Baseline levels of radionuclides concentration in the sea of Wakatobi and Kendari

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Abstract. The importance of an information about the baseline value of radionuclides in the sea of Wakatobi and Kendari to see how large the input or contamination of radionuclides in the area. This contamination can come from waste human activities such as industry and nuclear utilization activities that are biased carried by seawater currents and air gusts. Natural and anthropogenic radionuclide concentrations in the Wakatobi and Kendari seas have been measured using a Gamma spectrometer (HPGe). The monitoring results show that both ²²⁶Ra, ²³²Th, ⁴⁰K and ¹³⁷Cs indicate that they are in normal condition and do not exceed the safe limit. The data presented in this study will be very important and useful to be used as basic data in mapping the improvement of radionuclide contamination in the area.

1. Introduction
Wakatobi and Kendari are two places on Sulawesi’s southern island that have the potential to develop into excellent tourist destinations. Geographically, the Pacific Ocean and the Indian Ocean flank this region on both sides. This area is one of the areas passed by the Indonesian Through Flow (ITF) [1] line. Basically, ocean currents can bring many benefits such as heat transfer and nutrient distribution that greatly impacts the spread of biota in the ocean [2]. However, not all good things are carried by sea currents, some contaminants that have high mobility in the water are very likely to be carried by sea currents and spread throughout the area.

Radionuclide is a radioactive substance that can be a contamination. This radioactive substance is quite alarming because it is difficult to recognize especially this substance can also accumulate like a substance that does not emit radioactive. Some radionucelians such as ¹³⁷Cs (T₁/₂ = 30.07 th) which are common products of nuclear activity have water-soluble properties. When this isotope is released into the environment due to nuclear activities and disasters such as the Fukushima earthquake in 2011, it is very easily maneuverer in every environment due to its water-soluble nature. In addition, this radiocesium isotope can be harmful to humans because it can be evenly distributed in human body tissues consisting mostly of water. Therefore, the need for a database is especially to see if there is a spread of contaminants in the waters or in the area.

The monitoring of radiocesium in the Wakatobi and Kendari areas, particularly in marine waters, is still relatively restricted. This isotope is one of the most common indicators to see radioactive contamination that may enter Indonesian waters. Several earlier investigations, such as those...
conducted around the Wakatobi and Kendiri areas, namely around the Flores Sea [1], Manado in the north of Sulawesi [3], in Pare-Pare and Makassar in the south of Sulawesi [3], have looked into this radioactive contamination. In addition, several other studies have also carried out radiocesium monitoring in other places such as in the Jakarta Bay [4] and in the Indian Ocean south of the island of Java [5]. When viewed from previous studies, the importance of knowing the background value of radiocesium and other radinuclides in this area is due to the large potential for contamination that can enter the waters of Wakatobi and Kendari. This accumulation of contamination will be very dangerous because certain isotopes have a very good ability to settle in certain body tissues. As a result, water and sediment samples will be gathered for this study to determine the quantity of radiocesium in the water and the amount of natural radionuclide activity in the sediment. This information is critical for fundamental radiocesium data in Indonesian national seas in order to predict unfavourable events.

2. Methods

Sampling was carried out in 2018 in the Wakatobi and Kendiri regions. Samples were taken randomly to represent the area. Three sample sites were obtained in the Wakatobi area, and two sample points were taken in the Kendari area, with each sample point containing at least 1.5 kg of wet sediment and 60 liters of seawater samples. Sediment samples were collected in the field and then packaged snugly and neatly using plastic clips. Meanwhile, seawater samples were collected using a pump at each location and stored in a folding digest. After that, 10 grams of K$_2$Fe(CN)$_6$ and 10 grams of CuSO$_4$ were added to 60 liters of water. The solution is then stirred and shaken until homogeneous. The homogeneous solution was then allowed to stand for 3-5 hours so that the precipitate was completely submerged. The $^{137}$Cs-containing precipitate was obtained by slowly filtering it through filter paper. The filtered water sample is then securely and neatly stored using a plastic clip.

Both the water filter and sediment samples that have been prepared in the field are then transported to the marine radioecology laboratory for further preparation. The sediment sample and water filter were then dried using an oven (Memmert, Germany) for several days to reduce the amount of water in the sample. Filler samples that have been dried for 3-4 days are placed in containers, but sediment samples that have been dried for more than 4-5 days will solidify. As a result, the hardened sample must be broken into finer granules using a grinder (Fritsch, Germany). About 1 kg of finely ground sediment samples were added to the marinelli. Marinelli was then sealed, firmly closed, and held for 28 days to achieve $^{226}$Ra equilibrium.

The filler samples that are already in the container and the sediment samples that are already in the marinelli are counted alternately in the HPGe Gamma Spectrometer with a relative efficiency of 25%. This spectrometer will capture the gamma energy released by the sample. To reduce interference from natural radiation in the laboratory, each sample was counted for three days under lead shielding. The Genie 2000 Gamma Acquisition & Analysis application can be used to view the results of the analysis. We can see the photo peak energy gamma emitted by the sample in the form of a spectrum in this application. The isotope $^{137}$Cs, for example, will emit the same energy of 661.6 keV. The activity of the radionuclides in this application can also be calculated. To increase confidence in calculations, the gamma spectrometer routinely calibrates energy and efficiency using a standard CRM (Certified Reference Material) source and performs background calculations in the laboratory.

3. Results and discussion

3.1. $^{137}$Cs concentration

Based on the ITF route, Kendari is the first route through which seawater flows from the Celebes Sea and then meets the island of Wakatobi. When viewed from the analysis, seawater in the Kendari area at that time had an activity of 0.67 Bq m$^{-3}$ in Kendari 2 and in Kendari 1 no radiocesium was detected. Meanwhile, activity levels in Wakatobi waters range from 0.74 Bq m$^{-3}$ to 1.09 Bq m$^{-3}$. 


Table 1 displays these findings. When comparing the findings of this study to those of past studies, we find that it has a similar value to previous studies and is slightly larger.

### Table 1. Activity concentration of radiocesium (137Cs) in surface water.

| Sampling Site | Location | 137Cs (Bq m⁻³) |
|---------------|----------|----------------|
| Kendari 1     | E        | MDA            |
| Kendari 2     | O4° 07' 07.0" | 0.67 ± 0.07 |
| Wakatobi 1    | 05° 22' 03.4" | 1.02 ± 0.1 |
| Wakatobi 2    | 05° 26' 44.9" | 1.09 ± 0.1 |
| Wakatobi 3    | 05° 26' 40.6" | 0.74 ± 0.07 |

If it is seen from previous research that has been conducted in the area of Pare-Pare south of the island of Sulawesi in November 2011 [3]. The concentration of radiocesium in the seawater near the location at the time ranged from 0.13 to 0.32 Bq m⁻³. A year later, in September 2012, sampling was carried out in Manado, north of the island of Sulawesi, and it was discovered that the concentration of radiocesium in that year ranged from 0.12 to 0.31 Bq m⁻³. When we look over the last two years, the contamination in Fukusima in 2011 has not led to a significant increase. This could be due to the fact that the process of spreading contamination takes a long period. Because 137Cs is water soluble, it should be very easy to disseminate in seawater. However, the process takes time and is influenced by a number of natural elements, one of which being the rate at which sea water flows. As a result, an increase in 137Cs pollution in the sea waters of Kendari and Wakatobi is possible in this study. Even still, the radiocesium concentration in this study is reasonable and comparable to the background value of the Pacific Ocean before the Fukushima disaster [6].

Based on the results of this study, the data obtained can be used as an update for new background data around the Kendiri and Wakatobi Seas. A more extensive investigation is needed to determine whether the concentration of radiocesium pollution in the ITF is increasing as a result of natural factors like as time and ocean currents that transfer contamination into Indonesian seas.

### 3.2. Natural radionuclide concentration

Natural radionuclides are usually radionuclides that naturally exist somewhere. The amount of this radionuclide is highly dependent on the geology and the surrounding natural environment. From the results of the analysis of the gamma spectrometer, it was shown that the concentration of 226Ra was in the range of 10.45-36.35 Bq kg⁻¹. While the concentrations of 232Th and 40K have concentrations in the range 11.45 - 43.65 Bq kg⁻¹ and 50.3 - 325 Bq kg⁻¹ as shown in Table 2. From the results obtained, both Kendari and Wakatobi areas have similar natural radionuclide values. However, all natural radionuclides in Kendari are somewhat bigger than Wakatobi when examined from the table. This might be caused to mainland geological debris impacting the sampling region. In contrast to Wakatobi, which is largely surrounded by water.

### Table 2. Activity concentration (Bq kg⁻¹) of natural radionuclide in sediment

| Sampling Site | Location | 226Ra | 232Th | 40K  |
|---------------|----------|-------|-------|------|
| Kendari 1     | O4° 07' 07.0" | 16.65 ± 0.5 | 12.25 ± 0.6 | 52.3 ± 2.3 |
| Kendari 2     | O4° 07' 07.0" | 36.35 ± 1.0 | 43.65 ± 1.7 | 325 ± 12.1 |
| Wakatobi 1    | 05° 22' 03.4" | 10.45 ± 0.4 | 11.45 ± 0.1 | 46.6 ± 2.1 |
| Wakatobi 2    | 05° 26' 44.9" | 14.15 ± 0.5 | 26.55 ± 1.2 | 50.3 ± 2.3 |
| Wakatobi 3    | 05° 26' 40.6" | 18.75 ± 0.6 | 28.45 ± 0.2 | 88.1 ± 3.5 |

When viewed from the three isotopes, 40K dominated the radionuclides in the sediment samples followed by 232Th and the last 226Ra. The abundance of 40K is large because 40K is a product of
weathering of primary rocks. However, in this study $^{40}$K has a slightly smaller value compared to some existing references such as Bengkalis which has a range of 99.39 - 255.93 Bq kg$^{-1}$. Sluke with a range of 160.54-503.87 Bq kg$^{-1}$ and Kalimantan which has a range of 28.58 – 596.83 Bq kg$^{-1}$. Only Kendiri 2’s $^{40}$K value above 300 Bq kg$^{-1}$, while the other samples were below 100 Bq kg$^{-1}$. This might be due to the fact that the average sample obtained contains more sand than the sample collected in the Wakatobi 2 region. The sand itself has a lower absorption of radionuclides compared to organic substances that are generally found in soil types [7]. However, when comparing the $^{40}$K data in this study with several countries listed in the data report issued by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The $^{40}$K concentration in this study is still categorized as safe because the average $^{40}$K concentration in UNSCEAR has a range from 140 to 850 Bq kg$^{-1}$ [8].

Table 3. Comparison of activity concentrations (Bq kg$^{-1}$) of radionuclides in sediments around Indonesia

| Lokasi    | $^{226}$Ra (Bq kg$^{-1}$) | $^{232}$Th (Bq kg$^{-1}$) | $^{40}$K (Bq kg$^{-1}$) | Referensi |
|-----------|---------------------------|---------------------------|-------------------------|-----------|
| Kendari   | 16.65 – 36.35             | 12.25-43.65               | 52.3 -325               | This work |
| Wakatobi  | 10.45-18.75               | 11.45-28.45               | 46.6-88.1               | This work |
| Bengkalis | 25.01 – 109.62            | 16.03 – 49.80             | 99.39 – 255.93          | [9]       |
| Jakarta   | 42.00-64.92               | -                         | -                       | [4]       |
| Sluke     | 66.07-95.24               | -                         | 160.54-503.87           | [10]      |
| Kalimantan| 1.09 – 53.46              | 1.25 – 32.91              | 28.58 – 596.83          | [11]      |

This might be due to the fact that the Wakatobi and Kendari regions have less weathered main rocks and a higher sand content than other places. As a result, the concentration of $^{40}$K in this area is significantly lower than in other parts of Indonesia, as indicated in Table 2. However, this small abundance has a positive value because the smaller the natural radionuclide concentration, the potential danger of being exposed to radiological effects on humans will also increase getting smaller. Meanwhile, the activity concentrations of the isotopes $^{226}$Ra and $^{232}$Th in Kendari and Wakatobi are similar to those found elsewhere. When compared between Kendari and Wakatobi, the isotope concentrations of $^{226}$Ra and $^{232}$Th in Kendari are slightly higher than in Wakatobi. This may be due to the proximity of the sample point to the mainland which causes a large number of substances such as clay, organic matter and humic substances which tend to absorb more of these isotopes [12]. Unlike Wakatobi which is a small archipelago which is mostly surrounded by high seas.

Despite all that, the concentration of activity of these two isotopes is still at the background level and is considered safe. When compared to $^{226}$Ra and $^{232}$Th in this study with several other regions in Indonesia, these two activities are not much different from the others. Even when compared to many other nations in UNSCEAR, $^{226}$Ra and $^{232}$Th concentrations vary from 17 to 60 Bq kg$^{-1}$ and 11 to 64 Bq kg$^{-1}$, respectively [8]. As a result, when comparing the magnitude of activity of the three natural radionuclides in the Kendari and Wakatobi areas to activity in other regions and countries, the natural radionuclides in this area are still at background levels and not significantly different from the average in other regions.

4. Conclusions
The goal of this study is to collect data that may be utilized as a reference point for radionuclide baseline levels in Kendiri and Wakatobi. All samples obtained have been calculated and analyzed properly. Baseline levels of $^{137}$Cs in both Wakatobi and Kendali range from below MDA to 1.09 Bq m$^{-3}$. Natural radionuclides studied in this work include $^{226}$Ra, which has a range of 10.45 to 36.35 Bq
kg\(^{-1}\) \(^{232}\)Th, which has a range of 11.45 to 43.65 Bq kg\(^{-1}\), and \(^{40}\)K, which has a range of 46.6 to 325 Bq kg\(^{-1}\). Both natural radionuclides and \(^{137}\)Cs are still within safe limits and typical levels in the background level.

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