Radioactivity Assessment of Sediments in Negombo Lagoon Sri Lanka

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Abstract—The distributions of naturally occurring and anthropogenic radioactive materials were determined in surface sediments taken at 27 different locations along the bank of Negombo Lagoon in Sri Lanka. Hydrographic parameters of lagoon water and the grain size analyses of the sediment samples were also carried out for this study. The conductivity of the adjacent water was varied from 13.6 mS/cm to 55.4 mS/cm near to the southern end and the northern end of the lagoon, respectively, and equally salinity levels varied from 7.2 psu to 32.1 psu. The average pH in the water was 7.6 and average water temperature was 28.7 °C. The grain size analysis emphasized the mass fractions of the samples as sand (60.9%), fine sand (30.6%) and fine silt + clay (1.3%) in the sampling locations. The surface sediment samples of wet weight, 1 kg each from upper 5-10 cm layer, were oven dried at 105 °C for 24 hours to get a constant weight, homogenized and sieved through a 2 mm sieve (IAEA technical series no. 295). The radioactivity concentrations were determined using gamma spectrometry techniques. Ultra Low Background Broad Energy High Purity Ge Detector, BEGe (Model BE5030, Canberra) was used for radioactivity measurement with Canberra Industries’ Laboratory Source-less Calibration Software (LabSOCS) mathematical efficiency calibration approach and Geometry composer software. The mean activity concentration was found to be 24 ± 4, 67 ± 9, 181 ± 10, 59 ± 8, 3.5 ± 0.4 and 0.47 ± 0.08 Bq/kg for 238U, 232Th, 40K, 210Pb, 235U and 137Cs respectively. The mean absorbed dose rate in air, radium equivalent activity, external hazard index, annual gonadal dose equivalent and annual effective dose equivalent were 24 ± 4, 67 ± 9, 181 ± 10, 59 ± 8, 3.5 ± 0.4 and 0.47 ± 0.08 mSv/year, respectively. The results of this study will provide baseline information on the natural and artificial radioactive isotopes and environmental pollution associated with information on radiological risk.

Keywords—Gamma spectrometry, lagoon, radioactivity, sediments.

I. INTRODUCTION

The naturally occurring radio nuclides such as potassium-40, uranium and thorium series elements are abundant in every environment in the earth. The radiation associated with these radionuclides behaves as an important factor of the earth since its formation. According to UNSCEAR (1993), about 87% of the radiation exposure is due to the sources of the natural radiation and the anthropogenic radiation sources create the remains [1], [2]. The global environment was contaminated with anthropogenic radionuclides such as 137Cs due to the atmospheric testing of thermonuclear weapons, which took place primarily from the mid-1950s to the mid-1970s [3] and spread all over the world as a fallout radionuclide. Long-term exposure to uranium and radium through inhalation and irradiation has several health effects such as chronic lung diseases, acute leucopoenia, anaemia, and necrosis of the mouth. Radium causes bone, cranial, and nasal tumors. Thorium exposure can cause lung, pancreas, hepatic, bone, and kidney cancers and leukemia [4]. Knowledge about the distribution of radioactivity enables one to assess any possible radiological hazard to humankind by the living in such environments [5]. In general, the activity concentrations of radio nuclide increase inversely with the grain size [6] and density of the sediments [7], [8]. The uranium and thorium radionuclides are associated with heavy minerals and 40K is concentrated with clay minerals [9]. Additionally other parameters such as mineralogy, organic content and geochemical composition play an important role in the absorption of radioactive elements in the sediments.

In particular, elevated concentrations of several natural radionuclides in water and soils collected from different rivers, beaches, oceans and other landscapes throughout the world [10]-[12] were published and accessible to the scientific community. However scientific data of the natural and anthropogenic radio nuclides in the Sri Lankan marine and coastal environments are limited at the moment. Sri Lanka has numerous productive lagoon ecosystems along its coastline, which is over 1340 km long. Regrettably, some coastal lagoon ecosystems are being threatened by human-induced activities, as a result of growing urban recreational and industrial development of the coastal areas of Sri Lanka. The Negombo lagoon in the Western province, situated very close to the capital city, Colombo, is a major lagoon ecosystem which has recently experienced severe environmental degradation, both in and around the lagoon.

The aim of this study is to determine natural (238U, 232Th, 40K, 210Pb, 235U) and anthropogenic radioactivity levels (137Cs) in surface sediments of different locations in Negombo lagoon. Also, the associated radiological risk parameters and indexes such as average radium equivalent activity, the total absorbed dose rate, the external hazard index, the annual gonadal dose equivalent and the annual effective dose equivalent will be calculated and compared with the global levels published in the literature. These data will serve as the baseline level for naturally occurring and anthropogenic radionuclides in the study area.

II. MATERIALS AND METHODS

A. The Study Area

Negombo lagoon (70 12’ 0 N and 790 50’ 0 E to 70 6’ 0 N and 790 55’ 0 E) is a large, shallow basin, estuarine lagoon situated in the Western Province of Sri Lanka. The surface...
area of the lagoon is 35 km$^2$ [13] and maximum depth is about 2-3 m while most of very shallow areas are less than 50 cm. The lagoon is fed by fresh water from a number of small rivers and canals. It is linked to the sea at its northern end by a single narrow channel near to the city of Negombo.

B. Sampling and Sample Preparation

The surface sediment samples from the upper 5-10 cm layer were collected at 1 km intervals along the lagoon bank using a plastic scoop. The 27 sampling locations (Fig. 1) were selected and the sample size was around 1 kg in wet weight. The samples were placed into contamination-free plastic bags, labeled and then transported to the laboratory. The samples were air dried at room temperature divided into two halves (250 g dry weighted each), packed in air-tight bags and stored for radioactivity analysis and grain size analysis.

C. Hydrographic Parameters of Water

The hydrographic parameters of water lead the association, transport and biological activity of radionuclides in the adjacent environment. In this study, water temperature, pH, Rugged Dissolved Oxygen (RDO), Total Dissolved Solids (TDS), conductivity and salinity were determined by a portable meter (ORION STAR A329, Thermo Scientific) at 5-10 cm depth water layer. The variation of hydrographic parameters of water was presented in Fig. 2. The depth of the water column at the sample sites was ranged from 0.5 s–1.0 m.

Conductivity is one of the water quality parameters which are most useful and commonly measured. The conductivity of the water varied from 13.6 mS/cm to 55.4 mS/cm in the sampling locations close to the fresh water inputs at the southern end and near to the lagoon mouth at the northern end, respectively.

D. Grain Size Analysis of the Sediment Samples

The samples were segregated in four particle size classes by dry sieving technique as > 2 mm, 2-0.25 mm, 0.25-0.063 mm and < 0.063 mm. Weight fraction of samples in the different particle sizes is shown in Fig. 3. The maximum mass fraction for the samples lies in the 2.0-25 mm particle size class (60.9%) and 0.25-0.063 mm particle size class (30.6%), that are sand and fine sand fractions, respectively. The mass fraction of < 0.063 mm particle size was 1.3% and it from 29.3 °C to 35.1 °C.
represented the mix of fine slit and clay fraction in the sampling points.

E. Sample Preparation for Radioactivity Measurements

Samples were oven dried at 105 °C for 24 hours to get a constant weight, homogenized and sieved through a 2 mm sieve [14]. The sediment fraction of < 2 mm particle size was then filled into a plastic cylindrical container (8.3 cm diameter x 2.8 cm height). Each sample was sealed, weighed and stored for 30 days to achieve equilibrium for 238U and 232Th with their respective progeny.

F. Measurement Methodology

Sample preparation and all radioactivity measurements were made in the Sample Preparation Laboratory and Gammaspectrometry Laboratory of the Life Sciences Division, Sri Lanka Atomic Energy Board. Gamma spectrometry measurements were made with an Ultra-Low Background Broad Energy High Purity Ge Detector (BEGe) of 48% relative efficiency and resolution 2.0 keV at the 1332.5 keV of 60Co (Model BE5030, Canberra). The active area of the U-style cryostat detector was 5000 mm² and active diameter was 81 mm [15]. The detector was shielded in a 15 cm thick lead, internally lined with graded copper and tin.

III. RESULTS AND DISCUSSION

A. The Activity Concentrations of Interested Gamma Emitters in Sediments

The dry weight activity concentrations of the main gamma emitting radio nuclides of the U series, Th series, 40K, 235U, 210Pb and 137Cs in the sediment samples are shown in Table I.

The average concentrations of 238U, 232Th, 40K, 235U, 210Pb and 137Cs were found to be 23.6 ± 3.5, 67.3 ± 8.8, 181.2 ± 10.3, 3.5 ± 0.4, 59.1 ± 7.6 and 0.47 ± 0.08 Bq/kg (dry weight) in sediment samples, respectively.
The worldwide concentrations of the radio nuclides $^{238}$U, $^{232}$Th, and $^{40}$K have averages in the sediment samples of 25, 25, and 373 Bq/kg, respectively [16]. The results show that the mean activity concentrations of $^{40}$K radio nuclides is low and mean activity concentrations of $^{232}$Th and $^{238}$U are high and similar, and respectively comparable with the worldwide concentrations. For comparison, the activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K for river and coastal environmental sediments of different countries are presented in Table II.

The $^{232}$Th and $^{238}$U radio activity concentrations of the lagoon sediments were high compared to the $^{40}$K concentration. This result proves the fact of uranium and thorium nuclides are associated with heavy minerals and $^{40}$K is concentrated with clay minerals. The average sediment sample collected from Negombo lagoon bank contained maximum mass fraction of sand and find sand (over 90%) and very less mass fraction of fine silt+clay (1.3%). The relationship of distribution of $^{40}$K and percentage clay in the sediments is illustrated in Fig. 4.

The natural radio nuclides’, $^{238}$U, $^{232}$Th and $^{40}$K, activities did not show a uniform distribution depending on radioactivity values of the rocks, forming the geological structure of this region. The heat maps generated using ArcGIS visualize the distribution of radionuclides of $^{238}$U, $^{232}$Th and $^{40}$K. All the interested radionuclides have been concentrated in the mouth of lagoon where the water is salty and blackish.

The distribution of $^{238}$U, $^{232}$Th and $^{40}$K activity concentrations of sediment samples in Negombo lagoon bank are shown in Figs. 5 (a)-(c).

### Table I

<table>
<thead>
<tr>
<th>Country</th>
<th>Ra-226 Mean (Bq/kg)</th>
<th>Th-232 Mean (Bq/kg)</th>
<th>K-40 Mean (Bq/kg)</th>
<th>Reference</th>
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<td>India</td>
<td>(35.3)</td>
<td>(34.04)</td>
<td>(401.11)</td>
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<td>Bangladesh</td>
<td>(38)</td>
<td>(66)</td>
<td>(272)</td>
<td>[16]</td>
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<td>China</td>
<td>18-135</td>
<td>35-228</td>
<td>281-711</td>
<td>[17]</td>
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<td>Japan</td>
<td>5-130</td>
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<td>31-37</td>
<td>410-475</td>
<td>[19]</td>
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<td>Nigeria</td>
<td>(16)</td>
<td>(24)</td>
<td>(35)</td>
<td>[20]</td>
</tr>
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<td>Saudi Arabia</td>
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<td>5.3-58.9</td>
<td>324.6-1133</td>
<td>[21]</td>
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<td>Kuwait</td>
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<td>14.0-17.1</td>
<td>351.2-404.0</td>
<td>[22]</td>
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<td>Oman</td>
<td>11.8-22.7</td>
<td>10.7-25</td>
<td>223-535</td>
<td>[23]</td>
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<td>(18)</td>
<td>(316)</td>
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<td>7.50</td>
<td>100-700</td>
<td>[12]</td>
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<td>present work</td>
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### Table II

<table>
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<tr>
<th>Sample Code</th>
<th>40K Bq/kg</th>
<th>137Cs Bq/kg</th>
<th>210Pb Bq/kg</th>
<th>238U Series (Bq/kg)</th>
<th>232Th Series (Bq/kg)</th>
<th>235U Bq/kg</th>
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<tr>
<td>NL01</td>
<td>313 ± 6</td>
<td>0.30 ± 0.05</td>
<td>73 ± 12</td>
<td>35 ± 3</td>
<td>39 ± 4</td>
<td>5.13 ± 0.59</td>
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<td>NL02</td>
<td>81 ± 4</td>
<td>ND</td>
<td>9 ± 2</td>
<td>7 ± 1</td>
<td>9 ± 1</td>
<td>5.19 ± 0.14</td>
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<td>NL03</td>
<td>170 ± 8</td>
<td>38 ± 6</td>
<td>29 ± 2</td>
<td>33 ± 3</td>
<td>34 ± 3</td>
<td>4.06 ± 0.41</td>
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<td>NL04</td>
<td>84 ± 4</td>
<td>26 ± 4</td>
<td>18 ± 1</td>
<td>20 ± 2</td>
<td>21 ± 2</td>
<td>2.98 ± 0.29</td>
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<td>NL05</td>
<td>77 ± 6</td>
<td>ND</td>
<td>14 ± 1</td>
<td>15 ± 1</td>
<td>15 ± 2</td>
<td>2.12 ± 0.25</td>
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<td>63 ± 3</td>
<td>14 ± 2</td>
<td>8 ± 1</td>
<td>9 ± 1</td>
<td>10 ± 1</td>
<td>1.27 ± 0.16</td>
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<td>55 ± 3</td>
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<td>25 ± 4</td>
<td>17 ± 1</td>
<td>18 ± 2</td>
<td>2.34 ± 0.24</td>
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<td>83 ± 6</td>
<td>ND</td>
<td>17 ± 3</td>
<td>11 ± 1</td>
<td>12 ± 1</td>
<td>1.64 ± 0.19</td>
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<tr>
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<td>158 ± 14</td>
<td>0.54 ± 0.14</td>
<td>58 ± 10</td>
<td>23 ± 2</td>
<td>26 ± 3</td>
<td>4.78 ± 0.58</td>
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<td>152 ± 11</td>
<td>0.26 ± 0.04</td>
<td>46 ± 7</td>
<td>32 ± 3</td>
<td>36 ± 4</td>
<td>5.37 ± 0.58</td>
</tr>
<tr>
<td>NL12</td>
<td>106 ± 8</td>
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<td>11 ± 2</td>
<td>8 ± 1</td>
<td>9 ± 1</td>
<td>2.12 ± 0.16</td>
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<td>NL13</td>
<td>154 ± 12</td>
<td>ND</td>
<td>29 ± 5</td>
<td>19 ± 2</td>
<td>21 ± 2</td>
<td>3.47 ± 0.41</td>
</tr>
<tr>
<td>NL14</td>
<td>32 ± 2</td>
<td>ND</td>
<td>15 ± 3</td>
<td>4.8 ± 0.4</td>
<td>1 ± 1</td>
<td>2.12 ± 0.19</td>
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<td>NL15</td>
<td>36 ± 3</td>
<td>ND</td>
<td>26 ± 4</td>
<td>18 ± 2</td>
<td>20 ± 2</td>
<td>2.95 ± 0.35</td>
</tr>
<tr>
<td>NL16</td>
<td>37 ± 2</td>
<td>0.09 ± 0.03</td>
<td>19 ± 3</td>
<td>12 ± 1</td>
<td>14 ± 1</td>
<td>1.87 ± 0.18</td>
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<tr>
<td>NL17</td>
<td>63 ± 4</td>
<td>0.33 ± 0.08</td>
<td>340 ± 6</td>
<td>27 ± 2</td>
<td>31 ± 3</td>
<td>4.18 ± 0.43</td>
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<tr>
<td>NL18</td>
<td>138 ± 15</td>
<td>0.58 ± 0.15</td>
<td>63 ± 11</td>
<td>7 ± 1</td>
<td>8 ± 1</td>
<td>2.9 ± 0.04</td>
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<tr>
<td>NL19</td>
<td>137 ± 13</td>
<td>0.45 ± 0.09</td>
<td>49 ± 9</td>
<td>15 ± 2</td>
<td>17 ± 2</td>
<td>2.71 ± 0.36</td>
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<tr>
<td>NL20</td>
<td>256 ± 12</td>
<td>0.96 ± 0.13</td>
<td>121 ± 18</td>
<td>18 ± 1</td>
<td>19 ± 3</td>
<td>4.48 ± 0.45</td>
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<tr>
<td>NL21</td>
<td>447 ± 21</td>
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<td>50 ± 9</td>
<td>30 ± 2</td>
<td>33 ± 3</td>
<td>4.42 ± 0.56</td>
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<td>NL22</td>
<td>300 ± 14</td>
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<td>37 ± 7</td>
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<td>46 ± 4</td>
<td>4.8 ± 0.05</td>
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<td>1.2 ± 0.1</td>
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<td>4.63 ± 0.71</td>
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<td>NL26</td>
<td>351 ± 17</td>
<td>ND</td>
<td>40 ± 8</td>
<td>30 ± 2</td>
<td>33 ± 3</td>
<td>4.0 ± 0.5</td>
</tr>
</tbody>
</table>

The activity concentrations of $^{238}$U, $^{232}$Th, and $^{40}$K have averages in the sediment samples of 25, 25, and 373 Bq/kg, respectively [16]. The results show that the mean activity concentrations of $^{40}$K radio nuclides is low and mean activity concentrations of $^{232}$Th and $^{238}$U are high and similar, and respectively comparable with the worldwide concentrations. For comparison, the activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K for river and coastal environmental sediments of different countries are presented in Table II.

The $^{232}$Th and $^{238}$U radio activity concentrations of the lagoon sediments were high compared to the $^{40}$K concentration. This result proves the fact of uranium and thorium nuclides are associated with heavy minerals and $^{40}$K is concentrated with clay minerals. The average sediment sample collected from Negombo lagoon bank contained maximum mass fraction of sand and find sand (over 90%) and very less mass fraction of fine silt+clay (1.3%). The relationship of distribution of $^{40}$K and percentage clay in the sediments is illustrated in Fig. 4.
The geological compositions of the sampling points from NL 19 to NL 27 consist of a higher percentage of fine silt-clay than other sampling points, as shown in Fig. 3. Because of this variation of geologic composition, there is a significant difference among the concentration levels of natural radio nuclides existing. As well, 137Cs is released into the environment of the South Asian region as fallout radionuclide due to nuclear power plant accidents at Chernobyl, Ukraine in April 1986 and Fukushima, Japan in March 2011, as well as from atmospheric nuclear weapon tests conducted by several countries. Significant differences in 137Cs activity in sediment samples were observed in this study as in Fig. 6. The recorded 137Cs activities in sediment samples varied from 0.09 to 1.2 Bq/kg and average 137Cs activity was found to be 0.52 Bq/kg in 09 out of 25 sampling points.
**B. Calculation of Radiation Hazard Parameters**

Different known radiation health hazard indices analyses have been used in radiation studies to arrive at a better and safer conclusion on the health status of a radiated or irradiated person and environment. These indices, due to the radiation concentrations of top surface sediments of the Negombo lagoon, can be estimated using the results obtained from this study.

1. **Absorbed Dose Rate in Air (D)**

Absorbed dose is a physical dose representing the mean energy imparted to matter per unit mass by ionizing radiation. The contribution of natural radio nuclides to the absorbed dose rate in air (D) at 1 m above the ground depends on the natural specific activity concentration of 238U, 232Th and 40K. The absorbed dose rate in air can be calculated using (1) [26], [11]:

\[
D \left( \frac{\text{nGy}}{\text{h}} \right) = 0.427A_U + 0.662A_{Th} + 0.0432A_K
\]  

where D is the dose rate at 1 m above the ground, \(A_U\), \(A_{Th}\) and \(A_K\) are the activity concentrations of 238U, 232Th and 40K, respectively, in the samples. The conversion factors of 238U, 232Th and 40K are 0.427, 0.662 and 0.0432 nGy/h per Bq/kg, respectively [27]. The absorbed dose rates in air at Negombo lagoon varied from 10.1 to 154.6 nGy/h and the average dose rate was 60.8 nGy/h. The absorbed dose rates in air for the areas under investigation are listed in Table III. The average dose rate value in Negombo lagoon sediment is higher than the international recommended absorbed dose rate value of 55 nGy/h [11].

2. **Radium Equivalent Activity (Ra eq)**

The Gamma-ray radiation hazards due to the specified radio nuclides 226Ra, 232Th and 40K were assessed by different indices. Radium equivalent (Ra eq) is a common index used to compare the specific activities of materials containing 226Ra, 232Th and 40K by a single quantity, which takes into account the radiation hazards associated with them [28]. Radium equivalent activity is a widely used hazard index and it provides a useful guideline in regulating the safety standard dwellings. The radium equivalent activity represents a weighted sum of activities of the above-mentioned natural radio nuclides and is based on the estimation that 1 Bq/kg of 226 Ra, 0.7 Bq/kg of 232 Th, and 13 Bq/kg of 40 K produce the same radiation dose rates. The Ra-equivalent activity (Ra eq) can be calculated using (2) [29]:

\[
Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K
\]  

where \(A_{Ra}\), \(A_{Th}\) and \(A_K\) are the activity concentration of 226Ra, 232Th and 40K in Bq/kg respectively. Ra eq was estimated for the collected sediment samples and given in Table III. The values of Ra eq varied from 22.7 to 348.8 Bq/kg and average value of Ra eq was found to be 137.3 Bq/kg. The estimated average values of Ra eq in the present work were lower than the recommended maximum value of 370 Bq/kg [28]. While comparing the measured mean values from some of the other countries, it was observed that the values of this work were lower than the measured values of 493.8 Bq/kg in the Eastern Desert of Egypt [30], 366.9 Bq/kg in the southeast part of Eskisehir (Turkey) [31] and 266 Bq/kg in Xiaohuang Granite Area (China) [32].

3. **External Hazard Index (Hex)**

Many naturally occurring radio nuclides produce an external radiation field to which all human beings are exposed. In terms of dose, the principal primordial radio nuclides are 232Th, 238U and 40K. The external hazard index, \(H_{ex}\) was calculated for the sediment samples using (3) [29]:

\[
H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \leq 1
\]  

where \(A_{Ra}\), \(A_{Th}\) and \(A_K\) are the activity concentration of 226Ra, 232Th and 40K in Bq/kg, respectively. The results of Hex based on the criterion equation (3) are given in Table III. The results range from 0.06 to 0.95 and average value was found to be 0.4. All the values estimated for Hex in the present work are lower than 1. The average values of Hex were found to be 2.03 for Eastern Desert of Egypt [29], 0.99 for the...
southeast part of Eskisehir (Turkey) [31] and 0.84 for Xiazhuang Granite Area (China) [32].

4. Annual Gonadal Dose Equivalent (AGDE)

The gonads, bone marrow and bone surface cells are considered as organs of interest [11]. The AGDE for the residents of a building using a material with a given activity concentration of 226Ra, 232Th and 40K was calculated using (4) [33]:

\[
AGDE = \frac{\mu Sv}{year} = 3.09A_{Ra} + 4.18A_{Th} + 0.314A_{K}
\]

The obtained values of AGDE are listed in Table III. The values of AGDE varied from 70.4 to 1078.4 µSv/year. The average value was found to be 2398 mSv/year for Eastern Desert of Egypt [30]. This value of AGDE is higher than the world average value. The AEDE value was calculated to be 152 mSv/year in the Xiazhuang Granite Area (China) [32], 314.1 mSv/year in the southeast part of Eskisehir (Turkey) [31], 69.8 mSv/year in Istanbul (Turkey) [36]. These average values are generally higher than the results of the current study.

A summary of the aforementioned radiation hazard parameters is presented in Table IV.

IV. CONCLUSION

The activity levels and distribution of natural and anthropogenic terrestrial radionuclides of 238U, 226Ra, 232Th, and 40K were measured by gamma-ray spectrometry system for top surface sediment samples collected from Negombo lagoon, Sri Lanka. The activity concentrations of uranium, potassium and radium in the studied sediments are found to be normal, whereas thorium is having slightly greater value. The mean concentrations of the radio nuclides 238U, 232Th, 137Cs, and 40K in sediment samples determined in this study have been compared with literature values.

From the measured values, the average value of absorbed dose rate in air (D), radium equivalent activity (Ra(eq)), external hazard index (Hex), AGDE and AEDE were calculated. The outdoor air absorbed dose rates (D) due to terrestrial gamma rays for sediment have been calculated because of agricultural area and living in the surrounding. The radium equivalent activity (Ra(eq)), external hazard index (Hex) and AGDE are calculated to assess the radiological hazard of sand mixed with sediment since sand is used as construction materials in this region. The AEDE is higher than the world average. Nevertheless, the health effects due to natural radiation from the sediment of the Negombo lagoon are low and thus, the health hazards are insignificant. 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 sediments of other coastal marine environments of Sri Lanka. The results may also be used as reference data for monitoring possible radioactivity pollution in the future.
REFERENCES


