Health Risk Implications of Terrestrial Gamma Radiation Dose Rate in Central Jakarta, Indonesia: Short Communications

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Abstract
Terrestrial gamma radiation (TGR) dose rate measurement has been conducted around downtown region of Central Jakarta Indonesia. The real time count data was taken 1 m above the ground in eight sub district locations by using a portable gamma Survey meter of Exploranium GR-135 Plus Model. The reading position was determined by Garmin GPSMAP 62s. The average value of TGR dose rate of (47.76 ± 18.24) nSv h⁻¹ ranged from 6.40 nSv h⁻¹ to 120.90 nSv⁻¹, it is higher than in Indonesia average. The annual effective dose rate of 0.06 mSv contributes to fatal cancer risk of about 3.32 x 10⁻⁶ per year for each individual in Central Jakarta. For the subdistrict TGR dose rate value was varied, however all the result is not high enough to cause for alarm.

Keywords: terrestrial gamma radiation, health risks, dose assessment, Central Jakarta

1. Introduction
Background Radiation surveys were conducted in many countries around the world to establish a baseline level of natural radiation (Al-Sharkawy et al., 2012; Songs et al., 2012; Dent et al., 2013; Krishnamoorthy et al., 2013; Muntean et al., 2013; Mykowska & Hupka, 2014; Garba et al., 2014; Todorovic et al., 2014; Liu et al., 2015; Ramli et al., 2016). Background terrestrial gamma radiation dose rate is influenced by primordial radioactive concentration such as uranium, thorium and potassium (Apriantoro et al., 2013; Mohapatra et al., 2013; Krishnamoorthy et al., 2013; Sánchez-González et al., 2014; Karataşlı et al., 2016).

The annual effective dose values for terrestrial gamma radiation dose rate of 0.48 mSv with indoor and outdoor are 0.41 mSv and 0.07 mSv respectively (UNSCEAR, 2010). The abnormally high terrestrial gamma radiation in the world was found in Brazil, it is due to the presence of monazite sand along the Atlantic coast and volcanic intrusion in the Minas Gerias State. Dose rate in this area ranged up to 2.1 μGy h⁻¹ (Roser & Cullen, 1964; The Brazilian Academy of Science, 1977). In Indonesia the mean of terrestrial gamma radiation dose rate is 40 nGy h⁻¹ (~ 40 nSv h⁻¹)with range of 23.9 nGy.h⁻¹ to 40.1 nGy h⁻¹, and the high radiation dose rate was found in Bangka Island and Karimu Island, average dose rate in this area of 330 nGy h⁻¹ and 310 nGy h⁻¹ respectively (UNSCEAR, 2010).

The main purpose for the study is to determine the base line data of natural radiological background in downtown of Indonesia and its health implication.

2. Study Area
The study area of central Jakarta (Indonesia: JakartaPusat) as shown in Figure 1 is one of five district in the capital city of Indonesia. It is located between latitudes5.3200⁰to 6.3983⁰South and Longitude 106.3783⁰to 106.9717⁰East (KODIM JP, 2017). It is 4 m above the sea level. The climate is tropical with an annual average temperature of 27 °C. It has a population of 914,182 in the area of 47.9 km² (KODIM JP, 2017; BPS Jakarta, 2017). The main economic activities are industry, construction, wholesale and retail trading, cervices company, transportation and warehousing (BPS Jakarta, 2017). In study area, mostly the concrete house and apartment were built, the roads and drainage system were constructed.
Central Jakarta is underlied by three geological formations, they are alluvial, beach ridge deposits and alluvial fan deposits (Geological Research and Development Center, 1992). Rock formation consists of clay, silt, sand, gravel, and lump. In this area, a coastal region is composed of sedimentary rock like formation consisting coast of coarse sand, shell and mollusks. The Central Jakarta is overlaid by the differences soiltype of aqueps (endoaquepts, dystrudeptsaquic, andhalaquepts) and dystrudepts (Indonesia Center for Research and Development of Agricultural Land Resources, 2014).

3. Materials and Methods

3.1 Terrestrial Gamma Radiation (TGR) Dose Rates

The sampling points were determined randomly based on topography in 59 grid line positions for every 1 km² as shown in Figure 2. The Sampling points were taken about 1 km distance along the longitudinal and latitudinal in eight sub district regions. The geographic coordinates information was determined using a global positioning system (GPS) hardware by Garmin GPSMAP 62s. The detector to collect data was manufactured by Exploranium GR-135 Plus, ModelGR-135ND-H. It quickly and accurately detects and identifies gamma and neutron sources in the field (Leidos, 2017). It was calibrated by the National Atomic Energy Agency, it is a Secondary Standard Dosimetry Laboratory (SSDL). Measurements of terrestrial gamma radiation dose rates surveys were conducted from September 2016 to January 2017.

3.2 Estimation of Annual Effective Dose Rate

Using the conversion coefficient factors for absorbed dose in air to effective dose of 0.7 Sv Gy⁻¹ as recommended by UNSCEAR 2000, the annual effective dose ($H_e$) was calculated by using equation 1

$$H_e = \text{Effective dose rate per an hour (nSv/h)} \times 24 \times 365 \times OF \times 0.7 \times 10^{-6}$$

Where $H_e$ is annual effective dose in mSv, and OF Occupancy Factor that is 20% for outdoor activities.

3.3 Estimation of Health Risks

To estimate the risk of fatal cancer $\hat{R}_f$ for the population, Equation (2) below is used (Alvarez, 1997; Ramli et al., 2009):

$$\hat{R}_f = a \sum H_i$$

Where $a$ is the risk factor, which uses the value of 0.055 per sievert (public) for terrestrial gamma radiation dose rate (ICRP, 2007).
3.3 Estimating of Dose Distribution Map

Estimating for dose distribution was shown by Isodose Map which adopted using GIS Applications (Sanusi et al., 2014; Ramli et al., 2016). A inverse distance squared interpolation method was employed to convert the TGR dose rate at each point. Figure 3. Shown the TGR dose rate distribution map in Central Jakarta.

4. Results and Discussion

Mean of Terrestrial Gamma Radiation Dose rates, annual effective dose rate, health risk implications, and statistical analysis based on each sub-district in Central Jakarta shown in Table 1. Data was taken in real time and
the data was created to be normal distribution. the Kolmogorov-Smirnov value for each sub district is higher than 0.05, it may be assumed that the data have a normal. The high annual effective dose rate at sub district in Central Jakarta are in Cempaka Putih, Johar Baru and Gambir. The average value in that area is higher than the world average of 0.07 mSv. It contributes to health risk implication of about $3.85 \times 10^{-6}$ per year.

Table 1. Statistical analysis of TGR dose from different Sub district of Central Jakarta

<table>
<thead>
<tr>
<th>Statistical Parameters</th>
<th>Tanah Abang</th>
<th>Menteng</th>
<th>Senen</th>
<th>Cempaka Putih</th>
<th>Johar Baru</th>
<th>Gambir</th>
<th>Kema Yoran</th>
<th>Sawah Besar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area Square (km²)</td>
<td>9.31</td>
<td>6.53</td>
<td>6.53</td>
<td>4.69</td>
<td>2.30</td>
<td>7.59</td>
<td>7.26</td>
<td>6.21</td>
</tr>
<tr>
<td>N sample(Norm distribution)</td>
<td>576</td>
<td>504</td>
<td>511</td>
<td>560</td>
<td>385</td>
<td>456</td>
<td>534</td>
<td>553</td>
</tr>
<tr>
<td>Mean (nSv h⁻¹)</td>
<td>54.08</td>
<td>54.00</td>
<td>54.22</td>
<td>60.77</td>
<td>58.42</td>
<td>58.47</td>
<td>52.16</td>
<td>51.25</td>
</tr>
<tr>
<td>Std. Error (nSv h⁻¹)</td>
<td>0.94</td>
<td>0.90</td>
<td>0.91</td>
<td>1.07</td>
<td>0.89</td>
<td>0.98</td>
<td>0.95</td>
<td>0.91</td>
</tr>
<tr>
<td>Std. Dev (nSv h⁻¹)</td>
<td>22.51</td>
<td>20.16</td>
<td>20.55</td>
<td>25.43</td>
<td>17.49</td>
<td>21.03</td>
<td>21.94</td>
<td>21.52</td>
</tr>
<tr>
<td>Median (nSv h⁻¹)</td>
<td>57.94</td>
<td>55.69</td>
<td>56.63</td>
<td>63.69</td>
<td>57.00</td>
<td>60.19</td>
<td>55.32</td>
<td>54.38</td>
</tr>
<tr>
<td>Mode (nSv h⁻¹)</td>
<td>13.13</td>
<td>13.50</td>
<td>16.75</td>
<td>17.25</td>
<td>15.13</td>
<td>9.63</td>
<td>11.50</td>
<td></td>
</tr>
<tr>
<td>Minimum (nSv h⁻¹)</td>
<td>13.13</td>
<td>13.50</td>
<td>16.75</td>
<td>17.25</td>
<td>15.13</td>
<td>9.63</td>
<td>11.50</td>
<td></td>
</tr>
<tr>
<td>Maximum (nSv h⁻¹)</td>
<td>117.13</td>
<td>109.25</td>
<td>121.88</td>
<td>151.13</td>
<td>128.38</td>
<td>125.88</td>
<td>125.00</td>
<td>119.50</td>
</tr>
<tr>
<td>Kolmogorov-Smirnov</td>
<td>1.22</td>
<td>1.05</td>
<td>1.07</td>
<td>1.16</td>
<td>1.09</td>
<td>0.86</td>
<td>1.09</td>
<td>1.21</td>
</tr>
<tr>
<td>P value</td>
<td>0.10</td>
<td>0.22</td>
<td>0.21</td>
<td>0.13</td>
<td>0.18</td>
<td>0.46</td>
<td>0.19</td>
<td>0.11</td>
</tr>
<tr>
<td>Annual Effective dose rate (mSv)</td>
<td>0.066</td>
<td>0.066</td>
<td>0.067</td>
<td>0.075</td>
<td>0.072</td>
<td>0.072</td>
<td>0.064</td>
<td>0.064</td>
</tr>
<tr>
<td>Health risk ($10^{-6}$)</td>
<td>3.65</td>
<td>3.64</td>
<td>3.66</td>
<td>4.10</td>
<td>3.94</td>
<td>3.94</td>
<td>3.52</td>
<td>3.52</td>
</tr>
</tbody>
</table>

In overall from 3,481 data which the distribution is normal, the average value of TGR dose rate is $(47.76 \pm 18.24)$ nSv h⁻¹ ranged from 6.40 nSv h⁻¹ to 120.90 nSv h⁻¹. It was higher than Indonesia average of 40 nSv h⁻¹ as reported by UNSCEAR 2010. The annual effective dose rate for outdoor activities was calculated of 0.06 mSv.

The TGR dose rate results of Central Jakarta are not influenced by geological features and soil type background because it is not igneous rock or granite. The study area is located in downtown that predominantly disturbed land under commercial and vacant development, with concrete house, apartment, roads and drainage system were constructed. The high reading obtained in the study probably derived from the road in which its materials consists of sand, cement, rock and asphalt. The road materials mostly come from the other area outside Jakarta. They could be from the volcano material after the eruption such as Merapi of Central Java and Galanggung of West Java. However the annual effective dose rate for outdoor activities of 0.06 mSv is lower than world wide average of 0.07 mSv. It contributes to health risk implication, about $3.32 \times 10^{-6}$ per year. It means that about 1 in every 279,330 people in Central Jakarta might be at risk of cancer from terrestrial gamma radiation dose rate.

5. Conclusion

The average of natural terrestrial gamma radiation dose rate in Central Jakarta is approximately higher than the average value of Indonesia. However the population does not receive the background radiation exposure which is relatively high. The annual effective dose rate of 0.06 mSv contributes to fatal cancer risk about $3.32 \times 10^{-6}$ per year which is not high enough to cause for alarm.

The study should be continued to know the TGR dose rate effect of soil, water, radon and toron to health risk implications in the area.

Acknowledgements

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Competing Interests Statement

The authors declare that there are no competing or potential conflicts of interest.
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