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Comprehensive Review of the Investigation of Anthropogenic and Naturally Occurring Radionuclides in Different Parts of Bangladesh

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Abstract— *Authors attempt to depict a survey of anthropogenic ^{137}Cs and naturally occurring radionuclides (^{226}Ra, ^{228}Th, ^{232}Th, ^{214}Bi, ^{208}TI, ^{40}K) in undistributed soil, water, ship scrapped materials such as metal, rubber and foam and tree bark of ship breaking area, cynoglossids i.e. tongue soles and tea leaves collected from different parts of Bangladesh for detecting health hazards, environmental protection and radiation safety of the public. The assessment of such radionuclides in these samples is utmost important due to nuclear test and accident, fallout and disposal of radioactive wastes. These radiotracers have been investigated by using laboratory-based Gamma Spectrometry for Food and Environmental Samples. The observation of activity concentrations for ^{137}Cs, ^{226}Ra, ^{228}Th,^{232}Th, ^{214}Bi, ^{208}TI and ^{40}K have been presented in $Bq.Kg^{-1}$. The others radiological parameters such as gamma ray dose rate ($nGyh^{-1}$), Radium Equivalent Dose (Ra_{eq}) $Bq.Kg^{-1}$, Representative Level Index ($l_{\gamma r}$) $Bq.Kg^{-1}$ and Transfer Factor (TF) %. The Radiation Hazard Index (H_x) $Bq.Kg^{-1}$ also has been presented.*

Keywords—Radionuclides, Radioactivity, Activity Concentration, Radiological Parameters, Gamma Spectrometry.

I. INTRODUCTION

Assessment of any release of radioactivity to the environment is important the protection of public health, especially if the released radioactivity can enter into the food chain. Assessment demands rapid, reliable and practical techniques for analysis of various radionuclides [1]. In this context, distribution of ^{137}Cs and naturally occurring radionuclides for soil and water samples in the Terrene of Goainghat and Jaintapur Area of Sylhet district and the same for soil samples at the site of the Rooppur Nuclear Power Plant has been presented [2,3]. In [4], describes the study of the radioactivity in soil and tea leaf and transfer factor of those radionuclides. The environmental radioactivity levels, both natural and anthropogenic, in the ship scrapped materials such as metal, rubber and foam and tree bark of ship breaking area of Bhatiari, Chittagong in the southern part of Bangladesh have been analyzed [5]. The study on ^{214}Bi, ^{208}TI, ^{40}K and ^{137}Cs in soil of Chittagong Hills, Bangladesh has been provided to ascertain the baseline data to assess the public exposure of that area [6]. The radionuclides concentration in the cynoglossids i.e. tongue soles collected from the Kutubdia channel of Bangladesh have been estimated. The study consists of the analysis of seasonal occurrence of these radionuclides along with hydrological parameters and biochemical constituents of their living area [7]. In [8], presents the Gamma radiation dose from the naturally occurring radioclides in soil of the Potenga Sea Beach area of Bangladesh. In Potenga Sea Beach soil samples, the activities of ^{226}Ra, ^{232}Th and ^{40}K have been found to be higher than that of world average values. The radioactivity of naturally occurring radionuclides in water and sediment samples collected from the Meghna-Dakatia River at Chandpur of Bangladesh has been measured. Thus, the external outdoor radiation dose rate, radium equivalent activities, R_{eq} and representative level index, l_{yr} also have been estimated [9]. Activities of gamma-emitters ^{238}U,^{226}Ra, ^{232}Th and ^{40}K in tap water samples of Dhaka city have been analyzed by using High-Purity Germanium (HPGe) coaxial detector(EG &ORTEC) coupled with Silena Emcaplus Multichannel Analyzer System. The estimated effective dose and annual effective dose due to intake of different radionuclides for various age groups also have been provided [10]. The current research motivated to the recent trend and development in Radiological Research in Bangladesh. A comprehensive review of the investigation of anthropogenic ^{137}Cs and naturally occurring radionuclides (^{226}Ra, ^{228}Th, ^{232}Th, ^{214}Bi, ^{208}Tl, ^{40}K) in undistributed soil, water, ship scrapped materials such as metal, rubber and foam and tree bark of

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ship breaking area, cynoglossids i.e. tongue soles and tea leaf collected from different parts of Bangladesh.

II. MATERIALS AND METHOD

2.1: Sample Collection

Double identities should be placed on samples at collection time. It is advisable that a standard form with all relevant information such as date, location, fresh weight, weather, collector's name etc. to be filled up. Care should be taken that the sample is representative and suitable for specific purposes of the monitoring procedures [1].

In this context, M. N. Alam et al [2] study area was in Goainighat and Jaintapur of Sylhet disdrict located at 91^0 50′ to $92^0$13′ N and $24^0$56′ to $25^0$12′ E. The soil samples have been collected from 17 sites at a depth of 0-10 cm with the help of premeasured steel corer of size 10.5 cm dia and 25 cm height. Water samples have also been collected from 17 sites of natural reservoir corresponding to the location of soils, on the border area at a distance of 500 m to 4 km from each other during the period of September – October, 2000. The collected soils are of sedimentary rock and clay type and believe to be undistributed. Thereafter, N. Absar [4] research area was in Odalia tea Garden which was about 3000 sq. km situated in the hilly region of Fatickchari Chittagong disdrict of Bangladesh. Soil samples have been collected from 5 locations of the garden at a depth upto 20 cm from the surface and tea leaf sample for the same 5 locations [5].

2.2: Sample Preparation

Samples received in the laboratory may not in the proper physical form for analysis. They may require reduction in size, evaporating, drying of some form of homogenizing before taken for analysis. Some general consideration for handling and pretreatment of samples are needed. The samples with high levels of activity should be processed in a separate area from low level samples to avoid contamination [1].

All the soil samples M. N. Alam et al [2] have been dried in an oven at 110^0C for 48 h, pulverized and passed through sieve, weighed and then packed in cylindrical plastic containers (6.5 cm ×7.5 cm). They have been then sealed tightly with caps, wrapped with thick vinyl tape around their screw necks and stored for 4 weeks to allow secular equilibrium between ^{226}Ra, ^{232}Th and their daughter nuclei. Water samples were collected with 5-litre plastic jars from the natural reservoir. Each 5-litre water sample has been boiled to reduce its volume to 500 ml and packed into 500 ml cylindrical containers, sealed tightly and wrapped with thick vinyl tapes around their screw necks. These samples have been stored for 4 weeks too.

2.3: Measurement Procedure

The γ-ray activities of all the collected samples for ^{226}Ra, ^{232}Th, ^{214}Bi, ^{208}Tl, ^{40}K and ^{137}Cs have been analyzed by using a p-type coaxial lead shielded High Purity Germanium (HPGe) detector having relative efficiency of 30%, active volume 132 cm^3 , resolution (FWHM) of 1.85 KeV at 1332 KeV for ^{60}Co coupled with PCA and other accessories. The calibration of the peak efficiency of the detector was performed using IAEA reference samples ^{238}U (RGU-1), ^{232}Th (RGTh-1), ^{40}K (RGK-1) and ^{137}Cs (IAEA-152) [11]. The mentioned radiotracers were investigated by using a p-type coaxial lead shielded High Purity Germanium (HPGe) detector with Liquid Nitrogen (LN_2) cooling having relative efficiency of 20%, resolution (FWHM) of 1.80 KeV at 1332 KeV for ^{60}Co coupled with DSA-1000, Genie-2000 GAA software and other accessories [3]. The radioactivities of the investigated samples were measured for 10,000s by using the same Gamma Spectrometry configuration as described in N. Absar [4]. The ^{226}Ra (^{238}U) activity was determined individually from the net area of peak at energies of 351.9 keV (^{214}Pb), 1120 keV (^{214}Bi) and 1764 keV (^{214}Bi). ^{214}Pb and ^{214}Bi are the decay products of ^{238}U series. Similarly, the ^{232}Th activity was determined from the counts at peak energies of 238.6 keV (^{212}Pb), 727 keV (^{212}Bi), 911 keV (^{228}Ac) and 583 keV (^{208}Tl) [5]. The ^{40}K and ^{137}Cs radionuclides have been measured from their respective γ-ray energies 1460 KeV and 661.66 KeV respectively [1, 12].

2.4: Results and Discussion

Radiological parameters are very important for ensuring the public health and safety (reducing environmental radiation exposer), environmental protection and radioecological control. According to N. Alam et al [2], the activity concentration of ^{137}Cs in soil and water of the sampling area have been observed as 4.12 ± 0.32 to 30.53 ± 0.88 $Bq.kg^{-1}$ with an average value of 13.23 ± 6.76 $Bq.kg^{-1}$ and 1.0 ± 0.34 to 1.72 ± 0.61 $Bq.L^{-1}$. The activity concentration S. Roy et al [3] of ^{137}Cs in seven soil samples out of thirty of the Rooppur Nuclear Power Plant (RNPP) sampling area have been observed as 3.46 ± 0.48 to 5.86 ± 0.61 $Bq.kg^{-1}$ with an average value of 4.22 ± 0.78 $Bq.kg^{-1}$. In N. Absar [4] research, the average activity concentration of ^{137}Cs in the soil samples has been obtained as 2.84 ± 0.27 $Bq.kg^{-1}$ whereas the ^{137}Cs for tea samples was not present in all samples, therefore, no uptake has been recorded. Barua, et al [5] obtained the lower limit of detection for ^{137}Cs was 0.043679 $Bq.kg^{-1}$. In N. Alam et al [6], the activity concentration of ^{137}Cs in soil of Chittagong Hills varies from 1.08 ± 0.14 to 4.25 ± 0.48 $Bq.kg^{-1}$ with an average value of 2.66 $Bq.kg^{-1}$. According to J. Ferdous et al [10], no activity concentration of ^{137}Cs in tap water of Dhaka City has been detected.

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N. Alam et al [2], continued with the activity concentration of naturally occurring radionuclides like ^{226}Ra in soil and water have been recorded as 7.2 ± 1.0 – 57.70± 8.60 Bq.kg^{-1} and 5.70 ± 0.50 – 56.4 ± 1.20 mBq.L^{-1} respectively. Similarly, the activity concentration of ^{232}Th have been given as 28.80 ± 3.30 – 66.20± 4.10 Bq.kg^{-1} and 36.70 ± 2.30 – 67.0 ± 4.20 mBq.L^{-1} accordingly. Likewise, the activity concentration of ^{40}K for the same sample have been observed as 467 ± 5.0 – 656± 43 Bq.kg^{-1} and 7.90 ± 1.70 – 12.70± 2.0 mBq.L^{-1} respectively. S. Roy et al [3] furthermore evaluated the minimum and maximum radioactivity level of ^{226}Ra, ^{232}Th, and ^{40}K of soil samples as 21.87 ± 5.87 Bq.kg^{-1} and 55.66 ± 0.74 Bq.kg^{-1}, 31.28 ± 3.00 Bq.kg^{-1} and 78.01 Bq.kg^{-1} and 332.86 ± 48.95 Bq.kg^{-1} and 661.96 ± 63.56 Bq.kg^{-1} with an average value of 33.32 ± 7.96 Bq.kg^{-1}, 46.91 ± 12.24 Bq.kg^{-1} and 448.54 ± 89.86 Bq.kg^{-1} respectively. N. Absar [4] research continued with the average activity concentrations of ^{238}U, ^{232}Th, and ^{40}K of soil samples and the same for tea samples have been obtained as 44.55± 7.83 Bq.kg^{-1} and 5.66± 0.66 Bq.kg^{-1} ; 51.08± 10.80 Bq.kg^{-1} and 4.38± 0.50 Bq.kg^{-1} and 274.81± 78.01 Bq.kg^{-1} and 190± 30.50 Bq.kg^{-1} respectively. Barua, et al [5] measured the radionuclide concentrations of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K in various ship scrapped metal samples and the same from ship engine varied in the range of 6.89 ± 0.84 Bq.kg^{-1} - 15.27 ± 1.14 Bq.kg^{-1} and 415 ± 22.25 Bq.kg^{-1}, which is not comparable to others due the unknown reason; 6.78 ± 1.06 Bq.kg^{-1} -238 ± 8.98 Bq.kg^{-1} and 7.40 ± 0.67 Bq.kg^{-1} -67.32 ± 7.41Bq.kg^{-1} respectively. The levels of the above three radionuclides in the mixture of rubber and foam samples have been observed in the range of 7.78 ± 0.66 Bq.kg^{-1} -25.57 ± 1.53 Bq.kg^{-1} ; 8.62 ± 0.41 Bq.kg^{-1} -31.05 ± 1.55 Bq.kg^{-1} and 12.57 ± 0.88 Bq.kg^{-1} -312 ± 34.26 Bq.kg^{-1} accordingly. Barua, et al [5] also investigated the activity in tree barks (Eucalyptus and Jackfruit) which might helpful for understanding the effect of ship breaking on environmental radioactivity. N. Alam et al [6], the average radionuclide concentrations of ^{214}Bi , ^{208}Tl and ^{40}K in of Chittagong Hills have been estimated as 36.33 ± 15.65 Bq.kg^{-1} , 14.73 ± 8.54 Bq.kg^{-1} and 350.96± 113.34 Bq.kg^{-1} respectively. According to N. Alam et al [7], the range of ^{226}Ra activity has been measured as 9 ± 2 to 20 ± 5 Bq.kg^{-1} fresh weight (fw) with maximum in the edible portion of c. cynoglossus and minimum in the whole body of c. lingua. Seasonal variation of activity of radionuclides in different body parts of cynoglossids also have presented. Afterwards, the activity concentration of ^{232}Th has been found in the range 8 ± 1 to 17 ± 4 Bq.kg^{-1} fw with highest in the whole body of c. cynoglossus and lowest in the whole body of p. bilineata.Then, the range of ^{228}Th activity has been measured as 4 ± 1 to 14 ± 4 Bq.kg^{-1} fw with maximum in the offal of c. bilineatus and minimum in the edible portion of c. cynoglossus. At last, the radionuclides concentration of ^{40}K in the different body parts of cynoglossids i.e. tongue soles on a fw basis also have been detected as 81 ± 11 Bq.kg^{-1} to 227 ± 19 Bq.kg^{-1} fw with highest in the whole body of c. bilineatus and lowest in the edible portion of c. cynoglossus. Following S. Ghose et al [8] , mean the activities of ^{226}Ra, ^{232}Th and ^{40}K in the Potenga Sea Beach soil samples of high and low tide lines have been determined as 37 and 33; 76 and 54.7 and 424 and 432 Bq.kg^{-1} respectively. M.I. Chowdhury et al [9], the activity concentrations of ^{226}Ra, ^{228}Th, ^{232}Th, and ^{40}K (average activity concentration) in sediment and water samples of the Meghna and the Dakatia have been measured in the ranges from 12.0 ± 2.2 to 57.0 ± 10.0 Bq.kg^{-1} and 2.91 ± 1.7 to 14.01 ± 3.10 Bq.L^{-1}; 27.0 ± 4.0 to 104 ± 8.5 Bq.kg^{-1} and 1.21 ± 0.51 to 6.81 ± 0.27 Bq.L^{-1}; 25.0 ± 3.5 to 108 ± 9.70 Bq.kg^{-1} and 1.40 ± 0.50 to 7.20 ± 2.50 Bq.L^{-1} and 273 ± 54 Bq.kg^{-1} and 7.90 ± 1.90 Bq.L^{-1} respectively. According to J. Ferdous et al [10], the activity concentrations of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in tap water samples have been obtained as 0.82 ± 0.26 to 2.12 ± 0.32 Bq.L^{-1}; 0.014 ± 0.0054 to 0.040 ± 0.0055 Bq.L^{-1}; 0.16 ± 0.003 to 0.73 ± 0.027 Bq.L^{-1} and 2.04 ± 0.0094 to 6.40 ± 0.027 Bq.L^{-1} respectively. Activity concentration values for radionuclides of artificial (^{137}Cs) and all natural origin for bulk samples have been recommended by IAEA as 100 Bq.kg^{-1} and 1000 Bq.kg^{-1} respectively; only exception in ^{40}K which is 10000 Bq.kg^{-1} [13].

The absorbed dose rate in air one meter above the ground surface due to the radionuclides ^{226}Ra, ^{232}Th, and ^{40}K of soil has been estimated using the formula given by

$$D = [0.427C_{RA} + 0.662C_{TH} + 0.0432C_K]\, nGyh^{-1} \quad (1)$$

Where C_{RA} , C_{TH} and C_K are the average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K of soil samples in Bqkg^{-1}[14]. The dose rate N. Alam et al [2] due to ^{226}Ra, ^{232}Th, and ^{40}K of soil samples varied in the ranges from 59.66 to 89.84 nGyh^{-1}, with an average value of 74.76 nGyh^{-1}, which is higher than the world average value of 52 nGyh^{-1}. The dose rate S. Roy et al [3] due to ^{226}Ra, ^{232}Th, and ^{40}K of soil samples varied in the ranges from 50.90 to 103.46 nGyh^{-1}, with an average value of 69.45 nGyh^{-1}. According to N. Absar [4] research, the dose rate that has been calculated of 71.14 nGyh^{-1} is to be treated as outdoor dose that yielded annual effective dose much below the permissible limit of 1.0 mSv.y^{-1} recommended by the International Commission on Radiation Protection (ICRP) for general population [15]. The dose rate in S. Ghose et al

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[8] due to ^{226}Ra, ^{232}Th, and ^{40}K in soil samples of high and low tide lines varied in the ranges from 45.2 – 220 and 51 - 160 nGyh^{-1} respectively. The average dose rate in M. I. Chowdhury et al [9], of the river sediment has been found as 0.62 ± 0.22 mGy y^{-1}.The indoor dose contribution is assumed to be 1.2 times higher than the outdoor [16].

$$D_{indoor} = D_{outdoor} \times 1.2\ (nGyh^{-1}) \quad (2)$$

The annual effective dose equivalent D_{eff} from outdoor terrestrial gamma radiation is given by

$$D_{eff} = outdoor\ dose\ (nGyh^{-1}) \times 0.7(Sv\,.\,Gy^{-1}) \times 8{,}760(hy^{-1}) \times 0.2 \quad (3)$$

Where 0.2 is the outdoor dose occupancy factor and 0.7 Sv.Gy^{-1} is the quotient of effective dose equivalent rate to absorbed dose rate in air [17].

The annual effective dose due to intake of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in tap water samples of Dhaka city for five age groups are 104.10, 87.90, 75.73, 63.19 and 73.38 μSv.y^{-1} for 1 year, 5 year, 10 year, 15 year and above 18 year respectively in J. Ferdous et al [10]. These values are significantly lower than both the World Health Organization (WHO) and the International Commission on Radiological Protection (ICRP) limits.

The annual effective dose equivalent D_{eff} from indoor exposure is given by:

$$D_{eff} = indoor\ dose\ (nGyh^{-1}) \times 0.7(Sv\,.\,Gy^{-1}) \times 8{,}760(hy^{-1}) \times 0.8 \quad (4)$$

Where 0.8 has been used as the occupancy factor [17]. Therefore, the total annual effective dose equivalent from terrestrial radiation is sum of outdoor and indoor annual effective dose equivalent.

The γ-ray radiation hazards due to the radionuclides ^{226}Ra, ^{232}Th, and ^{40}K of soil samples has been assessed by two different indices. The most widely used radiation hazard index , Ra_{eq} , can be derived from the following formula:

$$Ra_{eq} = C_{RA} + \left(\frac{10}{7}\right) C_{TH} + \left(\frac{10}{130}\right) C_K \quad (5)$$

Where C_{RA}, C_{TH} and C_K are the average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in Bq.kg^{-1} respectively [18]. The values of Ra_{eq} for N. Alam et al [2] in soils varied from 121.8 to 187.5 Bq.kg^{-1} with an average value of 153.86 Bq.kg^{-1}. The values of Ra_{eq} for S. Roy et al [3] also in soils varied from 96.68 to 217.04 Bq.kg^{-1} with an average value of 134.80 Bq.kg^{-1} which is too low with respect to allowable limit 370 Bq.kg^{-1} as recommended by the IAEA but higher than the world average values of 89.25 Bq.kg^{-1} [1]. The mean value of the radium equivalent activity of the soil samples has been found to be 150.42 ± 29.11 Bq.kg^{-1} with the range of 175.79 ± 30.04 to 110.26 ± 29.50 Bq.kg^{-1} in N. Absar [4]. Barua, et al [5] calculated the Ra_{eq} in the range of 21-145 Bq.kg^{-1} except one scrapped metal from engine (760 Bq.kg^{-1}) is of radiological concern indeed. The Ra_{eq} for S. Ghose et al [8] due to ^{226}Ra, ^{232}Th, and ^{40}K in soil samples of high and low tide lines varied in the ranges from 80 – 428 and 93 - 300 Bq.kg^{-1} respectively. The values of Ra_{eq} for M. I. Chowdhury et al [9] in sediments varied from 114.0 ± 48.0 to 478.0 ± 89.0 Bq.kg^{-1} with an average value of 320.0 ± 82.0Bq.kg^{-1}.

The another radiation hazard index, used to estimate the level of γ-radiation associated with the natural radionuclides in soil, representative level index ($I_{\gamma r}$) defined as follows

$$I_{\gamma r} = \left(\frac{C_{RA}}{150} + \frac{C_{TH}}{100} + \frac{C_K}{1500}\right) \quad (6)$$

Where C_{RA}, C_{TH} and C_K are the average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in Bq.kg^{-1} respectively [19]. N. Alam et al study calculated the $I_{\gamma r}$ for soil samples varied from 0.77 to 1.37 Bq.kg^{-1} with an average value of 1.08 Bq.kg^{-1} which is higher than world average values of 0.66 Bq.kg^{-1}[12]. The mean value of $I_{\gamma r}$ for the soil sample has been obtained 1.22 ± 0.24 Bq.kg^{-1} with the range of 1.46 ± 0.24 to 0.94 ± 0.23 Bq.kg^{-1} in N. Absar [4]. The $I_{\gamma r}$ for S. Ghose et. Al [8] due to ^{226}Ra, ^{232}Th, and ^{40}K in soil samples of high and low tide lines varied in the ranges from 0.6 – 3.0 and 0.7 – 2.0 Bq.kg^{-1} respectively. The value of $I_{\gamma r}$ for the sediments sample has been obtained in the range of 0.70 ± 0.32 to 1.21 ± 0.46 Bq.kg^{-1} with mean value of 0.95 ± 0.28 Bq.kg^{-1} in M. I. Chowdhury et al [9].

The Transfer Factor (TF) is defined by the following equation:

$$TF = \frac{Radioactivity\ in\ Plant(Bq/kgDW)}{Radioactivity\ in\ Soil\ (Bq/kgDW)} \quad (7)$$

The transfer mechanism of radionuclides, represented by TF, is widely used to describe the soil-to-plant transfer of radionuclides through plant roots. The concentration of a nuclide in a plant or plant part (in Bq.kg^{-1}, dry weight), is assumed to be linearly related to its concentration in soil within the rooting zone also in Bq.kg^{-1}, dry weight) [20]. In N. Absar [4], the average activity concentration of ^{137}Cs in tea samples <0.4 Bq.kg^{-1}, so no uptake found. The

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transfer factor (TF) of ^{238}U, ^{232}Th, and ^{40}K for soil–to-tea samples have been found as 0.13± 0.08, 0.09± 0.05 and 0.69± 0.39 respectively. The average TF of ^{226}Ra, ^{228}Th, ^{232}Th and ^{40}K for sediment-to-water has been recorded as 0.21± 0.15, 0.05± 0.02, 0.06± 0.03 and 0.03 ± 0.01 respectively in M. I. Chowdhury et al [9].

TF value in excess of unity imply active bioaccumulation of the activity. The values less than unity mean either strong binding of the radionuclides with soil, little or no accumulation in the plant [4].

The external radiation hazard index H_{ext} and internal radiation hazard index H_{int} has been calculated by using the following formula:

$$H_{ext} = {}^{A_U}/_{370} + {}^{A_{Th}}/_{259} + {}^{A_K}/_{4810} \quad (8)$$

$$H_{int} = {}^{A_U}/_{185} + {}^{A_{Th}}/_{259} + {}^{A_K}/_{4810} \quad (9)$$

Where, the numerical quantities of equations (8) and (9) are in units of Bq.kg^{-1} and A_U, A_{Th} and A_K are the activity concentrations of the radionuclides ^{238}U,^{232}Th, and ^{40}K respectively [21]. The values of H_{ext} and H_{int} have been observed in the ranges from 0.30± 0.08 to 0.50± 0.08 and 0.62± 0.10 to 0.39± 0.10 with the mean value of 0.41± 0.08 and 0.51± 0.10 respectively in N. Absar [4]. The H_{ext} in Barua, et al [5] varied from 0.06 to 0.39. Since these values are lower than unity, the external radiation hazard in the ship breaking area is low.

The radon mass exhalation rate is calculated by following the equation given below

$$R_m = \lambda_{Rn} C_{soil.Ra} F_r \quad (10)$$

Where, $C_{soil.Ra}$ is the activity mass concentration of ^{226}Ra (Bq.kg^{-1}) in soil, λ_{Rn} is the decay constant of ^{222}Rn (2.1×10^{-6} s^{-1}) and F_r is the emanation co-efficient[22]. In S. Ghose et. Al [8], the ^{222}Rn emanation co-efficient ranged from 10-27.5% with a mean value of 15.32% and the ^{222}Rn exhalation rate ranged from 4.89-20.4 μBq.kg^{-1}.s^{-1} with a mean value of 10.63 μBq.kg^{-1}.s^{-1}.

III. CONCLUSION

The recent trend and development in the Radiological Research in Bangladesh has been presented in this study. Firstly, a chronological survey of the investigation of anthropogenic ^{137}Cs and naturally occurring radionuclides (^{226}Ra, ^{228}Th, ^{232}Th, ^{214}Bi, ^{208}Tl, ^{40}K) in undistributed soil, water, ship scrapped materials such as metal, rubber and foam and tree bark of ship breaking area, cynoglossids i.e. tongue soles and tea leaf collected from different parts of Bangladesh has been provided. Afterwards, the matter of sample collection, sample preparation and measurement procedure has been depicted as well. At the end, radioactivity analysis of the samples has been presented for detecting health hazards to ensure public health and safety.

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