DETERMINATION OF RADIOLOGICAL HAZARDS WITH THE RADIOACTIVITY LEVELS OF SOIL IN THE INDUSTRIAL AREA, MANDALAY

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Abstract

The activities of naturally occurring radionuclides in five soil samples from the industrial area of Mandalay were calculated from experimental results which were obtained by using a NaI(Tl) detector. From these results, the percentage contribution of the radioactivity in the soil samples was shown with the greater percentage K-40 (81.08%), Ra-226 (10.29%) and Th-232 (8.63%). The calculated amounts of radionuclides were compared with their maximum admissible limits of UNSCEAR (2000). In order to assess the radiological hazards of the radioactivity in soil, radium equivalent activity, absorbed dose rate, external and internal hazard indices were calculated and the computed hazards were shown with average values of 228.33 Bq/kg, 106.26 nGy/h, 0.62 and 0.84 respectively. The present result was shown that the mean external and internal hazard indices value was less than 1.0, as recommended for safety globally (EC, 1999).

Keywords: Natural radioactivity, radiation hazards, soil, NaI(Tl) detector

Introduction

The spontaneous decomposition or disintegration of a nucleus forming a different nucleus and producing one or more additional particles is called Radioactivity. Natural radionuclide in soil contributes a significant amount of background radiation exposure to the population through inhalation and ingestion. The main contributors of radionuclides are ^{226}Ra, ^{232}Th and ^{40}K. Since these radionuclides in soil are not uniformly distributed and vary from region to region. The radioactivity concentration of these nuclides above permissible level is very harmful to the human body. Therefore, measurements of natural radioactivity in soil and the radiation doses are of great interest to the researchers which have led the nationwide surveys throughout the world. Naturally occurring radionuclides are known as to be present in varying proportions in rocks and soil of different geological formations around the world. Their concentrations and associated external doses in different environments depend on the geology and geographical conditions in such environments. Exposure to natural terrestrial radiation in the outdoor environment is predominantly from radionuclides that are present in the upper 30 cm layer of the soil. Human exposure pathways include: root uptake from contaminated soil, direct ingestion of radionuclides deposited on plant leaves, consumption of water animals, ingestion of contaminated water, inhalation of soil dust, and the direct exposure to gamma ray emitted from primordial radionuclides in the indoor and outdoor environments, etc.

Soil pollution, also known as soil contamination, is caused by man-made, harmful chemicals penetrating the earth and causing deterioration. There are many health risks associated with soil pollution, through direct contact with the soil or from air contaminants. Whether it's in industrialized countries where soil pollution has regulations, or in developing countries with no such capabilities, the matter of soil pollution is a major problem.

The present study area lies within the sub-humid tropical zone and soil samples were randomly collected from five different locations in Industrial Zone, Mandalay. The aim of the

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present work is to search the possibility of uranium deposition as ore and health risk assessment associated with thorium and potassium in the study area. This work was undertaken to measure the activity concentrations and γ-ray absorbed doses of the naturally occurring radionuclides in soil samples of industrial zone. Moreover, another aim of the present work is to create the public awareness about the radiation hazards and the workers those who are working in this area. This study will also be helpful to establish a research base line in this area.

Theoretical Background

Efficiency of a Detector

The efficiency of a detector is the proportionality constant which relates the activity of the source being counted and the number of counts observed. This efficiency is calculated by using the following relation

$$\varepsilon = \frac{N_A}{A_t\, t P_\gamma} \qquad (1)$$

where, ε = detector efficiency, N_A= the net area of the full energy peak, A_t = the present activity of the standard sources, t = counting time, P_γ=gamma emission rate

Activity Concentrations of Soil Samples

The activity concentrations of radionuclides in the samples were determined by well-known standard gamma ray spectrometry using a NaI(Tl) detector. The activity concentration of each radionuclide in the soil samples was calculated using the following equation.

$$A = \frac{N_A}{\varepsilon P_\gamma\, mt} \qquad (2)$$

where, A = activity concentrations of the sample in $Bqkg^{-1}$, N_A = the net area of the full energy peak, ε = detector efficiency, P_γ = gamma emission rate,

m = mass of the measured sample (in kg), t = counting time (in second)

Some Radiological Indices

(i) Radium Equivalent Activity

To represent the activity levels of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with each component, a common radiological index has been introduced (Diab et al., 2008). This index is called the Radium Equivalent Activity (Ra_{eq}) and is mathematically defined by (UNSCEAR, 2000):

$$Ra_{eq}=A_{Ra}+ 1.43A_{Th}+ 0.077A_K \qquad (3)$$

(ii) External Radiation Hazard Index

The model of the external hazard index (H_{ex}) places an upper limit to the external gamma radiation dose from building materials to unity, which corresponds to a radium equivalent activity of 370 Bq/kg. It is defined as:

$$H_{ex} = (A_{Ra}/370\ (Bq/kg) + A_{Th}/259(Bq/kg) + A_K/4810(Bq/kg)) \leq 1 \qquad (4)$$

(iii) Internal Radiation Hazard Index

Radon and its short-lived products are also hazardous to the respiratory organs. So, internal exposure to radon and its short-lived products is quantified by internal hazard index and is expressed mathematically as

$$H_{in} = (A_{Ra}/185 + A_{Th}/259 + A_K/4810) \leq 1 \quad (5)$$

(iv) Calculation of Absorbed Dose Rate (D)

Absorbed dose measures the energy deposited in a medium by ionizing radiation per unit mass, which may be measured as joules per kilogram when it is represented by the equivalent SI unit, gray (Gy). The external terrestrial gamma radiation absorbed dose in air at 1 m above the ground level is calculated by using the following equation (UNSCEAR 2000; Kurnaz et al. 2007):

$$D = 0.462\ A_{Ra} + 0.621\ A_{Th} + 0.0417\ A_K \quad (6)$$

where, A_{Ra}, A_{Th} and A_K are the mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively.

Materials and Methods

Description of the Study Area

This study was carried out with the industrial zones in Mandalay, Myanmar. Mandalay is located 21.97 latitude and 96.08 longitudes and it is situated at 83 meters above sea level. According to reports, over 1100 factories were situated in the Mandalay Industrial Zones. The study area is surrounded by factories.

Sample Collection and Preparation

Untreated soil samples (S-1) to (S-5) were collected randomly from five different locations of the industrial zone. The geographic location of the study area and the photograph of samples were shown in figure (1).

The top surfaces of the soils at all the soil sampling sites were scraped off to remove stones, vegetation and organic debris. Thereafter, the soil samples at each of the sites were collected at a depth of 15cm, thoroughly mixed and loaded in the polyethylene bags. The soil samples were sun dried and then carefully placed for drying at a room temperature to achieve a constant weight, then pulverized and sieved. 200 g of each sample which packed into a tightly closed plastic container and sealed with a tape, was stored for at least one month to ensure secular equilibrium.

Experimental Set Up and Procedure

The samples' radionuclide contents were measured and analyzed by Gamma-ray spectrometric measurements using NaI(Tl) scintillation detector (3"×3") connected to MCA and Gamma Vision 32 software. In this present work, coarse gain is 20, fine gain is 13 and conversion gain is 2048 with counting time 10800s. Firstly, the gamma ray spectrometer was be calibrated by using the four standard sources (Ba-133 (0.276 and 0.384MeV, 10.3 years), Co-60 (1.173 and 1.332MeV, 5.27 years), Cs-137 (0.622MeV, 30.07 years) and Na-22 (0.511MeV, 2.6 years)) with their activities 1μCi. The energy calibration curve as a function of channel number was shown in figure (2). This experiment work was performed at the Experimental

Nuclear Lab, University of Mandalay. The energy calibration was made using different point sources in the energy range 276 keV–1332 keV while the efficiency calibration of the detector was made using a 200 g mixed IAEA-448 soil standard containing ^{226}Ra, ^{214}Pb, ^{214}Bi and ^{228}Ac. The detector efficiency calibration curves as a function of energy was shown in figure (3).

Prior to measurement of samples, the environmental background radiation at the laboratory site was determined with an identical empty container used in the sample measurement with counting time 10800s. Next, each sample was placed in face to face geometry with the detector within the same period. The resultant spectra of each sample were recorded. Measurement condition was shown in figure (4). And then, this experiment was performed with keeping the samples one by one on the top of the detector.

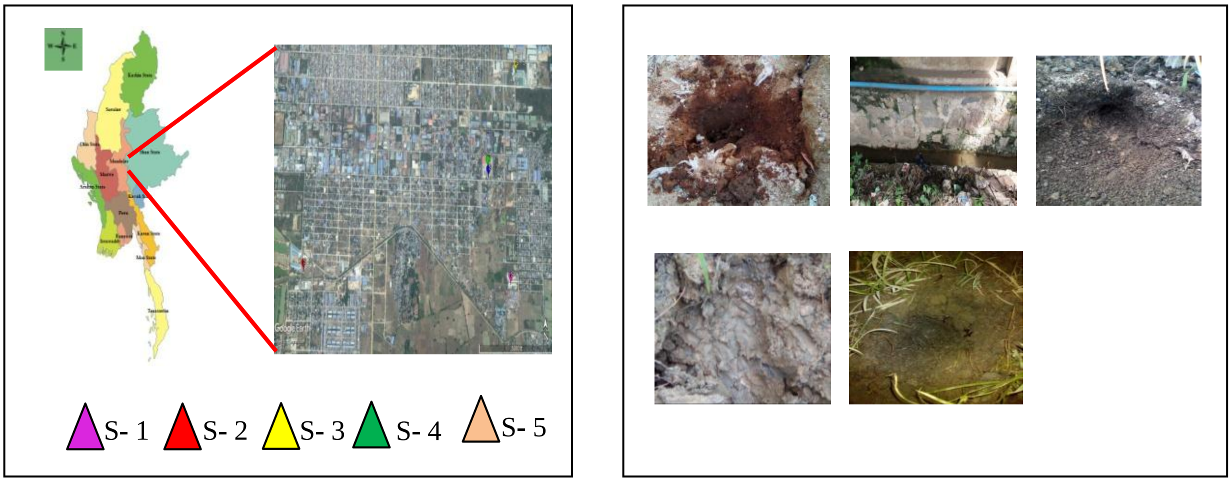

Figure 1 The geographic location of study area and the photographs of selected soil samples (S-1 to S-5)

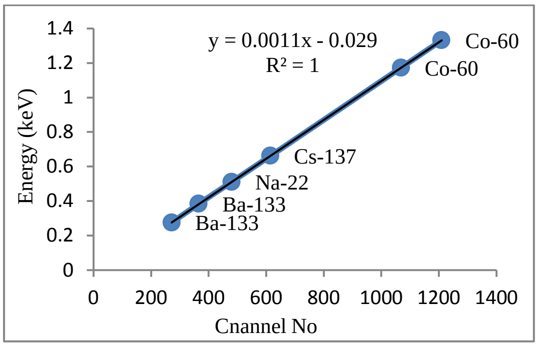

Figure 2 The energy calibration curve of NaI(Tl) detector

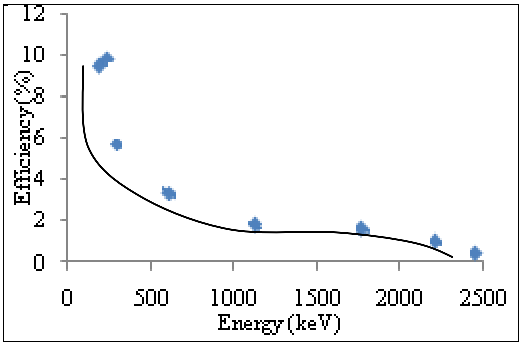

Figure 3 The efficiency curve of NaI(Tl) detector using IAEA-448 reference material

Figure 4 The measurement arrangement with the NaI(Tl) detector

Results and Discussion

The aim of the present work was to search the possibility of naturally occurring radionuclides deposition and health risk assessment associated with Th-232, Ra-226 and K-40 in the study area. From the gamma spectrometric analysis using Gamma Vision 32 software, activity concentrations of each observed naturally occurring radionuclides in the soil samples were calculated and then activity of Ra-226, Th-232 and K-40 were also determined from the results. In order to assess the health effects of each sample, the radiation hazards such as radium equivalent activity (Ra_{eq}), external (H_{ex}) and internal (H_{in}) hazard index, and absorbed dose rate (D) were calculated from the activities of Ra-226, Th-232 and K-40.

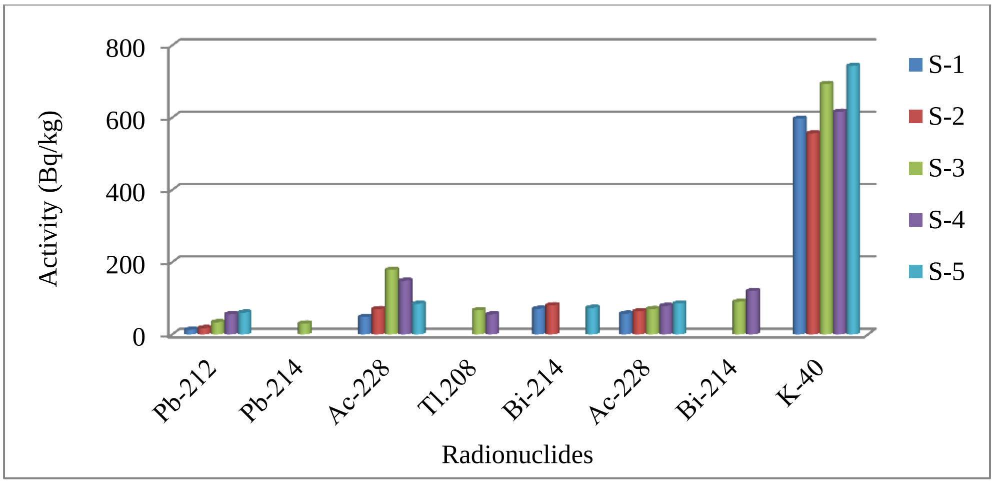

Figure 5 Comparison for natural radioactivities in soil samples at different locations for present study

Table 1 Calculated mean activity concentrations in soil samples

Sr.No	Sample Name	A_{Ra}(Bq/kg)	A_{th}(Bq/kg)	A_k(Bq/kg)
1	S-1	71.17±13.25	39.71±18.83	596.78±49.18
2	S-2	80.91±12.17	50.73±18.68	556.32±47.09
3	S-3	60.41±24.43	87.55±17.14	693.05±50.34
4	S-4	120.47±53.54	84.89±17.05	615.97±46.85
5	S-5	73.87±12.32	78.39±20.34	742.93±50.81
Minimum		60.41±24.43	39.71±18.83	556.32±47.09
Maximum		120.47±53.54	87.55±17.14	742.93±50.81
Average		81.366±23.14	68.254±18.41	641.01±48.85
Standard		35	35	420

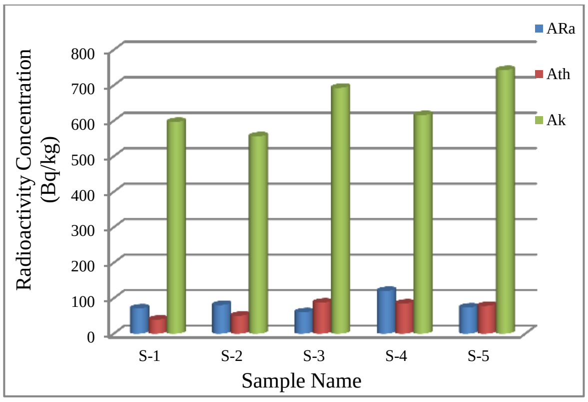

Figure 6 The variation of mean activity concentrations in soil samples

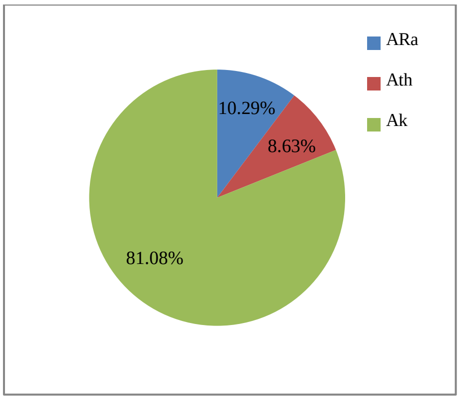

Figure 7 Percentage in mean activity concentrations in soil samples

The overall result was indicated that ^{40}K was contributed the most to the radionuclides content of soil while ^{232}Th contributes the least in the case. The results have shown that, for soil samples, the activity of Th-232 was ranged between (39.71 Bq/kg) to (87.55 Bq/kg), with the average value (68.25 Bq/kg), the activity of Ra-226 was ranged between (60.41 Bq/kg) to (120.47 Bq/kg), with the average value of (81.37 Bq/kg), while the activity of K-40 was ranged between (556.32 Bq/kg) to (742.93 Bq/kg), with the average value of (641.01Bq/kg). The Figure was shown the percentage contribution of the radionuclides in the soil samples with the greater percentage K-40 (81.08%), Ra-226 (10.29%) and Th-232 (8.63%).

Table 2 Calculated radiological hazards of the radioactivity in soil samples

Sr.No	**Sample Name**	**Ra_{eq} (Bq/kg)**	**H_{ex}**	**H_{in}**	**D(nGy h^{-1})**
1	S-1	173.91	0.47	0.66	82.01
2	S-2	196.29	0.53	0.75	91.69
3	S-3	238.97	0.65	0.81	110.69
4	S-4	289.29	0.78	1.11	133.63
5	S-5	243.17	0.66	0.86	113.27
Minimum		173.91	0.47	0.66	82.01
Maximum		289.29	0.78	1.11	133.63
Average		228.33	0.62	0.84	106.26
Standard		370	1.0	1.0	60

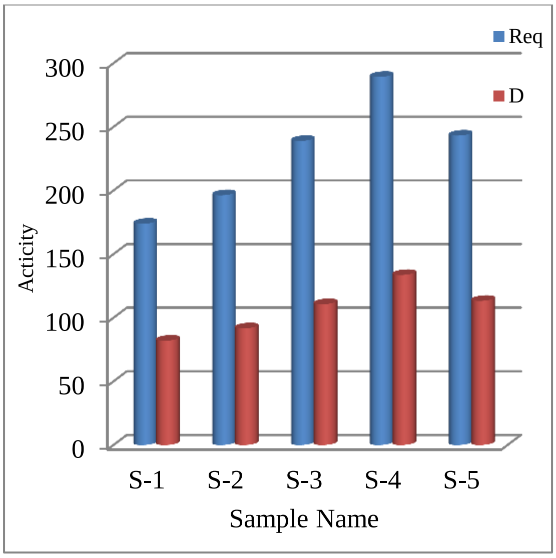

Figure 8 Comparison plot for concentration of Radium equivalent activity and absorbed dose rate of soil samples

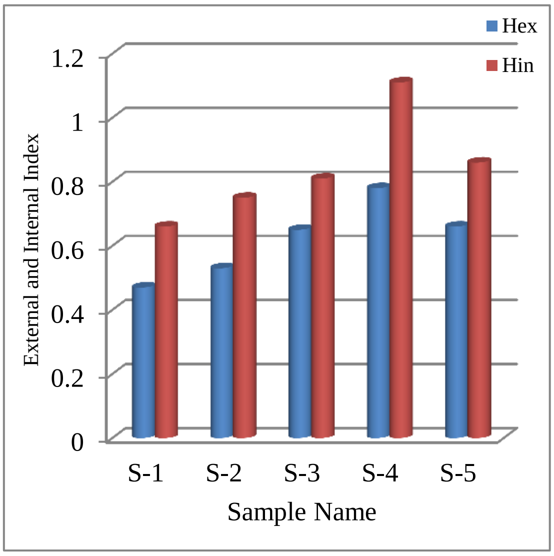

Figure 9 Variation of External and internal hazard index of soil samples

The highest radium equivalent activity and absorbed dose rate were obtained to be 289.29 and 133.63 while the lowest were 173.91 and 82.01. The mean values were calculated to be 228.33 and 106.26. Furthermore, the highest external and internal hazard index were obtained to be 0.78 and 1.11 while the lowest were 0.47 and 0.66. The mean value was calculated to be 0.62 and 0.84.

Conclusion

This present study was evaluated the activity concentrations of radionuclides and hazard indices for soil in the industrial area of Mandalay with the use of gamma spectrometer. These data was shown that the activity concentration of naturally occurring radionuclides in soil samples was within the world average range which are 420(100-700) Bq/kg for K-40 but that of Ra-226 and Th-232 were slightly higher than the range [35(10-50) and 35(7-50)] respectively (UNSCEAR, 2000). The slight variation of the radioactivity content in soil with different locations was mainly observed due to soil type, formation and transport process involved in the study area. The average radium equivalent activity in all samples was below the standard recommended values except for absorbed dose rate. But, the external and internal hazard indices were also found less than unity [European Commission on Radiation Protection (EC,1999)] which indicates that there is no probability of immediate health effect on workers and public due to natural radioactivity present in the samples of the study area and the radiation exposure of the people in this area from the surface soils does not pose any negative radiological effect on them and their environs. So, it is concluded that this present work was only established the information on the natural radioactivity status of only five locations in industrial area and other soil properties should also be considered in further research studies for all soil samples.

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