0.5mm	2.70	3.00	2.60
Alloy:Pb,Zn,Fe	1.60	2.00	1.70

Table2. lists and compares the equivalent dose in calculation, simulation and measurement for deferent shielding with Ba-133

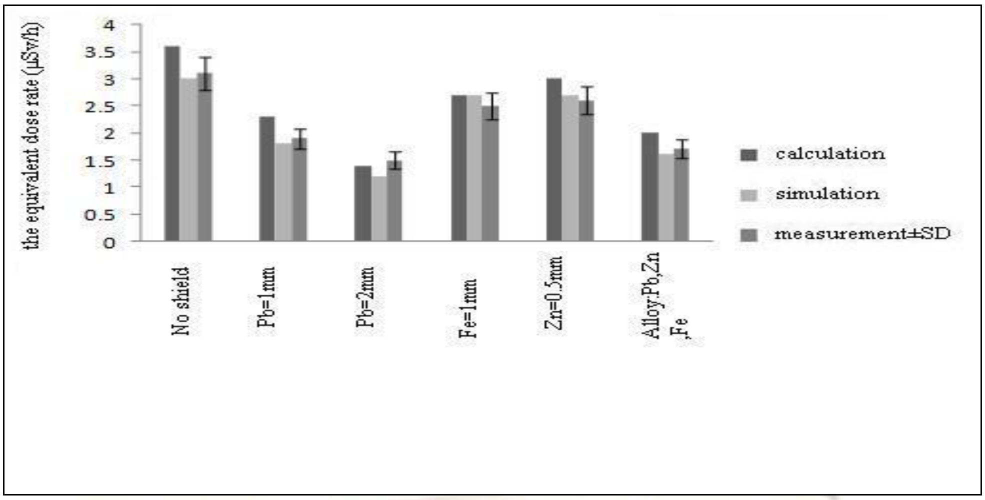


Figure 3. The equivalent dose rate in calculation, simulation and measurement for deferent shielding with Ba-133

Table 3 summarizes the equivalent dose rate reading of the two radiopharmaceuticals ,Cs-137 and Ba-133 with the presence of the different shield in thickness 0.5 mm, which all results calculated by mount carlo simulation at the completion of reading. The equivalent dose rate results were entered into a chart (f.g4)

The results of research demonstrated that the reduced weight Bi sheet and Pb-Bi and Bi-W-Sb alloy in comparing of the same thickness of lead aprons is 10% , 26% and 5% respectively .All of them produced the same attenuation with lead.

equivalent dose rate for two radiopharmaceuticals ,Cs-137 and Ba-133					
Shild / **Radionuclide**	Pb	Bi	Bi, Sb,W	Bi,Pb	Sn,Bi
Ba-133	2.40	2.30	2.40	2.40	2.40
Cs-137	5.30	5.28	5.30	5.30	5.30

Table 3 results of the equivalent dose rate for two radio pharmaceuticals , Cs-137 and Ba-133 with the presence of the different shield in thickness 0.5 mm equivalent dose rate(µSv/h)

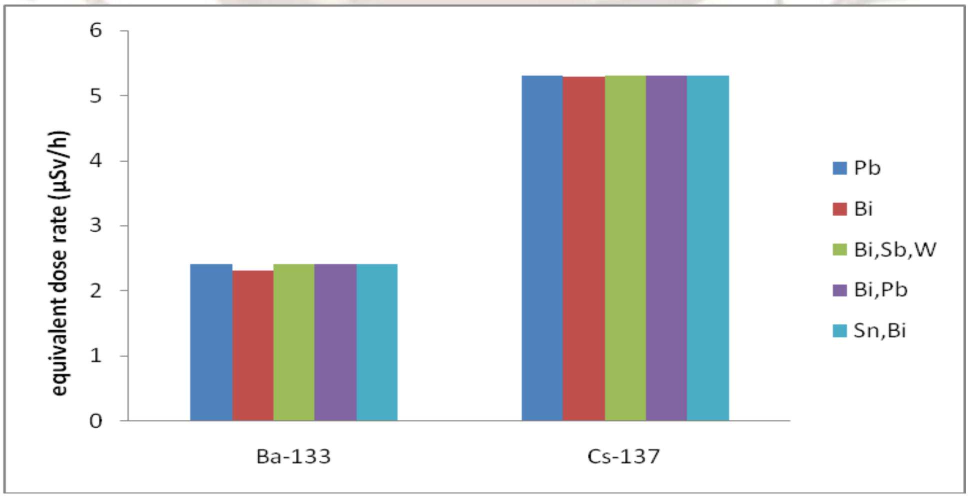


Figure 4 . Shielding effect in terms of equivalent dose rate of non-lead and lead aprons against gamma rays 0. 5mm Pb equivalent, for Cs-137 and Ba-133

IV. DISCUSSION

- The use of a bismuth sheet and protective aprons are made from alloy containing as (Bismuth-Tungsten- Antimony) and a number of shielding materials are made from composite materials such as (Bismuth- Lead) for protection from gamma radiation of Cs-137 , Ba-133 , provided 10% ,5% and 26% the reduction in weight of aprons respectively. those have the same attenuation with lead aprons.
- Overall, In most areas Radiation protective aprons is available in thickness of at least 0.5 mm lead-equivalent.the above results (table 3and f.g 3) showed that the bismuth shielding significantly decreased weight of apron, and it was better at reducing the exposure related to lead at all energies within the ranges used, also the alloy containing as (Barium-Tungsten, and Antimony) or the Bismuth-Lead shielding because of reducing weight and same attenuating was more efficient than lead apron for wearing in the diagnostic energy ranges .The compared results with above mentioned material showed that the lightweight aprons, such as those produced by composite materials containing as(Bismuth- Lead)offer weight saving for nuclear medicine staff.

REFERENCES

[1] Takano Y., Okazaki K., Ono K. and Kai M. Experimental and Theoretical Studies on Radiation Protective Effect of a Lighter Non-lead Protective Apron, Nippon Hoshasen Gijutsu Gakkai Zasshi (Jpn J Radiol Technol) 61(7) 1027-1032 (2005). (in Japanese)

[2] Mc Elroy, N. L. Efficacy of various syringe shields for99mTc. Health Physics. 41(3), 535–542 (1981).

[3] Smart, R. Task Specific Monitoring of Nuclear Medicine Technologists Radiation Exposure. Radiat. Prot. Dosim.109(3), 201–209

[4] ARPANSA-Australian Radiation Protection and Nuclear Safety Agency, Aprons for Protection Against X-rays, 2009

[5] Klein LW, Miller DL, Balter S, et al: Occupational Health Hazards in Theinterventional Laboratory: Time For A Safer Environment. J Vasc IntervRadiol 20:147-152,2009

[6] Khalil, T. M., Abdel-Moty, E. M. and Rosomoff, H. L. Ergonomics. In: Back Pain, Guide to Preventionand Rehabilitation. New York: Van Nostrand (1993)

[7] Ross A. M., Segal J., Borenstien D., Jenkins E. and Cho S. Prevalence of Spinal Disc Disease Among Interventional Cardiologists. Am. J. Cardiol. 79, 68–70(1997)

[8] International Commission on Radiological Protection.1990 Recommendations of the International Commission on Radiological Protection. ICRP 60,Oxford: Pergamon Press (1991)

[9] Kujala U. M., Taimela S., Viljanen T., Jutila H.,Viitasalo J. T., Videman T. and Battie M. C. Physical Loading and Performance as Predictors of Back Pain in Healthy Adults. A 5-year Prospective Study. Eur. J. Appl. Physiol. 73(5), 452–458 (1996)

[10] Smart, R. Task Specific Monitoring of Nuclear Medicine Technologists Radiation Exposure. Radiat. Prot. Dosim