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Study of Natural and Artificial Radioactivity in some Food Grains

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Abstract

Background: Food is indispensable to human life, thus an important parameter of environmental science. The presence of radionuclides in food grains poses a number of health hazards, especially when these radionuclides are deposited in the human body, through food. The main objective of this study is to determine the radioactivity concentration of gamma emitting radionuclides e.g. ^{238}U, ^{232}Th, ^{40}K and gross alpha, gross beta activity in food grain sample. **Method:** Fifteen samples of food grain were collected from the different market of Dhaka City, six samples were domestic (Bangladesh), and nine samples were imported from different country. The food grain samples were prepared and analyzed by High Purity Germanium (HPGe) and Zinc Sulphide Scintillation Detector, ZnS(Ag). **Results:** The measured radioactivity concentration of ^{238}U, ^{232}Th, ^{40}K ranges from 7.53 to 35.17 $Bq.kg^{-1}$ with an average of

22.12 ±0.14 Bq.kg^{-1}, 4.53 to 30.38 Bq.kg^{-1} with an average of 14.5 ±0.09 Bq.kg^{-1} and 17 to 232.3 Bq.kg^{-1} with an average of 145.79 ±0.57 Bq.kg^{-1}. The gross alpha activity and gross beta activity under investigation ranges from 2.72 to 261.77 Bq.kg^{-1} with an average of 71.07 ±1.7 Bq.kg^{-1} and 36.81 to 351.94 Bq.kg^{-1} with an average of 164.3 ±11.28 Bq.kg^{-1}. **Conclusion:** This study will helpful to prepare the data for the activity concentration of gamma emitting radionuclides and gross alpha & gross beta radioactivity in food grain, which will be used to compare the activity level of radionuclides in different type of food grains.

Keywords: Radioactivity, food grains, High Purity Germanium (HPGe) and Zinc Sulphide Scintillation Detector, ZnS(Ag).

Introduction

Food is indispensable to human life, thus an important parameter of environmental science. The presence of radionuclides in food grains poses a number of health hazards, especially when these radionuclides are deposited in the human body, through food. It is well known that food can be a source of radiation, as it contains certain amounts of naturally occurring radionuclides. Their levels in food may be increased through a number of human activities such as nuclear fuel cycle and medical or other uses of radionuclides. As the part of radiation protection programme, it is very important to assess the effective dose in order to predict possible biological damage to the organism.

Natural radionuclides are found in every constituent of the environment; air, water and soil, and additionally in food and in humans, as humans are products of the environment. According to Kessaratikoon and Awaekechi (2008), these natural radionuclides and their decay products from U-238 and Th-232 series together with K-40 are primordial radionuclides, which originated from the earth’s crust and are the sources of natural radioactivity in the environment [3]. They are available in trace quantities in all level of ground formation exposing radiation to all life forms [4-6]. These radionuclides are ingested or inhaled in the air, food and water. Foodstuffs are known to contain natural and man made radionuclides which after ingestion, contribute to an effective internal dose. The naturally occurring radionuclides especially ^{40}K and the radionuclides of 238Uand 232Th series are the major source of natural radiation exposure to the man. It has been estimated that at least one-eighth of the mean annual effective dose due to natural sources is caused by the consumption of foodstuff [1]. Man made radionuclides, produced by human activities also contribute to the environmental radioactivity, and one of these important radionuclides of environmental concern, is 137Cs [2]. For contamination assessment of the foodstuff consumed by the population, it is very important to know the baseline value, or the level of radiation dose of both natural and synthetic radionuclides received by them.

The aim of this study has been to investigate the concentrations of some long lived radionuclides in domestic and imported foodstuff in Bangladesh. These concentrations can be useful as baseline values for the estimation of the internal radiation dose.

Materials and Methods

Sample Collection and Sample Preparation

In order to measure gamma, gross alpha and gross beta activity in food grain, fifteen samples were collected from different markets of Dhaka city on dated 23.09.14 to 30.10.14. The samples were appropriately coded from 1 to 15 and transferred to Environmental Radioactivity Monitoring Laboratory of Health Physics Division at Atomic Energy Centre, Dhaka for the analysis of activity concentration.

Fifteen plastic containers were washed with distilled water and left to dry to avoid sample contamination. The collected weight of each sample was 500 gm, and then the samples were dried by microwave oven at 110°C and grind by a milling machine. Figure 3.3 shows Sample dried in microwave oven. About (200-300) gm of grind sample were filled up in plastic containers and sealed by black cloggy tape. One month later samples are loaded into a coaxial high-purity germanium (HPGe) detector for counting gamma. After measurement of gamma each sample were opened and taken 0.5 gm grind sample and mixed with 1 ml glue. Then it was transferred to a 2 inch stainless steel counting planchet and dried under IR lamp, cooled and weighed to determine dry residue. Samples were drying by Infra Red Lamp and samples in the planchet. The sample residue was kept in desiccators to avoid moisture.

Sample Measurements

To qualitatively identify the contents of radionuclides in food grain sample and to quantitatively determine their activities, all prepared samples were measured by means of gamma-ray spectrometry system using high-purity germanium detector for 10000sec. The equal counting time for background and sample measurement was chosen to minimize the uncertainty in the net counts. The spectrum of each sample was analyzed and the identification of unknown radionuclides was carried out by considering their peak centroid energies. The centroid energies of the peaks from the spectrum were compared with the reference gamma-ray energies obtained from Nuclear Data, Atomic Energy Centre (AEC) and other nuclear data. The radionuclides contained in the samples were identified and the areas under the peaks then determined the activity concentrations of each nuclide.

Determination of the Activity Concentration

The number of counts under the full-energy peak areas (corrected for background peak areas), the counting time, the absolute full-energy peak efficiency for the energy of interest and the gamma-ray emission probability corresponding to the peak energy are used for the calculation of the activity concentration of a particular radionuclide in the measured samples. One problem with the direct determination of the activity of ^{238}U and ^{232}Th is due to the low relative gamma-ray intensities following their decay. However, in a state of secular equilibrium, the activity of ^{238}U and ^{232}Th can be estimated through several intensive gamma-ray lines of their daughter products in the decay chains. The activity concentrations of ^{238}U and ^{232}Th were determined from the average concentration of nuclides [Pb^{214} (295.2keV), Pb^{214} (351.9keV), Bi^{214} (609.3keV), Bi^{214} (1120.2keV)] and [Pb^{212} (238.6keV), Tl^{208} (583.1keV), & Ac^{228} (911.2keV), Ac^{228} (968.9keV)] respectively. The activity concentrations of ^{40}K were determined directly by measurement of the gamma-ray transitions at 1460.8keV. The activity concentrations of Pb^{214} (295.2keV), Pb^{214} (351.9keV), Bi^{214} (609.3keV), Bi^{214} (1120.2keV), Pb^{212} (238.6keV), Tl^{208} (583.1keV), & Ac^{228} (911.2keV), Ac^{228} (968.9keV) and ^{40}K (1460.8keV) for different locations. The specific activity, in terms of the activity concentration, is defined as the activity per unit mass of the sample. The specific activity of individual radionuclides in soil samples is given by the following equation:

$$A = {(N \times 100 \times 1000)}\Big/{(p_\gamma \times \varepsilon \times W)}$$

Where,

N = Net counts per second (c.p.s) = (Sample c.p.s) – (Background c.p.s)

$P\gamma$ = Transition probability or Branching ratio

ε = Efficiency in %

W = Weight of the sample in kg

Zinc Sulphide Scintillation Detector

ZnS Scintillation counter is a dual phosphor detector or dual scintillator detectors coupling two scintillating materials to a photomultiplier tube. These detectors are sometimes referred to as a "phoswich" (for phosphor sandwich). This type of detector is used primarily because it does not need a supply of counting gas. Without a high pressure gas supply the detector and counting system can be moved and located more easily. There is also no safety hazard from the P-10 gas bottle. A common phoswich detector for many years was a layer of cesium fluoride (CsF) bonded to a sodium iodide (NaI) crystal. The combination was optically coupled to a photo-multiplier tube (PMT). The MPC-2000-B-DP contains a custom designed detector with a zinc sulfide layer bonded to a plastic scintillator. The combination is optically coupled to a PMT. The outermost layer detects alpha particles, and the inner layer detects beta particles. In general, and compared to a gas flow detector, the DP (phoswich) detector offers equivalent alpha efficiency, and slightly lower beta efficiency. Background performance is somewhat similar, but is very much dependant on the environment.

Gross Alpha and Gross Beta Activities calculation

For gross alpha and beta activity each samples was counted for 120 minutes. The results were displayed as count per minute, activity and standard deviation. The data were acquired for alpha and beta mode. The alpha and beta count rate as well as alpha activity and beta activity were calculated using the following formula:

Gross Alpha Activity: $$A\_DPM = \frac{A\_NET\_CPM \times 100}{A\_EFF}$$

Where, *A_DPM*= Net Alpha Disintegrations per Minute

A_NET_CPM= Net Alpha Counts per Minute

A_EFF= Alpha Efficiency Percent.

Gross Beta Activity: $B\_DPM = \frac{B\_NET\_CPM \times 100}{B\_EFF}$

Where, *B_DPM* = Net Beta Disintegrations per Minute

B_NET_CPM = Net Beta Counts per Minute

B_ EFF = Beta Efficiency Percent.

Results and Discussion

Fifteen Food Grain samples were collected from the different markets of Dhaka city, six samples were Bangladeshi and nine samples were imported from different country. The samples were stored and prepared in the Laboratory of Health Physics Division at Atomic Energy Centre, Dhaka. The instrumentation used to determine the gamma, gross alpha and gross beta activities was High-Purity germanium Detector (HPGe) and Zinc Sulphide Scintillation Detector ZnS(Ag). The purpose of this present study is to determine the gamma, gross alpha and gross beta activities in food grain samples. The determination of their activity concentrations in samples are presented in this chapter. The results of gamma, Gross Alpha and Gross Beta of food grain samples are given in Table 1 and 2.

Gamma Activities in food grain sample

The measured activities of gamma in food grain sample are gathered in Table 1. The activity of the sample is given in Bq.kg^{-1} and the measurement errors shown in Table 1 represent one- sigma uncertainties. From Table 1, it is observed that the gamma activity ranges for food grain samples from 7.528 to 35.17 Bq.kg^{-1} for Uranium-238, 4.53 to 30.38 Bq.kg^{-1} for Thorium-232 and 17 to 232.3 Bq.kg^{-1} for K-40. The highest gamma activity for Uranium-238 in Lentil is 35.17 $\pm$ 0.15 Bq.kg^{-1} which is imported from Nepal. The lowest gamma activity for Uranium-238 in Bangladeshi Lentil is 7.528 $\pm$ 0.11 Bq.kg^{-1} which is collected from Dhaka City. The average gamma activity found in the food grain samples for Uranium-238 is 22.12 $\pm$ 0.14 Bq.kg^{-1}. The highest gamma activity for Thorium-232 in Lentil is 30.38 $\pm$ 0.15 Bq.kg^{-1} which is imported from Nepal. The lowest gamma activity in White Wheat is 4.53 $\pm$ 0.03 Bq.kg^{-1} which is imported from Australia. The average gamma activity found in the food grain samples is 14.5 $\pm$ 0.09 Bq.kg^{-}

[1].The highest gamma activity for K-40 in Lentil is 232 $\pm$ 0.62 Bq.kg^{-1} which is imported from Nepal. The lowest gamma activity in Bangladeshi Lentil is 17 $\pm$ 0.49 Bq.kg^{-1} which is collected from Dhaka City. The average gamma activity found in the food grain samples for is 145.79 $\pm$ 0.57 Bq.kg^{-1}.

The bar diagrams of gamma activity in food grain samples are shown in Figure 1. From the figure 1 it is shown that the gamma activity in Lentil (Nepal) is higher than other food grain samples for Uranium-238, the gamma activity in Lentil (Nepal) is higher than other food grain samples for Thorium-232 and the gamma activity in Vetch (Bangladesh) is higher than other food grain samples for K-40 due to the presence of higher activity concentration of gamma emitting radionuclides. Lentil and Vetch is more than other investigated food grain sample.

Gross Alpha and gross beta Activities in Food Grain sample

The measured activities of gross alpha and gross beta in food grain are gathered in Table 2. The activity of the sample is given in Bq.kg^{-1} and the measurement errors shown in Table 2 represent one- sigma uncertainties. From Table 2, it is observed that the gross alpha activity ranges for food grain samples from 2.72 $\pm$ 0.26 to 261.77 $\pm$ 2.79 Bq.kg^{-1}.The highest gross alpha activity in Indian Rice sample is 261.77 $\pm$ 2.79 Bq.kg^{-1} which is imported from India, the lowest gross alpha activity in Sunned Rice sample is 2.72 $\pm$ 0.26 Bq.kg^{-1} which is imported Thailand**.** The average gross alpha activity found in the food grain samples is 71.08 $\pm$ 0.17 Bq.kg^{-1}. It is found that the gross beta activity ranges for food grain samples from 36.81 to 351.94 Bq.kg^{-1} from Table 2, the highest gross beta activity found in Biri-28 rice sample is 351.94 $\pm$ 13.95 Bq.kg^{-1}which is Bangladeshi sample. The lowest gross beta activity found in White Wheat sample is 36.81 $\pm$ 10.85 Bq.kg^{-1} which is imported from Australia. The average gross beta activities found in the Food grain samples is 164.3 $\pm$ 11.28 Bq.kg^{-1}.

The bar diagrams of gross alpha activity and gross beta activity in food grain samples are shown in Figure 4.2 and 4.3. From the figure 4.2 it is shown that the gross alpha activity in Indian rice (India) sample is higher than other food grain samples due to the presence of higher activity concentration of alpha emitting radionuclides. From the figure 4.3 it is found that the gross beta activity in Biri-28 rice (Bangladesh) sample is higher than other food grain samples due to the presence of beta emitting radionuclides. Indian rice and Biri-28 rice is more than other investigated food grain sample.

Comparison of Gamma activity of Environmental samples with other countries

A comparison of gamma radioactivity in food grain samples of Bangladesh with different countries around the world is shown in Table 3.Comparing the results of gamma activity in food grain sample from the present study of Bangladesh is higher for the U-238 and Th-232 and lower for the K-40 than other food crops and grains samples from the different parts of Iraq and lower than the food crops of India.

Comparison of Gross alpha and Gross beta activity of Environmental samples with other countries.

A comparison of gross alpha and gross beta radioactivity in food grain samples of Bangladesh with different countries around the world is shown in Table 4.Comparing the results of gross alpha and gross beta activity in food grain sample from the present study of Bangladesh are lower than other food crops and grains samples from the different parts of India and other country.

Food grain is the parts of the nature and any natural products are not completely free of radioactive isotopes due to the presence of gamma, beta and alpha emitters from the natural decay series of uranium, thorium and actinium and other single isotopes such as ^{40}K. The main gamma emitters are Uranium, Thorium and other single isotopes such as ^{40}K. The main alpha emitters are ^{238}U, ^{234}U, ^{232}Th, ^{226}Ra and ^{210}Po and the main beta emitters are ^{40}K, ^{228}Ra, ^{210}Pb that can be present in food grain different concentrations. In case of food grain samples of the present study the concentration of gamma, gross alpha and gross beta activity is typically lower than the other countries of the world. There is a limited data for Gamma, Gross Alpha and Gross Beta in Bangladesh, this study will helpful of prepare baseline data for gamma, gross alpha and gross beta in food grain sample, which will be used as finger print for the comparison of radioactivity level.

Natural and anthropogenic radionuclides are found in terrestrial and aquatic food chains, with subsequent transfer to humans through ingestion of food. Therefore, there is a global interest in human radiation exposure due to radionuclide intake from food. Among the types of food that are commonly consumed worldwide is rice. Hence, studies on the radioactivity of rice have been performed in various regions across the globe. Results of these studies helped in establishing baselines of radiation exposure to people from consumption of rice. A thorough literature search reveals a small number of studies on the radionuclide content of food consumed in Kuwait . Such scarcity was the main motive to conduct the current study, in order to meet the important national requirement of establishing a baseline of radioactivity exposure to the general public from food consumption.

Figures and Tables

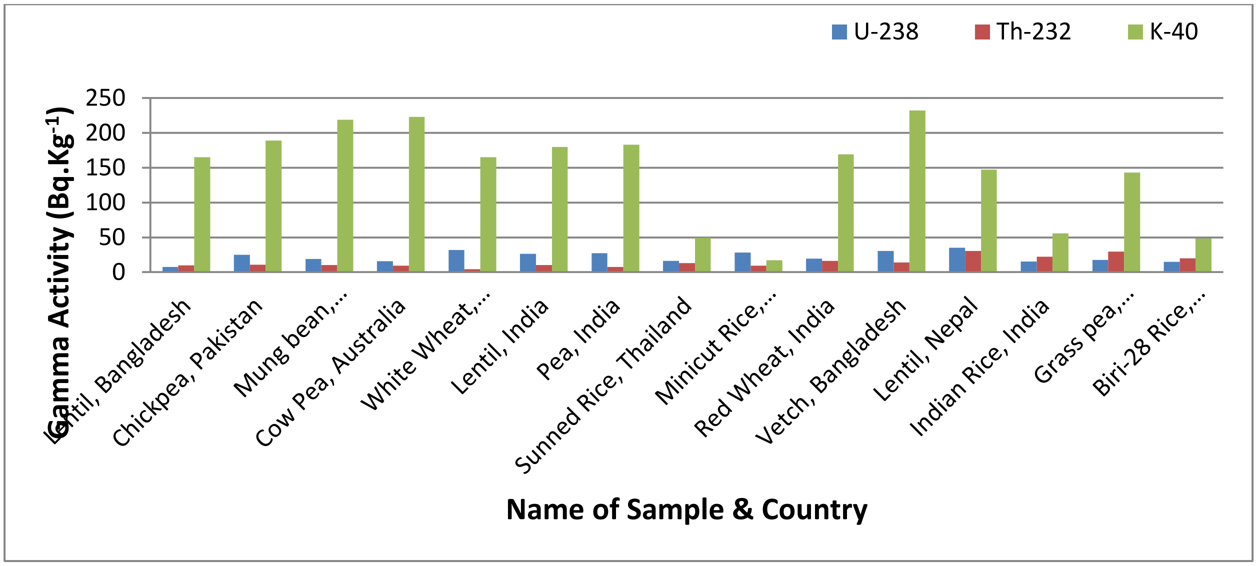

Fig. 1: A bar diagram of gamma activity of food grain Samples

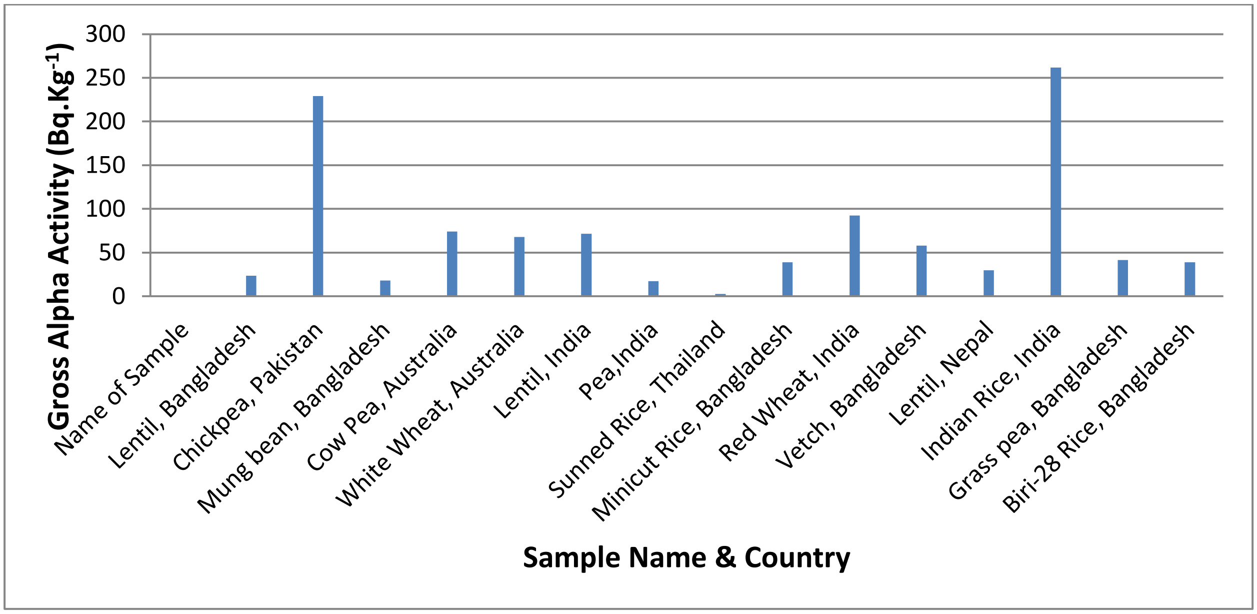

Fig. 2: A bar diagram of gross Alpha activity of food grain Samples

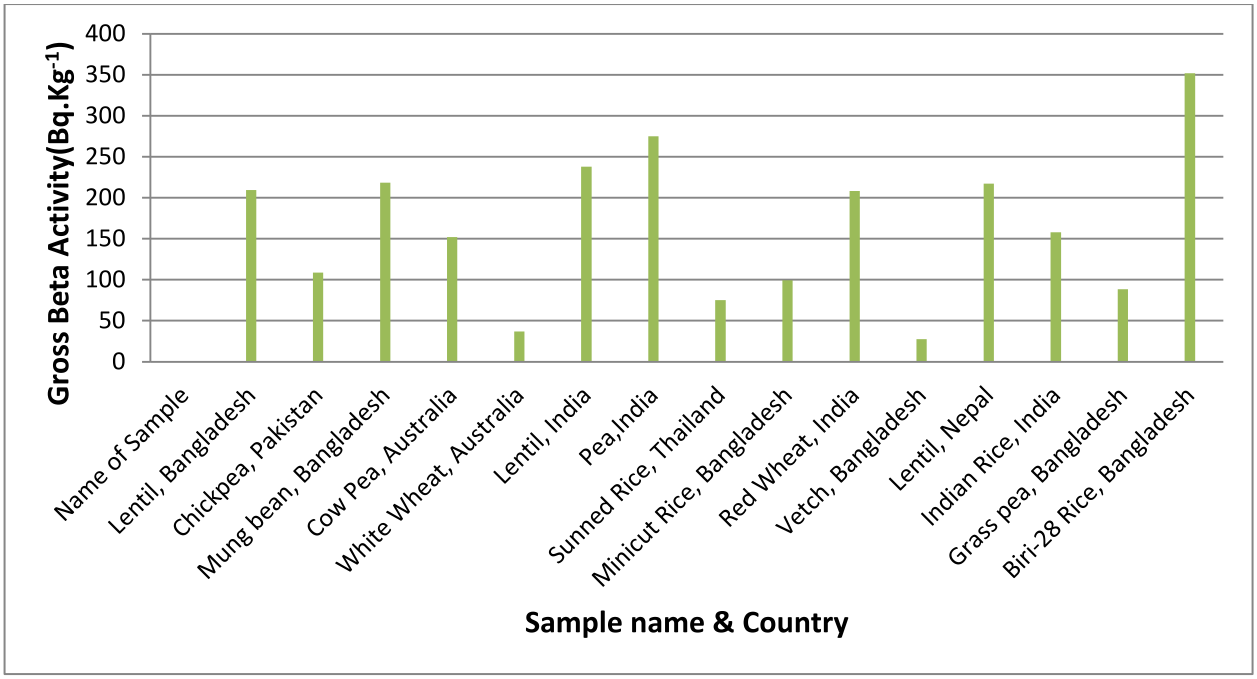

Fig. 3: A bar diagram of gross Beta activity of food grain Samples

Table1: Activity in Food Grain Samples

Sample No.	Sample Name	Country	Activity for U-238 $Bq.kg^{-1}$	Activity for Th-232 $Bq.kg^{-1}$	Activity for K-40 $Bq.kg^{-1}$
1	Lentil	Bangladesh	7.53 ±0.11	9.67 ±0.09	165 ±0.53
2	Chickpea	Pakistan	25.3 ±0.13	10.6 ±0.08	189 ±0.63
3	Mung bean	Bangladesh	19.3 ±0.11	10.3 ±0.09	219 ±0.58
4	Cow Pea	Australia	15.6 ±0.08	9.61 ±0.1	223 ±0.65
5	White Wheat	Australia	32.1 ±0.27	4.53 ±0.03	165 ±0.65
6	Lentil	Nepal	26.5 ±0.17	10.3 ±0.05	180 ±0.57
7	Pea	India	27.2 ±0.16	7.55 ±0.08	183 ±0.64
8	Sunned Rice	Thailand	16.5 ±0.09	13.0 ±0.08	49.5 ±0.42
9	Minicut Rice	Bangladesh	28.4 ±0.13	9.27 ±0.1	17.0 ±0.49
10	Red Wheat	India	19.5 ±0.17	16.4 ±0.1	170 ±0.67
11	Vetch	Bangladesh	30.5 ±0.19	13.8 ±0.12	232 ±0.62
12	Lentil	India	35.2 ±0.15	30.4 ±0.15	148 ±0.59
13	Indian Rice	India	15.3 ±0.11	22.3 ±0.09	55.9 ±0.42
14	grass pea	Bangladesh	17.9 ±0.1	29.8 ±0.15	143 ±0.58
15	Biri-28 Rice	Bangladesh	15.1 ±0.11	20.2 ±0.1	48.5 ±0.49
		Average	**22.1 ±0.14**	**14.5 ±0.09**	**146 ±0.57**
		Maximum	**35.2 ±0.15**	**30.4 ±0.15**	**232 ±0.62**
		Minimum	**7.53 ±0.11**	**4.53 ±0.03**	**17.0 ±0.49**

Table 2: Gross Alpha and Gross Beta Activity in Food Grain Samples

Sample No.	Sample Name	Country	Gross Alpha Activity **$Bq.kg^{-1}$**	Gross Beta Activity **$Bq.kg^{-1}$**
1	Lentil	Bangladesh	23.6 ± 0.85	209 ± 11.3
2	Chickpea	Pakistan	229 ± 3.5	109 ± 11.1
3	Mung bean	Bangladesh	18.1 ± 0.74	219 ± 11.3
4	Cow Pea	Australia	74.3 ± 1.64	152 ± 11.1
5	White Wheat	Australia	67.9 ± 1.31	36.8 ± 10.9
6	Lentil	Nepal	71.6 ± 1.73	238 ± 11.3
7	Pea	India	17.2 ± 0.75	275 ± 11.8
8	Sunned Rice	Thailand	2.72 ± 0.26	75.3 ± 10.7
9	Minicut Rice	Bangladesh	39.0 ± 4.98	99.5 ± 10.7
10	Red Wheat	India	92.4 ± 1.77	208 ± 11.1
11	Vetch	Bangladesh	58.0 ± 1.55	27.5 ± 11.2
12	Lentil	India	29.9 ± 0.92	217 ± 10.8
13	Indian Rice	India	262 ± 2.79	158 ± 10.8
14	grass pea	Bangladesh	41.7 ± 1.49	88.6 ± 11.2
15	Biri-28 Rice	Bangladesh	39 ± 1.27	352 ± 13.9
		Average	**78.1 ± 1.7**	**164 ± 11.3**
		Maximum	**262 ± 2.79**	**352 ± 13.9**
		Minimum	**2.72 ± 0.26**	**36.8 ± 10.9**

Table 3: Comparison gamma activity in environment sample

Country	Type of Sample	Range of Gamma $Bq.kg^{-1}$
Southwest India	Food Crops	127.696
Iraq	Legumes	U-238 1.450 ±0.096 to 12.307 ±0.387 Th-232 0.371 ±0.058 to 9.289 ±0.465 K-40 64.096 ±1.037 to 603.397 ±8.757
Jordan	Grains	17.7 -245.64

Table 4: Comparison of gross alpha and gross beta radioactivity in food grain Samples

Country	Type of Sample	Range of Gross Alpha $Bq.kg^{-1}$	Range of Gross Beta $Bq.kg^{-1}$
Rajasthan (India)	Grains	48.0 to 477.0	1440.0 ± 70.0
Jordan	Grains	11. to 132.67	124.34 to 790.58
Southwest India	food crops	497.0 ± 72.0	10946.0 ± 583.0

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