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Pakistan Institute of Nuclear Science and Technology
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C O N T E N T S

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(Results for the period Jan - Dec 1978)

(M. Umar Faruq, Nighat Parveen, Bashir Ahmed, Abdul Aziz)

A B S T R A C T

Gamma spectrometric analyses of air and other environmental samples from PINSTECH were carried out. Air particulate samples were analysed by a Ge(Li) detector on a computer based multichannel analyser. Other environmental samples were analysed by a Na(Tl) scintillation detector spectrometer and a multichannel analyser with manual analysis.

Concentration of radionuclides in the media was determined and the sources of their production were identified. Age of the fall out was estimated from the ratios of the fission products.

1. INTRODUCTION

Gamma spectrometric analyses of the environmental samples were carried out under the programme of "Environmental Surveillance" at PINSTECH. Air particulate samples were analysed by a Ge(Li) detector spectrometric system on a computer based multichannel analyser. Vegetables, meat and other environmental samples which have very simple gamma spectra were analysed by a NaI(Tl) scintillation detector spectrometer on a multichannel analyser without computerised analysis.

The report briefly describes procedures of sampling and gamma spectrometric analyses of environmental media at PINSTECH and gives results of the analyses for the period from January to December 1978.

2. SAMPLING OF ENVIRONMENTAL MEDIA

The environmental media sampled for gamma spectrometry were air-borne particulates, agricultural products including vegetables, wheat etc. and other items such as meats, poultry, fish and prepared meal.

2.1 Air Particulates

Air was sampled by a high velocity centrifugal fan Model 580/2 from Soconak Air Products Ltd. U.K. through Delbag Micro-sorben-98 polystyrene filter medium at the rate of 400 m^3/h. The flow rate of air was accurately measured by a locally designed "Orifice flow meter". Air particulate filters were changed every week, pressed to a compact disc gemetry of 6.5cm dia and 2cm thickness by means of a locally devised hydraulic press machine and analysed by gamma spectrometry. The final shape of the pressed filters was identical to that of Ho 166m gamma calibration source.

2.2 Items of Diet

Vegetables, meat and fish samples were collected biannually from the local market. Wheat samples were procured from suburban localities on each harvest. Prepared meal samples from PINSTECH cafeteria were collected each month. A minimum of 3 to 5 kg. dry weight of samples was taken for analysis.

These samples were analysed after ashing to reduce the volume of the samples. Incidently ashing is also preliminary step to the subsequent radiochemical analyses.

3. GAMMA SPECTROMETRIC ANALYSIS

Air particulate samples which contained a variety of fission and activation radio nuclides were analysed by a Ge(Li) detector having a resolution of 1.84 KeV FWHM at 1332 KeV and an efficiency of 12.2 % for 1332 KeV gamma rays relative to the effiency of a standard 3" x 3" NaI(T1) Scintillation detector. The back ground of the detector was reduced by an 8cm thick lead shielding with a copper lining of 0.5cm thick which absorbed low energy X-rays emitted by the lead. Ge(Li) gamma spectra were analysed by a PDP-11/05 computer based multichannel analyser MCA 8100. A description of this system is given in a separate report to be published.

Washed vegetable; meat and other food samples were analysed by a 3" x 3" NaI(T1) scintillation detector which had a resolution of 84 KeV (FWHM) at 661 KeV and 128.8 KeV at 1460 KeV. The efficiency of the detector was 44 % for a point Cs 137 source (661 KeV gamma energy) placed at a distance of 25cm from the detector. The detector was shielded by 8cm thick lead with 1mm thick copper lining. The gamma spectra were analysed by comparing intergated counts under various gamma energy peaks.

4. RESULTS AND DISCUSSION

Table 1 shows concentration of gamma emitting radionuclides in air at ground level at PINSTECH during the year 1978. Column 3 of this table lists fission and activation products in the fall out from nuclear weapon tests and a cosmogenic radionuclide. The fall out radionuclides are Ce 141, 144; Ru 103, 106; Zr 95/Nb95, Sb 125 and Bi 207. Be 7 is a cosmogenic radionuclide produced in the atmosphere. These radionuclides have also been reported by other environmental monitoring laboratories conducting fall out studies (1,2). The range of concentration of radionuclides given in the table is comparable to that reported by these laboratories. A typical Ge(Li) gamma spectrum of air samples is shown in Fig 1.

Column 3 of Table 1 gives radionuclides produced in the PARR-1 by neutron activation. Ag110M is produced by the irradiation of silver in the control rod of the reactor. Cr 51, Au 198 and Hg 203 are produced in the reactor by neutron activation and later on these radionuclides are processed in the radio-isotope production laboratory at PINSTECH. Cd 109 like Ag110m is also an activation product present in the reactor effluent by virtue of neutron activation of the structural material of the reactor.

Table 2 gives radioactivity ratios of the fission products present in the fall out. The ratios of the fission product activities of appreciably different half lives is in fact a useful index for the determination of the "age" of the fall out (3). The activity ratios of Zr95/Cs137 and Ce144/Cs137 etc. are usually determined for predicting the age of fall out. The initial ratios of these fission product activities have been calculated from the fission yields of U^{230} by 14 MeV neutrons (4,5). The initial ratios of fresh fission products are: Zr95/Cs137 = 145 and Ce144/Cs137 = 30. The decay of these ratios is governed by the respective half lives of the component radionuclides and can be tabulated for reference. In the case of Zr95/Cs137 the decay rate has the half life of almost 65 days (the half life of Zr95) as Cs137 has comparatively long half life. In case of the injection of fresh fall out new ratios are established after the expiry of some "disturbed period" and the new ratios decay with the composite half lives of the component radionuclides. These new ratios can be calculated knowing the existing ratios at the time of the fresh injection and the fresh activity injected into the atmosphere (3).

In Table 2 the average ratio of Zr 95/Cs 137 in the first four weeks of January 1978 is about 1.96. Taking the initial ratio of Zr 95/Cs 137 as 145 and assuming the decay of this ratio with a uniform half life of 65 days during 1977 it can be estimated that fall out received at PINSTECH in January 1978 originated about 14 months back. This fall out

was from the chinese high yield atmospheric explosion of 17th November 1976 as given in our previous report (6). Similar prediction can be made if the decay of the other fission product ratios are followed. It may be mentioned that there was a nuclear explosion by China on 17th Sept. 1977 as well; but being of low-yield its fall out was not received at PINSTECH as indicated by the absence of short lived Ba 140-La140 which are indicative of the arrival of fresh fall out. Similarly there was a low yield explosion by China in March 1978 which was also not recorded in our fall out measurements.

Table 3 and 4 show concentration of gamma emitting radionuclides in some items of diet. In most of the measurements only K40, a naturally occurring radionuclide is found. Normally its concentration in the meat is more than its concentration in the bone. However in some cases bone shows more K40 concentration than meat. It may be due to an unidentified source of error in the individual measurements or partly it may be due to a large statistical spread discussed below.

It can be noticed from the results reported in Table 1 4 that while the order of magnitude of the concentration of the gamma emitters in the environment is the same, there is a considerable spread in the individual values. These wide variations can be explained as follows: The percentage deviation in the determination of the concentration is contributed by the deviation due to sampling (σ_s) and the deviation due to analytical techniques (σ_a) in the measurement. Sampling variability can be estimated by taking a large number of samples. Such estimates made by some workers give a maximum value of σ_s as 20 % (3). Analytical (in our case counting) error may range from 4 to as high as 70 % with a mean value of about 40 % as indicated by our gamma spectrometric analysis by the computer. The maximum

composite (or net) deviation will therefore be [illegible]. It may be mentioned that another variability due to meteorological factors in the case of air sampling may be much higher due to random processes involved in the atmospheric phenomena (3). In the reports of some environmental measurement laboratories an error between 20 to 100 % and in a few cases even-higher have also been indicated in the measured values of the concentration (1).

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TABLE: 1 **Concentration of Gamma Emitting Radionuclides in air at Ground Level at PINSTECH During 78.**

(1) Period of sampling		(2)	(3) Radionuclides of fallout and Cosmogenic Origin (concentration pCi/Km³)										(4)	
Month	Week	Gross Gamma (CPS/Km³)	Ce-141	Ce-144	Ru-103	Ru-106	Zr-95	Nb-95	Cs-137	Sb-125	Bi-207	Be-7	Reactor Corrosion and Activation Products (concentration pCi/Km³)	
Jan.	06-01-78	-	-	51.68	-	9.93	8.43	22.20	4.27	-	-	279.85	-	
	13-01-78	0.41	-	47.86	-	8.92	5.85	17.67	-	-	-	196.82	AG-110M	6.92
	20-01-78	0.46	-	33.26	-	11.16	6.84	17.32	2.98	-	-	271.60	-	
	27-01-78	0.45	-	71.85	-	11.86	7.01	17.82	4.39	7.53	-	191.28	AG-110M	3.41
Feb.	03-02-78	0.38	-	72.13	-	11.58	6.85	15.12	-	-	-	180.71	AG-110M	1.72
	10-02-78	0.39	-	90.19	-	14.47	7.39	17.46	5.64	8.92	-	243.71	-	
	18-02-78	-	-	93.49	-	13.90	7.92	16.07	5.82	8.77	-	192.11	CR-51	6.77
	24-02-78	0.46	-	85.17	-	15.03	7.99	17.18	6.30	-	-	169.82	AG-110M	12.44
March	02-03-78	0.31	-	37.67	2.41	6.30	3.16	7.08	2.26	4.34	-	79.69	-	
	09-03-78	0.31	-	70.09	-	10.20	5.93	10.23	4.89	5.74	-	180.05	AG-110M	3.89
	16-03-78	0.24	-	61.37	-	7.43	4.64	9.22	4.11	-	-	117.61	-	
	23-03-78	0.31	-	75.46	-	12.06	5.14	10.96	5.95	5.81	-	163.79	-	
	30-03-78	-	-	153.07	31.10	-	14.77	19.49	10.18	14.22	-	293.83	-	

Continued from Pre-Page (TABLE -1)

(1) Period of sampling		(2)	(3) Radionuclides of fallout and Cosmogenic Origin (concentration pCi/Km3)										(4)
Month	Week	Gross Gamma (CPS/Km3)	Ce-141	Ce-144	Ru-103	Ru-106	Zr-95	Nb-95	Cs-137	Sb-125	Bi-207	Be-7	Reactor Corrosion and Activation Products (concentration pCi/Km3)
	07-04-78	0.97	-	83.48	-	13.86	6.00	8.40	5.92	-	-	200.85	-
	14-04-78	-	2.44	62.80	-	10.32	5.33	7.58	4.75	6.89	-	152.24	-
Apr.	21-04-78	-	-	111.06	-	18.94	-	22.90	-	13.06	-	311.92	Ag-110m=31.77
	28-04-78	-	-	61.29	-	7.54	2.66	6.07	4.26	6.04	-	149.28	-
	05-05-78	0.83	-	70.11	-	9.04	2.73	5.99	4.80	5.93	-	195.53	-
	12-05-78	0.34	-	68.89	-	10.98	3.41	6.07	5.83	7.77	-	199.26	-
May	19-05-78	0.41	-	71.64	-	11.04	3.84	7.13	6.04	8.45	-	229.66	-
	26-05-78	0.34	-	52.29	-	8.10	3.96	5.71	4.07	7.43	-	157.21	-
	02-06-78	0.28	-	46.52	-	7.04	2.87	4.35	6.68	8.41	-	183.95	-
	09-06-78	0.31	-	56.23	-	9.79	2.88	4.62	4.90	7.19	-	193.31	-
June	16-06-78	0.22	-	57.93	-	9.19	2.03	4.24	4.71	5.28	-	200.26	-
	23-06-78	1.02	-	34.73	-	4.57	-	1.10	2.44	-	-	95.95	-
	30-06-78	0.34	-	48.52	-	6.19	-	2.56	3.63	4.70	-	126.30	-

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(Table-1)

(1) Period of Sampling		(2)	(3) Radionuclides of fallout and Cosmogenic Origin (concentration pCi/Km³)										(4)
Month	Week	Gross Gamma (CPS/Km³)	Ce-141	Ce-144	Ru-103	Ru-106	Zr-95	Nb-95	Cs-137	Sb-125	Bi-207	Be-7	Reactor Corrosion and Activation Products (concentration pCi/Km³)
Jul.	07-07-78	0.50	-	27.17	-	5.83	-	6.46	-	-	-	98.78	-
	14-07-78	0.14	-	24.37	-	4.18	-	2.18	1.39	-	-	69.89	-
	21-07-78	0.14	-	24.26	-	3.69	-	0.81	3.58	-	-	43.91	-
	28-07-78	0.18	-	8.28	-	3.06	-	-	-	-	-	109.16	HG-203 = 3.10
Aug.	04-08-78	0.44	-	21.15	-	4.92	-	23.64	1.90	-	-	133.17	-
	11-08-78	0.06	-	8.47	-	2.07	-	-	1.28	-	-	103.24	-
	18-08-78	0.06	-	6.15	-	1.31	-	-	-	-	-	74.83	-
	25-08-78	0.16	-	5.68	-	1.18	-	-	0.85	-	-	95.23	-
Sept.	01-09-78	0.28	-	12.29	-	2.68	-	5.40	1.39	-	-	216.14	HG-203 = 1.26
	08-09-78	0.09	-	19.82	-	3.90	-	-	3.33	-	-	282.74	CD-109 = 9.65
	15-09-78	0.22	-	10.77	-	2.77	-	-	1.40	-	-	264.65	-
	22-09-78	0.21	-	10.13	-	1.84	-	4.93	1.15	-	-	243.01	-
	29-09-78	0.23	-	-	-	1.47	-	4.08	-	-	-	154.24	CD-109 = 9.20 CR-51 = 18.09 HG-203 = 1.03

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(Table-1)

(1) Period of Sampling		(2)	(3) Radionuclides of fallout and Cosmogenic Origin (concentration pCi/Km^3)									(4)
Month	Week	Gross Gamma (CPS/Km^3)	Ce-141	Ce-144	Ru-103	Ru-106	Zr-95	Nb-95	Cs-137	Sb-125	Bi-207	Be-7	Reactor Corrosion and Activation Products (concentration pCi/Km^3)
	06-10-78	0.20	-	6.50	1.58	-	-	1.18	-	-		290.75	HG-203 = 1.01, CR-51 =29.04
	13-10-78	0.66	-	-	2.68	-	6.68	-	-	-		386.79	HG-203 =10.12, CR-51 =29.70, AU-98 = 0.97, CS-136 = 5.98
Oct.													
	20-10-78	0.21	-	7.61	3.19	-	-	1.60	-	-		266.46	HG-203 = 8.24, MN-54 = 0.64, CR-51 =12.08
	27-10-78	-	-	6.08	2.05	-	3.49	0.98	-	0.60		211.94	HG-203 = 2.67, CR-51 =17.75, AG-110M=12.54, CS-136 = 1.54
	03-11-78	0.16	-	3.69	-	-	-	-	-	-		80.65	CR-51 = 6.86
	10-11-78	0.18	-	6.27	1.26	-	-	-	-	-		168.39	CD-109 =12.11
Nov.	17-11-78	0.18	-	4.76	-	-	-	-	-	-		124.59	HG-203 = 0.87 CR-51 =10.73
	24-11-78	0.26	-	7.57	-	-	0.80	1.60	-	-		125.49	AG-110M= 1.26
	01-12-78	0.13	-	2.68	-	-	-	-	-	0.27		158.39	-
	08-12-78	0.10	-	-	0.76	-	-	-	-	-		107.24	HG-203 = 0.90
Dec.	15-12-78	-	-	16.74	3.78	-	-	-	-	-		195.11	AG-110M= 1.75
	22-12-78	0.11	-	8.78	1.92	-	-	-	-	-		159.76	AG-110M= 0.88
	29-12-78	0.26	-	25.05	-	-	2.32	-	-	-		346.59	-

TABLE: 8 Radioactivity Ratios of Fission Products in the Fallout Received at PINSTECH during 1978

Sampling Period		Fission Products ratios		
Month	Week	CE-144/ CS-137	ZR-95/ CS-137	ZR-95/ CE-144
Jan.	06-01-78	18.11	1.98	0.16
	13-01-78	-	-	0.12
	20-01-78	17.90	2.30	0.13
	27-01-78	16.37	1.60	0.10
Feb.	03-02-78	-	-	0.09
	10-02-78	15.96	1.31	0.08
	18-02-78	16.05	1.36	0.08
	24-02-78	13.91	1.27	0.09
March	02-03-78	16.70	1.40	0.08
	09-03-78	14.33	1.21	0.08
	16-03-78	14.91	1.12	0.08
	23-03-78	12.69	0.86	0.07
	30-03-78	15.04	1.45	0.10

Sampling Period		Fission Products ratios		
Month	Week	CE-144 CS-137	ZR-95/ CS-137	ZR-95/ CE-144
April	07-04-78	15.13	1.09	0.07
	14-04-78	13.23	1.18	0.08
	21-04-78	-	-	-
	28-04-78	14.40	0.63	0.04
May	05-05-78	14.60	0.37	0.04
	12-05-78	11.82	0.58	0.05
	19-05-78	11.85	0.64	0.05
	26-05-78	12.83	0.97	0.08
June	02-06-78	06.96	0.43	0.06
	09-06-78	06.96	0.43	0.05
	16-06-78	12.29	0.43	0.04
	23-06-78	14.22	-	-
	30-06-78	13.36	-	-

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Sampling Period		Fission-Products ratios		
Month	Week	CE-144/ CS-137	ZR-95/ CS-137	ZR-95/ CE-144
July	07-07-78	-	-	-
	14-07-78	17.49	-	-
	21-07-78	06.89	-	-
	28-07-78	-	-	-
Aug.	04-08-78	11.10	-	-
	11-08-78	06.92	-	-
	18-08-78	-	-	-
	25-08-78	6.72	-	-
Sept.	01-09-78	8.87	-	-
	08-09-78	5.95	-	-
	15-09-78	7.67	-	-
	22-09-78	8.81	-	-
	29-09-78	-	-	-

Sampling Period		Fission Products ratios		
Month	Week	CE-144/ CS-137	ZR-95/ CS-137	ZR-95/ CE-144
Oct.	06-10-78	5.53	-	-
	13-10-78	-	-	-
	20-10-78	4.76	-	-
	27-10-78	6.25	-	-
Nov.	03-11-78	-	-	-
	10-11-78	-	-	-
	17-11-78	-	-	-
	24-11-78	4.74	-	-
Dec.	01-12-78	-	-	-
	08-12-78	-	-	-
	15-12-78	-	-	-
	22-12-78	-	-	-
	29-12-78	-	-	-

TABLE: 3 Concentration of Gamma Emitting Radionuclides in Items of Diet - PINSTECH -1978

Period of SAMPLING	February - April 1978			December 1978		
Type of Sample	Gross Gamma CPS/KG	Radionuclide Concn. $x10^{-4}$ uC/KG		Gross Gamma CPS/KG	Radionuclide Concn. $x10^{-4}$ uC/KG	
		Cs 137	K 40		Cs 137	K 40
VEGETABLES						
Peas	0.89	-	5.83	*	*	*
Tomatoes	0.74	-	9.05	0.88	-	3.46
Turnips	0.96	-	4.01	1.26	-	17.15
Cauliflower	0.85	-	45.89	*	-	*
Spinach	1.92	-	27.5	1.03	-	19.87
Onions	0.79	-	13.17	0.93	-	15.49
Potatoes	*	*	*	0.96	-	19.02
MEATS						
Beef meat	0.99	0.45	11.30	0.12	-	-
Beef bone	0.32	-	16.30	0.42	-	7.42
Mutton meat	0.22	-	24.60	0.28	0.07	17.80
Mutton bone	0.20	-	14.70	0.21	0.41	0.72
Chicken meat	0.82	-	9.79	1.12	-	7.19
Chicken bone	0.23	-	6.43	0.85	-	7.54
Fish meat	0.16	-	0.196	0.72	-	3.07
Fish bone	0.32	-	10.40	0.19	-	1.83

* Sample not collected
- Concentrats below detection limit

TABLE: 4 Concentration of Gamma Emitting Radionuclides in PINSTECH Mess Meals During 1978

Period	Gross Gamma CPS/Kg	Radionuclide Concentration x 10^{-4} µCi/Kg	
		Cs 137	K 40
Jan.	0.65	-	6.86
Feb.	0.13	-	2.28
March	0.56	-	5.90
April	0.22	-	5.20
May	0.77	-	7.91
June	0.49	-	5.43
July	0.27	-	4.17
Aug.	0.32	-	7.60
Sept.	0.57	-	8.20
Oct.	1.06	-	10.30
Nov.	0.56	-	10.50
Dec.	0.89	-	15.80
Wheat (Site Kerno Thanda Pani)	12.78	1.47 x 10^{-2} µCi/Kg	2.22 x 10^{-3} µCi/Kg

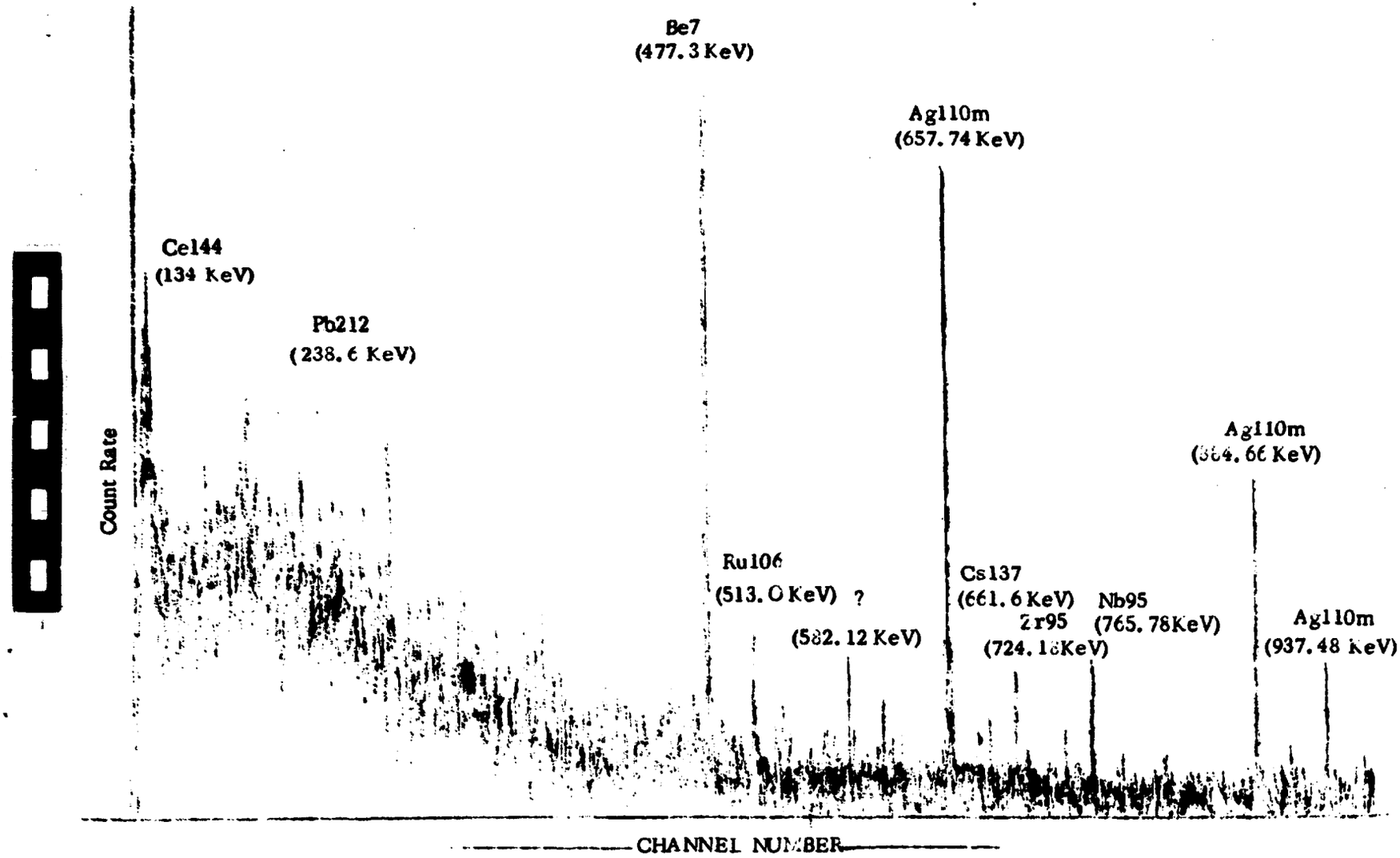

Fig. 1: A typical Gamma Spectrum of Air Particulate Samples by a Ge(Li) Detector.

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