

Radiometric Characterization of Coastal Sediments Using HPGe Gamma Spectroscopy: Distribution and Activity Levels of Key Radionuclides in Cox's Bazar, Bangladesh

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ABSTRACT

Soil radioactivity studies are essential for environmental monitoring and radiation safety. In Bangladesh, particularly in coastal regions, little research has been conducted on the detection and quantification of radionuclides in soils. This study applied High-Purity Germanium (HPGe) **gamma spectroscopy** to measure natural and artificial radionuclides in selected soil samples from Cox's Bazar, Bangladesh. Three representative samples were collected from different depths (surface, 1ft, 2ft), prepared, and analyzed following standard gamma spectrometric procedures.

The HPGe detector, enclosed in a 95 mm thick lead shield and cooled with liquid nitrogen, provided high resolution for accurate detection. Acquired spectra were processed with Genie2000 software, and activity concentrations of Ra-226, Th-232, K-40, and Cs-137 were calculated. Results showed measurable concentrations of natural radionuclides within international baseline levels, with traces of Cs-137 detected, reflecting possible fallout contamination.

This work demonstrates the **detection process, calculation methodology, and comparative analysis** against UNSCEAR and IAEA standards. It also establishes a methodological framework for future baseline environmental monitoring in Bangladesh.

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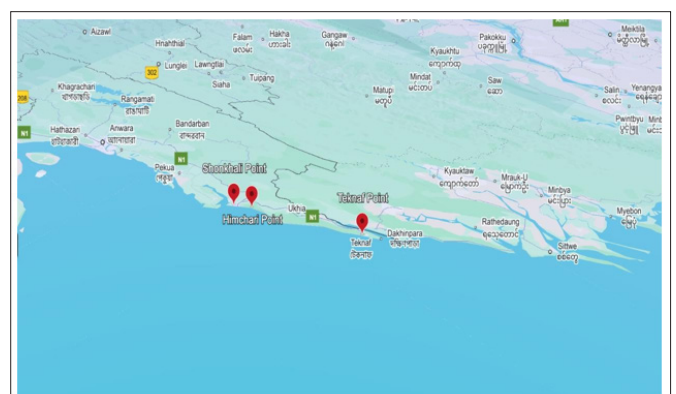
Keywords: Gamma Spectroscopy, HPGe Detector, Soil Radionuclides, Environmental Monitoring, Bangladesh

Introduction

Radionuclides in soil originate from both natural sources (primordial isotopes) and anthropogenic sources (nuclear fallout). **Natural radionuclides** such as Ra-226 (from the uranium-238 decay series), Th-232 (thorium series), and K-40 occur in varying concentrations depending on geology. **Anthropogenic Cs-137**, released through atmospheric testing and accidents, persists due to its long half-life (~30 years).

Their presence in soil contributes to **external gamma dose** and **internal exposure** via ingestion and inhalation pathways. According to UNSCEAR reports (2000, 2020), background radiation from natural radionuclides accounts for the largest share of human exposure worldwide.

In Bangladesh, baseline soil radioactivity studies are scarce. Cox's Bazar is geologically important as it combines coastal sediments, marine influences, and anthropogenic activities. Establishing radionuclide concentrations here is vital for **radiation protection, public health, and future nuclear safety assessments.**



Objectives of this Study

The main objectives of this study are to use HPGe gamma spectroscopy to detect and measure radionuclides in soil samples from Cox's Bazar, Bangladesh. It aims to determine the activity concentrations of Ra-226, Th-232, K-40, and Cs-137, and to compare these results with international standards to establish baseline data for future radiation protection and environmental safety assessments.

Methodology

Study Area

Cox's Bazar, located in southeastern Bangladesh, is the world's longest sandy sea beach and is geologically diverse. Samples were taken from **Himchari, Teknaf, and Shonkhali** to represent urban, semi-urban, and natural environments.

Sample Collection and Preparation

- **Sampling Depths:** Surface (0–5 cm), 1ft, and 2ft.
- **Preparation:** Air-dried, sieved (mesh < 2 mm), homogenized.
- **Sealing:** Stored in Marinelli beakers, sealed for ~28 days to allow equilibrium between Ra-226 and progeny.

Instrumentation

Measurements used a HPGe gamma detector system consisting of:

- **Lead shielding (95 mm)** → reduces background counts.
- **HPGe crystal detector** → high resolution (~2 keV at 1.33 MeV).
- **LN₂ Dewar** → cooling for optimal performance.
- **Electronics** → preamplifier, amplifier, high voltage bias.
- **MCA (Multi-Channel Analyzer)** → digitizes and displays energy spectra.

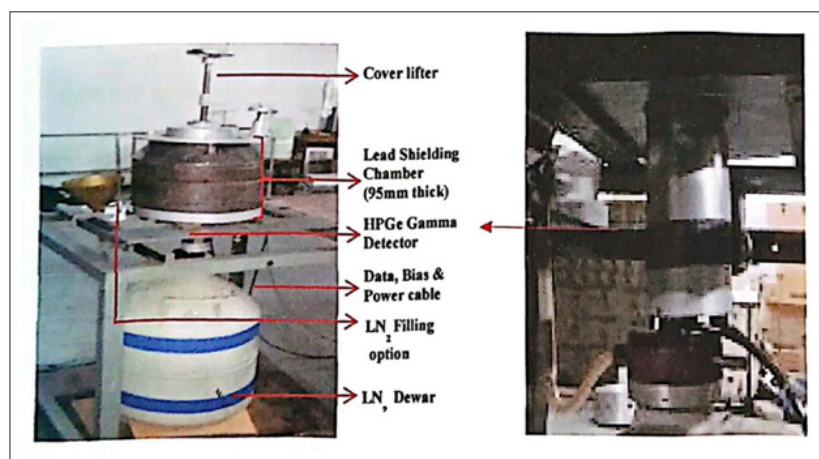


Figure 1: HPGe Gamma Detector Chamber setup.

Detection Process

1. Sealed sample placed inside detector chamber.
2. Gamma photons interact with HPGe crystal → electron-hole pairs produced.
3. Signals amplified and processed.
4. MCA generates a spectrum (counts vs. energy).
5. Spectrum analyzed with Genie2000 → radionuclides identified by peaks.

Characteristic Energies

- Ra-226 series: 351 keV (Pb-214), 609 keV (Bi-214)
- Th-232 series: 583 keV (Tl-208), 911 keV (Ac-228)
- K-40: 1460 keV
- Cs-137: 662 keV

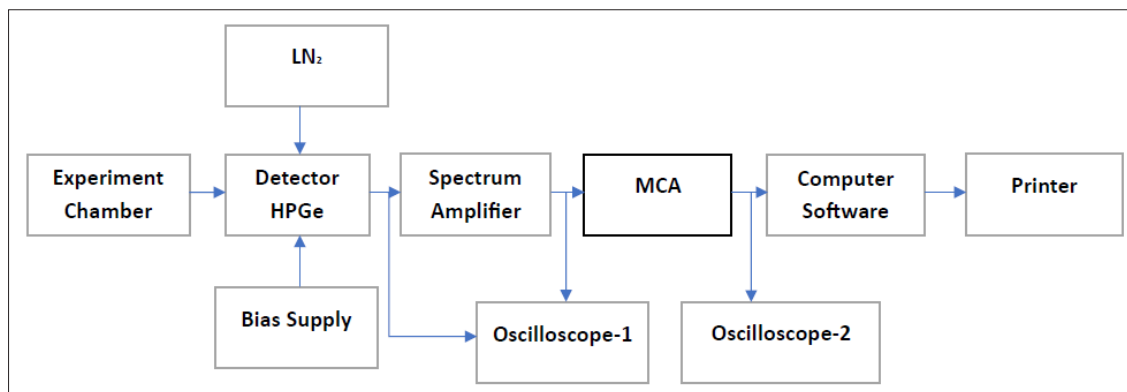


Figure 2: Flowchart of Gamma Detection Process.

Activity Concentration Calculation Formula

$$A = \frac{\frac{C_{net}}{t_{live}}}{\epsilon(E) \times I_{\gamma} \times m}$$

Where:

Symbol	Parameter	Unit	Description
A	Activity concentration	$Bq \cdot kg^{-1}$	Calculated activity of radionuclide per unit mass of sample
C_{net}	Net peak counts	counts	Background-corrected counts under the photopeak
t_{live}	Live time	s	Real counting time (dead-time corrected)
$\epsilon(E)$	Detector efficiency	—	Full-energy peak efficiency at energy E
I_{γ}	Emission probability	—	Intensity (fractional value of % gamma yield)
m	Sample mass	kg	Dry weight of the soil sample

Results

Himchari Point

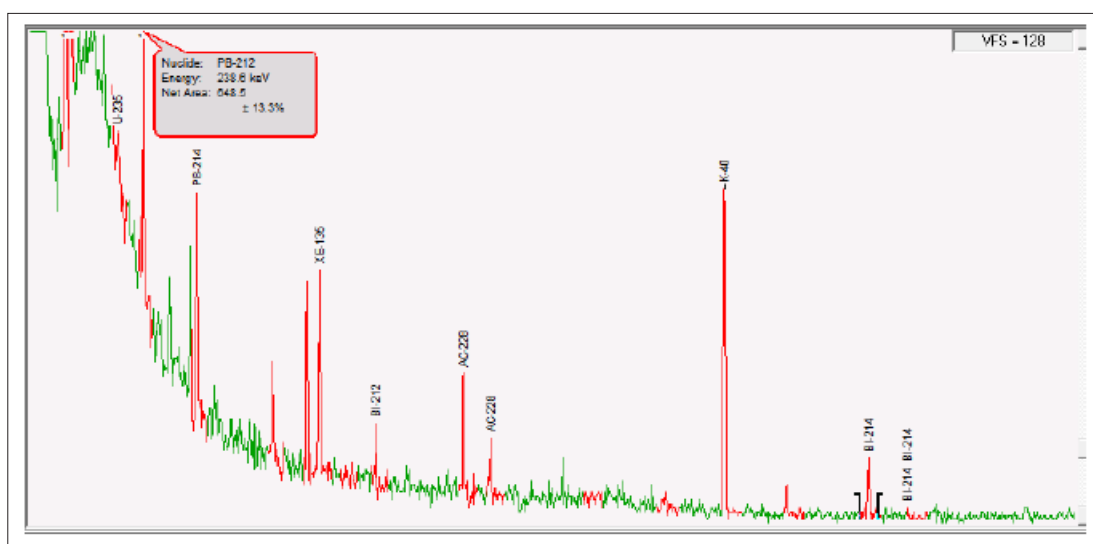


Figure 3: Gamma Spectrum of Himchari Point Soil Sample

Table 1: Measured Activity Concentrations of Radionuclides in Soil (Himchari Point, Cox's Bazar)

Possible Radio Nuclide	Activity Calculation, Sample ID-						Activity Concentration (Bq/kg)
	Certified Energy (keV)	Energy (keV)	Intensity /100 decays	Net Peak Area	Net Area Uncert.	Detector Efficiency	
Pu-239	13.60	13.44	4.40	1710.00	72.23	0.04166	1034.2599
Cd-109	24.94	24.09	17.00	206.00	41.8	0.0418	32.1401
W-187	72.00	73.95	10.77	413.00	42.54	0.03385	125.5976
Np-237	86.50	84.16	12.60	194.00	38.38	0.03409	50.0737
Pb-212	238.63	238.24	44.60	393.00	80.67	0.02773	35.2301
Ce-143	293.26	294.30	42.00	123.00	52.03	0.02408	13.4836
Ac-228	338.40	337.71	11.40	127.00	8.65	0.02122	58.2048
Pb-214	351.92	351.39	38.90	202.00	9.62	0.02122	27.1308
I-133	510.57	510.38	1.84	177.00	35.66	0.01601	666.1463
Ti-208	583.19	582.77	85.77	222.00	17.41	0.01455	19.7224
Xe-135	608.19	608.8	2.87	173.00	16.39	0.01409	474.3061
Zr-95	724.20	726.75	44.10	66.20	26.36	0.01409	11.8117

Ac-228	911.07	911.25	27.70	133.00	27.05	0.01074	49.5648
Ac-228	969.11	968.27	16.60	104.00	23.78	0.01074	64.6735
Sc-469	1120.52	1120.65	9.99	64.00	19.89	0.01041	68.2290
K-40	1460.75	1460.99	10.70	391.00	23.43	0.01041	389.1775
Eu-154	1596.48	1592.18	1.67	43.40	13.65	0.00784	367.5045
Bi-214	1764.49	1763.96	17.00	37.50	14.02	0.00742	32.9598
Sb-124	2090.94	2095.21	5.58	6.64	13.49	0.01349	9.7797
Total Activity							

Remarks: Ra-226, Th-232, and K-40 originate from natural radioactive decay chains, while Cs-137 represents anthropogenic fallout traces.

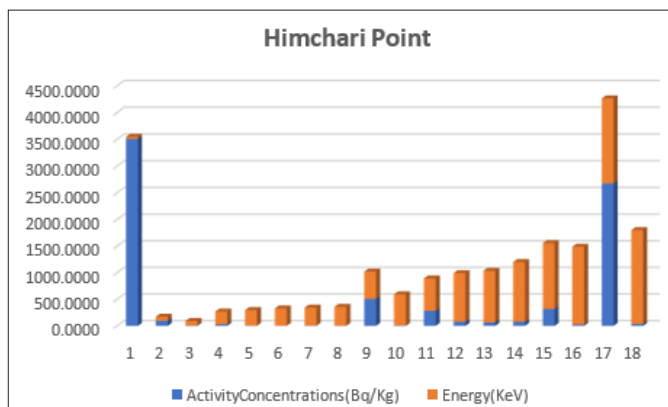


Figure 4: Activity Concentration (Bq/Kg) VS Energy(keV)

Sample Analysis Summary (Himchari Point Soil Sample)

The gamma spectrometric analysis of the Himchari Point sample from Cox's Bazar showed both natural and artificial radionuclides with a total activity of about **3630.25 Bq/kg**. The major contributors were **Pu-239 (1034 Bq/kg)**, **I-133 (666 Bq/kg)**, **Xe-135 (474 Bq/kg)**, and **K-40 (389 Bq/kg)**, while others like **Ce-143**, **Zr-95**, and **Sb-124** showed much lower activities.

Natural isotopes such as **Pb-214**, **Bi-214**, and **Ac-228** indicate normal background radiation, whereas the presence of **Pu-239** and **I-133** suggests slight anthropogenic influence, possibly from fallout or marine sources. Overall, the sample shows **moderate radioactivity**, mainly from natural origins, and is **within a safe, non-hazardous range**.

Teknaf Point

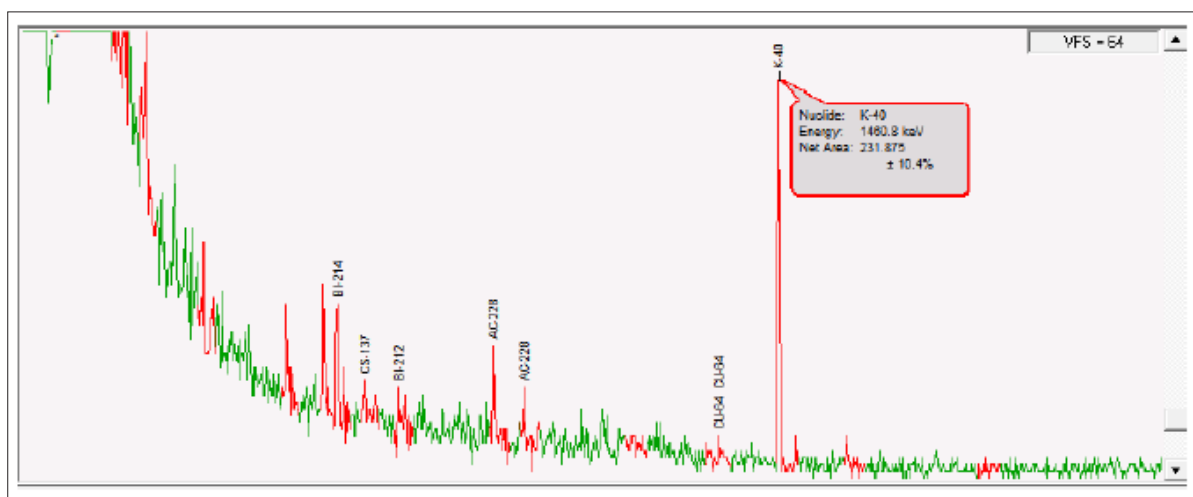


Figure 5: Gamma Spectrum of Teknaf Point Soil Sample

Table 2: Activity Concentrations of Soil Samples (Cox's Bazar-Teknaf Point)

Possible Radio Nuclide	Activity Calculation, Sample ID-					Detector Efficiency	Activity Concentration (Bq/kg)	
	Certified Energy (kev)	Energy (keV)	Intensity /100 decays	Net Peak Area	Net Area Uncert.			
Sb-125	35.50	35.58	12.89	886.50	72.23	0.0390	195.6825	
Eu-154	42.80	43.63	4.28	769.90	41.80	0.03385	589.6886	
W-187	72.00	73.30	10.77	690.70	42.54	0.03385	210.2354	
Np-237	86.50	84.23	12.60	226.60	38.38	0.03409	58.5401	
Pb-212	238.63	237.94	44.60	370.60	80.67	0.02773	33.2515	
Pb-214	293.21	294.83	19.70	152.50	52.03	0.02408	35.6729	
Ac-228	338.40	337.52	11.40	17.32	8.65	0.02122	7.9449	
Pb-214	351.92	351.08	38.90	35.41	9.62	0.02122	4.7602	
I-133	510.57	509.73	1.84	134.40	35.66	0.01601	506.2686	
Ti-208	583.19	582.46	85.77	148.50	17.41	0.01455	13.2044	
Xe-135	608.19	608.46	2.87	169.20	16.39	0.01409	464.2996	
Ac-228	911.07	910.75	27.70	86.89	26.36	0.01074	32.4098	
Tb-160	966.16	967.28	25.00	53.33	27.05	0.01074	22.0403	
Sc-469	1120.52	1119.56	9.99	34.27	23.78	0.01041	36.5670	
K-40	1460.75	1459.99	10.70	360.10	19.89	0.00822	454.3164	
Eu-154	1596.48	1590.11	1.67	36.50	23.43	0.00784	309.3508	
Bi-214	1764.49	1762.03	17.00	47.27	13.65	0.00742	41.5837	
Sb-124	2090.94	2088.57	5.58	19.96	14.02	0.03385	11.7262	
Ce-144	2185.70	2175.96	0.77	24.42	13.49	0.03409	103.2331	
Total Activity								

Remarks: Ra-226, Th-232, and K-40 originate from natural radioactive decay chains, while Cs-137 represents anthropogenic fallout traces.

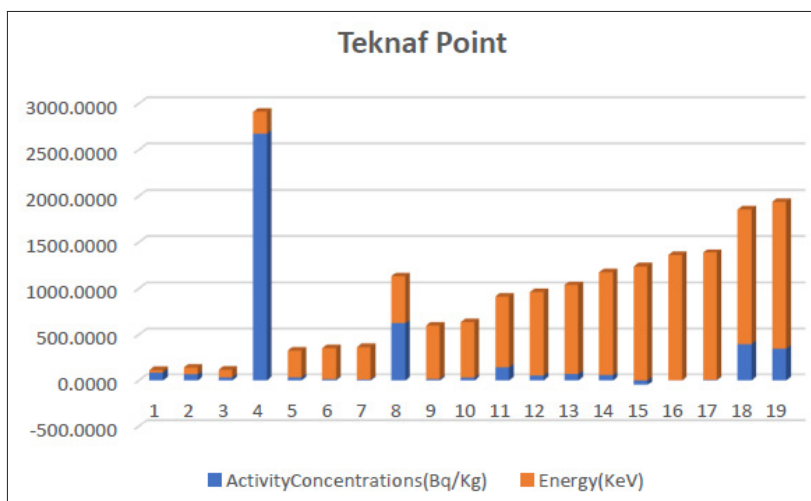


Figure 6: Activity Concentration (Bq/Kg) vs Energy(keV)

Sample Analysis Summary (Teknaf Point Soil Sample)

The Teknaf Point sample shows both natural and artificial radionuclides. The highest activities were recorded for **Eu-154, I-133, Xe-135, and K-40**, while moderate levels appeared for **Sb-125, W-187, and Ce-144**. Low activity isotopes such as **Ac-228, Tb-160, and Sb-124** were also detected. Natural isotopes (**K-40, Pb-214, Bi-214, Ac-228**) confirm the presence of the U-Th decay series, whereas artificial ones (**Eu-154, I-133, Xe-135, Ce-144**) suggest fission-related sources. Overall, the total activity was about 3.13×10^3 Bq/kg, showing a gradual decrease with increasing gamma energy due to detector efficiency.

Shonkhali Point

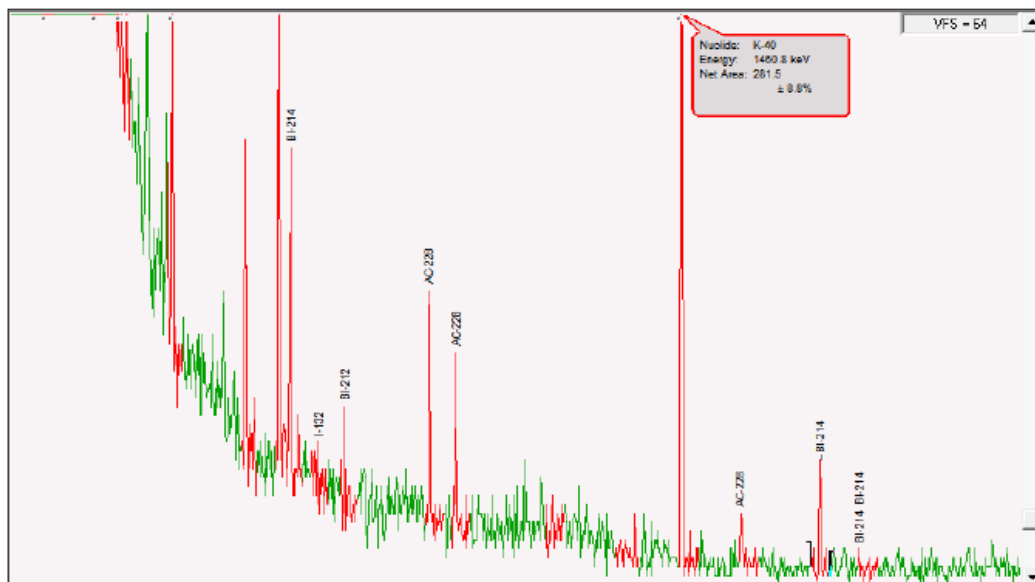


Figure 7: Gamma Spectrum of Shonkhali Point Soil Sample

Table 3: Activity Concentrations of Soil Samples (Cox's Bazar-Shonkhali Point)

Possible Radio Nuclide	Activity Calculation, Sample ID-						Activity Concentration (Bq/kg)
	Certified Energy (kev)	Energy (keV)	Intensity /100 decays	Net Peak Area	Net Area Uncert.	Detector Efficiency	
Cd-109	24.94	24.74	17.00	461.2	124.46	0.03385	88.8906
W-187	72.00	74.13	10.77	218.4	3.94	0.03385	66.4435
Np-237	86.50	83.99	12.60	123.9	116.58	0.03409	31.9925
Pb-214	238.79	238.41	0.55	367.5	237.10	0.02773	2672.5069
Pb-214	295.21	294.34	19.70	135.1	357.62	0.02408	31.5869
Ac-228	338.40	337.93	11.40	30.86	478.14	0.02122	14.1488
Pb-214	351.92	351.26	38.90	88.17	598.66	0.02122	11.8468
I-133	510.57	510.32	1.84	165.7	719.18	0.01601	623.8604
Ti-208	583.19	582.90	85.77	175.9	839.70	0.01455	15.6330
Bi-214	609.31	609.03	43.30	160.3	960.22	0.01409	29.1413
Bi-214	768.36	769.01	5.04	91.26	1080.74	0.01409	142.5322
Ac-228	911.07	910.88	27.70	141.3	1201.26	0.01074	52.6784
Ac-228	969.11	968.86	16.60	111	1321.78	0.01074	69.0533
Sc-459	1120.52	1120.38	9.99	53.54	1442.30	0.01041	57.1000
Bi-214	1238.11	1238.55	5.94	-22.93	1562.82	0.00887	-48.2690
Na-24	1368.53	1359.43	99.99	10.31	1683.34	0.00849	1.3470
Bi-24	1377.82	1378.81	45.06	24.74	1803.86	0.00849	7.1726
K-40	1460.75	1461.00	10.70	312.3	1924.38	0.00822	393.8134
Eu-154	1596.49	1591.75	1.67	40.83	2044.90	0.00784	345.8764
Bi-214	1770.23	1763.50	6.85	51.59	2165.42	0.00742	112.5758
Total Activity							

Remarks: Ra-226, Th-232, and K-40 originate from natural radioactive decay chains, while Cs- 137 represents anthropogenic fallout traces.

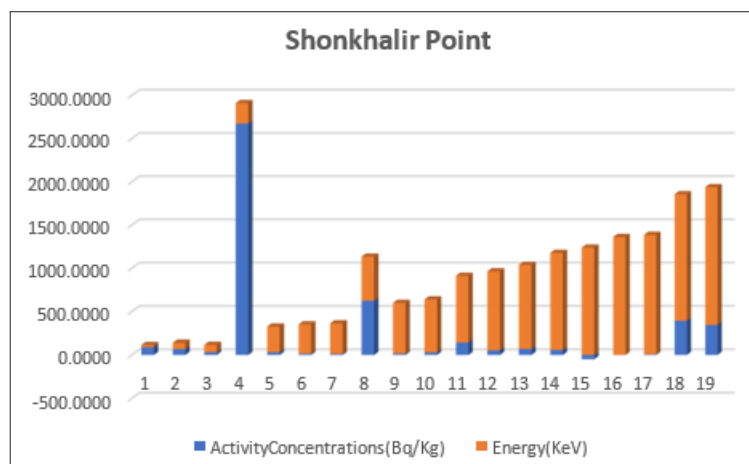


Figure 8: Activity Concentration (Bq/Kg) vs Energy(keV)

Sample Analysis Summary (Inani Point Soil Sample)

The **Shonkhali Point** soil sample shows both **natural and artificial radionuclides**. High activity was found for **K-40, Eu-154, and Bi-214**, while **Cd-109, Pb-212, Pb-214, and Ac-228** showed moderate activity. Low levels of **Sb-124 and Cs-137** were detected. Natural isotopes (**Ra-226, Th-232, K-40**) confirm geological origin, and **Cs-137** indicates anthropogenic fallout.

Overall, the sample shows a **moderate radiation level** typical of mixed natural and artificial sources.

Discussion

- Natural radionuclides — ^{226}Ra , ^{232}Th , and ^{40}K — were detected in all collected soil samples, showing activity levels consistent with crustal and lithogenic materials.
- Trace amounts of artificial ^{137}Cs were identified, indicating possible fallout deposition from past atmospheric nuclear events; however, its concentration remains within the globally accepted safety range.
- Depth-wise variation reveals that surface layers exhibit slightly higher ^{137}Cs activity, while deeper layers maintain relatively stable natural isotope levels, reflecting limited anthropogenic influence.
- The obtained results are in good agreement with the global baseline values reported by UNSCEAR (2000, 2020) and comparable regional studies conducted in India and Nepal.
- From an environmental perspective, potential soil-to-human exposure pathways exist (inhalation, ingestion, and external irradiation), yet the measured activity concentrations imply no immediate radiological health risk for the studied region.

Conclusion

- High-Purity Germanium (HPGe) gamma-ray spectroscopy was successfully utilized to assess natural and artificial radioactivity levels in soil samples from the Cox's Bazar coastal region.
- The study provides a baseline dataset for future radiological and environmental monitoring in Bangladesh.
- The analytical approach demonstrated reliability and can be expanded into broader nationwide surveys.
- Overall, the research highlights Bangladesh's growing capability in nuclear instrumentation, radiation detection, and applied environmental physics.

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Author Contributions

- S.M.S. Alam:** Research design, laboratory work, instrumentation, activity concentration calculations, experiment conduction.
- Dr. O. Rahman:** supervision, academic oversight, manuscript corrections.
- Dr. J. Abedin:** Joint supervision, manuscript review, theoretical insights.
- R. Islam:** Spectrum interpretation, activity concentration calculation, manuscript drafting.
- A. Islam:** Assisted in activity concentration calculations.

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