Review of tritium in Bangladesh before commissioning of NPP Rooppur

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Abstract. The comprehensive review article was carried out to present an overview of the tritium radioactivity concentrations in different components of observed freshwater ecosystems, primarily underground water (for drinking) and precipitation in People’s Republic of Bangladesh. Most of the reported data have been obtained using either 3He in-growth technique which is an indirect method or using direct method with liquid scintillation counter. The results of the radio-ecological monitoring of environment in Bangladesh show that the tritium content in groundwater, precipitation and river water vary from 0-25 TU, 5-10 TU and 5-10 TU respectively. Around proposed Rooppur Nuclear Power Plant site, tritium radionuclide concentration of 6.7-17.6 TU, <25.2 TU, <25.2 TU and 3.4-10.1 TU were obtained for surface water of Padma, bottom sediments, aquatic flora and drinking water respectively. Globally, the natural and technogenic background of tritium is assumed to be 2.2±0.7 Bq/L (18.5±5.9 TU) and 5 Bq/L (42.0 TU) respectively. Henceforth, the investigation authenticated that the tritium content in all samples is below cut-off point that requires intervention. The results obtained during the radio-ecological studies allow for subsequent evaluation of radiation doses and radiological health hazards that organisms/people experience due to the anthropogenic changes of background radiation in the studied regions.

1. Introduction
Tritium (\(^3\)H) is one of the radioactive isotopes of hydrogen existing in the environment either as tritiated water (HTO) or as organically bound tritium (OBT) [1]. Being a weak beta emitter, it emits an electron with median energy of 5.7 keV, maximum energy of 18.6 keV, and has a physical half-life of 12.3 years [1-2]. Natural source of tritium is through the action of cosmic rays in the upper atmosphere while technogenic origin is through scheduled releases by almost all nuclear facilities (nuclear power plants, defense facilities, fusion facilities, fuel processing plants, etc) and through thermonuclear explosions in atmosphere during 1950s and early 1960s. When ingested with food, water, or inhaled air, as well as through damaged body coverings, tritium can become a source of risk if it enters the cells and tissues of the body. OBT through substituting hydrogen in the DNA molecule can instigate considerable damage to genetic material and instill high risk of deep-rooted reverberations of radiation [1; 3].

2. Materials and methods
The research paper set forth a synopsis of the tritium radioactivity concentrations in different components of observed freshwater ecosystems, underground water for drinking purpose and precipitation in Bangladesh (BD). Tritium radioactivity corresponding to the site of the first Nuclear
Power Plant (NPP) in Bangladesh, that is Rooppur has also been included in the present study. In the referenced articles, the $^3$H analysis was performed either using $^3$He in-growth technique [4-7] which is an indirect method or using direct method with a liquid scintillation counter [8-10].

The results obtained during the radio-ecological studies allow for the obtaining data about the content of tritium radionuclide in the environment in Bangladesh which also include area in the vicinity of Rooppur NPP and subsequent evaluation of radiation doses and radiological risks that organisms/people experience due to the anthropogenic changes of tritium background radiation in these studied localities.

3. Results
The results of the radio-ecological surveillance of habitat in Bangladesh is presented in table 1 while outcomes of study carried out around Rooppur Nuclear Power Plant is represented in table 2. In the aforementioned tables, 1 Bq/kg of tritium activity corresponds to 8.390 ± 0.015 TU [11; 13], making use of the new value for the tritium half-life [12] and the CODATA 1998 value for the Avogadro constant [14]. One tritium unit (TU) is commensurate with one atom of tritium in $10^{18}$ atoms of hydrogen. Additionally, figure 1 represents the distribution of $^3$H content (2006-2008) in southern site shallow wells, central site shallow wells and intermediate wells [8] while in figure 2 the spatial distribution of $^3$H content (2006-2008) in shallow groundwater and intermediate groundwater [8] is emphasized.

4. Discussion
The meticulous analysis of the different works set forth in the preceding section in order to determine tritium concentration and subsequent deduction of radiation doses and radiological risks involved due to the background presence of tritium in Bangladesh is carried out in the current segment.

4.1. Bengal Delta Study.
In Bangladesh, about 97% of the populace depends on groundwater as a source of innocuous potable water [15]. Therefore, an exhaustive study [8] covering about 85% land area of Bangladesh excluding only the eastern Tertiary Hill Range was carried out to assess groundwater using isotopes technique during the period 2006-2008. Tritium concentration was measured applying liquid scintillation counter after electrolytic enrichment and was found to fluctuate between 0-5.0 TU (shown in table 1) in 328 groundwater samples that were analysed. Globally, the natural and anthropogenic background of tritium is assumed to be 2.2±0.7 Bq/L (18.5±5.9 TU) and 5 Bq/L (42.0 TU) respectively [11]. So the results obtained in the Bengal Delta study is below the mean global value and several orders of magnitude below the level demanding intervention, according to the Russian radiation safety legislation.

Two well-defined clusters of shallow groundwater can be seen in figure 1 [8] having $^3$H content <1.1 TU and >1.1 TU. And as for five intermediate depth ground waters, four samples show $^3$H values even at greater depths ranging from 76 to 168 m while $^3$H is absent for the sample collected at a depth of 152 m.

Tritium was obtained in majority of the samples that were analysed as is shown in the spatial distribution in figure 2 [8]. This is a proof that the active recharge nourished Bengal Delta aquifers all over the country. Active recharge of 0.5-0.7 TU nourished groundwater of intermediate depths of 88-134 m at west-central setting. But higher tritium concentrations were obtained at the north and central sites as shown in figure 2. Tritium concentrations of 1.1-5.0 TU in groundwater of these regions signal that considerable percentage of water is post-bomb in nature. Conversely, sites in the southern segment demonstrate low tritium concentrations at shallow depth with maximum concentration of 1.1 TU. This signifies the fact that these ground waters are pre-bomb in origin. Somewhat large times are required for water to travel to the aquifer in these unsaturated regions. Consequently, tritium concentration decreases due to radioactive decay during the long travel time.
Table 1. $^3$H concentrations in groundwater, river water and precipitation across different areas of Bangladesh (BD).

| Component          | Location               | Year       | Depth (m) | Tritium Level (TU) | Tritium Level (Bq/l) | Reference |
|--------------------|------------------------|------------|-----------|--------------------|-----------------------|-----------|
| Groundwater        | 9 south-western districts | 1999       | 10-335    | 0-7.2             | 0-0.86                | [4]       |
|                    | 4 western districts     | 2000       | 10-90     | 0-7.2             | 0-0.86                | [4]       |
|                    | Eastern, south-eastern  | 1999-2000  | 0-280     | 0-25              | 0-3.0                 | [5]       |
|                    | Araihaizar, Central     | 2003       | <20       | 0.4-5.4           | 0.05-0.64             | [6]       |
|                    |                        |            | 9         | 5.02± 0.16        | 0.60±0.02             |           |
|                    |                        |            | 14        | 9.23±0.27         | 1.10±0.03             |           |
|                    |                        |            | 18        | 18.5±0.5          | 2.21±0.06             |           |
|                    | Munshiganj, Southern    | 2004       | 24        | 12.4±0.4          | 1.48±0.05             | [7]       |
|                    |                        |            | 30        | 2.22±0.13         | 0.26+0.02             |           |
|                    |                        |            | 38        | 0.12±0.08         | 0.01±0.01             |           |
|                    |                        |            | 46-107    | 0-0.04±0.09       | 0-0.01±0.01           |           |
|                    | Bengal Delta (85 % land area of BD except eastern Tertiary Hill range) | 2006-2008 | 7-152     | 0-5.0             | 0-0.60                | [8]       |
|                    |                        | 1953       |           | 5.9               | 0.70                  |           |
|                    |                        | 1955       |           | 9.7               | 1.16                  |           |
|                    |                        | 1958       |           | 111.2             | 13.25                 |           |
|                    |                        | 1962       |           | 224.2             | 26.72                 |           |
|                    |                        | 1963       |           | 597.2             | 71.18                 | [9]       |
|                    |                        | 1964       |           | 383.2             | 45.67                 |           |
|                    |                        | 1965       |           | 199.4             | 23.77                 |           |
|                    |                        | 1966       |           | 114.1             | 13.60                 |           |
|                    |                        | 1985-1995  |           | 5-10              | 0.60-1.19             |           |
| Precipitation      | Dhaka, Central         | NA         |           |                   |                      |           |
| River water        | 9 south-western districts and 4 western districts | 1999, 2000 | Surface water | 5-10              | 0.60-1.19             | [4]       |

Table 2. The content of tritium in the components of freshwater ecosystems in the vicinity of Rooppur NPP [10].

| Component              | Tritium Unit (TU) | Tritium Level (Bq/kg (L)) |
|------------------------|-------------------|---------------------------|
| Surface water of Padma| 6.7-17.6          | 0.8-2.1                   |
| Bottom sediments       | <25.2             | <3                        |
| Aquatic flora          | <25.2             | <3                        |
| Drinking water         | 3.4-10.1          | 0.4 – 1.2                 |
4.2. Some Other Groundwater Studies.

In [7], groundwater dynamics were studied using noble gases and tritium in the rural Munshiganj district as representative of southern region of Bangladesh. In the investigation carried out in January 2004 by Klump et.al., the samples of $^3\text{H}$ were analysed using the $^3\text{He}$ in-growth method using a high-sensitivity compressor-source noble gas mass spectrometer. From table 1, it can be seen that the $^3\text{H}$ content is positively correlated with depth and peaks at a value of 18.5 TU at a depth of approximately 20 m. At depths below 20 m, $^3\text{H}$ concentration decreases, and below approximately 35 m, the groundwater is virtually free of $^3\text{H}$. In conclusion, the environmental tracer data suggest the presence of a young, shallow groundwater body that contains bomb-derived $^3\text{H}$, indicating ages less than roughly 55 years, and of an old, deep groundwater body, which is virtually $^3\text{H}$ free. The peak concentration of 18.5 TU is relatively low and below the average global value indicating negligible danger to populace due to tritium radiation.

Figure 1. Distribution of $^3\text{H}$ content (2006-2008) in southern site shallow wells, central site shallow wells and intermediate wells [8].

Figure 2. Spatial distribution of $^3\text{H}$ content (2006-2008) in shallow groundwater and intermediate groundwater [8].
Groundwater in the central part of Bangladesh was investigated by Stute et. al. [6] using indirect method of $^3$He in-growth technique. Araihazar Upazila was selected as representative of central region of Bangladesh. Like in other studies, tritium concentration of 0.4-5.4 TU in groundwater samples at depths below 20 m collected from this region is below world mean value of 25 TU (2.2±0.7 Bq/L) and hence tritium radioactivity in this region is relatively low.

Tritium concentration was also found out in ground water and in river water [4]. In May 1999, during the first sampling campaign conducted in nine south-western regions of Bangladesh, 36 water samples were collected from shallow and deep tube wells, ranging in depth from 10 to 335 m. During the second mission organized in January 2000 in four western parts of Bangladesh, 20 samples from shallow and deep tube wells, ranging in depth from 10 to 90 m were collected. The concentration of tritium in underground water from both south-western and western districts was relatively low and measured 0-7.2 TU, showing that danger from tritium radioactivity is negligible. River water in the region also has a similar trivial tritium content. The low tritium content of shallow groundwater is consistent with recharge from local rain and floodwaters. The absence of tritium in many of the shallow samples indicates relatively large travel times in the unsaturated zone (several years to tens of years), resulting in the loss of tritium by radioactive decay before reaching the aquifer.

4.3. Study of Precipitation.

Research [9] reconstructed annual mean $^3$H concentration in precipitation utilizing International Atomic Energy Agency (IAEA)/ World Meteorological Organization (WMO) database for Dhaka, Bangladesh, for 1953-1995 in order to apply the $^3$H and $^3$H/$^3$He methods to constrain the groundwater flow regime in Bangladesh.

Tritium concentration in precipitation before 1953 was about 5 tritium units (TU). In the 1950s and early 1960s atmospheric nuclear tests introduced much higher amounts of tritium into the atmosphere. Consequently, in 1963/64, the concentration in precipitation increased by three orders of magnitude in the northern hemisphere as compared to that arising from the cosmic rays [16]. The peak concentration of tritium in precipitation occurred in 1963 which in case of Dhaka, Bangladesh amounted to 597.2 TU. Since then, tritium concentration has decreased substantially to present levels of about 5-10 TU in the Northern Hemisphere which is same as the pre-nuclear tests level. Present day precipitation in Bangladesh is estimated to have a tritium content of around 5-10 TU which is below the threshold point that requires intervention.

4.4. Research in the Vicinity of Rooppur Nuclear Power Plant.

The site around the first NPP in Bangladesh, i.e. Rooppur NPP was investigated [10-11] and tritium concentration assessed using liquid scintillation counter. The results are illustrated in table 2. Panov et. al. in their research [10] measured tritium radionuclide concentration of 0.8-2.1 Bq/L, <3 Bq/kg, <3 Bq/kg and 0.4-1.2 Bq/L for surface water of Padma, bottom sediments, aquatic flora and drinking water respectively. Henceforth, the investigation authenticated that the tritium content in the surface waters of the Padma River together with the components of freshwater ecosystem in the vicinity of the Rooppur NPP is below the world average value and possesses no radiological threat to the population residing in the locality.

5. Conclusion

The extensive review article presents an overview of the tritium radioactivity concentrations in different components of observed freshwater ecosystems, underground water for drinking purpose and precipitation in Bangladesh with special attention given to the site of the first Rooppur NPP in Bangladesh. The tritium content in groundwater, precipitation and river water fluctuates between 0-25 TU, 5-10 TU and 5-10 TU respectively as obtained from the radio-ecological monitoring of environment in Bangladesh. The tritium radionuclide concentration of 6.7-17.6 TU, <25.2 TU, <25.2 TU and 3.4-10.1 TU were detected around Rooppur NPP for surface water of Padma, bottom sediments, aquatic flora and drinking water respectively.

On the basis of these results, one can state that tritium concentration in groundwater, precipitation and different components of observed freshwater ecosystem is relatively low (0 to 25 TU) all over
Bangladesh at this moment in time and is below the cut-off point that demands intervention. This comprehensive review study provides a baseline of tritium concentration in Bangladesh including the proposed Rooppur NPP site area and will allow the observation of changes and the evaluation of radiation doses and radiological health hazards that organisms/people experience due to the technogenic changes of radiation on the environmental situation in these studied regions.

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