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INVESTIGATION OF RADIONUCLIDE CONCENTRATION IN SOIL SAMPLES COLLECTED FROM MINHLA COAL MINE REGION

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Abstract

The aim of this research work is to investigate the radionuclides and calculate the activities of the collected samples from Kan Toke coal mine areas, Minhla Township, Magway Region. The radionuclide concentrations in soil samples were examined by using NaI (Tl) gamma ray spectrometry. There are four soil samples. From the analysis of the obtained spectra, peaks of ^{212}Pb (77.11 keV), ^{212}Pb (238.63 keV), ^{228}Ac (338.32 keV), ^{208}Tl (583.19 keV), ^{208}Tl (860.56 keV), ^{214}Bi (1120.3 keV) and ^{40}K (1461 keV) were found. It is also found that the observed radionuclides except ^{40}K (1461 keV) are the decay products of ^{238}U and ^{232}Th natural radioactive series. The concentrations of these radionuclides were determined by Gamma Vision 32 software. The highest activity of ^{212}Pb (77.11 keV) was found in soil sample 1. The highest activity of ^{212}Pb (238.63 keV) was found in soil sample 3. The highest activity of ^{228}Ac (338.32 keV) was found in soil sample 3. The highest activity of ^{208}Tl (583.19 keV) was found in soil sample 3. The highest activity of ^{208}Tl (860.56 keV) was found in soil sample 1. The highest activity of ^{214}Bi (1120.3 keV) was found in soil sample 1. The highest activity of ^{40}K (1461 keV) was found in soil sample 4. The concentrations of radionuclides contained in Kan Toke coal mine areas are not very high compared with IAEA standard, the samples have very small amount of radionuclides.

Keywords: Soil Samples, NaI(Tl) Scintillation Detector, Activity, Radionuclides, Standard Gamma Sources.

Introduction

Soil

Soil is a material which nourishes and supports growing plants. (Includes rocks, water, snow, and even air – all of which are capable of supporting plant life). And soil is loose surface of the earth as distinguished from solid bedrock. Soil contains mixture of mineral matter, organic matter, water and air. (Example: Loam soil = 45% mineral matter, 5% organic matter, 20-30% water, and 20-30% air). This composition of loam soil is shown in Figure (1).

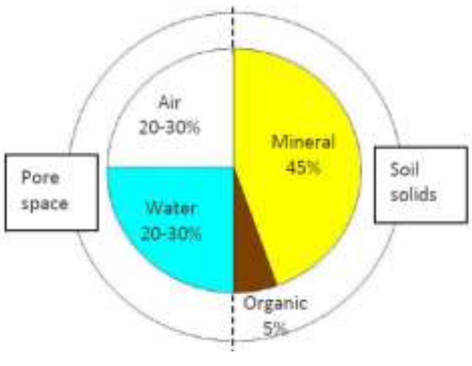

Figure 1 Composition of a loam surface soil when conditions are for plant growth

Soil is collection of natural bodies of the earth's surface, in places modified or even made by man or earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors. Its upper limit is air or shallow water. Its lower limit is the lower limit of biologic

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activity, which generally coincides with the common rooting depth of native perennial plants, the depth to which soil weathering has been effective, or both.

Soil is a collection of natural bodies occupying portions of the earth's surface that supports plants and that have properties due to the integrated effect of climate and living matter, acting upon parent material, as conditioned by relief, over periods of time.

Experimental Procedure

Sample Collection and Preparation

Four types of soil samples are collected from different places of Kan Toke coal mine area, Minhla Township, Magway Region. Soil sample 2 is about 200ft from soil sample 1, and soil sample 3 is also about 200ft from soil sample 2. Soil sample 4 is collected from the Gway Cho stream flowing across the coal mine areas. Soil samples were dried at shelter, avoiding the loss of any volatile radionuclide. The dried samples were pulverized and sieved to pass through a 1-2mm mesh. The meshed soil samples were transferred to plastic sample cup. The plastic sample cup used in this research was as shown in Figure (2). The detection system of the scintillation detector is shown in Figure (3).

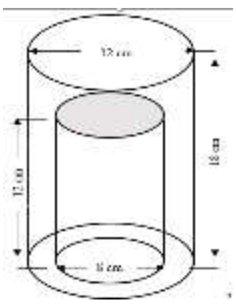


Figure 2 Plastic Sample Cup

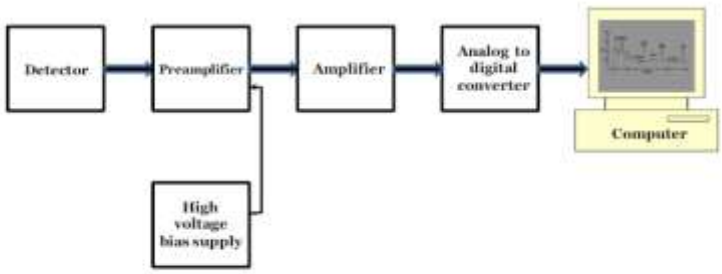


Figure 3 Experimental setup

Energy Resolution of the NaI(Tl) Detector

For a perfect detector, the photopeak is expected to be a delta function. Which is in contrast to the widened peaks in the measured energy spectrum, this widening contains contributions from a range of separate effects such as charge collection statistics, electronic noise, fluctuations in PMT gain, variations in the detector response over its active volume and drifts in parameters over the course of the measurement. The energy resolution is defined as the Full Width at Half Maximum (FWHM) in percentage.

$$R = \frac{\mathrm{FWHM}}{H_0} \times 100\% \qquad (1)$$

Where, FWHM is the full width at half maximum of the full-energy peak and H_0 is the mean pulse height corresponding to the same peak.

Experimental Set-Up

Gamma spectrometric analysis of the samples was performed with a computer based gamma spectrometry system for qualitative and quantitative determination of gamma emitting radionuclides. The system included Thallium doped, sodium iodide NaI(Tl) scintillation detector (Model 296) photomultiplier tube, high voltage power supply, preamplifier (Model 142 PC) fast spectroscopy amplifier (Model 671), a pulse stored multi-channel analyzer (MCA) together with Gamma Vision-32 software were installed in PC. The operation voltage for NaI(Tl) scintillation detector is 1000V. The whole system including detector and all other modules were from ORTEC.

The detector resolution was 8% at 662 keV energy of ^{137}Cs. The detectors were placed in low-background shields made of 7.5 cm thick old lead (Pb) rings, which were lined with cosmic rays, cadmium, other radiation in environment and copper to reduce the effect of X-rays.

Energy Calibration

The energy of radioactive elements in soil samples were unknown. The standard radioactive sources of known energies were used to calibrate the spectrometer. Four standard sources such as, 6 different energies including all ranges of energy low, medium and high, ^{241}Am (60 keV), ^{137}Cs (661.66 keV), ^{22}Na (511 keV and 1274.53 keV) and ^{60}Co (1173.24 keV and 1332 keV) were used for 600 seconds placing at 5 cm above the detector cap. The datas are as shown in Table (1) and the energy calibration curve is as shown in Figure (3). Establishing a direct relationship between photo peak energy and channel number could do the energy calibration process.

Table 1 The Standard Gamma Sources

Used in the Energy Calibration Data

Source	Energy (keV)	Channel
^{241}Am	60	91.1
^{137}Cs	661.66	621
^{22}Na	511	488.83
	1274.53	1168
^{60}Co	1173.24	1080
	1332	1218

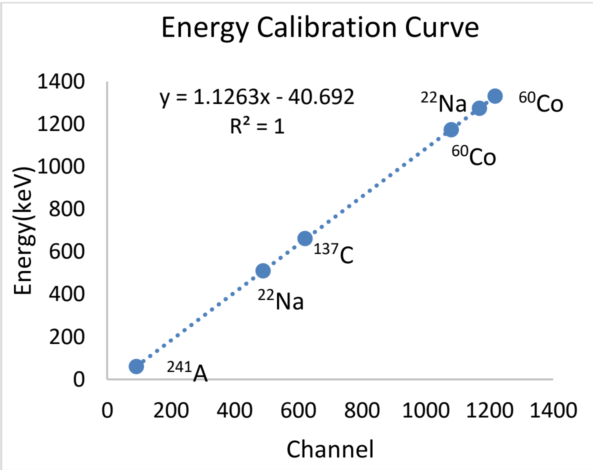


Figure 4 Energy Calibration Curve

Calculation of Activity

The activity of radionuclide present in the samples was calculated by following equation

$$A = \frac{N_A}{m\varepsilon P_\gamma T} \qquad (2)$$

where, N_A = net count area for sample

m = mass of sample

P_γ = gamma ray intensity

T = counting time (in second)

ε = efficiency of the interest gamma energy

Experimental Procedure

In gamma ray spectroscopy system, sodium crystal mounted a photomultiplier tube, preamplifier, amplifier, a pulse store multi-channel analyzer (MCA), high-voltage power supply and data readout devices are included.

In this experiment, NaI (Tl) 3 inches x 3 inches scintillation detector is used to detect the gamma radiation after passing through the samples and then passed informations (electron pulses) are amplified by the preamplifier and the fast spectroscopy amplifier and collected by using MCA based on personal computer. The operating voltage used in scintillation detector is 1000V dc. First, the background was measured for three hours. This value is fixed for all measurements and measuring time is 10800 seconds in each sample. At the end of the counting period, the spectrum that was recorded may be displayed on the screen. The spectra stored in MCA were analyzed by the application of Gamma-Vision 32 software. Using the displayed information, unknown radioisotopes can be identified radionuclides with activity concentrations, a picture of the spectrum and then determination of the gross area and net area of full energy peak. The activities of different radionuclides can be calculated by using the equation (2).

Figure 5 Side view of the detection system

Figure 6 Diagram of the experimental arrangement of the detection system

Results and Discussion

The activity concentrations of radionuclides in soil samples were presented in Tables (2), (3), (4) and (5). The comparison of activity concentrations of radionuclides in soil samples were presented in Table (6). The activity concentrations of ^{212}Pb (77.11 keV) was found with values of 26.17 Bq/kg in sample 1, 20.7 Bq/kg in sample 2, 21.74 Bq/kg in sample 3 and 17.55 Bq/kg in soil sample 4. The highest activity of ^{212}Pb (77.11 keV) was found in soil sample 1. The activity concentrations of ^{212}Pb (238.63 keV) was found with values of 7.94 Bq/kg in sample 1, 9.34 Bq/kg in sample 2, 12.58 Bq/kg in sample 3 and 6.28 Bq/kg in soil sample 4. The highest activity of ^{212}Pb (238.63 keV) was found in soil sample 3. The activity concentrations of ^{228}Ac (338.32 keV) was found with values of 20.18 Bq/kg in sample 1, 27.31 Bq/kg in sample 2, 27.37 Bq/kg in sample 3 and 15.05 Bq/kg in soil sample 4. The highest activity of ^{228}Ac (338.32 keV) was found in soil sample 3. The activity concentrations of ^{208}Tl (583.19 keV) was found with values of 4.77 Bq/kg in sample 1, 5.29 Bq/kg in sample 2, 6.58 Bq/kg in sample 3 and 4.48 Bq/kg in soil sample 4. The highest activity of ^{208}Tl (583.19 keV) was found in soil sample 3. The activity concentrations of ^{208}Tl (860.56 keV) was found with values of 11.42 Bq/kg in sample 1 and 2.81 Bq/kg in sample 2. The highest activity of ^{208}Tl (860.56 keV) was found in soil sample 1. The activity concentrations of ^{214}Bi (1120.3 keV) was found with values of 10.13 Bq/kg in sample 1 and 0.03 Bq/kg in sample 2. The highest activity of ^{214}Bi (1120.3 keV) was found in soil sample 1The activity concentrations of ^{40}K (1461 keV) was found with values of 203.63 Bq/kg in sample 1, 154.29 Bq/kg in sample 2, 163.34 Bq/kg in sample 3 and 304.06 Bq/kg in soil sample 4. The highest activity of ^{40}K (1461 keV) was found in soil sample 4. The background spectrum and soil sample spectrums were shown in Figure (6) to (10).

Table 2 Activity concentrations of radionuclides in soil sample 1

Sr.No	Radionuclide	Energy(keV)	Activity (Bq/kg)
1	^{212}Pb	77.11	26.17
2	^{212}Pb	238.63	7.94
3	^{228}Ac	338.32	20.18
4	^{208}Tl	583.19	4.77
5	^{208}Tl	860.56	11.42
6	^{214}Bi	1120.29	10.13
7	^{40}K	1461	203.63

Table 3 Activity concentrations of radionuclides in soil sample 2

Sr.No	Radionuclide	Energy(keV)	Activity (Bq/kg)
1	^{212}Pb	77.11	20.7
2	^{212}Pb	238.63	9.34
3	^{228}Ac	338.32	27.31
4	^{208}Tl	583.19	5.29
5	^{208}Tl	860.56	2.81
6	^{214}Bi	1120.29	0.03
7	^{40}K	1461	154.29

Table 4 Activity concentrations of radionuclides in soil sample 3

Sr.No	Radionuclide	Energy(keV)	Activity (Bq/kg)
1	^{212}Pb	77.11	21.74
2	^{212}Pb	238.63	12.58
3	^{228}Ac	338.32	27.37
4	^{208}Tl	583.19	6.58
5	^{40}K	1461	163.34

Table 5 Activity concentrations of radionuclides in soil sample 4

Sr.No	Radionuclide	Energy(keV)	Activity (Bq/kg)
1	^{212}Pb	77.11	17.55
2	^{212}Pb	238.63	6.28
3	^{228}Ac	338.32	15.05
4	^{208}Tl	583.19	4.48
5	^{40}K	1461	304.06

Table 6 Comparison of activity concentrations of radionuclides in soil samples

Sr.No	Radionuclide	Energy (keV)	Soil sample 1	Soil sample 2	Soil sample 3	Soil sample 4
1	^{212}Pb	77.11	**26.17**	20.7	21.74	17.55
2	^{212}Pb	238.63	7.94	9.34	**12.58**	6.28
3	^{228}Ac	338.32	20.18	27.31	**27.37**	15.05
4	^{208}Tl	583.19	4.77	5.29	**6.58**	4.48
5	^{208}Tl	860.56	**11.42**	2.81	ND	ND
6	^{214}Bi	1120.3	**10.13**	0.03	ND	ND
7	^{40}K	1461	203.63	154.29	163.34	**304.06**

Conclusion

In this research work, the soil samples from Kan Toke coal mine areas, Minhla Township, Magway Region were examined by using NaI (Tl) detector and analyzed by Gamma Vision 32 software. There are four soil samples. From the analysis of the obtained spectra, the radionuclides present in soil sample 1,2, 3 and 4 are [^{212}Pb (77.11 keV), ^{212}Pb (238.63 keV),^{228}Ac (338.32 keV), ^{208}Tl (583.19 keV), ^{208}Tl (860.56 keV), ^{214}Bi (1120.3 keV) and ^{40}K (1461 keV)]. It is also found that the observed radionuclides except ^{40}K (1461 keV) are the decay products of ^{238}U and ^{232}Th natural radioactive series. The highest activity of ^{212}Pb (77.11 keV) was found in soil sample 1. The highest activity of ^{212}Pb (238.63 keV) was found in soil sample 3. The highest activity of ^{228}Ac (338.32 keV) was found in soil sample 3. The highest activity of ^{208}Tl (583.19 keV) was found in soil sample 3. The highest activity of ^{208}Tl (860.56 keV) was found in soil sample 1. The highest activity of ^{214}Bi (1120.3 keV) was found in soil sample 1. The highest activity of ^{40}K (1461 keV) was found in soil sample 4. The concentrations of radionuclides contained in Kan Toke coal mine areas are not very high compared with IAEA standard, the samples have very small amount of radionuclides.

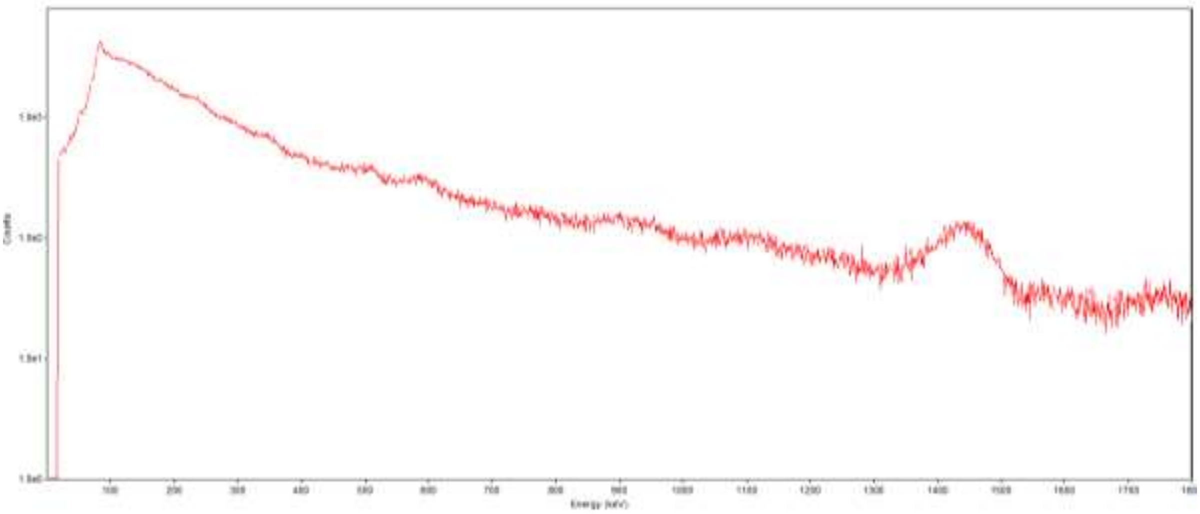


Figure 6 The energy spectrum of the background radiation

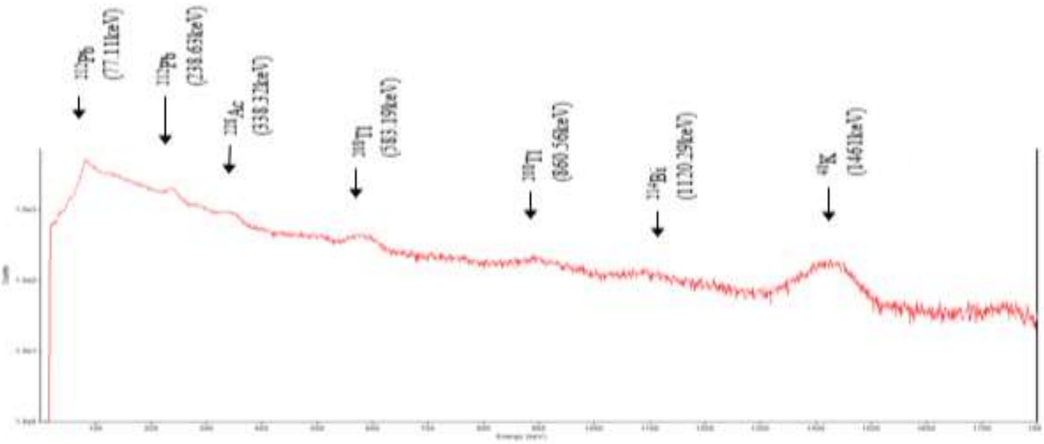


Figure 7 The energy spectrum of the soil sample 1

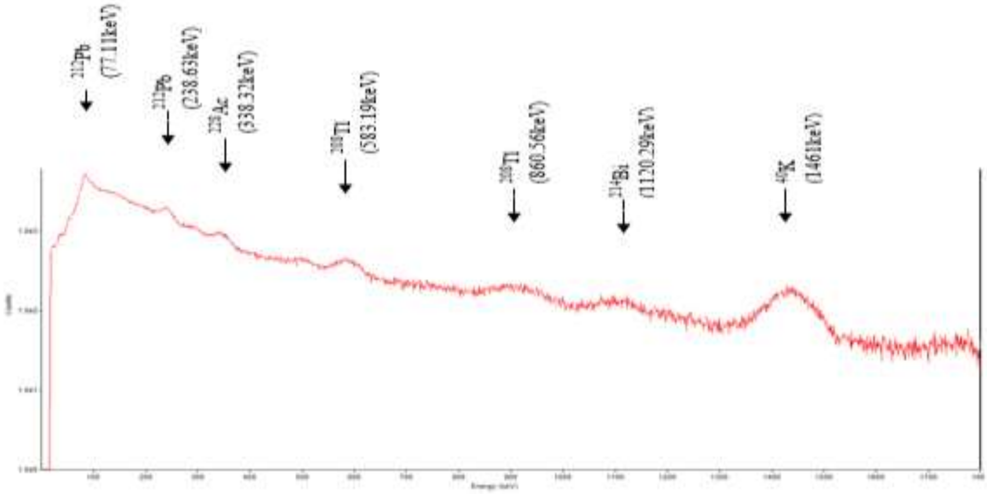
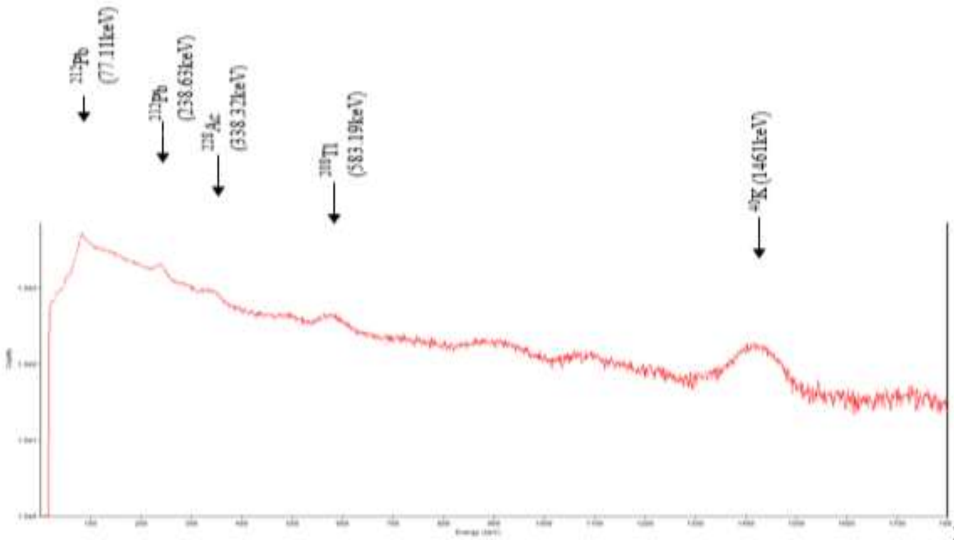


Figure 8 The energy spectrum of the soil sample 2



Figure

Figure 9 The energy spectrum of the soil sample 3

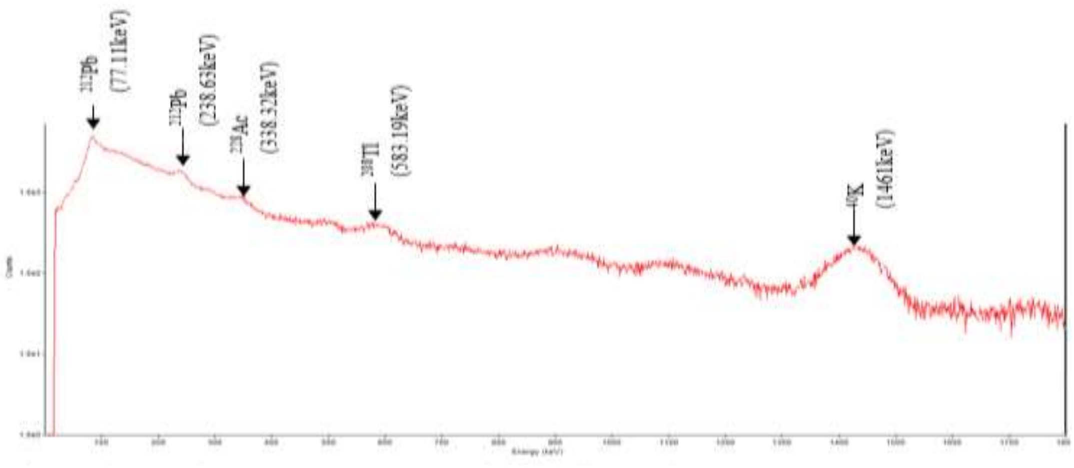


Figure 10 The energy spectrum of the soil sample 4

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