Baseline concentration of Polonium-210 (\(^{210}\)Po) in several biota from Jakarta Bay

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Abstract. Nuclide \(^{210}\)Po is the main contributor to internal doses due to ingestion of radionuclide in humans, and enters the human body through the consumption of food, including seafood. The research aim is to analyse the activity of the \(^{210}\)Po, in several species of biota that commonly available in the Jakarta Bay. The sample consist of tuna, tenggiri (mackerel), kakap merah (red snapper), Shrimp and green mussel were collected in 2017. The activity of \(^{210}\)Po in the edible part of that biota ranged from 9.05 ± 3.05 to 137.37±37 Bq/kg of fresh biota, and the highest activity in the green mussel and the lowest for tuna. This result were comparable to those presented by other study from several regions of the world and the UNSCEAR data. The daily intake of \(^{210}\)Po from these biota varied between 0.24 and 14.27 Bq year\(^{-1}\). The estimated dose of \(^{210}\)Po intake ranged from 0.03 – 3.6 µSv year\(^{-1}\) are lower than the average natural radiation received by humans globally. This study contributes to the Indonesia baseline data of \(^{210}\)Po in marine biota.

1. Introduction

The Jakarta Bay which is the estuary of 13 major rivers in Jakarta, starting from the mouth of the Cisadane River in the west to the mouth of the Citarum River in the east, gets enormous environmental pressures. The form of received environmental stresses is the accumulation of non-degradable waste including the deterioration of the quality of the biological species and ultimately towards the extinction of various biological species. The heavy environmental burden on the Jakarta Bay due to the final disposal of wastewater from various businesses and settlements [1]. Besides the pressures from industry and domestic sectors, Jakarta Bay potentially receives radioactive input from nuclear facility operations such as research reactors and supporting installations through the Cisadane River.

The operation of nuclear facilities such as research reactor and its supporting installation in Serpong Nuclear Area might release controlled radionuclides to Cisadane River and then flow to Jakarta Bay. In the future, Jakarta Bay would receive more radionuclides due to the planning of contraction of Experimental Nuclear Power Plant (NPP) with 10MW capacity.

Operation of nuclear facilities like Siwabessy research reactor in Serpong area releases radionuclide to the environment, that is transported into Cisadane River and flows to Jakarta Bay [2][3]. The distribution of anthropogenic radionuclides in Jakarta Bay will be possible through the atmospheric fallout and the discharged of radionuclides effluent from normal operation of the reactor.

Natural radionuclide produces by human activities such as coal mining, fertilizer plant, motor vehicle also from burning of coal in the thermal power plants that using the earth material will increase the activity of natural radionuclides in the environment [4] could be present in Jakarta Bay. In anthropogenic pollution related to human activity, the consumable biota has been used as an indicator of the pollution levels in the environment from natural or artificial sources.
The distribution and transfer of radionuclides in marine environments have received important attention lately. Sediment plays as a deposit site of radionuclides and through the bioaccumulation process in various marine biota will lead to increase concentration and availability of radionuclides in species involved in the food chain. Consumption of marine biota is considered a potential bio indicator because they can take and accumulate radionuclides from seawater or sediments in the environment. Monitoring radionuclide levels in edible marine biota is important because they are a source of protein that is easily available and cheap but contributes significantly to the increase in the dose of natural radiation in humans [5].

One of the radionuclides which can increase the radiation doses in human, both internally and externally is $^{210}$Po. Nuclide $^{210}$Po in the consumed marine biota, will contribute about 18% of the average internal dose for humans. $^{210}$Po is in secular equilibrium with $^{210}$Pb that is formed naturally in rocks, soils, and sediments containing $^{238}$U. In the atmosphere, $^{210}$Po is the natural decay of radon gas which then enters the sea. Besides that, $^{218}$Po flows to sea with river water and sediment discharges. Compare with meat and dairy products, fruit and vegetables, the activity of $^{210}$Po and $^{210}$Pb are relatively higher in marine biotas [6].

The Uranium ($^{238}$U) decay series is a primary source of the naturally occurring radionuclide in the marine environments. $^{210}$Po is one of most radiotoxic natural radionuclides that belong to $^{238}$U series. Its high radiotoxicity comes from the fact that it is an alpha particle emitters with a relatively high linear energy transfer [7]. It has been well known that $^{210}$Po is accumulated in high concentrations in various marine organisms, which make it responsible for the majority of the absorbed dose received by a human from seafood ingestion. It may contribute almost 80% of the total dose received by human. Therefore, it is of great concern to estimate the radiological health hazard from $^{210}$Po that come from seafood since it is considered one of the primary sources of animal protein in the human diet [7]. Nuclide $^{210}$Po is the main contributor to internal doses due to ingestion of radionuclide in humans, and mostly found in the human liver, kidneys and bone [8].

Polonium-210 is one of the radioactive elements in the natural environment, and the effects of the $^{210}$Po on living biotas and the safety of them in recent years, has been one of the most important issues in radioecology [9]. Radiological protection Polonium ($^{210}$Po) and radioactive lead ($^{210}$Pb) in marine biotas have drawn attention of scientists because of their higher concentrations compare to those in terrestrial biotas [9] and also because $^{210}$Po concentrations in marine biota often are much concentrated in comparison to those of $^{210}$Pb, as a radioactive grandparent [9].

The first study of $^{210}$Po in marine biota reported that high activity of unsupported $^{210}$Po in plankton is about 110 Bq/kg (dry weight), and later reports gave the information on unsupported $^{210}$Po in marine fish, crustacean and whales [10]. Another analysis was reported that a high $^{210}$Po activity in other marine biota [7]. The preliminary data were summarized and reviewed by Cherry and Shannon (1974) who noted the importance of $^{210}$Po as an internal main source of the radiation dose received in the marine biotas [10].

A research that was done in Mallipattinam ecosystem of Tamil Nadu, India, found the concentrations of $^{210}$Po in fish ranged between 16 - 190 Bq/kg [6] and in Arabian Gulf, the activity of $^{210}$Po in the commonly consumed fish in the Arabian Gulf countries, were reported at 0.1 to 14.7 Bq/kg (fresh weight) [7] and activity of $^{210}$Po in mussel and oyster along the southern tip of India were 47.8 ± 5.9 and 45.3 ± 7.1 Bq/kg [11].

The distribution and accumulation of $^{210}$Po in the marine biotas, especially bioaccumulation processes with certain soft tissues, are interesting to study due to the behavior and properties of $^{210}$Po in the marine environment [12]. This study is aimed to determine the concentration of $^{210}$Pb within several marine biota that are commonly available.

2. Material and methods

2.1. Sampling site

Samples were collected from the local fishermen from fish market in Tanjung Pasir, Teluk Naga Tangerang Banten on August 2017. The samples were washed with tap water and deionized water. The samples were identified by their ecology, morphology, and distribution were obtained from Indonesia.
Fishery Database. The sample consists of tuna, tenggiri (mackerel), kakap merah (red snapper), shrimp and green mussel. Soft tissues were separated from bones and shells, then washed well with deionized water to remove adventitious salt. Each sample was drained with paper towel and weight, then transfer to the freeze-drying equipment to dry about 24 hours. The samples were then ground and the resulted powder was analyzed for $^{210}$Po.

2.2. Sample preparation and analysis
To find a proven method, it is necessary to validate existing methods and be adapted to the equipment and materials available in the laboratory. The method to be validated, adopted from the Guidelines for the Sampling, Preparation, and Radio-Analysis of Marine Matrices module [13] uses IAEA-414 material reference. A total of 1 g of reference samples of IAEA-414 material and biota samples were dissolved with concentrated nitric acid, followed by addition of a polonium tracer. The reflux was carried out for several hours at 60°C. Afterward, 1 mL of H$_2$O$_2$ was added to the sample and evaporated to dryness. The residue was then dissolved in 0.1 M HCl and filtered. A half gram of ascorbic acid was then added to the aliquot and stirred by magnetic stirrer for several minutes at 90 °C until the acid dissolves completely. A silver disc was then inserted (using clamp) into the solution, and stirred for 4 hours at 90°C. Po will be deposited on the surface of the silver disc. The clamp with silver disc was then removed from the solution, rinsed with deionized water and ethanol and then aired. The $^{210}$Po and $^{209}$Po measurements were performed with the alpha spectrometer.

2.3. Data analysis
The concentration of $^{210}$Po was determined using the following equation [13] :

\[
A_d (Po - 210) = \frac{A_{act} - 209)}{Bq/l} \cdot \frac{f_1 f_2 f_3}{N_{net}(Po - 210)} \times 1000
\]

(1)

Activity of $^{210}$Po at the sampling date ($A_{act}$), Bq/kg

\[
A_d (Po - 210) = \frac{A_{act} (Po - 210)}{f_1 f_2 f_3}
\]

(2)

Where $N_{net}$ is the net count area, $f_1$ is correction factor for tracer decay during sample counting, $f_2$ is correction factor for tracer decay between separation start date and counting start date and $f_3$ is correction factor tracer decay between sampling and separation date.

2.4. Dose assessment for seafood consumer
The following formula has been used for calculating dose assessment for consumption of $^{210}$Po from the edible tissue of marine biotas, known as CED, annual committed effective dose (Sv) [5]

\[
CED = A \times I \times D \times M \times E \times F
\]

(3)

Where $A$ is activity of $^{210}$Po in marine biota samples (Bq/kg), $I$ is the average daily consumption determined based on the fish consumption survey, $D$ values is $^{210}$Po dose conversion factor per unit intake which is for adults (1.2 x10$^6$ Sv/Bq), $M$ is modifying factor, time between fish catch and consumption (0.6 for $^{210}$Po), $E$ is the exposure frequency (365 days/year) and $F$ is the real fraction consumed (70% for fish, determined based on the fish consumption survey).

3. Result and discussion

3.1. Activity of $^{210}$Po in marine biota
The activity of $^{210}$Po in all marine biota samples was analyzed in this study list in table 1. The results of the analysis showed that the highest activity of the $^{210}$Po in marine biotas was noted for green mussel and the lowest for tuna, which represent different values among marine biota species.
Table 1. Activity of $^{210}$Po in marine biotas from the Jakarta Bay.

| Sample                  | Location         | $^{210}$Po (Bq/kg) dry weight |
|-------------------------|------------------|-------------------------------|
| Tuna                    | Jakarta Bay      | 9.05 ± 3.05                   |
| Tenggiri (mackerel)     | Jakarta Bay      | 67.34 ± 13.82                 |
| Kakap merah (red snapper)| Jakarta Bay  | 35.03 ± 12.41                 |
| Shrimp                  | Jakarta Bay      | 9.12 ± 2.80                   |
| Green mussel            | Jakarta Bay      | 137.37 ± 25.49                |

The activity of $^{210}$Po in consumed marine biota found in the present work were compared to those presented by other authors from several regions of the world and the UNSCEAR data [7] (Table 2). It can be summarized from the table that the activity of $^{210}$Po presented here is comparable with other research. The comparison results base on the wide variations of marine biotas species not only for fish but also for mussel, oyster and other. The variation of $^{210}$Po activity can be affected by many factors such as: activity $^{210}$Po in the environment, different kind of marine biota and different targeted organs. The $^{210}$Po activity in the marine environment is dependent on the existence and distribution of these sources.

Table 2. Comparison of $^{210}$Po activity in this study with other studies.

| Country                  | $^{210}$Po (Bq/kg) | Reference |
|--------------------------|--------------------|-----------|
| Norway                   | Salmon 0.013 (w.w.)| [14]      |
| Gulf country             | Fish 0.1 – 14.7 (w.w)| [7]      |
| India                    | Fish 16 – 190 (d.w.)| [6]      |
| India                    | Brown Mussel 78.09 - 320.00 (w.w)| [15] |
| Arabian country          | Mussel 47.8 ± 5.9 (w.w) | [11] |
|                          | oyster 45.3 ± 7.1 (w.w) | [11] |
| Slovenian and Italian coasts in the Gulf of Trieste | Mussel 222–399 (d.w) | [16] |
| Indonesia                | 9.05 – 139 (d.w)   | This study |

3.2. Internal committed effective dose

Seafood, like fishes, shrimp and mussels, are largely consumed by the local people in daily consumption, but the activity of $^{210}$Po in those biota is needed to estimate the committed effective dose (CED) ingested by the seafood consumption. The main source of $^{210}$Po in seafood is from ingestion, with very little uptake from water. The distribution of $^{210}$Po inside seafood is not homogeneous where organs and soft tissues contain higher concentrations than other parts of fish and other seafood.

The daily intake depends on the activity of $^{210}$Po from the edible tissue of marine biota species, and annual consumption rate. The annual consumption rate of seafood varies among consumers of different nations and age groups. In this study, the $^{210}$Po CED was based on the consumption rates of seafood that was published by the Directorate General of Capture Fisheries of Indonesia [17].

The results of daily intake of $^{210}$Po from these biota varied between 0.24 and 14.27 Bq/year, that is comparable-to the value from the southern tip of India [5] that gave daily intake of $^{210}$Po from tuna as 0.41 to 0.93 Bq/year. The dose calculated from this study was 0.03 – 3.6 μSv/year, lower than the values reported for fish obtained from India was 62.7–141.8 μSv/year [5]. The calculated doses are lower than the average natural radiation received by humans globally [5].

In Norway, the internal committed dose estimate for consumer showed that doses were no higher than 1.2 μSv/year for children and 4.0 μSv/year for adults [14]. A study from Syria reported that the radiation dose received by Syrian people was 682 nSv/year [18]. The annual ingestion dose reported from southeast of India was estimated between 5.1 to 4.9 mSv/year [9].

The dose calculations depend on national consumption rate which is different among nations. The consumption rate of fish for Indonesian population is 0.2 kg/y and the consumption rate was differed
greatly between the people living on the coast and in the highlands. If the rate becomes ten times higher, the dose will also higher.

A study conducted in Sudan uses 0.43 mSv/Bq as $^{210}$Po dose conversion factor [7], while in this study uses 0.2 mSv/Bq. The dose conversion factor used in the present study is approximately 2 times lower than those used in Sudan. Thus, the choice of the dose conversion factor, the consumption rate and activity concentrations of $^{210}$Po in the biota have a significant contribution to the variation of the committed effective dose [7].

The shape and volume of marine biotas will influence the deposition of radiation energy in soft tissue and will give a good approximation of absorbed radiation doses. Marine biota will accumulate $^{210}$Po and other trans-uranic like plutonium, in internal organs following absorption from ingested food in marine biota. Nuclide $^{210}$Po will be accumulated mostly in internal organs, and in these circumstances the absorbed dose and the biological effects of alpha radiation in the organism will be very different. The models during this study still assume uniform distribution of radionuclides within the body volume, however, future analysis in dose calculation models should take into consideration the processes of radionuclide accumulation and distribution in non-human [19].

4. Conclusions

The concentration of $^{210}$Po in the edible part of the commonly biota available in the Jakarta Bay ranged from 9.05 ± 3.05 to 137.37±37 Bq/kg of wet weight of biota, and the highest activity was green mussel and the lowest for tuna. This result were comparable to those presented by other study from several regions of the world and the UNSCEAR data. The daily intake of $^{210}$Po from these biota varied between 0.24 and 14.27 Bq year$^{-1}$. The estimated dose of $^{210}$Po intake ranged from 0.03 – 3.6 µSv/year are lower than the average natural radiation received by humans globally. This study contributes to the Indonesia baseline data of $^{210}$Po in marine biota.

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