Journal of Nuclear and Particle Physics 2013, 3(3): 40-44
DOI: 10.5923/j.jnpp.20130303.03

Radiological Risk Analysis of Soil inside the Ship Breaking Area, Chittagong, Bangladesh

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Abstract The radioactivity of naturally occurring and anthropogenic radionuclides in soil collected from the ship breaking areas VHATIARY SHIP BREAKERS LTD. and ZIAN SHIP BREAKING LTD. Chittagong. Bangladesh, were measured by using gamma spectrum of germanium detector coupled with digital spectrum analyzer (DSA). In the present work, the radioactivity of ^{238}U in soil samples ranged from 49.60±2.14 Bq.kg^{-1} to 14.00± 1.19 Bq.kg^{-1} with an average value of 23.66±1.55 Bq.kg^{-1}. The activity ^{232}Th ranged from 41.52±5.73 Bq.kg^{-1} to 22.79±1.42 Bq.kg^{-1} with an average activity of 34.33±3.57 Bq.kg^{-1}. For ^{40}K, radioactivity ranged from 845.74±76.39 Bq.kg^{-1} to 620.39±36.91 Bq.kg^{-1} with an average activity of 702.32±50.34 Bq.kg^{-1}. The activity concentration of ^{137}Cs was not found in any sample at the ship breaking area. It is clear from the experiment that the specific activity of natural radionuclide ^{40}K and radiological hazard parameters like dose rate, radium equivalent activities and representative level index in above mentioned ship breaking areas are high compared with world average and there were no anthropogenic radionuclides present in the investigated ship breaking areas. The finding experimental data of this work would be useful to assess the population exposure from radionuclides in soil as well as base line data of natural radioactivity for the Chittagong ship breaking area.

Keywords Environmental radioactivity, Specific radioactivity, HPGe Gamma-ray spectrometry, Environmental materials, Radium equivalent activity, Gamma absorbed dose rate, Annual effective dose rate

1. Introduction

The importance of radiation risk caused by natural radioactivity was first underlined in the European Council Directive 96/29EURATOM which set forth basic safety standards for the protection of the health of workers and the general public against the danger arising from ionizing radiation. Since this directive came into effect, a lot of research on this matter has been carried out. The occupational hazards in some Naturally Occurring Radioactive Material (NORM) have been quite well-identified[1]. However, the use of anthropogenic radioactivity standards, which were clearly defined in a regulatory context often ignored the natural causes of radioactivity or assessed them on a case by case basis resulting in the substantial understatement of the risk from those other sources of radiation. Finally, the potential detrimental effect on the environment of NORM is rarely taken into consideration when an environmental risk assessment (ERA) is carried out[2]. The present trend of environmental radioactivity study has come forward to save human life from the effects of atomic radiation originating from NORM and anthropogenic radionuclides of nuclear activities. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions, and appear at different levels in the soils of each region in the world [4, 5, 6]. It is important to make studies on distribution of various radionuclides present in the soil and the different factors that distribute the various radionuclides from soil to food chain and their subsequent transfer to the human body. So, for the assessment of radiation hazard in Bangladesh, it is essential to determine the concentration of terrestrial radionuclides throughout the country. As a part of it, this study was conducted at the ship breaking yards. Ship breaking activities in Bangladesh is concentrated in Sitakund (Bhatiary to Barwalia), just north of Chittagong city on the Bay of Bengal. It is of paramount importance to the macro and micro economies of poverty stricken Bangladesh. Ship breaking activities present both challenges and opportunities for our coastal zone management. Meeting the increasing demand for raw materials such as steel needs to be balanced with the negative impact this nag on our coastal environment and the conditions of the workers. On average 180-250 old ships each year are scrapped in about 30 ship breaking yards located in this coast. Around 200,000 people are engaged in different business related to the ship breaking activity. This

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Published online at http://journal.sapub.org/jnpp

research work found out the distribution of different radionuclides in soil of these ship breaking yards and thereby assessed the radiation hazard. So, this work will be valuable in the development of rules and regulation for the health and environmental safety in the ship breaking industry.

2. Materials and Methods

2.1. Sample Collection and Preparation

In order to determine the radioactivity of naturally occurring and anthropogenic radionuclides in the soil, a total number of 12 samples were collected from Ship Breaking Area, Chittagong, Bangladesh. All samples were collected from two yards, ZIAN SHIP BREAKING LTD. and VHATIARY SHIP BREAKERS LTD. Intervel and the locations are shown in the Figure-1.

Figure 1. Goggle map shows the ship breaking yard from where the samples were collected

All the solid and powdered samples were air dried under laboratory temperature. All solid samples were cleaned and dried at about 120°C in the electric oven for about 24 hours to remove added moisture and thereafter crushed to fine powder with mortar and pestle. Each of the samples was transferred to sealed cylindrical plastic container of diameter 7 cm and 3.5 cm in height, marked individually with identification parameter such as name and the location of the sample, date of preparation and net weight. All the samples containers were sealed tightly with cap and wrapped with Teflon and thick vinyl tapes inside and outside around their screw necks and finally air tightened with polythene pack and stored for minimum four weeks to allow for the attainment of secular equilibrium between the long lived ^{238}U and ^{232}Th and their short lived progeny [7,8].

2.2. Radioactive Analysis of Soil Samples

Since most of the radio-nuclides are gamma emitters, gamma spectroscopy can reveal dominant sources of radioactivity. A high purity germanium (HPGe) detector was used to record the gamma ray emissions from the soil samples. This gamma detector was coupled with a digital spectrum analyzer, DSA-1000, which provided a full featured multichannel analyzer of 16K channel based on digital signal processing techniques. Canberra's Genie-2000 spectroscopy software was used to record and analyze the gamma ray spectra of soil samples. Determination of counting efficiency and calibration were done by using the standard samples provided by the International Atomic Energy Commission (IAEA); these reference samples were RGU-1 for ^{238}U series, RGTh-1 for ^{232}Th series, RGK-1 for ^{40}K and IAEA-152 for ^{137}Cs. Figure-2 shows the energy efficiency curve:

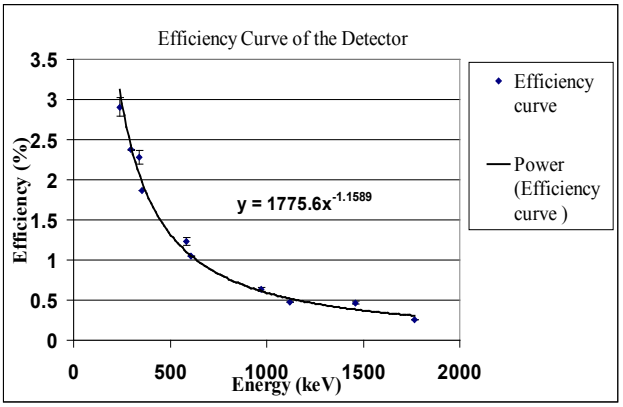

Figure 2. Energy efficiency curve of HPGe detector

The detector was placed inside a massive lead shield in order to reduce the background radiation. After adjustment of the necessary parameters such as resolution, peak to Compton ratio etc, and measurement of minimum detectable activity of the detector, each of the collected samples were placed on the top of the detector within the shielding arrangement [9]. Moreover, a background spectrum was recorded for 20,000 seconds for a blank sample container of the same geometry of the detector. This background reading was subtracted from the sample reading to determine the net count originated from the sample [7]. Gamma spectrum for each soil and reference sample was also recorded for 20,000 seconds. Since each soil sample was kept hermetically for more than one month, analysis of gamma spectrum was done on the assumption of secular equilibrium state in ^{238}U and ^{232}Th series. Activity of ^{238}U radionuclide was determined from the observed counts at gamma energies 241.98 keV, 295.21 keV and 351.92 keV emitted by the daughter nuclide ^{214}Pb and also at energies 609.31 keV, 1120.29 keV and 1764.49 keV emitted by the another daughter ^{214}Bi. For the

radionuclide ^{232}Th, counts at energies 238.63 keV of ^{212}Pb, 338.40 keV, 911.07 keV and 969.11 keV of ^{228}Ac and 583.19 of ^{208}Tl were used. Gamma peaks at energies 1460.75 keV and 661.66 keV, respectively, were used for the determination of activities of ^{40}K and ^{137}Cs. Then the activities were calculated by using the formula:

$$\text{Activity} = \frac{CPS \times 100 \times 1000}{\%Eff. \times I \times Sampleweight(gm)} \quad (1)$$

Where, CPS = Net counts per second

% Eff. = Efficiency of the gamma energy.

I =Intensity of the measured gamma from the radio-nuclide.

3. Results and Discussion

3.1. Activity Concentrations

Table 1. The activity concentrations of natural radionuclides ^{238}U, ^{232}Th and ^{40}K in the soil samples

Sample ID	U-238 Bq/Kg	Th-232 Bq/Kg	K-40 Bq/Kg	Cs-137 Bq/Kg
S-01	22.50±1.49	35.32±2.32	639.07±42.80	ND[1]
S-02	15.00±1.41	38.61±2.56	690.25±48.09	ND
S-03	16.55±1.45	41.52±2.60	648.76±47.80	ND
S-04	14.00±1.33	31.69±2.34	716.67±45.83	ND
S-05	37.52±1.68	36.13±1.42	706.16±36.91	ND
S-06	15.5±1.23	30.78±3.65	845.74±39.67	ND
S-07	20.77±1.55	37.45±5.02	638.05±47.77	ND
S-08	19.04±1.19	22.79±4.39	691.60±46.90	ND
S-09	26.39±1.66	31.12±5.02	691.03±48.19	ND
S-10	22.56±1.58	27.42±4.87	620.38±47.58	ND
S-11	49.60±2.14	39.33±5.73	798.57±76.39	ND
S-12	24.48±1.92	39.76±2.92	741.55±76.15	ND
Average	23.66±1.55	34.33±3.57	702.32±50.34	ND

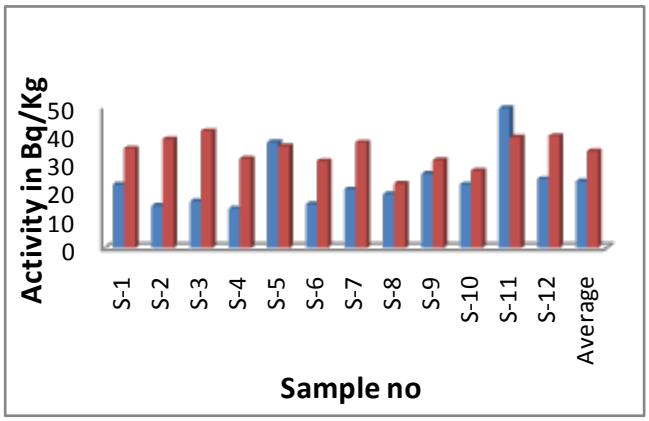

Figure 3. Activity concentration of U-238 and Th-232 in different soil sample

The measured activity concentrations of natural radionuclides ^{238}U, ^{232}Th and ^{40}K in the soil samples are given in Table-1. The study shows that the highest activity of ^{238}U was found to be 49.60±2.14Bq.kg^{-1} in sample no- 11, lowest in sample no-4, was 14.00±1.33 Bq.kg^{-1} with an average activity of 23.66±1.55 Bq.kg^{-1}. The highest activity of ^{232}Th was found to be 41.52±5.73 Bq.kg-1 in sample no-03, lowest in sample no- 8, was 22.79±1.42 Bq.kg^{-1} with an average activity of 34.33±3.57 Bq.kg^{-1}. The highest activity of ^{40}K was found 845.74±76.39 Bq.kg-1 in sample no-06, lowest in sample no-10, was 620.39±36.91 Bq.kg^{-1} with an average activity of 702.32±50.34 Bq.kg^{-1}. And figure-3 represents the activity concentration of ^{238}U and ^{232}Th in different soil sample. Figure -4 compare the measured values of natural radionuclides with world average values.

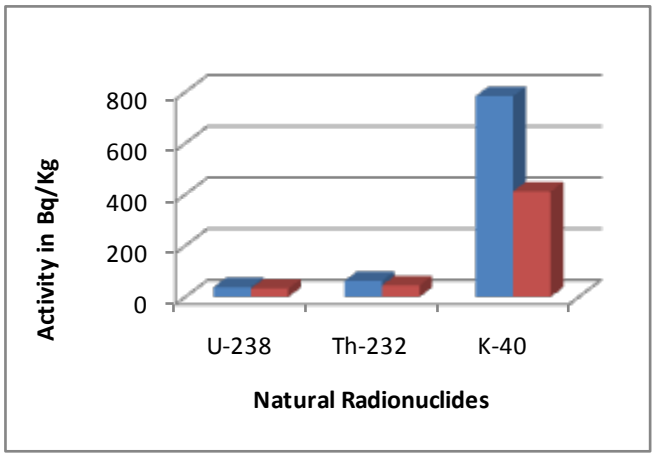

Figure 4. Comparison of natural radionuclides with world average values

3.2. Radiation Hazard Parameters

3.2.1. The outdoor gamma ray exposure rate in air at one meter height above the ground due to natural radionuclides in soils was calculated by the following formula [3]:

$$D\ (nGyh^{-1}) = 0.462A_U + 0.604A_{Th} + 0.0417A_K \quad (2)$$

Where, A_U, A_{Th}, *and* A_K are the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively in soils in units of *Bq/kg*. This dose rate is found in the range of 79.97±7.64 nGyh^{-1} to 51.40±3.17 nGyh^{-1} with an average of 60.95±4.97 nGyh^{-1} which is greater than the world value 59 nGyh^{-1}[11].

3.2.2. To estimate the annual effective dose rates, the conversion coefficient from absorbed dose rate in air (D_{air}) to effective dose (0.7) and outdoor occupancy factor (0.2) proposed by UNSCEAR (2008) were used. The effective dose rate (mSv/a) was calculated using the formula [12]:

$$H\ (mSv/a) = D_{air} \times 0.7 \times 0.2 \times 24 \times 365 \times 10^{-6} \quad (3)$$

The resulting average of annual effective dose is 0.07±0.01 mSv/a with ranges from 0.10±0.01 mSv/a to 0.06±0.001 mSv/a. while the world average annual effective dose is 0.07 mSv/a [11].

3.2.3. For the estimation of radiation hazards due to natural radio-nuclides it is now common practice to calculate the radium equivalent activity (Ra_{eq}) and representative level index ($I_{\gamma r}$) using the following equation[13]:

$$Ra_{eq}\ (Bq/kg) = A_U + 1.43A_{Th} + 0.077A_K \quad (4)$$

$$I_{\gamma r}\ (Bq/kg) = (1/150)\ A_U + (1/100)\ A_{Th} + (1/1500)\ A_K) \quad (5)$$

[1] ND=Not detected

Table 2. The values of outdoor dose rate, annual effective dose, radium equivalent activities and representative level index in smples

Sample ID	D (nGy/h)	H (mSv/a)	Ra_{eq} (Bq/kg)	$I_{\gamma r}$ (Bq/kg)
S-1	58.37±3.88	0.07	122.11±8.11	0.93±0.06
S-2	59.03±4.20	0.07	123.24±8.76	0.95±0.07
S-3	59.77±4.23	0.07	125.77±8.84	0.96±0.07
S-4	55.49±3.94	0.07	114.40±8.20	0.89±0.06
S-5	68.60±3.17	0.08	143.45±6.55	1.08±0.05
S-6	61.04±4.43	0.07	124.58±9.50	0.98±0.07
S-7	58.82±5.74	0.07	123.36±12.39	0.94±0.09
S-8	51.40±5.16	0.06	104.79±11.07	0.82±0.08
S-9	59.80±5.81	0.07	124.00±12.53	0.95±0.09
S-10	52.85±5.66	0.06	109.45±12.20	0.84±0.09
S-11	79.97±7.64	0.10	167.21±16.20	1.26±0.12
S-12	66.25±5.83	0.08	138.32±11.95	1.06±0.09
Average	60.95±4.97	0.07	126.72±10.53	0.97±0.08

Table 3. Comparison of results of the present study with corresponding world average values worldwide value and regional study

Radiological Parameters	Present Study	Regional study[15]	World average[3, 11,14]
U-238 in Bq/Kg	23.66±1.55	37.9±20	33
Th-232 in Bq/kg	34.33±3.57	65.9±12.2	45
K-40 in Bq/kg	702.32±50.34	272±35	412
Radium equivalent activity, Raeq	126.72±10.53	151±39	89
Representative level index, $I_{\gamma r}$ (Bq/kg)	0.97±0.08	1.08±0.27	0.66
Outdoor dose rate, D (nGy/h)	60.95±4.97	70.78±18.26	59
Annual effective dose rate, H (mSv/a)	0.07	------	0.07

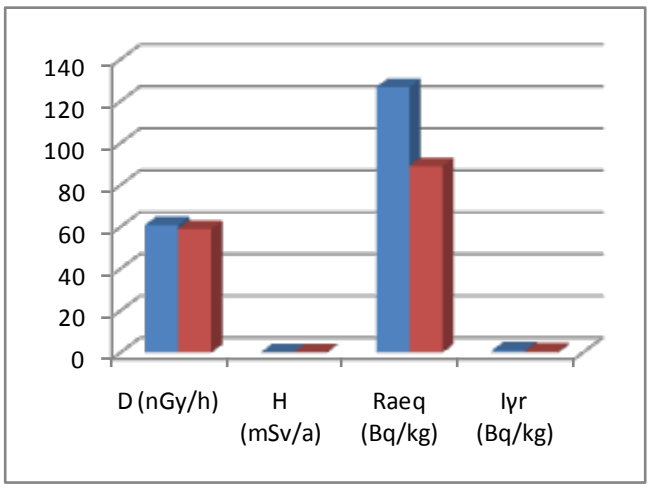

Figure 5. Comparison of radiological hazard parameters values with world average value

Table 4. Comparison of the measured mean specific activities of natural radionuclides in soil samples with the values reported for various countries in literature

Name of country	Mean specific activity (Bq kg^{-1})		
	^{238}U	^{232}Th	^{40}K
United States[11]	40	35	370
China[11]	32	41	440
India[11]	29	64	400
Japan[11]	33	28	310
Iran[11]	28	22	640
Denmark[11]	17	19	460
Belgium[11]	26	27	380
Switzerland[11]	40	25	370
Poland[11]	26	21	410
Romania[11]	32	38	490
Greece[11]	25	21	360
Portugal[11]	44	51	840
Bangladesh[18]	30.93	61.65	467.8
Bangladesh (Dhaka)[17]	33	16	574
Bangladesh (Ship yards)[16]	31	63	364
Worldwide mean[3]	33	45	412
Bangladesh (Present work (ship yard))	23.66	34.33	702.32

Where A_U, A_{Th} and A_K are the specific activities of ^{238}U, ^{232}Th and ^{40}K (in $Bq.kg^{-1}$) respectively . The resulting average of radium equivalent activity (Ra_{eq}) is 126.72±10.53 $BqKg^{-1}$ with ranges from 167.21±16.20 $BqKg^{-1}$ to 104.78±6.55 $BqKg^{-1}$. And the resulting average of representative level index ($I_{\gamma r}$) is 0.97 $BqKg^{-1}$ with ranges from 1.26 $BqKg^{-1}$ to 0.82 $BqKg^{-1}$.

The above values for each sample are shown in the table-2 given below. And comparisons of these values with world average as well as regional study and with other countries are shown in figure-5, table-3 and table-4 respectively.

4. Conclusions

The activity concentrations of natural radionuclides ^{238}U, ^{232}Th and ^{40}K in the soil samples are 23.66±1.55 $Bq.kg^{-1}$, 34.33±3.57 $Bq.kg^{-1}$ and 702.32±50.34 $Bq.kg^{-1}$. Present study shows that the activity concentrations of ^{40}K are greater than the value of the world average (412 $Bq.kg^{-1}$ for ^{40}K) [3]. Also the value of outdoor dose rate, radium equivalent activities and representative level index are higher than the world average value. There are no fallout radionuclides ^{137}Cs. The increasing trend of ^{40K} is due to the presence of loamy and clay sediments [19] and may be due to the high content of monazite [20].

The obtained data cover a wide area in ship breaking area of Chittagong. The mean concentrations of the radionuclides ^{238}U, ^{232}Th and ^{40}K in soil samples determined in this study compare suitably with literature values. But the ^{137}Cs activity concentrations of all places are below the detectable range. This study can be used as a

baseline for future investigations and the data obtained in this study may be useful for natural radioactivity mapping. It seems necessary to determine the radioactivity concentrations in soils and sediments of other parts of Chittagong, Bangladesh. The results may also be used as a reference data for monitoring possible radioactivity pollutions in future.

ACKNOWLEDGEMENTS

Authors are grateful to M. Kamal, director of the Radioactivity Testing and Monitoring Laboratory, Chittagong for his valuable suggestions in this study.

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