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Archives of Physics Research, 2011, 2 (2): 87-94 (http://scholarsresearchlibrary.com/archive.html)



Polymer waste for shielding from low energy photons

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ABSTRACT

The feasibility of polymer waste like packaging bags has been explored as shielding material for Fe-55 source that emits 5.959 keV Mn K x-rays and for x-rays emitted from metals like Fe, Cu, Ni and Zn etc. used in the experimental setups. For this targets from waste material were used as absorber of 3.84, 5.959 and 8.67 keV K X-rays of Ca, Mn and Zn respectively. The x-rays were produced in a compact single reflection setup by irradiating Ca/Mn/Zn target with photons from a low power x-ray tube. A Si (PIN) detector with resolution 200 eV at 5.959 keV was used to record the K x-rays. Moreover, to know the constituting elements of the polymers, the spectra of photons emitted from the polymers on their irradiations with tube photons were recorded in the same setup. It is found that the presence of chlorine in polymer wastes has enhanced their capability to absorb the low energies. In comparison to known polymers; PVC, LDP, PP and PC, the waste materials were found superior with regard to their shielding characteristics.

Keywords: Fluorescent x-rays, Absorption, Shielding, Energy Dispersive x-ray fluorescence.

INTRODUCTION

The radioactive source Fe-55 that emits 5.959 keV Mn K x-rays is widely used as low energy photon source in x-ray fluorescence XRF measurements. Mostly, the metals like Fe, Ni, Cu and Zn etc., used in the experimental setups, become source of low energy photons (their characteristic x-rays) on exposure to the experimental radiation and interfere with the actual measurements. The low energy (<10 keV) photons are not harmful but longer exposure can cause problems. Shielding applications require materials those provide safety and protection for environment and people and exhibit low weight at acceptable cost. During storage and transportation, shielding is no problem. But handling of sources involves requirements like thickness/shape of shield and its properties; transparency, electrical conductivity and elasticity etc. The economical and light weight plastics almost fulfil all these qualities and are being used as shielding material to attenuate and absorb radiations [2-3]. Metal requires lots of mechanical labour for making shields for complex shapes and assemblies whereas plastics provide design freedom due to their flexibility and high malleability. Constituents of plastics are mostly

hydrocarbons and are environmentally neutral during disposal and resistive to oxidation etc. Due to low cost and availability in abundance of plastic, it has been studied as a shielding material for low energy photons. The shielding characteristics of three different packaging bag plastics were checked in the existing energy dispersive X-ray Fluorescence (EDXRF) setup in the Lab [4, 5]. The details of measurements, results and discussions and conclusion are given in the following sections.

MATERIALS AND METHODS

Experimental Samples: Three different plastic packaging bags (say A, B and C) were selected. The samples of different thicknesses were prepared by pressing a number of layers of same sheet in hydraulic pressing machine with gradient pressure of 50 tons to remove the air between the consecutive layers, 70 tons after one minute for pressing of sheets and later on the pressure was released to 25 tons for the adjustment of layers because of excess pressing. After releasing the whole pressure, samples were left in the machine for half an hour and sample thicknesses were measured using a screw gauge with least count 0.01mm.

Table 1. Thickness of sample layers in mm

No. of layers	Samples thicknesses in mm.		
	Α	В	С
1	0.12	0.13	0.13
5	0.50	0.68	0.64
10	1.01	1.25	1.28

Experimental Setup: The used experimental set up comprises a compact single reflection geometry made from a single iron piece, side window low power (100W) Neptune x-ray tube with Rh anode as photon source and Amptek Si (PIN) Peltier cooled detector with resolution 200 eV at 5.959 keV (Fig.1). Low energy photons; Ca, Mn and Zn K x-rays in the range, 3-9 keV were procured in the reflection geometry by irradiating, in turn, the briquette targets of CaCO₃ and MnC₂O₄ and metallic target of Zn with photons from the tube operated at anode voltages 5, 7 and 10KV respectively. The fluorescent x-rays emitted by the targets were detected in the detector and its outputs were processed in a multi channel analyser (MCA) which produces spectra of counts vs. channel number.



Fig 1. Energy Dispersive X-ray Fluorescence (EDXRF) set up with plastic sample as absorber for transmitted spectrum of Ca/Mn/Zn targets. (In the setup, distances and collimation sizes are not according to the scale; Size of collimation between; x-ray tube window and target = 0.8 cm, target and absorber = 1.0 cm., absorber and detector = 4mm. Distance between; x-ray tube window and target = 3.5cm, target and absorber = 0.5cm, absorber and detector = 3.8 cm)

To study the absorption characteristics of plastics in transmission setup, plastic samples with 1, 5 and 10 layers were inserted one by one in the targets' x-ray path, between detector end of the compact geometry and the detector. After fine collimation of transmitted x-rays, the x-ray spectra with different absorbers were recorded. The experiment was run for the sufficient times to achieve the counting statistics < 0.1-5% in each measurement. The transmitted spectra of different samples at three photon energies are shown in Figs 2 - 4.



FIG 2. SPECTRA OF Ca K X-RAYS TRANSMITTED THROUGH THREE DIFFERENT LAYERS (1,5 & 10) OF EACH OF THE THREE PLASTIC ABSORBERS(A,B,C)





RESULTS AND DISCUSSION

The spectrum of transmitted Ca K X-rays in Fig.2 without absorber shows Ca K α and K β x-ray peaks riding on the scattered Bramsstrahlung at 3.67 keV and 3.99 keV respectively and atmospheric argon K x-ray Peak along with scattered Rh L X-rays at 2.8 keV. However, in the absorbed spectra with single layers, the absorption at K α energy is more than that at K β energy. With 5 and 10 layers thickness of each plastic sample, K α is completely absorbed but some counts under K β are found. The absorption for only single layers around the Ar region shows a little shift from 2.8 keV to 2.65 keV. The spectra (Fig.3 & 4) of Mn and Zn K x-rays with absorber samples, show K α and K β x-ray peaks of Mn at 5.91 and 6.52 keV and that of Zn at 8.68 and 9.63 keV. For Mn K x-rays, almost complete absorption is there at both K α and K β x-ray energies at 5 layers of absorbers and for 10 layers counts under the peaks are negligible. In the transmitted spectra of Zn target, the absorption in samples A, B, C shows almost continuous increase with the number of layers.

		Samples		
No. of layers	Net area under the K x-rays with absorber layers ; %age absorption			
•	Α	В	С	
	(Net area under the Ca K x-	(Net area under the Ca K x-rays without absorber = 683982 ± 1178)		
1	$2707 \pm 64;$ 99.60	1735±58; 99.75	2110±64; 99.69	
5	776±29; 99.89	719±31; 99.90	770 ±30; 99.89	
10	798±32; 99.88	752±30; 99.89	775 ±32; 99.89	
	(Net area under the Mn K x-rays without absorber = 246711 ± 1011)			
1	54289±429; 78.00	44023±377; 82.16	49908±402; 79.77	
5	188±19; 99.93	26±14; 99.99	30±23; 99.99	
10	6±2; 100.00	1±1; 100.00	0±0; 100.00	
	(Net area under the Zn K x-rays without absorber = 1560410 ± 1982)			
1	777678±1372; 50.17	666486±1328; 42.71	762863 ± 1380; 51.12	
5	102227±494; 93.45	37431 ±310; 97.61	74228 ±425; 95.25	
10	7626±126; 99.52	$1455 \pm 60;$ 99.91	2451 ±86; 99.85	

Table 2. Net Area under Ca, Mn and Zn K x-ray peaks in transmitted spectra from three different layers (1	1,5
& 10) to each of three plastic absorbers (A, B, C).	

For quantitative estimation of absorption, the net area under the Ca, Mn and Zn K x-ray peaks in transmitted spectra of each absorber at three thicknesses were found and listed in table.2 along with the contents of percentage absorption.

The listed values for Ca show more than 99% absorption of its x-rays in the plastic samples. Almost all the samples follow the similar trend. For 5 and 10 layers, within counting statistics the counts are comparable, therefore, above 5 layers the thicknesses correspond to the saturation thickness. For Mn K x-rays with single layer the absorption is up to 82% and with 5 layers it is 99% and ~100% with10 layers. For Zn K x-rays, the table values show absorption up to 51% with single layer and 99.5% with 10 layer thicknesses and still saturation of absorption is not there.

Further to solve the mystery of shifting of Ar peak energy from 2.8 keV to 2.65 keV (Fig.2) in the absorbed spectra with single layer of absorbers, the x-ray fluorescence spectrum of plastics were recorded by replacing the (Ca/Mn/Zn) targets with plastic absorbers at 5 kV tube voltage. (Fig.5)



The fluorescent spectra of all the plastic targets have a peak at 2.58 keV, which was at the same energy as that obtained with $CuCl_2$ and RbCl targets in place of plastic targets (fig. 6).

This confirmed the energy 2.58 keV as K x-ray energy of chlorine and predicts the presence of Cl in the plastic samples. The observed net counts under the Cl peaks in the plastic spectra are given in the table 3.

No. of layers	Samples Net area under the Cl K x-rays peaks in each sample.		
	Α	В	С
1	387000 ± 775	417827 ± 803	457959 ± 835
5	431179 ± 811	425281 ± 810	344109 ± 737
10	465718 ± 846	469759 ± 849	358338 ± 752

Table 2 Not Anag under ableming	V V nov nooles in three lo	$r_{10} = (1 - 5 - 10) \circ f \circ \circ \circ h$	of three complets (A D C)
Table 5. Net Area under chlorine	е к л-гау реаку пі штее іа	vers(1, 5 \propto 10) of each	of three samples(A, D, C)
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In samples A and B, Cl contents seem to increase with thickness. But in sample C the trend changes, with increase in layers the number of counts decreases up to 5 layers and there is slight increase for 10 layers. The trend may be associated with the comparatively large contents of Cl in the sample and self absorption of Cl K x-rays in sample C.

To have the comparison of plastic samples with standard polymers; Polypropylene (PP), Low density Polyethylene (LDP), Polycarbonate (PC) and Polyvinylchloride (PVC), the fluorescent spectra of these standards at 5kV voltage were recorded (Fig 7)



The recorded spectra of standards show that in PVC the peak is at 2.65 keV while for the others LDP, PC and PP the peak is at 2.84, 2.77 and 2.81 keV respectively. As mentioned earlier in the text, the energies are for composite peaks of polymer chlorine K x-rays, atmospheric argon K x-rays and scattered Rh L X-rays of tube anode. The composite peak energy E is given

as $E = \frac{\sum_{i}^{i} E_{i} I_{i}}{\sum_{i} I_{i}}$; where E_{i} and I_{i} are energy and intensity of ith component. In PVC spectrum,

peak at 2.65 keV justifies the higher chlorine content in PVC, moreover, its name Polyvinylchloride also supports it. Applying the same criteria for all the polymers, the chlorine contents in samples are in the order; plastic wastes (A, B & C) >> PVC > PC > PP > LDP. The absorption characteristics and shielding ability of PVC (0.12 mm) and PC (0.48mm) were also

compared with the single layer and 4 layers of plastic samples for similar thicknesses of the samples and out comes are listed in table 4.

ndard Polvmer			
(Net area under the Ca K x-rays without absorber = 379990 ± 654)			
PVC 18028 ± 478; 95.26 PC 2289 ± 146; 99.40			
(Net area under the Mn K x-rays without absorber = 246711 ± 1011)			
PVC 187138±870; 24.15 PC 55080±529; 65.51			
(Net area under the Zn K x-rays without absorber = 216723 ± 275)			
PVC 156575 ± 626; 27.76 130441±565; 39.82			
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<u>Table 4</u> .	Net Area under Ca, Mn and Zn K X-ray peaks in transmitted spectra from 1 and 4 layers of each of
	the three samples (A, B, C) and single layer of standard polymers PVC and PC.

The listed results specifies that the percentage absorption of Ca, Mn & Zn K x-ray peaks are nearly 4%, 55% and 24% respectively more in single layer plastic samples than that of PVC and are nearly 0.5%, 34%, 53 % more in four layer plastic samples than that of PC. Even, in single layer of all plastic samples it is 0.4%, 14%, 12 % more than that of PC.

CONCLUSION

All the observations support the superiority of shielding/absorbing characteristics of these plastic wastes as compared to those of standard polymers; Polypropylene (PP), Low density Polyethylene (LDP), Polycarbonate (PC) and Polyvinylchloride (PVC). The observed higher chlorine contents in plastic waste enhance the low energy absorbing characteristics of the samples. Hence the use of these waste plastics is being recommended for the weightless and economic shielding purpose that gives freedom from complicated machining process and flexibility in moulding and designing. Though the use of plastic is being banned because of environmental problem of its disposal but even then its utility for economical shielding design that provides safety and protection for environment and people is being supported here.

Acknowledgement

The financial assistance from BRNS, Government of India in the form of research project grant numbered 2007/37/6/BRNS/251 for this experimental work is highly acknowledged.

REFERENCES

[1] E Amato; D Lizio; J.Radiol.Prot., 2009, 29, 239.

[2] JM Yaffe; EG Mawdsley; M Lilley; R Servant; G Reh; *Health Physics*, **1991**, 60, 661.

[3] PH Murphy; Y Wu; SA Glaze; *Radiology*, 1993, 186, 269.

[4] S Gupta; K Deep; L Jain; MA Ansari; VK Mittal; R Mittal; Appl. Radiat. Isotopes, 2010, 68, 1922.

[5] G. Kaur; R. Mittal; *Proc.* 14th Punjab Sci. Cong.(PSC14), S.L.I.E.T, Longowal, **2011**, (abstract cop-10).