

Study of Gamma Ray Backscattering with Special Reference to Admixture of Kerosene and Petrol

Chikkappa Udagani

Department of Studies and Research in Physics, Tumkur University, Tumkur, India

Abstract: *This paper presents the experimental study of gamma ray backscattering from water, kerosene, petrol and admixture of kerosene and petrol. Kerosene is the most common adulterant used for petrol. The main intension of this experimental work is to study the variation of backscattered gamma ray intensity with density of sample and thereby knowing the presence of kerosene in petrol. The gamma backscattering technique is an analytical tool for testing materials non-destructively. In this experimental work ¹³⁷Cs-radioactive source and GSpec gamma spectroscopy system consisting 2" X 2" NaI (TI) detector have been used. From the experimental results it is found that for fixed height, the count rate under backscattering peak is maximum for pure water followed by kerosene and minimum for petrol and also the count rate under backscattering peak increases with increasing amount of kerosene in the admixture of petrol and kerosene. This important result is useful for quantitative estimation of kerosene presence in petrol.*

Keywords: admixture, adulterant, backscattering, kerosene, petrol

1. Introduction

The gamma backscattering technique is a non-destructive testing. The non-destructive (NDT) testing of materials is the method of testing materials without causing any damage to the materials. In NDT, nuclear radiations and ultrasonic waves can be used as tools. The method of using nuclear radiations such as X-rays and gamma rays is useful in harsh conditions. When gamma photons pass through matter, collide with the atomic electrons and after many collisions some emerge from the surface of backscattering sample they entered. The gamma photons that emerge are said to be back-scattered gamma photons. In the gamma backscattering the incident gamma photons are scattered backward compared to their incident direction. The gamma backscattering technique is highly sensitive technique that can be applied to bulk samples and is relatively free of reagent and laboratory contamination. Analysis can be performed on a sample as-received. This avoids contamination from excess sample handling and reagent addition. This method is based on the measurement of Compton scattering photons [1]. The pulse height spectrum produced by gamma rays shows a peak within 0.2 MeV to 0.25 MeV. This peak is due to Compton scattering of gamma rays from nearby scattering materials and is called backscattered peak. For fixed gamma ray energy, intensity of backscatter gamma photons depends on scattering angle, experimental environment and density of material of interest. The number of backscattering photons increases according to the target thickness, eventually reaching saturation [2], [3]. The Compton scattering of gamma photons has the potential to inspect the materials under study. The gamma backscattering technique can be used effectively in those cases where the detector cannot be placed in the opposite side of the source relative to the object [4]. The gamma backscattering technique was used to monitor corrosion in steel tube in a circulating tube [5]. Calculations for designing thickness gauges have performed [6]. The gamma backscattering technique is useful in investigating historical objects [7]. The number of backscattering photons increases according to the thickness of target material [8]. The backscattered gamma beam will undergo attenuation in its way to the detector. The count rate

in the detector is expected to change with thickness following the relation [4]:

$$C = K1 \{1 - \exp [-(\mu + \mu') t]\}$$

Where C is the count rate, K1 is a constant and μ and μ' are linear attenuation coefficients of incident and scattered gamma radiation beams respectively and t is the thickness of the target material. The values of μ and μ' depend on energy of gamma radiation and density of backscattering material. The purpose of this study is to evaluate the variation of intensity of backscattering gamma photons as a function of density of liquid sample and examine the potential application of gamma backscattering technique in analyzing the presence of kerosene in petrol. Kerosene is the most common adulterant used in India for petrol [9]. Adulteration of petroleum products increases the emission of harmful pollutants and cause severe health problems [10].

2. Experimental Work

The pc based Gamma Ray Spectroscopy system, GSpec communicates with PC through USB port. Data Acquisition and Control is through PC based application software, SAAS (Spectrum Acquisition and Analysis Software). GSpec is powered through USB port. The GSpec has 1k multi-channel analyzer (MCA). Energy calibration of MCA was carried out by selecting two or three energy peaks. The spectrum stabilization can be achieved by storing the energy calibration and applying the conversion factors at a fixed time interval. This is done automatically as the spectrum is being acquired. The Spectrum Stabilization Menu prompts user to enter the value of energy and also to enter the value of time interval. The gamma spectrometry system was initially tested for resolution, constancy and linear characteristics to fix the best operating conditions by performing preliminary experiments. The detector resolution was found to be 6% for 662 keV gamma rays at operating voltage 750V. In the present experimental work water, kerosene, petrol and kerosene – petrol mixtures of different density have been subjected to study the gamma ray backscattering. The kerosene and petrol were obtained commercially. The glass beakers were cleaned using

distilled water and detergent. Water, kerosene and petrol were taken in three separate glass beakers. The kerosene – petrol mixtures of different densities were obtained by adding kerosene to petrol in different proportion. To prepare the kerosene – petrol mixture, the petrol was taken in clean glass beaker. The required amount of kerosene was gently added to the beaker. The mixture was stirred gently to get homogeneous mixture. The two kerosene – petrol mixtures of density 0.744gm/cm^3 and 0.761gm/cm^3 were prepared. Table (1) shows the density of samples used in this experimental work. The schematic of experimental arrangement for studying backscattering of gamma rays from samples is as shown in the Figure. (1).

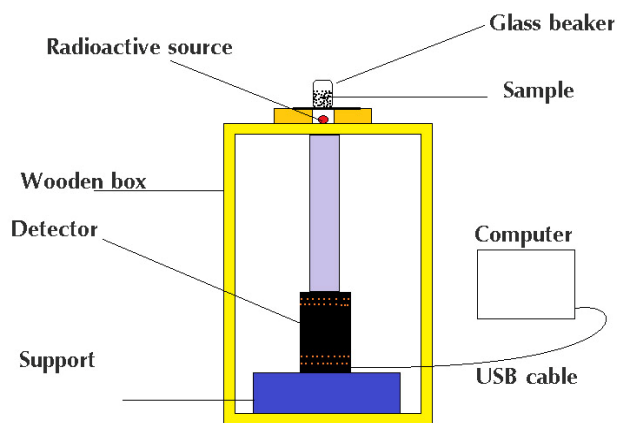


Figure 1: Experimental arrangement.

In order to minimize the unwanted signals, walls and floors of the room and other scattering materials were kept as far as away from the experimental setup. The ^{137}Cs - radioactive source was kept in line with the Gamma spectrometer assembly at a distance of 1.5cm. The ^{137}Cs is suitable for gamma backscattering study because it emits monoenergetic gamma rays of energy 662 keV. The clean empty glass beaker was kept above the ^{137}Cs - source in line with both ^{137}Cs - source and Gamma spectrometer assembly. First the spectrum of gamma rays from ^{137}Cs - radioactive source without backscattering sample was recorded for 100 seconds. Spectrum analysis is done by selecting the Region of Interest (ROI). Spectrum analysis is the most important function of the SAAS. This is done by selecting the Region of Interest or ROI. ROI will be selected between the start and stop channels as desired. From the recorded spectrum the backscattering peak has been identified and Region of Interest (ROI) was fixed for experimental work. The SAAS gives integral counts, background counts and background subtracted counts under ROI. In this work the gamma rays from ^{137}Cs - radioactive source are backscattered almost at 180° and backscattered peak was found with 200keV centroid.

The schematic of recorded spectrum with ROI is as shown in the Figure (2). Without disturbing the initial experimental geometry, water was filled into the glass beaker using injection syringe to a height of 1cm. The gamma ray spectrum was recorded for 100 seconds. The number of counts under ROI was noted. The experiment was repeated with different heights of water. The same procedure was employed for kerosene, petrol and kerosene- petrol mixtures.

The gamma back scattered count rates with varying height of samples are tabulated in the Table (2).

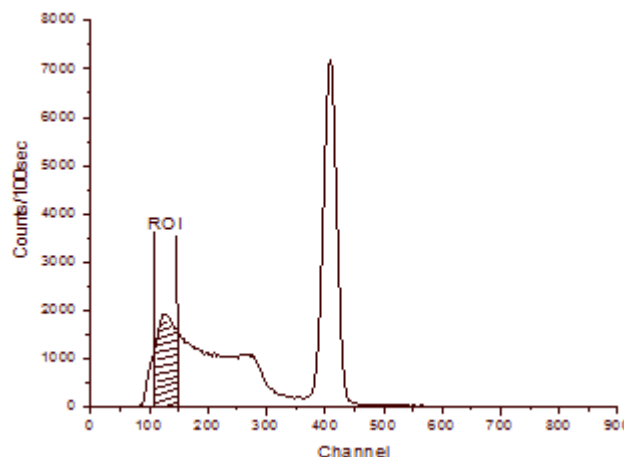


Figure 2: The schematic of recorded spectrum with ROI

Table 1: Density of samples

Sample	Index	Density(gm/cm^3)
Water	W	1.00
Kerosene	K	0.781
Petrol	P	0.737
Kerosene- petrol mixture1	KP1	0.75
Kerosene- petrol mixture2	KP2	0.761

3. Results and Discussion

The ^{137}Cs - radioactive source was used in the present work. The backscattering gamma spectrum was obtained by placing ^{137}Cs - radioactive source in between detector assembly and backscattering sample. The radioactive source was placed in line with backscattering sample and detector assembly. The distance between radioactive source and backscattering sample and distance between the radioactive source and detector assembly were optimized by making preliminary experiments. The distance between the detector assembly and the radioactive source was kept constant at 1.5cm throughout the experiment. In order to eliminate low background noise, the lower level discriminator (LLD) was adjusted at 10. The gain was adjusted to get well defined gamma ray spectrum. The stability of the gamma spectroscopy system was constantly maintained by using stabilization menu. The operating voltage was kept constant at 750 V to fix the best operating conditions. The geometry of the experimental arrangement was kept undisturbed throughout the experimental work. Due to fixed experimental geometry and the good stabilization the centroid has fixed at nearly 200 keV. The ROI analysis for backscattering samples is shown in the Table (2). The table shows the centroid of ROI, number of counts under ROI and count rate (counts/sec). The Figure (3) shows the plots of count rate of backscattered gamma photons versus height of backscattered sample. Figure (4) shows count rate versus density for fixed height 5cm.

Table 2: ROI analysis for samples.

Sample	Index	Density (gm/cm ³)	Height (cm)	Centroid (keV)	Counts for 100 sec	Count rate
Water	W	1.00	0	202.460	13784.833	137.8483
			1	201.678	18433.333	184.3333
			2	200.977	19471.667	194.7167
			3	201.430	20031.000	200.3100
			4	201.572	20570.667	205.7067
			5	201.017	20296.000	202.9600
			6	200.518	19714.000	197.1400
			7	200.206	19483.500	194.8350
Kerosene	K	0.781	0	201.947	13866.833	138.6683
			1	201.944	17919.167	179.1917
			2	201.335	18331.000	183.3100
			3	201.717	19424.500	194.2450
			4	201.436	19960.167	199.6017
			5	201.543	19560.500	195.6050
			6	201.273	19290.667	192.9067
			7	200.996	19124.500	191.2450
Petrol	P	0.737	0	201.851	13804.667	138.0467
			1	201.935	16664.667	166.6467
			2	200.931	17576.000	175.7600
			3	200.698	18337.167	183.3717
			4	200.976	18731.833	187.3183
			5	201.295	19024.333	190.2433
			6	200.813	18685.500	186.8550
			7	200.857	18599.833	185.9983
Kerosene- petrol mixture1	KP1	0.744	0	201.373	13762.333	137.6233
			1	201.219	17317.167	173.1717
			2	200.709	17949.167	179.4917
			3	200.905	18681.167	186.8117
			4	201.068	19351.500	193.5150
			5	200.862	19298.333	192.9833
			6	200.692	18809.667	188.0967
			7	201.438	18782.667	187.8267
Kerosene- petrol mixture2	KP2	0.761	0	201.996	13723.833	137.2383
			1	202.960	17322.333	173.2233
			2	201.979	17998.500	179.9850
			3	201.030	19120.333	191.2033
			4	201.138	19493.667	194.9367
			5	201.713	19351.833	193.5183
			6	200.663	18958.667	189.5867
			7	201.189	18750.833	187.5083

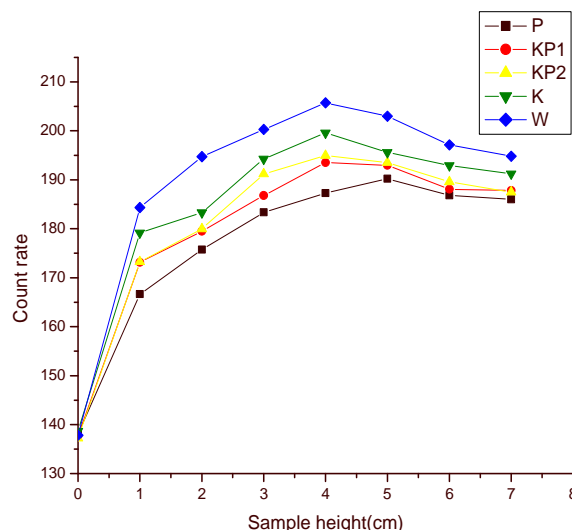


Figure 3: Count Rate versus sample height.

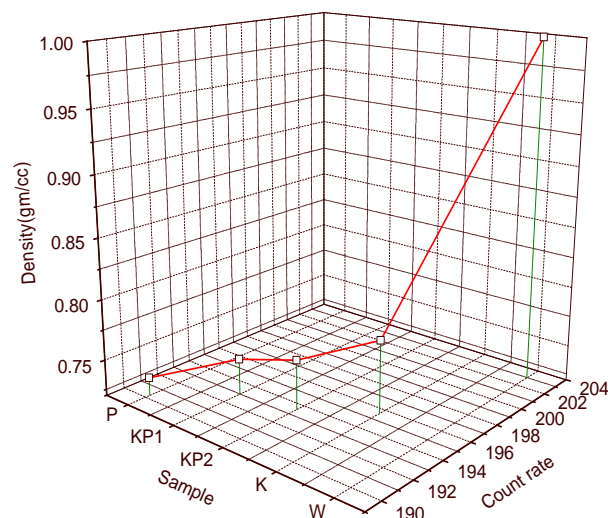


Figure 4: Count Rate versus density for fixed sample height

4. Conclusion

From the Figure (3) it can be seen that count rate increases with increasing height of sample up to certain distance and thereafter it decreases slowly for greater height. For water, kerosene and kerosene- petrol mixture2 the count rate increases up to 4cm and decreases for greater height. For kerosene – petrol mixture1 and petrol the count rate increases up to 5cm and decreases for greater height. From the Figure (4) it is observed that for fixed height of sample i.e., 5cm, the count rate has maximum value for water because of its relatively high density followed by kerosene, kerosene- petrol mixture2 and kerosene – petrol mixture1 and has minimum value for petrol because of its relatively low density. From this experiment it is found that intensity of backscattered gamma photons is a function of sample density. It is possible to estimate the presence of kerosene in petrol by gamma backscattering technique. The gamma backscattering technique is very useful as sensitive

analytical technique for performing quantitative analysis of adulteration in variety of samples. This technique can also be used to monitor minute variation of fluid level. Because of its accuracy and reliability it is used as important reference for other analytical methods.

5. Future Scope

The present work is purely based on experimental work. Inorder to understand the backscattering of gamma rays and its potential use, more and more theoretical work is needed.

References

- [1] Glenn F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, Inc (2000).
- [2] Gurvinderjit Singh, Manpreet Singh, B.S. Sandhu, Bhajan Singh, Experimental Investigation of Multiple Scattering Of 662 Kev Gamma Rays in Zinc at 90°, Radiation Physics and Chemistry, Vol. 76, 2007, Pp. 750–758.
- [3] Manpreet Singh, Gurvinderjit Singh, B.S. Sandhu, Bhajan Singh, Effect of Detector Collimator and Sample Thickness on 0.662 MeV Multiply Compton-Scattered Gamma Rays, Applied Radiation and Isotopes, Vol. 64, 2006, pp 373–378.
- [4] Samir Abdul Majid and Ahmed Balamesh, Imaging Corrosion Under Insulation by Gamma Ray Backscattering Method, Middle East Nondestructive Testing Conference & Exhibition - 27-30 Nov 2005 Bahrain, Manama.
- [5] U.M. Dawood, Use of the Gamma-Ray Backscattering Technique to Monitor in a Circulating Ring, Corrosion, Vol.51, 1995, pp.660- 663.
- [6] B.S. Moon, Y.K. Kim, J.T. Kim, C.E. Chung and S.B. Hong, A Design of the Thickness Gauze Using the Compton Gamma – ray Backscattering, Journal of the Korean Nuclear Society, Vol.32, 2000, pp.457- 464.
- [7] I.L.M. Silva, et al, Tube Defects Inspection Technique by Compton Gamma Backscattering, Nucl.Inst.Meth.Vol.A422, 1999, pp. 957- 963.
- [8] G.Harding and B. Schreiber, Coherent X-Ray Scatter Imaging and its Applications in Biomedical Science and Industry, Radiation Physics and Chemistry, Vol.56, Issues 1-2, 1999, pp 229-245.
- [9] Adulteration of Petrol and Diesel in Indian Fuel Bunkers, India Transport News and Analysis, January 13, 2012.
- [10] Amith P. Gawande and Jayanth P. Kaware, Sci.Revs.Chem. Commun. Vol. 3, 2013, pp.161- 171.

Author Profile



Dr. Chikkappa Udagani has obtained MSc with gold medal from Kuvempu University and has completed Ph.D from the same University. Presently he is working as Assistant Professor in the Department of Studies and Research in Physics, Tumkur University, India.