Volume 18, No 3 | International Journal of Radiation Research, July 2020

Natural gamma radiation level detection in agriculture soil after Aila disaster and comparison with deep soil gamma activity in a specific area of Sundarban region, Satkhira, Banglsdesh

Sk.A.K. Arafin[1*], A. El-Taher[2], A.K.M. Fazlul Hoque[3], M. Ashraful Hoque[4], J. Ferdous[4], M. Joynal Abedin[5]

[1]Department of Natural Sciences, Faculty of Science and Information Technology, Daffodil International University, Sukrabad, Dhaka-1207, Bangladesh
[2]Department of Physics, Al-Azhar University, Faculty of Science, Assuit 71452, Egypt
[3]Office of the Registrar, Daffodil International University, Sukrabad, Dhaka-1207, Bangladesh
[4]Health Physics Division, Atomic Energy Centre, Dhaka, Bangladesh
[5]Accelerator Facilities Division, Atomic Energy Centre, Dhaka, Bangladesh

► ***Original article***

***Corresponding authors:**
Dr. Sk. Abdul Kader Arafin,
E-mail:
skak_arafin@daffodilvarsity.edu.bd

Revised: July 2019
Accepted: August 2019

Int. J. Radiat. Res., July 2020; 18(3): 397-404

DOI: 10.18869/acadpub.ijrr.18.3.397

ABSTRACT

Background: The present work was conducted on some soil samples collected from Shamnagar upazila of Satkhira district of south-west part of world largest mangrove forest Sundarban Rezion, Bangladesh which were affected by natural disaster cyclone Aila. ***Materials and Methods:*** The soil samples were analyzed to determine terrestrial γ-ray activity using HPGe γ-ray spectrometry. The measurements conducted in the current study showed that primordial radionuclides namely the ^{238}U and ^{232}Th and ^{40}K are contained in all the soil samples. ***Results and Discussion***: The obtained results of the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K were found to be within the range of the world average of 17-60, 11-64, 140-850 $Bq.kg^{-1}$ reported by UNSCEAR. The radiation dose is below the permissible limit of $1mSvy^{-1}$ recommended by IAEA (2007). No peak of ^{137}Cs from the decay activity was found in the spectrum in the present work. ***Conclusion:*** The present work will be useful in providing environmental monitoring data base of those particular areas.

Keywords: *Disaster, Aila, health, natural radiation.*

INTRODUCTION

Ionizing radiation and its impact in health is one of the great concern to the health concern people now a days. The environment is rapidly changing its nature especially the coastal areas time to time when the natural disaster like Sidor, Aila, etc are striking on coastal areas. Most of the government and non-governmental agencies try to calculate the prompt damage of the property and human condition. Scientific community and regulatory entities, concern was raised regarding the distribution of contaminants as a result of the natural disaster (Aila) in the environmental ingredients like soil, water, air, plants and vegetables, etc and the subsequent increased potential exposure and potential health hazards to residents of the area of concern. Natural or background radiations are also great issues for human health. International Atomic Energy Agency (IAEA) and Environmental Protection Agency, America (EPA) published a guideline to follow the natural radiation exposure to human health. Soil and sediment are great sources of natural radiation exposure. Sources of radiation may also transfer into our food and biological chain from soil causing further health hazards [1-7]. Human beings are exposed outdoors to the natural radiation that originates predominantly from the upper 30 cm of the soil [8]. Only radionuclides with half-lives comparable with the age of the earth or their corresponding decay products existing in terrestrial material such as ^{232}Th, ^{238}U and ^{40}K are of great interest. Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soil and rock plays an important role in radiation protection and measurement [9-10]. Every day, people inhale and ingest radionuclides from air, food and water. They are also exposed to natural radiation from cosmic rays, particularly at high altitude. On an average, 80% of the annual dose that a person receives from background radiation is due to naturally occurring terrestrial and cosmic radiation sources [11]. If the dose is low or is delivered over a long period of time (low dose rate), there is greater likelihood for damaged cells to successfully repair themselves. However, long-term effects may still occur if the cell damage is repaired but incorporates errors, transforming an irradiated cell that still retains its capacity for cell division. This transformation may lead to cancer after years or even decades have passed [12]. This risk is higher for children and adolescents, as they are significantly more sensitive to radiation exposure than adults. Epidemiological studies on populations exposed to radiation showed a significant increase of cancer risk at doses above 100 mSv [13]. After some incident like Fukushima, Japan, voice is raising from some of the corners that the natural radiation level is increasing in see water. Hence humans should be aware of their natural environment with regard to the radiation effects due to the naturally occurring and induced radioactive elements the level of exposure to radiation needs to be ascertained. Also knowledge about the distribution of radioactivity present in natural materials enables one to assess any possible radiological hazard to humankind by the use of such materials. The aim of present study was focused on determining the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for soil from Sundarban Region, Satkhira, Bangladesh, and calculation of the radiation hazard parameters.

MATERIALS AND METHODS

To determine the natural radioactivity level of some selected place of Aila affected Shamnagar Upazila, Satkhira, Bangladesh. Shamnagar Upazila, Satkhira is located in between 21°36' and 22°24' north latitudes and in between 89°00' and 89°19' east longitudes shown in figure 1. In total 21 soil samples were collected from 3 Unions namely Gabura, Padma Pukur and Buri Goalini of that Upazila are shown by yellow dot on the map. Where 16 of them were from the agriculture level of soil and 5 of them were from deep soil. 16 soil samples were collected from 5 to 20 cm depth to avoid the very recent upper surface soil and dust deposition and to ensure the cultivated soil for agricultural purpose. For ensuring the homogeneity of the soil a considerable amount of soil was collected from each location. After that each collected soil was mixture properly and a proportionate amount finally preserved for research purpose. Additionally 5 soil samples were collected from a depth of 130 cm to 150 cm. All the samples were used for the analysis of radioactivity level determination. All the soil samples were dried at 80 °C into a temperature controlled electric oven for a week (198 hours). Then the dried samples were mashed by using an agate motor and hand grandeur. The physical and machine work was done at the Health Physics Division (HPD) of Atomic Energy Center Dhaka (AECD). The dried powder soil samples were taken into individual cylindrical plastic container of geometry ~154 cm^2 (7 cm in diameter and 4 cm in height). The soil samples of each container were simply shaken by hand to allow the powder homogenously settle down in the container. The weight of empty plastic container was measured by a digital electronic balance and thereafter the dried sample was placed into the container and total weight was measured by the same balance. The net weight of sample was determined by simply subtracting the weight of empty plastic container from the one having the sample contained in it. Then the sample contained containers were sealed tightly and wrapped with 1 inch thick vinyl tapes around the screw necks to avoid the sample

[DOI: 10.18869/acadpub.ijrr.18.3.397]

coming in contact with air. For the assessment of radioactive level each sample was kept under incubation for 30 to 40 days and thus allowed radioactive secular equilibrium to happen between the long lived ^{238}U and ^{232}Th and their short lived progeny [14].

The samples were then prepared and irradiated for activity measurements. Before irradiation of the samples the efficiency of the HPGe detector was measured, because for the bulk samples detector efficiency could vary as it depends on the volume and the distance of the samples. In the present study a reliable efficiency vs energy curve for the HPGe gamma-ray detector was determined by measuring the known activity of the uranium standard reference materials (RGU-1), thorium standard reference materials (RGTh-1) and potassium standard reference materials (RGK-1) provided by the IAEA, Vienna [15].

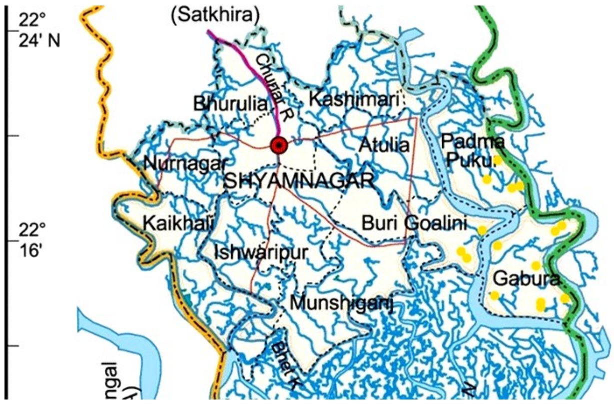

Figure 1. Map for sample collection location.

Radiological Hazards

Radium equivalent (Raeq)

The radium equivalent activity was used to obtain the sum of activities to compare the activity concentration of soil samples, which contain ^{226}Ra, ^{232}Th and ^{40}K. The equivalent activities of radium (Raeq) were calculated based on the estimate that 370 $Bqkg^{-1}$ of ^{226}Ra and 259 $Bqkg^{-1}$ of ^{232}Th and 4810 $Bqkg^{-1}$ of ^{40}K produced the same gamma dose rate; Raeq is given by Beretka and Mathew [16].

$$Raeq = A_{Ra} + 1.43A_{Th} + 0.077A_{k} \quad (1)$$

Where A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K ($Bqkg^{-1}$) respectively.

Absorbed gamma dose rate (D)

The absorbed dose rates due to gamma radiations in air at 100 cm above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were calculated based on guidelines provided by UNSCEAR [16]. The conversion factor used to compute dose rate (D) in air per unit activity concentration in $BqKg^{-1}$ (dry weight) corresponds to 0.462 $nGyh^{-1}$ for ^{226}Ra, 0.604 $nGyh^{-1}$ for ^{232}Th and 0.042 $nGyh^{-1}$ for ^{40}K. Therefore D can calculate as follows:

$$D = 0.462A_{Ra}+0.604A_{Th}+0.0417A_{K} \quad (2)$$

Where A_{Ra}, A_{Th} and A_K having the same meaning as in equitation (1).

External hazard index (Hex)

The external hazard index (Hex) was determined from the criterion formula as follow Where C_{Ra}, C_{Th} and C_K having the same meaning as in equitation (1).

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4180} \leq 1 \quad (3)$$

Internal and gamma hazard index

On the other hand, the internal hazard index (Hin) gives the internal exposure to carcinogenic radon and its short-lived, while gamma hazard index called the representative level index, $I_{\gamma r}$, is defined from the following formula [NEA, 1979], and it is given by the following equations Beretka and Mathew [16] Where C_{Ra}, C_{Th} and C_K having the same meaning as in equitation (1).

$$Hin = (CRa /185 + CTh /259 + CK /4810) \le 1 \quad (4)$$

$$I\gamma r = 0.0067\ ARa + 0.01\ ATh + 0.00067\ AK \quad (5)$$

RESULTS AND DISCUSSION

The total 21 samples (Surface soil: 16, Deep soil: 5) were collected for the measurement of specific radioactivity values from different Union of Shamnagar Upazila, Satkhira. The measured radioactivity values (Bq kg^{-1}) with uncertainties (± lσ) of the samples are given in table 1 and table 2 for deep soil and surface soil respectively. The activity values found for deep soil are: 28.84±2.83 - 47.81±4.27 (mean: 40.65±3.92), 39.83±3.72 - 62.56±1.14 (mean: 50.61±2.78) and 434.12±25.20 - 548.31±27.82 (mean: 476.62±24.51) Bq kg^{-1} in ^{238}U, ^{232}Th and ^{40}K respectively. Whereas the specific radioactivity values arising from ^{238}U, ^{232}Th and ^{40}K in the surface soil are found to vary within the range: 15.13±5.37 - 55.43±3.25, 16.86±4.37-62.32±2.14 and 213.64±21.34 - 572.25±25.81 Bq.kg^{-1}, having mean values 35.59±3.94, 37.69±3.92 and 398.73±24.19 Bq kg^{-1} respectively.

Table 1. Specific radioactivity values measured in soil samples of Shamnagar Upazila, Satkhira (Deep Soil).

Sl. No.	Sample ID	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})
1	Shamnagar (Deep)-1	38.54±5.28	62.56±1.14	438.10±23.09
2	Shamnagar (Deep)-2	47.81±4.27	57.25±2.13	456.76±24.36
3	Shamnagar (Deep)-3	40.70±2.52	39.83±3.72	504.79±22.10
4	Shamnagar (Deep)-4	28.84±2.83	50.53±4.37	434.12±25.20
5	Shamnagar (Deep)-5	47.36±4.71	42.88±2.53	548.31±27.82
	Average	40.65±3.92	50.61±2.78	476.62±24.51

Table 2. Specific radioactivity values measured in surface soil samples of different Unions in Shamnagar Upazila, Satkhira.

Sl. No.	Sample ID	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})
1	Shamnagar-1	48.75±7.33	49.87±4.71	348.41±23.56
2	Shamnagar-2	15.13±5.37	41.43±3.83	382.49±22.68
3	Shamnagar-3	32.12±2.81	40.07±5.36	572.25±25.81
4	Shamnagar-4	36.85±1.49	40.69±6.34	511.78±23.61
5	Shamnagar-5	25.52±3.21	16.86±4.37	240.50±21.61
6	Shamnagar-6	40.70±2.52	31.83±3.72	304.79±22.10
7	Shamnagar-7	41.32±4.14	31.94±2.33	437.44±21.37
8	Shamnagar-8	33.86±3.34	39.41±4.28	523.79±26.37
9	Shamnagar-9	27.14±3.84	41.94±3.80	267.38±23.16
10	Shamnagar-10	52.51±5.58	49.34±4.58	527.45±23.42
11	Shamnagar-11	27.39±3.33	24.16±2.24	358.41±23.79
12	Shamnagar-12	48.56±5.21	62.32±2.14	486.10±27.22
13	Shamnagar-13	25.47±2.51	43.82±3.57	313.71±23.29
14	Shamnagar-14	55.43±3.25	33.82±3.28	413.52±33.21
15	Shamnagar-15	31.22±7.79	31.73±3.51	478.01±24.51
16	Shamnagar-16	27.47±1.31	23.82±4.58	213.64±21.34
	Average	35.59±3.94	37.69±3.92	398.73±24.19

[DOI: 10.18869/acadpub.ijrr.18.3.397]

The activity of the samples differs possibly due to the difference in geological properties. In contrast, the activity concentrations of the 3 radionuclides in 5 soil samples collected both as surface soil and deep soil from Shamnagar show clear difference between the activity of surface soil and deep soil. The differences of their activity of naturally occurring radionuclides ^{238}U, ^{232}Th and ^{40}K are shown in table 3 and a comparisons are shown in figure 2.

The mean values of the presently measured specific radioactivity of ^{238}U, ^{232}Th and ^{40}K natural radionuclides in soil samples are compared with the corresponding reported data from different countries (17-27) in table 4.

Table 3. Comparison activity from ^{238}U, ^{232}Th and ^{40}K in surface soil and deep soil samples of Shamnagar, Satkhira.

Sl. No	Sample ID	^{238}U (Bq.Kg^{-1}) Surface Soil	^{238}U (Bq.Kg^{-1}) Deep Soil	^{232}Th (Bq.Kg^{-1}) Surface Soil	^{232}Th (Bq.Kg^{-1}) Deep Soil	^{40}K (Bq.Kg^{-1}) Surface Soil	^{40}K (Bq.Kg^{-1}) Deep Soil
1	Shamnagar -1	15.13±5.37	38.54±5.28	41.43±3.83	62.56±1.14	382.49±22.68	438.10±23.09
2	Shamnagar -2	40.70±2.52	47.81±4.27	31.83±3.72	57.25±2.13	304.79±22.10	456.76±24.36
3	Shamnagar -3	27.39±3.33	40.70±2.52	24.16±2.24	39.83±3.72	358.41±23.79	504.79±22.10
4	Shamnagar -4	25.47±2.51	28.84±2.83	43.82±3.57	50.53±4.37	313.71±23.29	434.12±25.20
5	Shamnagar -5	31.22±7.79	47.36±4.71	31.73±3.51	42.88±2.53	478.01±24.51	548.31±27.82
Average		27.98±4.30	40.65±3.92	34.59±3.37	50.61±2.78	367.48±23.27	476.62±24.51

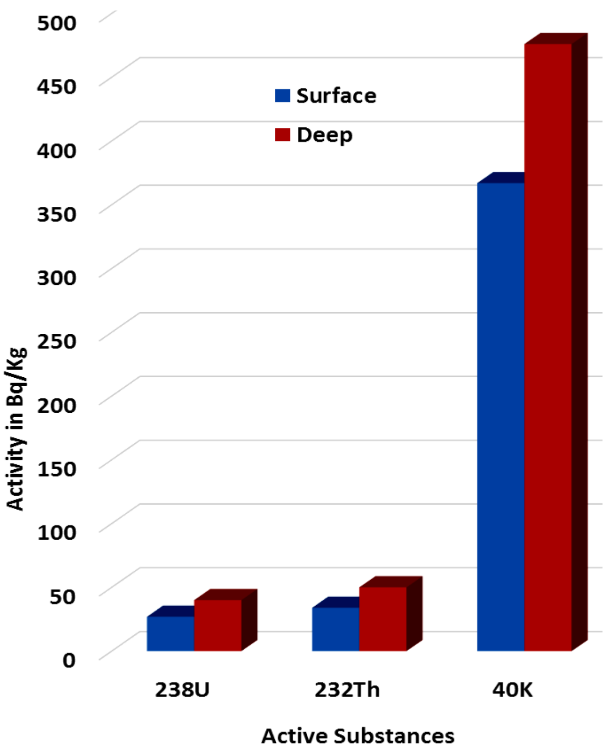

Figure 2. Comparison of average activity of ^{238}U, ^{232}Th and ^{40}K amongst the surface soil and deep soil samples of Shamnagar, Satkhira.

Table 4. Comparison of the measured mean specific radioactivities of natural radionuclides in soil samples with the values reported from various countries (17-27).

Shamnagar, satkhira (Present Study)	36	38	399	56
Bangladesh	34	41	350	-
Bangladesh (Dhaka)	33	16	574	-
Egypt	17	18	320	32
United States	40	35	370	47
China	32	95	440	62
Hong Kong SAR	59	64	530	87
India	29	64	400	56
Japan	33	-	310	53
Korea	-	22	670	79
Iran	28	19	640	71
Denmark	17	27	460	52
Sweden	42	42	780	-
Belgium	26	50	380	43
Ireland	60	26	350	-
Luxembourg	35	25	620	49
Switzerland	40	30	370	45
Bulgaria	45	21	400	70
Hungary	33	28	370	-
Poland	26	38	410	45
Slovakia	32	38	520	-
Romania	32	21	490	59
Greece	25	51	360	56
Portugal	44	33	840	84
Spain	32	33	470	76
Worldwide mean	33	36	474	54

[DOI: 10.18869/acadpub.ijrr.18.3.397]

It is worth mentioning that a clear difference between the radioactivities of surface soil with deep soil for 5 different samples of Shamnagar Upazila is observed (table 3 and figure 2) in the work.

The radium equivalent activity (Ra_{eq}), external γ-absorbed dose (D) and annual effective dose (AED) for Shamnagar Upazila were respectively 66.46±10.98 - 171.70±10.18 Bq/kg (mean: 117.34±11.11 Bq/kg), 32.07±5.03 - 80.49±4.84 nGy/h (mean: 55.95±5.20 nGy/h) and 65.49±10.27 - 164.36±9.89 μSv/yr (mean: 114.25±10.62 μSv/yr) respectively. External hazard index (H_{ex}), internal hazard index (H_{in}) and excess lifetime cancer risk (ELCR) in Shamnagar Upazila correspond to 0.18±0.03 - 0.47±0.03 (mean: 0.324±0.03), 0.245±0.04 - 0.57±0.03 (mean: 0.402±0.04) and 229.2 - 575.3 (mean: 399.9) respectively (table 5).

The calculated values of the external hazard index, internal hazard index, and excess lifetime cancer risk (table 6) are lower than the safe limits (<1) recommended by UNSCEAR-2000.

Table 5. Radium equivalent activity, external effective dose and annual effective dose at Shamnagar, Satkhira.

Sl. No.	Sample ID	Ra_{eq} activity in Bq kg^{-1}	External absorbed dose (D) in $nGyh^{-1}$	Annual effective dose (AED) in μSvy^{-1}
1	Shamnagar-1	144.45±15.71	67.27±7.22	137.38±14.74
2	Shamnagar-2	101.15±12.43	48.08±5.75	98.17±11.73
3	Shamnagar-3	129.48±12.28	63.07±5.62	128.80±11.48
4	Shamnagar-4	130.87±12.21	63.09±5.51	128.84±11.25
5	Shamnagar-5	66.46±10.98	32.07±5.03	65.49±10.27
6	Shamnagar-6	107.55±9.39	50.82±4.34	103.80±8.86
7	Shamnagar-7	117.62±8.97	56.75±4.22	115.89±8.61
8	Shamnagar-8	126.88±11.31	61.44±5.24	125.47±10.69
9	Shamnagar-9	105.83±10.90	49.10±5.04	100.26±10.30
10	Shamnagar-10	159.99±13.77	76.21±6.33	155.63±12.92
11	Shamnagar-11	87.03±8.20	42.30±3.89	86.37±7.94
12	Shamnagar-12	171.70±10.18	80.49±4.84	164.36±9.89
13	Shamnagar-13	110.09±9.25	51.41±4.29	104.97±8.77
14	Shamnagar-14	132.74±10.27	63.40±4.88	129.47±9.96
15	Shamnagar-15	110.05±14.53	53.66±6.75	109.58±13.78
16	Shamnagar-16	76.49±9.35	36.05±4.27	73.62±8.71
	Average	117.34±11.11	55.95±5.20	114.25±10.62

Table 6. External hazard index, internal hazard index and excess lifetime cancer risk at Shamnagar Upazila, Satkhira.

Sl. No.	Sample ID	External hazard index, H_{ex}	Internal hazard index, H_{in}	Excess lifetime cancer risk (ELCR) x 10^{-6}
1	Shamnagar-1	0.40±0.04	0.51±0.06	480.5
2	Shamnagar-2	0.28±0.03	0.302±0.05	343.6
3	Shamnagar-3	0.36±0.03	0.43±0.04	450.8
4	Shamnagar-4	0.36±0.03	0.44±0.03	450.9
5	Shamnagar-5	0.18±0.03	0.245±0.04	229.2
6	Shamnagar-6	0.30±0.03	0.39±0.03	363.3
7	Shamnagar-7	0.33±0.02	0.42±0.03	405.6
8	Shamnagar-8	0.35±0.03	0.426±0.03	439.1
9	Shamnagar-9	0.29±0.03	0.344±0.04	350.9
10	Shamnagar-10	0.44±0.04	0.56±0.04	544.7
11	Shamnagar-11	0.24±0.02	0.304±0.05	302.3
12	Shamnagar-12	0.47±0.03	0.57±0.03	575.3
13	Shamnagar-13	0.30±0.03	0.35±0.04	367.4
14	Shamnagar-14	0.37±0.03	0.50±0.04	453.1
15	Shamnagar-15	0.31±0.04	0.376±0.06	383.5
16	Shamnagar-16	0.21±0.03	0.27±0.03	257.7
	Average	0.324±0.03	0.402±0.04	399.9

[DOI: 10.18869/acadpub.ijrr.18.3.397]

Occasionally, the locations are inundated by sea water, like by cyclone Aila, but at the same time some of the sample collected areas might have shown lower results due to the effect of rain water. Thus the activities may affect the geological properties of the soil and thus play a role in the removal of natural radionuclides from sea water and deposition in the soil. All these values are comparable with the world average and however, they don't exceed the dose recommended value by UNSCEAR-2000.

In this study we have calculated the excess lifetime cancer risks. Yet we were not able to evaluate the health hazards of the assessed values on the population, since reliable, standardized mortality and morbidity statistics were not accessible. It is worth mentioning that this study was limited to assessment of background radiation levels only.

In the present work of radioactivity analysis, it is observed that the highest average natural radioactivity value found in the soil samples did not exceed the limit recommended by IAEA. It was also observed in this study and from similar worldwide studies that in the ultimate dose rate the radionuclide ^{232}Th contributes maximum to the total dose rate compared with ^{238}U and ^{40}K. Our results are comparable with those values previously extracted values by some other researchers of the country. The excess life time cancer is not so high (>10^{-3}) compared to the other cancer originating causes. No peak of ^{137}Cs at 661 keV from the decay activity as well as no fall out was found. However, Prompt investigation is necessary to check the soil status after any natural devastation by cyclone of the locality.

Conflicts of interest: *Declared none.*

REFERENCES

1. Kannana V, Rajana MP, Iyengara, MAR, Ramesh R (2002) Distribution of natural and anthropogenic radionuclides in soil and beach sand samples of Kalpakkam (India) using hyper pure germanium (HPGe) gamma ray spectrometry. *Applied Radiation and Isotopes, **57**: 109–119*.
2. Suresh G, Ramasamy V, Meenakshisundaram V, Venkatachalapathy R, Ponnusamy V (2011) A relationship between the natural radioactivity and mineralogical composition of the Ponnaiyar river sediments, India. *Journal of Environmental Radioactivity, **102**: 370-377*.
3. El-Taher A (2011) Terrestrial gamma radioactivity levels and their corresponding extent exposure of environmental samples from Wadi El Assuity protective area, Assuit, Upper Egypt. *J Rad Protect Dosi, **145 (4)**: 405-410*.
4. Al-Zahrani JH and El-Taher A (2014) Radioactivity Measurements and Radiation Dose Assessments in Soil of Al-Qassim region, Saudi Arabia, Indian. *J pure Appl Phys, **(52)**: 147-154*.
5. Hendry JH, Simon SL, Wojcik V, Sohrabi M, Burkart W, Cardis E, Laurier C, Tirmarche M, Hayata I (2009) Human exposure to high natural background radiation: What can it teach us about radiation risks? *Jr Radiol Prot, **29(2A)**: A29-42*.
6. Moubissi AB, Abiama PE, Ekogo TB, Ben- Bolies GH, Mouandza YL (2018) Study of natural radioactivity to Assess of radiation hazards from soil samples collected from Mounana in south-east of Gabon. *Int J Radiat Res, **16(4)**: 443-453*.
7. Taqi AH, Shaker AM, Battawy AA (2018) Natural radioactivity assessment in soil samples from Kirkuk city of Iraq using HPGe detector. *Int J Radiat Res, **16(4)**: 455-463*.
8. Gulan L, Milenkovic B, Stajic JM, Vuckovic B, Krstic D, Zeremski T, Ninkov J (2013) Correlation between radioactivity levels and heavy metal content in the soils of the North Kosovska Mitrovica environment. *Environ Sci Process Impacts, **15(9)**: 1735-42*.
9. Chikasawa K, Ishii T, Ugiyama H (2001) Terrestrial gamma radiation in Kochi Prefecture, Japan. *J Health Sci, **47**: 361–72*.
10. Rani A and Singh S (2005) Natural radioactivity levels in soil samples from some areas of Himachal Pradesh, India using γ- ray spectrometry. *Atmospheric Environ, **39**: 6306-14*.
11. Germanium Detectors Data Sheet - CANBERRA Industries ©2016 Mirion Technologies (Canberra), Inc.
12. Ionizing radiation, health effects and protective measures. WHO Publications on ionizing radiation (April 2016)
13. Fazel R, Krumholz HM, Wang Y, Ross JS, Chen J, Ting HH, *et al.*, (2009) Exposure to low-dose ionizing radiation from medical imaging procedures. *N Engl J Med, **361(9)**: 849–57*.
14. Children's Health and the Environment, WHO Training Package for the Health Sector, World Health Organization. www.who.int/ceh.
15. Schotzing U and Debertin K (1989) Photon emission probabilities per decay of ^{226}Ra and ^{232}Th in equilibrium with their daughter products. *Applied Radiat and Isot, **34**: 533-538*.
16. Radiometric Reference Materials; RUG-1, RGTh-1 and RGK -1: International Atomic Energy Agency (IAEA). Report: IAEA/RL/148, Vienna, January 1987.
17. Beretka J and Mathew PJ (1985) Natural radioactivity of Australian building materials, industrial wastes and by-

[DOI: 10.18869/acadpub.ijrr.18.3.397]

products. *Health Physics,* ***48****: 87-95*.
18. UNSCEAR (2000) Sources and effects of ionizing radia on, Vol. 1. United Na ons Scien fic CommiNee on the Effects of Atomic Radiation. Report of the General Assembly with Scien fic Annexes. United Na ons, New York.
19. Bijoy SB (2014) Investigation on Elemental and Radionuclide Contamination of Soil in Some Ship Breaking Areas of Chittagong, Bangladesh. Ph.D. Thesis. Department of Physics. Chittagong University of Engineering and Technology.
20. El-Taher A and Abdel Halim MAK (2014) Elemental analysis of soils from Toshki by using Instrumental Neutron Activation Analysis Techniques. *Journal of Radioanalytical and Nuclear Chemistry,* ***300****: 431-435*.
21. Uosif MAM and El-Taher A (2006) The Assessment of the radiation hazard indices due to uranium and thorium in some Egyptian environmental matrices. *J Phys D: Appl Phys,* ***39****: 4516-4521*.
22. Knoll GF (1979) Radiation detection and measurement. John Willey and Sons, New York.
23. Rackhkova NG, Shuktomova II, Taskaev AI (2010) The state of natural radionuclides of uranium, radium and thorium in soils. *Eurasian Soil Scien,* ***43****: 651-658*.
24. Arafin Sk. AK, Mir Md Akramuzzaman AKM, Fazlul Hoque M, Ashraful Hoque M, Ferdous J (2016) Terrestrial gamma ray activity in soil from Aila affected two Upazila at Khulna and Bagerhat district. *IJARR,* ***1(9)****: 10-1*.
25. Uosif MAM and El-Taher A (2008) Radiological assessment of Abo-Tartur phosphate, western desert, Egypt. *Radiat Prot Dosim,* ***130(2)****: 228-235.*
26. Abdel Halim MAK and El-Taher A (2014) Elemental analysis of Limestone by using Instrumental Neutron Activation Analysis. *J Radioanal Nucl Chem,* ***(299)****: 1949-1953*.
27. Madkour HA, El-Taher A, Ahmed AN, Mohamed AW, El-Erian TM (2012) Contamination of coastal sediments in El-Hamrawein Harbour, Red Sea Egypt. *J Environ Sci Tech,* ***5 (4)****: 210-221*.

[DOI: 10.18869/acadpub.ijrr.18.3.397]