Characteristic of natural radionuclide in the rivers of Palembang, Pontianak and Palangkaraya

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Abstract. River water is very beneficial for households and industries. River functions for households are include drinking, washing, bathing, transportation and tourism. River functions for the industry are electrical energy sources, irrigation, aquaculture, transportation of industrial products and others. Therefore, the characteristics of the Musi River in Palembang, the Kapuas River in Pontianak, and the Kahayan River in Palangkaraya, need to be researched, especially the natural radionuclide content. Water is taken 1 liter each with a plastic container at several sampling locations every 3 km along the river, especially water located near the industry. Samples were taken to the laboratory, allowed to stand for a month, put in Marinelli 1 Liter and measured by gamma spectrometry. The measured radionuclides were Pb-201, Th-230, Th-234, Ra-226, Th-228, U-238, K-40 and Cs-137. Radionuclides found in the three river waters are Ra-226, Th-228 and K-40. The concentrations of Ra-226 radionuclide in Palembang, Pontianak and Palangkaraya are 0.06-3.09; 0.02-3.92; and 0.09-4.07 Bq/L respectively. Th-228 concentrations in Palembang, Pontianak and Palangkaraya are 0.03-0.60; 0.05-2.32; and 0.06-1.09 Bq/L respectively. K-40 concentrations in Palembang, Pontianak and Palangkaraya are 0.19-1.99; 0.19-58.41 and 0.69-1.95 Bq/L. The average concentration of natural radionuclides found in the three river waters is still below the limit value of environmental radioactivity, according to PERKA BAPETEN No. 7 of 2013 namely Ra-226 (1 Bq/L), Th-228 (0.35 Bq/L), Th-232 (0.73 Bq/L), Cs-137 (0.25 Bq/L) and K-40 (1.104 Bq/L).

1. Introduction

River water is very useful for households and industries. The function of the river for households includes drinking water, washing, bathing, transportation and tourism. The function of the river for the industry is as a source of electrical energy, irrigation, aquaculture, transportation of industrial products and others [1]. River water is water that flows from upstream to downstream which is usually in the form of water flow from springs, rainwater runoff or from the addition of domestic or industrial water discharges. Disposing of waste into the river will make the river ecosystem polluted. In addition, the radioactive element dissolved in water will cause contamination of the ecosystem [2].

Palembang, Pontianak and Palangkaraya are three big cities that have three large rivers that are densely traversed by ships, both large and small. The three cities are harbor areas which are visited by ships, and also are areas with many industrial areas that discharge their waste into the big river. Therefore, it is necessary to collect and analyze data on the spread of radioactivity of the natural environment as basic data of natural radiation in river water to the three big cities. According to Smith, J.T., the concentration of radionuclides in water masses is determined by the factor of radionuclide
distribution in river water environments and water mass movements, whereas in estuarine waters, radionuclide concentrations depend on size, food production and interaction of river water with seawater [3]. Radionuclides which are absorbed relatively little by sediment, have the possibility to be widely distributed, such as Ra-226, K-40, Th-228, Th-234, Th-232, Th-230, and Cs-137. The naturally occurring radioisotopes of K-40 as well as the U-238 series and Th-232 series are the main sources of gamma radiation in rocks, soils and water [4].

The measurement of radionuclide concentrations is prioritized, because it is long-lived, accumulates in critical organs in the body and is toxic. Th-228 has $T (1/2) = 1,913$ years emitting gamma radiation at $E = 583$ KeV with abundance in nature of 0.435. Th-228 is a derivative of Th-232 (Thorium series). Th-228 enters the body through breathing (inhalation) which is derived from dust containing radioactive material and through ingestion (ingestion) that is from food containing radioactive material accidentally. Th-228 most settles on the bones, because the nature of Th-228 is almost the same as calcium. The residency of Th-228 in the bone is - 8000 days. Th-228 contamination can be through external contamination that is attached to or attached to the outside of the human body, while internal contamination through breathing (inhalation) and ingestion (ingestion). Th-228 entering the mouth continues into the stomach, small intestine, and large intestine [5]. Another crucial radioactive family is the thorium-232 series. Thorium is 3-4 times more abundant than uranium in the earth's crust, but owing to the poor solubility it occurs in waters. Radium-228 belongs to this series and it may become a critical contaminant, as its radiotoxicity is relatively high [4].

Ra-226 has $T (1/2) = 1602$ years, emitting gamma radiation at Energy $609.31$ KeV and abundance in nature 0.446. Ra-226 is one of the U-238 derivatives (U-238 series). Ra-226 concentration in soil is around 0.03 Bq / g. If Ra-226 enters the human body with a high enough concentration, Ra-226 can replace calcium 'in the bone structure [6]. In the case of low Ra-226 input, it is very likely that the Ra-226 input fraction can be higher than the normal input of 1 g Ca / day. This can occur in cases of calcium deficiency. The biological half-life or Ra-226 natural bone retention time is 45 years. Biology half-life is the time needed to remove material from organs or the whole body to half the original amount [7].

Cs-137 has $T (1/2) = 30$ years, emits gamma radiation at $E = 661.66$ KeV and an abundance of 0.85, has high enough radiotoxicity and can accumulate in the body with critical organs of the liver, muscles and spleen and in the environment behave like the element of Potassium.

K-40 has $T (1/2) = 1.25 \times 10^8$ years, emitting gamma radiation at $E = 1,460.8$ KeV and abundance in nature is 0.106. The distribution of K-40 in the environment follows the spread of the stable isotope of K-39. K-40 is found in many green vegetables and enters the body through food pathways, the levels in the human body are approximately 60 Bq / kg body weight. K-40 is homogeneously distributed through all organs and tissues of the body rapidly changing between all organs and tissues with a half-life of 58 days [7].

The characteristics of radionuclide content from upstream to downstream need to be known in Musi river water of Palembang, Kapuas river of Pontianak and Kahayan river of Palangkaraya. The purpose of this study is to study the characteristics of several types of natural radioactivity from river water samples in Palembang, Palangkaraya and Pontianak as basic radionuclide data in Indonesia.
2. Method

River water samples were taken at Musi River, Palembang, Kapuas River, Pontianak, and Kahayan River, Palangkaraya, 2 liters in jerry cans. River water sampling is done every 3 km or every time there is a riverbank industry using a speed boat. Each river water is evaporated until the water volume becomes 1 liter. Water samples introduced into Marinelli containers are used for radioactivity measurements and identification of gamma-transmitting radionuclides.

According to the IAEA (2004), the water samples were inserted into Marinelli, labeled and left for a month (30 days) to achieve radioactive equilibrium before the counting of Ra-226 and Th-232 decays, so that the gamma transmitter can be counted, because of the Ra-226 and Th-232 alpha emitters [8]. After a month, gamma counting was done for 3 days using an HPGe (High Pure Germanium) detector.

Before counting with HPGe detectors, measurements of water quality properties were performed, namely water temperature (T1 and T2 are replications), pH (degree of acidity, pH1 and pH2 are replications) of water, dissolved oxygen (Dissolved Oxygen, DO), TDS (Total Dissolved Solids), turbidity (NTU, Nephelometric Turbidity Units), Oxidation Reduction Potential (ORP), conductivity and pH / mV. TDS measure the number of solid particles dissolved in drinking water that are not visible to the eye. TDS Meter has units of ppm units (mg / L). With the TDS Meter, various dissolved particles such as manganese, copper, iron, aluminum and others contained in the water will be measured in quantity, so they can be checked for drinking or dangerous for health. ORP is used to measure the reduction-oxidation potential of chemicals dissolved in water. NTU (Nephelometric Turbidity Units) to measure the level of turbidity due to pollution. COD Meter (Chemical Oxygen Demand) is a tool used to measure the amount of oxygen in the water that is needed to break down all organic matter. In making measurements, water samples in the dissolved oxygen content in the sample for 5 days have undergone an incubation process in dark conditions and a constant temperature. COD values are expressed in milligrams of oxygen per liter (mg / L) [9].

3. Results and Analysis

The locations of river water sampling are drawn from the points of three cities in Figures 1, 2 and 3. There are 16 measurement locations in the Musi river water, Palembang, while in the Kahayang, Palangkaraya and Kapuas rivers, Pontianak, there are 13 and 16 measurement locations respectively. Most of the rivers are surrounded by the presence of industries, in addition to housing or people's homes.
Figure 2. Sampling points in the Palangkaraya Kahayan river water are shown as green.

The characteristics of river water quality in Palembang, Palangkaraya and Pontianak are shown in Tables 1, 2 and 3 respectively. The average of Musi river water in Palembang is weak acid, because the average pH of 1 and pH 2 is slightly below 7. pH from 1 to 3 is include strong acids, while pH from 3 to 7 includes weak acids. A pH equal to 7 is neutral. pH 1 and pH 2 are a repetition. Acidic properties are corrosive to metal goods and contain H + ions. River water in Palembang is acidic, because there is a large factory of Pupuk Sriwijaya (PUSRI) on the edge of the river. The average of the Kahayan river water in Palangkaraya is weak base, because the average pH 1 and pH 2 are slightly above 7. pH from 7 to 9 includes a weak base, while pH from 9 to 14 includes strong base. This base nature is damaging to the skin and feels bitter, unsuitable for drinking water [10]. Kahayan river water is base, not acidic, because there are many oil companies (PERTAMINA) and palm oil companies (CPO) in this watershed. Kapuas river water in Pontianak tends to be neutral (not acidic and not base), because pH 1 is below slightly 7 and pH 2 is slightly above 7. This is reasonable, because around the Kapuas river there are many acids producing (fertilizer, rubber, cement and others) and base producing (PERTAMINA, CPO and others), thus neutralizing each other.

Figure 3. Sampling points in the Pontianak Kapuas river water are shown as red.
The water temperature of the Musi River in Palembang and the Kahayan river in Palangkaraya are between 28 and 29 °C at T1 and T2. T1 and T2 are a repetition. While the temperature of the Kapuas river water in Pontianak is between 29 and 30 °C at T1 and T2. This is because Pontianak is on the equator, so the Kapuas river water is hotter than the temperature of river water in Palembang and Palangkaraya.

### Table 1. Properties of Palembang river water quality

| Sample | pH 1 | pH 2 | T1 (°C) | T2 (°C) | pH/ mV | Potensial redox (ORP) mV | Conductivity/elektrolit (mS/cm) | Turbidity NTU | DO mg/L | TDS ppm/ (mg/L) |
|--------|------|------|---------|---------|--------|-----------------|-------------------------------|---------------|--------|----------------|
| Aquadest | 6.80 | 7.12 | 29.5   | 28.76   | -13    | 347             | 0.002                        | 800           | 1.94   | 0.001         |
| 1      | 7.19 | 7.2  | 29.5   | 28.5    | -19    | 276             | 0.115                        | 800           | 1.58   | 0.085         |
| 2      | 7.89 | 5.81 | 29.6   | 28.4    | -77    | 409             | 0.131                        | 800           | 1.75   | 0.080         |
| 3      | 7.63 | 6.54 | 29.6   | 28.58   | -28    | 351             | 0.124                        | 800           | 1.63   | 0.061         |
| 4      | 6.89 | 6.07 | 29.4   | 28.56   | -59    | 397             | 0.092                        | 800           | 2.68   | 0.085         |
| 5      | 6.81 | 6.31 | 29.5   | 28.45   | -43    | 388             | 0.095                        | 800           | 1.68   | 0.085         |
| 6      | 7.53 | 6.12 | 29.5   | 28.53   | -56    | 387             | 0.131                        | 800           | 1.6    | 0.084         |
| 7      | 7.67 | 5.84 | 29.5   | 28.55   | -75    | 415             | 0.128                        | 800           | 1.64   | 0.064         |
| 8      | 6.95 | 5.9  | 29.5   | 28.2    | -71    | 426             | 0.097                        | 800           | 1.57   | 0.066         |
| 9      | 6.41 | 6.4  | 29.5   | 28.5    | -30    | 381             | 0.102                        | 800           | 1.05   | 0.097         |
| 10     | 6.38 | 6.25 | 29.5   | 28.27   | -47    | 424             | 0.148                        | 800           | 1.63   | 0.084         |
| 11     | 7.58 | 5.86 | 30.0   | 28.29   | -73    | 416             | 0.129                        | 800           | 1.7    | 0.069         |
| 12     | 6.70 | 5.90 | 29.5   | 28.26   | -71    | 429             | 0.106                        | 800           | 1.52   | 0.153         |
| 13     | 6.33 | 6.4  | 29.4   | 28.41   | -36    | 403             | 0.234                        | 800           | 1.7    | 0.082         |
| 14     | 7.57 | 5.75 | 29.4   | 28.41   | -80    | 424             | 0.126                        | 800           | 1.69   | 0.061         |
| 15     | 6.86 | 5.95 | 29.4   | 28.31   | -68    | 427             | 0.094                        | 800           | 1.66   | 0.063         |
| 16     | 6.73 | 5.94 | 29.4   | 28.3    | -66    | 431             | 0.097                        | 800           | 1.94   | 0.075         |

### Table 2. Properties of Palangkaraya river water quality

| Sample | pH 1 | pH 2 | T1 (°C) | T2 (°C) | pH/ mV | Potensial redox (ORP) mV | Conductivity/elektrolit (mS/cm) | Turbidity NTU | DO mg/L | TDS ppm/ (mg/L) |
|--------|------|------|---------|---------|--------|-----------------|-------------------------------|---------------|--------|----------------|
| Aquadest | 6.80 | 7.12 | 29.5   | 28.76   | -13    | 347             | 0.002                        | 800           | 1.94   | 0.001         |
| 1      | 7.76 | 7.37 | 28.5   | 29.33   | -29    | 262             | 0.085                        | 800           | 1.75   | 0.056         |
| 2      | 6.56 | 7.35 | 28.9   | 29.45   | -30    | 325             | 0.028                        | 800           | 1.68   | 0.018         |
| 3      | 6.85 | 7.35 | 28.9   | 29.39   | -28    | 314             | 0.033                        | 800           | 1.63   | 0.021         |
| 4      | 6.44 | 7.43 | 28.9   | 29.26   | -34    | 298             | 0.027                        | 800           | 1.76   | 0.017         |
| 5      | 7.82 | 7.32 | 29.00  | 29.82   | -26    | 295             | 0.07                         | 800           | 1.60   | 0.046         |
| 6      | 7.58 | 7.34 | 28.9   | 29.48   | -27    | 262             | 0.069                        | 800           | 1.69   | 0.045         |
| 7      | 6.66 | 7.3  | 28.9   | 29.45   | -24    | 344             | 0.027                        | 800           | 1.80   | 0.017         |
| 8      | 7.65 | 7.31 | 29.00  | 29.34   | -25    | 310             | 0.059                        | 800           | 1.63   | 0.038         |
| 9      | 7.18 | 7.14 | 28.90  | 29.29   | -13    | 242             | 0.089                        | 800           | 1.81   | 0.058         |
| 10     | 6.81 | 7.29 | 29.00  | 29.78   | -23    | 335             | 0.044                        | 800           | 1.79   | 0.029         |
| 11     | 6.44 | 7.51 | 29.00  | 29.54   | -38    | 319             | 0.027                        | 800           | 1.71   | 0.018         |
| 12     | 7.97 | 7.26 | 29.00  | 29.36   | -22    | 316             | 0.092                        | 800           | 1.68   | 0.060         |
| 13     | 7.11 | 7.39 | 28.90  | 29.12   | -30    | 258             | 0.064                        | 800           | 1.87   | 0.042         |
below the limit value of environmental radioactivity, according to PERKA BAPETEN No. 7 of 2013 1.95 Bq / L. The average concentration of natural radionuclides found in the three river waters is still minimum. K-40 concentrations in Palembang, Pontianak and Palangkaraya were 0.19- 1.99; 0.19-58.41 and 0.69-1.09 Bq / L. Th- 228 concentrations in K-40 and Th- 228. The concentrations of Ra -226 radionuclide in Palembang, Palangkaraya and Pontianak respectively were 0.03-0.60; 0.05-2.32; and 0.06-1.09 Bq / L. The most common radionuclides appearing in river water in these three cities were Ra-226, 228 and Cs-137. The most common radionuclides appearing in river water in these three cities were Ra-226, Th-228, Th-230, Th-232, and Cs-137. The most common radionuclides appearing in river water in these three cities were Ra-226, Th-228, Th-230, Th-234, and Th-232. The content of the elements in the Musi river water, Palembang, is shown in Table 4.

- Fe (iron), Cr (Crom), Zn (zinc), Mg (Magnesium), Na (Sodium) and element K (Potassium). Zn and Mg elements are abundant in the Musi river water. Thus, the river water is not good for local residents drinking water consumption. The possibility of this Musi river water is polluted, due to the many industries around the Musi river, especially the presence of quite large fertilizer factories and other factories.

The pH / mV values in Palembang river water (-77) are mostly greater than in Palangkaraya (-23) and in Pontianak (-23). Thus, the potential electrical energy of river water in Palembang is lower than in Pontianak and Palangkaraya. Likewise, the value of Oxidation Reduction Potential (mV) in average river water in Palembang is greater in the ability to carry out oxidation reductions in chemicals dissolved in the water. The conductivity (mS / cm) value of river water in Palembang is also the same, mostly higher than that of Palangkaraya and Pontianak river water. The turbidity in river water turbidity in all three cities is the same, namely 800 NTU.

Most of the dissolved oxygen (DO) in Pontianak river water is greater than the river water DO in Palangkaraya and Palembang. This means that the availability of oxygen for living things in river waters in Pontianak is better than in Palangkaraya and Palembang. Whereas the TDS value in Palembang river water is greater than in Palangkaraya and Pontianak. This means that the river water in Palembang contains many solid particles that are not as good as drinking water. Because the TDS value of the river water in Palembang is high, then the content of the elements of the Musi river is measured using the AAS (Atomic Absorption Spectrometry). The content of the elements in the Musi river water, Palembang, is shown in Table 4.

The content of heavy metal elements dominates their presence in the Musi River water, Palembang, such as the elements of Fe (iron), Cr (Crom), Zn (zinc), Mg (Magnesium), Na (Sodium) and element K (Potassium). Zn and Mg elements are abundant in the Musi river water. Thus, the river water is not good for local residents drinking water consumption. The possibility of this Musi river water is polluted, due to the many industries around the Musi river, especially the presence of quite large fertilizer factories and other factories.

Radionuclide content found in river water in Palembang, Palangkaraya and Pontianak is shown in Tables 6, 7 and 8. The measured radionuclides were Ra-226, K-40, Th-228, Th-230, Th-234, Th-232, and Cs-137. The most common radionuclides appearing in river water in these three cities were Ra-226, K-40 and Th-228. The concentrations of Ra-226 radionuclide in Palembang, Palangkaraya and Pontianak respectively are 0.04-2.50; 0.15-4.07; and 0.12-3.92 Bq / L. Th-228 concentrations in Palembang, Pontianak and Palangkaraya respectively were 0.03-0.60; 0.05-2.32; and 0.06-1.09 Bq / L. K-40 concentrations in Palembang, Pontianak and Palangkaraya were 0.19-1.99; 0.19-58.41 and 0.69-1.95 Bq / L. The average concentration of natural radionuclides found in the three river waters is still below the limit value of environmental radioactivity, according to PERKA BAPETEN No. 7 of 2013.

Table 3. Properties of Pontianak river water quality

| Sample | pH 1 | pH 2 | T1 (°C) | T2 (°C) | pH/ mV | Potensial Redox (ORP) mV | Conductivity/ elektrolit (mS/cm) | Turbidity NTU | DO mg/L | TDS ppm/ (mg/L) |
|--------|------|------|---------|---------|--------|----------------------|---------------------------------|----------------|---------|----------------|
| Aquadest | 6.80 | 7.12 | 29.50 | 28.76 | -13 | 347 | 0.002 | 800 | 1.81 | 0.001 |
| 1      | 6.95 | 7.22 | 30.10 | 29.80 | -19 | 305 | 0.084 | 800 | 1.91 | 0.055 |
| 2      | 6.12 | 7.21 | 29.80 | 29.48 | -19 | 366 | 0.056 | 800 | 3.25 | 0.036 |
| 3      | 6.06 | 7.21 | 29.80 | 29.48 | -22 | 363 | 0.057 | 800 | 3.41 | 0.037 |
| 4      | 6.01 | 7.16 | 30.00 | 29.67 | -15 | 353 | 0.055 | 800 | 1.85 | 0.036 |
| 5      | 6.94 | 6.75 | 29.80 | 29.47 | -21 | 335 | 0.082 | 800 | 2.88 | 0.053 |
| 6      | 6.82 | 7.28 | 29.90 | 29.51 | -23 | 341 | 0.080 | 800 | 3.01 | 0.052 |
| 7      | 6.06 | 7.18 | 30.10 | 29.69 | -16 | 339 | 0.055 | 800 | 1.76 | 0.036 |
| 8      | 6.86 | 7.62 | 30.10 | 29.58 | -22 | 333 | 0.083 | 800 | 3.17 | 0.054 |
| 9      | 6.62 | 7.23 | 30.00 | 29.53 | -20 | 344 | 0.086 | 800 | 2.78 | 0.056 |
| 10     | 6.48 | 7.18 | 30.10 | 29.63 | -17 | 337 | 0.073 | 800 | 2.12 | 0.047 |
| 11     | 5.07 | 7.16 | 30.10 | 29.73 | -15 | 378 | 0.063 | 800 | 1.74 | 0.041 |
| 12     | 6.41 | 7.22 | 30.20 | 29.66 | -19 | 346 | 0.090 | 800 | 2.54 | 0.058 |
| 13     | 5.63 | 7.16 | 30.00 | 29.61 | -15 | 372 | 0.067 | 800 | 2.37 | 0.043 |
| 14     | 6.19 | 7.12 | 30.00 | 29.63 | -12 | 352 | 0.055 | 800 | 2.18 | 0.036 |
| 15     | 6.22 | 7.19 | 29.90 | 29.59 | -17 | 344 | 0.054 | 800 | 2.15 | 0.035 |
| 16     | 5.33 | 7.21 | 30.10 | 29.69 | -18 | 342 | 0.050 | 800 | 1.85 | 0.033 |
namely Ra-226 (1 Bq/L), Th-228 (0.35 Bq/L), Th-232 (0.73 Bq/L), Cs-137 (0.25 Bq/L) and K-40 (1.104 Bq/L).

Ra-226, Th-228 and K-40 radionuclide concentrations from upstream to downstream tend to increase in concentration, although they are still fluctuating and some have empty concentrations. Thus, the movement of river water flow from upstream to downstream, also affects the concentration of radionuclides they contain, although the influence of radionuclides from industry contributes to the addition of natural radionuclides to the river water.

Table 4. Content of elements in Musi river water, Palembang.

| No. | Location | Concentration (ppm) |
|-----|----------|---------------------|
|     | Mn       | Fe      | Cd    | Ni    | Cr    | Zn    | Pb    | Mg    | K     | Na     |
| 1   | Ampera Bridge, front of pasar 16 ilir Settlement | 0.044 | 9.723 | 0.094 | 1.237 | 3.118 | 23,576 | 0.368 | 39,184 | 13,729 | 12,598 |
| 2   | New POM Port | 0.015 | 9.470 | 0.313 | 0.983 | 3.118 | 18,170 | 0.368 | 40,776 | 12,119 | 11,122 |
| 3   | Container Port | 0.010 | 9.361 | 0.406 | 1.797 | 2.529 | 26,373 | 1.211 | 46,138 | 14,735 | 8,360 |
| 4   | POM Solar SPBU in the river | 0.059 | 9.723 | 0.031 | Nd | Nd | 29,424 | 0.895 | 13,732 | 9,833 |
| 5   | PUSRI | 0.118 | 9.470 | 0.594 | 1.627 | 4,882 | 16,881 | 0.684 | 19,334 | 12,342 | 10,893 |
| 6   | PUSRI Port | Nd | 9.783 | 0.156 | 1.288 | 0.765 | 26,915 | 1.158 | 22,633 | 13,433 | 11,142 |
| 7   | PUSRI Coal | Nd | 9.289 | 0.281 | Nd | 1,941 | 28,848 | 0.790 | 7,492 | 14,906 | 9,430 |
| 8   | Rubber Company | Nd | 8.807 | 0.219 | 0.271 | 3,118 | 25,949 | 1.368 | 14,410 | 14,637 | 11,398 |
| 9   | Tiga Roda Cement Factory | 0.147 | 9.783 | 0.281 | 1.627 | Nd | 22,068 | 0.947 | 11,887 | 13,799 | 10,633 |
| 10  | Oil Refinery, Gerong River | Nd | 9.711 | 0.156 | 1.458 | 6,059 | 28,407 | 0.790 | 14,727 | 13,348 | 11,501 |
| 11  | Oil Refinery, Gerong River | Nd | 9.590 | 0.500 | 0.949 | 3,706 | 29,170 | 1,474 | 4,009 | 14,162 | 10,950 |
| 12  | Pertamina Marine region II, Gerong River | Nd | 9.711 | 0.063 | 1.458 | 5,471 | 28,576 | 1,000 | 39,880 | 13,242 | 6,0433 |
| 13  | Pertamina Housing | 0.118 | 9.615 | 0.563 | Nd | 5,471 | 24,458 | 0.526 | 8,323 | 15,338 | 11,782 |
| 14  | Rubber Company, PT. Hoktong Plaju | Nd | 8.675 | 0.063 | 0.271 | 7,824 | 28,983 | 0.790 | 15,241 | 17,054 | 10,418 |
| 15  | Gang lama Plaju Housing | Nd | 9.675 | 0.344 | Nd | 3,118 | 29,983 | 0.947 | 26,497 | 14,301 | 10,713 |

Nd = Not detection
Table 5. The concentration of radionuclides in the Palembang river water

| No. | Location                                          | Ra-226 | K-40 | Th-228 | Th-232 |
|-----|---------------------------------------------------|--------|------|--------|--------|
| 1   | Ampera Bridge, front of Pasar 16 Ilir (upstream)  | 0,28   |      |        |        |
| 2   | Settlement                                        | 0,23   | 1,03 |        |        |
| 3   | New POM Port                                      | 0,46   | 0,50 | 0,24   |        |
| 4   | Container Port                                    | 0,74   | 0,34 |        |        |
| 5   | POM Solar SPBU in the river                       | 0,67   | 0,19 | 0,24   |        |
| 6   | PUSRI                                             | 0,40   |      |        |        |
| 7   | PUSRI Port                                        | 0,04   | 1,64 | 0,40   | 0,16   |
| 8   | PUSRI Coal                                        | 0,43   | 1,22 | 0,24   |        |
| 9   | Rubber Company                                    | 0,74   | 1,15 | 0,04   |        |
| 10  | Tiga Roda Cement Factory                          | 0,41   | 1,99 | 0,31   |        |
| 11  | Oil Refenery, Gerong River                        | 0,45   | 1,15 | 0,06   |        |
| 12  | Oil Refenery, Gerong River                        | 0,28   |      |        |        |
| 13  | Pertamina Marine region, Gerong (downstream)      | 0,29   | 1,87 |        |        |
| 14  | Pertamina Housing                                 | -      | -    |        |        |
| 15  | Rubber Company, PT. Hoktong Plaju                 | 0,37   |      |        |        |
| 16  | Gang lama Plaju Housing                           | 2,50   | 0,61 | 0,60   |        |

Table 6. Concentration of radionuclides in the Palangkaraya river water

| No. | Location                                          | Ra-226 | K-40 | Th-228 | Th-232 | Cs-137 |
|-----|---------------------------------------------------|--------|------|--------|--------|--------|
| 1   | Near Pasar Jabiren (downstream)                   | 4,07   | 1,95 | 0,87   | 0,36   |        |
| 2   | Flamboyan Dock                                   | 3,10   | 0,74 | 0,77   | 0,12   |        |
| 3   | PDAM                                              | 0,37   | 0,69 | 0,20   |        |        |
| 4   | Kahayan Bridge (upstream)                         | 3,30   | 1,12 | 0,79   |        |        |
| 5   | Dermaga Rambang                                  | 0,43   | 1,11 | 0,22   |        |        |
| 6   | Petrol grocery store gasoline                     | 0,36   | 1,09 | 0,65   | 0,26   |        |
| 7   | Recreation Rawa Rofi                             | 0,57   | 1,91 | 0,22   |        |        |
| 8   | Oil Palm Company                                 | 0,28   |      |        | 0,18   |        |
| 9   | near the boat gas station                         | 0,42   |      |        |        |        |
| 10  | Timber Company                                   | 0,15   | 1,38 | 0,71   | 0,48   |        |
| 11  | Tanjung Pinang School                            | 0,51   |      | 0,01   |        |        |
| 12  | Plantation                                        | 3,95   | 1,07 | 0,63   |        |        |
| 13  | Housing                                           | 0,64   | 1,49 | 0,22   |        |        |

A comparison of the average Ra-226 radionuclide concentration in river water from several researchers is shown in Table 8. The measurement results of the Ra-226 concentration compared to the results of other researchers do not differ much, one of which depends on the natural conditions of the river water, the content of its natural elements, river flow, buildings around the river.
Table 7. The concentration of radionuclides in the Pontianak river water

| No. | Location                                      | Ra-226 | K-40 | Th-228 | Th-232 |
|-----|----------------------------------------------|--------|------|--------|--------|
| 1   | Container Port, Kel. Sungai Jawi Luar        | 0.51   | 1.26 | 0.22   |        |
| 2   | Kayu Manis II Housing, Pakedai               | 1.54   |      |        | 0.19   |
| 3   | Oil Palm Company (downstream)                | 0.12   |      |        |        |
| 4   | Cement Factory, Pakedai, Pontianak           | 3.16   | 1.40 | 0.15   |        |
| 5   | Petrol Seller, Pakedai, Pontianak            | 3.92   | 2.09 | 1.05   |        |
| 6   | Tongkang Pasir, Pakedai, Pontianak           | 0.28   |      |        |        |
| 7   | Pertamina, Pakedai, Pontianak                | 2.95   |      | 0.65   |        |
| 8   | Fertilizer warehouse, Pakedai                | 0.62   | 0.80 | 0.01   |        |
| 9   | Rubber Factory, Pakedai, Pontianak           | 0.20   |      | 0.31   |        |
| 10  | Pasar Puring, Pakedai, Pontianak             | 0.55   |      | 0.46   |        |
| 11  | Plastic Factory, Pakedai, Pontianak          | 0.51   | 1.26 | 0.05   |        |
| 12  | Coffee Factory, Pakedai, Pontianak           | 0.19   |      |        |        |
| 13  | Rubber Factory, Pakedai, Pontianak           | 0.18   |      |        |        |
| 14  | Kapuas Park, Pakedai, Pontianak             | 2.01   | 58.41| 2.32   | 2.20   |
| 15  | Pasar pagi, Pakedai, Pontianak               | 0.23   |      |        |        |
| 16  | Sand Mine, Pengharapan, Kapur, Kubu Raya (upstream) | 0.49   | 0.19 | 0.20   |        |

Table 8. Comparison of Ra-226 radionuclide concentrations in river water in several locations

| No. | Location                  | References                           | Concentration of Ra-226 (Bq/L) |
|-----|---------------------------|--------------------------------------|-------------------------------|
| 1   | Musi River, Palembang    | Gatot S., etc. 2019                  | 1.20                          |
| 2   | Kapuas River, Pontianak  | Gatot S. etc. 2019                   | 1.90                          |
| 3   | Kahayan River, Palangkaraya | Gatot S. etc. 2019                  | 1.96                          |
| 4   | Code River, Yogyakarta   | Badrus Zaman, etc 2007 [11]         | 0.33                          |
| 5   | Mangkang River, Semarang | Sukirno, etc., 2005 [12]            | 0.006                         |
| 6   | Nile River, Red Sea, Egypt| Arafat, A.A. etc., 2016 [4]         | 5.33                          |
| 7   | Cauvery River, India     | Shahul Hameed, etc.1997 [13]        | 0.009                         |

4. Conclusion

The measured radionuclides in rivers water of Palembang, Pontianak and Palangkaraya were Ra-226, K-40, Th-228, Th-230, Th-234, Th-232, and Cs-137. The most common radionuclides found in river water in these three cities were Ra-226, K-40 and Th-228. The concentrations of Ra-226 radionuclide in Palembang, Palangkaraya and Pontianak are 0.04-2.50; 0.15-4.07; and 0.12-3.92 Bq/L respectively. Th-228 concentrations in Palembang, Pontianak and Palangkaraya are 0.03-0.60; 0.05-2.32; and 0.06-1.09 Bq/L respectively. K-40 concentrations in Palembang, Pontianak and Palangkaraya are 0.19-1.99; 0.19-58.41 and 0.69-1.95 Bq/L respectively. The average concentration of natural radionuclides found in the three river waters is still below the limit value of environmental radioactivity, according to PERKA BAPETEN No. 7 of 2013 namely Ra-226 (1 Bq/L), Th-228 (0.35 Bq/L), Th-232 (0.73 Bq/L), Cs-137 (0.25 Bq/L) and K-40 (1.104 Bq/L).
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