Mercury concentrations in Yellowfin tuna (*Thunnus albacares*) and Indian mackerel (*Rastrelliger kanagurta*) from Bitung Fish Auction Market, North Sulawesi

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Abstract. Mercury is one of the heavy metals which rapidly accumulated into fish muscles. Accumulated mercury in the body of fish came from a polluted environment and their prey. Consuming fish infected with high-concentrated mercury could endanger human health. The purpose of this study was to observe the concentration of mercury in Yellowfin Tuna and Indian Mackerel samples from Bitung Fish Auction Market, North Sulawesi. Samples were divided into two categories, fillet and frozen fillet for Yellowfin Tuna’s samples, fillet and whole fish for Indian Mackerel’s samples. Mercury in samples was analyzed in Toxicology Laboratorium at Research Centre for Oceanography Indonesian Institute of Sciences (RCO-IIS) using Mercury Analyzer model MA-3000. The results showed that mercury concentrations in Yellowfin Tuna’s samples were 67.54 µg/kg and 737.84 µg/kg for fillet and frozen fillet, respectively. Meanwhile, mercury concentrations in Indian Mackerel fillet and whole fish samples were 146.35 µg/kg and 38.35 µg/kg, respectively. The mercury concentrations in the samples complied with SNI 7387-2009 and BPOM No. 23 – 2017 mercury standards.

1. Introduction

Seafood consumer in North Sulawesi has increased every year. Statistics Indonesian (BPS) data shows that people of North Sulawesi consumed 14.08 grams of fish in a day. If fishes were taken from contaminated waters, they would be contaminated by heavy metals and at-risk if consumed by humans. One of the heavy metals that have a high risk to human health is mercury [1,2]. Mercury in marine biota is in methyl or methylated mercury form (CH₃Hg⁺) [3]. The highest bioaccumulation of MeHg is in the food chain, where the highest peak of the food chain has the highest mercury accumulation. It due to predators which accumulated mercury from the environment and prey.

Yellowfin Tuna (*Thunnus albacares*) is known as a top predator position in the food chain. The research found 0.11 ppm mercury levels in Yellowfin Tuna from the Sulawesi Sea. It means that these fish have complied with SNI 7387-2009 (Indonesia National Standards, maximum mercury in fish 0.5 ppm) and safe for consumption [4]. However, mercury in 64 Yellowfin Tuna samples which were obtained from Aceh, Jakarta, Cilacap, and Bitung’s water, was not detected [5].
Indian Mackerel (*Rastrelliger kanagurta*) is a group of small pelagic fish and herbivorous fish. A study detected 1.346 ppm mercury in Indian Mackerel from coastal areas of Panambungan village, Makassar [6]. This value indicates that the level of mercury in Indian Mackerel is quite large and has not complied with the SNI standard.

The purpose of this study is to determine the concentration of mercury in Yellowfin Tuna, and Indian Mackerel then compared with SNI 7387-2009 and BPOM (Indonesia Foods and Drugs Agency) No. 23-2017 standard.

2. Research Methods

2.1. Tools and materials

Yellowfin Tuna and Indian Mackerel’s samples were purchased in Bitung Fish Auction, North Sulawesi. The location of purchase samples can be seen in Figure 1. Each sample was purchased in two types, fresh fish and frozen fish for the Yellowfin Tuna, large fish, and small fish for Indian Mackerel. The samples were sent to the Biogeochemistry Laboratorium RCO IIS for mercury analyzing. Analysis of mercury was using a Mercury Analyzer MA-3000 model produced by Nippon Instruments.

![Figure 1. Samples of Yellowfin Tuna and Indian Mackerel purchase location.](image)

Twenty-two samples of Yellowfin Tuna consisting of 12 fillet samples (TF 1 - TF 12) and ten frozen fillet samples (TFR 1 - TFR 10). Thirteen samples of Indian Mackerel consisting of 6 fillet samples (KF 1 - KF 6) and seven whole fish samples (KW 1 - KW 7).

2.2. Sample preparation

Both individuals and whole fish samples have measured for length and weight to get the morphometry data. The fish was taken part by cut fillet flesh. Fillet samples weighed and recorded in the logbook for additional information on the morphometry data. After data collecting is complete, fish minced and placed on a petri dish that has been labeled to put in the oven for 48 hours at 40 °C. Samples that have been finished in the oven then crushed to powder samples using a mortar and pestle. The powder sample inserted into the plastic wrap that has been marked using a permanent marker.

Analysis of the samples using an MA-3000 can be conducted with a sample in the form of powder. The powder sample of 10-15 mg was weighed using an analytical balance. After weighed, the samples...
were put into the boat and then arranged in the boat tray. Boat tray inserted to Mercury Analyzer after all samples were inserted into boats. Sample code and weight of the powder samples previously inputted into the MA-3000's Excel. To start the analysis, click the box 'measure sample' in the left column. The results came out into the table of mercury concentration in each sample.

### 3. Results and discussion

#### 3.1. Yellowfin Tuna’s samples morphometry

Morphometry of Yellowfin Tuna's fillet samples consists of individual length, individual weight, and sample weight. Meanwhile, the morphometry of Yellowfin Tuna's frozen fillet samples only consists of the sample weight. Individual length and individual weight were assumed based on the sample weight and literature that are used as a reference. Yellowfin Tuna's morphometry can be seen in Table 1.

#### 3.2. Indian Mackerel’s samples morphometry

Morphometry of Indian Mackerel’s samples consists of individual length, individual weight, and sample weight. Morphometry of Indian Mackerel’s samples are presented in Table 2.

| No. | Code | Local name | Species name | Length (cm) | Individual Weight (g) | Sample Weight (g) | Description |
|-----|------|------------|--------------|-------------|-----------------------|-------------------|-------------|
| 1.  | TF 1 | Tuna       | T. albacares | 32          | 451                   | 84                | fillet sample |
| 2.  | TF 2 | Tuna       | T. albacares | 32          | 495                   | 97                | fillet sample |
| 3.  | TF 3 | Tuna       | T. albacares | 33          | 513                   | 101               | fillet sample |
| 4.  | TF 4 | Tuna       | T. albacares | 31          | 421                   | 100               | fillet sample |
| 5.  | TF 5 | Tuna       | T. albacares | 32.5        | 515                   | 75                | fillet sample |
| 6.  | TF 6 | Tuna       | T. albacares | 33.5        | 502                   | 114               | fillet sample |
| 7.  | TF 7 | Tuna       | T. albacares | 31          | 484                   | 109               | fillet sample |
| 8.  | TF 8 | Tuna       | T. albacares | 32          | 498                   | 119               | fillet sample |
| 9.  | TF 9 | Tuna       | T. albacares | 32          | 424                   | 72                | fillet sample |
| 10. | TF 10| Tuna       | T. albacares | 32          | 433                   | 112               | fillet sample |
| 11. | TF 11| Tuna       | T. albacares | 33.5        | 529                   | 112               | fillet sample |
| 12. | TF 12| Tuna       | T. albacares | 35.6        | 692                   | 155               | fillet sample |
| 13. | TFR 1| Tuna       | T. albacares | 32<sup>a</sup> | 493<sup>b</sup> | 92               | frozen fillets |
| 14. | TFR 2| Tuna       | T. albacares | 37<sup>a</sup> | 750<sup>b</sup> | 164              | frozen fillets |
| 15. | TFR 3| Tuna       | T. albacares | 37<sup>a</sup> | 748<sup>b</sup> | 162              | frozen fillets |
| 16. | TFR 4| Tuna       | T. albacares | 11.5<sup>a</sup> | 294<sup>b</sup> | 54               | frozen fillets |
| 17. | TFR 5| Tuna       | T. albacares | 32.5<sup>a</sup> | 516<sup>b</sup> | 76               | frozen fillets |
| 18. | TFR 6| Tuna       | T. albacares | 35<sup>a</sup> | 680<sup>b</sup> | 143              | frozen fillets |
| 19. | TFR 7| Tuna       | T. albacares | 10<sup>a</sup> | 287<sup>b</sup> | 47               | frozen fillets |
| 20. | TFR 8| Tuna       | T. albacares | 33.5<sup>a</sup> | 504<sup>b</sup> | 116              | frozen fillets |
21. TFR 9 Tuna *T. albacares* 32<sup>a)</sup> 494<sup>b)</sup> 96 frozen fillets
22. TFR 10 Tuna *T. albacares* 33<sup>a)</sup> 520<sup>b)</sup> 80 frozen fillets

<sup>a</sup> Assumption of individual length based on sample weight.
<sup>b</sup> Assumptions of individual weight based on sample weight.

### Table 2. Morphometry of Indian Mackerel’s sample.

| No. | Code | Local Name | Species Name | Length (cm) | Individual Weight (g) | Sample Weight (g) | Description     |
|-----|------|------------|--------------|-------------|-----------------------|-------------------|-----------------|
| 1.  | KF 1 | Mackerel   | *R. kanagurta* | 28          | 281                   | 43                | fillet sample   |
| 2.  | KF 2 | Mackerel   | *R. kanagurta* | 27.5        | 284                   | 36                | fillet sample   |
| 3.  | KF 3 | Mackerel   | *R. kanagurta* | 27          | 246                   | 40                | fillet sample   |
| 4.  | KF 4 | Mackerel   | *R. kanagurta* | 28          | 276                   | 39                | fillet sample   |
| 5.  | KF 5 | Mackerel   | *R. kanagurta* | 28.5        | 284                   | 44                | fillet sample   |
| 6.  | KF 6 | Mackerel   | *R. kanagurta* | 27.5        | 255                   | 45                | fillet sample   |
| 7.  | KW 1 | Mackerel   | *R. kanagurta* | 15.7        | 58                    | 58                | whole fish      |
| 8.  | KW 2 | Mackerel   | *R. kanagurta* | 15.9        | 60                    | 60                | whole fish      |
| 9.  | KW 3 | Mackerel   | *R. kanagurta* | 15.5        | 56                    | 56                | whole fish      |
| 10. | KW 4 | Mackerel   | *R. kanagurta* | 16          | 72                    | 72                | whole fish      |
| 11. | KW 5 | Mackerel   | *R. kanagurta* | 17          | 90                    | 90                | whole fish      |
| 12. | KW 6 | Mackerel   | *R. kanagurta* | 17.5        | 79                    | 79                | whole fish      |
| 13. | KW 7 | Mackerel   | *R. kanagurta* | 15.5        | 66                    | 66                | whole fish      |

#### 3.3. Mercury concentration in Yellowfin Tuna

The fish fillet samples were analyzed by a total of 36 samples (12 samples with three repetitions). The concentration of mercury in Yellowfin Tuna fish fillet samples are shown in Figure 2.

The mercury concentration of all fillet samples is in a safe value from SNI standard (1000 ppb) and BPOM standard (400 ppb). It means that Yellowfin Tuna's samples, which purchased at Bitung Fish Auction, are safe for consumption because they have complied with BPOM and SNI law standards. The results of this study are similar to the results of a research about mercury levels in Yellowfin Tuna from the Sulawesi Sea (60 ppb from Kwandang Fish Auction and 110 ppb from Gentuna Fish Auction)[4]. Yellowfin Tuna’s samples taken from those Fish Auctions are safe for consumption because of detected mercury levels have complied with BPOM and SNI standards.

Samples of frozen fillets were analyzed, including 30 samples (10 samples with three repetitions). The concentration of mercury in Yellowfin Tuna frozen fillet samples are shown in Figure 3.

Two samples (TFR 4 and TFR 9) are at the highest mercury values, i.e., 1167.514 µg / kg for TFR 4 and 1369.4 µg / kg for TFR 9. The high concentration of mercury in these two samples caused by the absorption of heavy metals mercury from the water used to freezing fish meat. The fish fillet freezing process with Glazing techniques. Glazing technique is a technique to freezing fish fillet commonly made by distributors fillet fish flesh by cooling the fish fillets first in the freezer, then dipped into the cold sea.
Figure 2. Mercury concentrations in Yellowfin Tuna fish fillet samples.

Figure 3. Mercury concentrations in Yellowfin Tuna frozen fillet samples.

Water and stored using ice cubes [7]. The concentration of mercury in ice blocks and materials from Bandung detected levels of mercury in ice cubes from ice depot which is generally used to freeze fish along with the storage time of ice blocks and air contamination when ice blocks are distributed.

The concentration of mercury from frozen fillet samples is greater than the concentration of fish fillet samples. The average mercury concentration from frozen fillet samples is 737.84 µg / kg, while the average concentration of mercury from fish fillet samples reached 67.54 µg / kg.
Table 3. Comparison of the mean Hg concentrations in Yellowfin Tuna to other studies.

| No. | Origin                        | Total Samples | Average/Range of Length (cm) | Average/Range of Weight (kg) | Hg Conc. (µg/kg) | Reference |
|-----|-------------------------------|---------------|-----------------------------|-----------------------------|------------------|-----------|
| 1.  | Retail market in Sri Lanka    | 37            | -                           | -                           | 280              | [8]       |
| 2.  | Seafood Exporter in Sri Lanka | 65            | 64-180                      | -                           | 480              | [9]       |
| 3.  | Jakarta Fishing Port          | 165           | -                           | 1-100                       | 270.4            | [10]      |
| 4.  | Japanese restaurants in Brazil| 20            | -                           | 0.15                        | 213.515          | [11]      |
| 5.  | Bitung Fish Auction           | 22            | 10-37                       | 0.047-0.164                 | 402.69           | This study|

3.4. Mercury concentration in Indian Mackerel
Indian Mackerel fish fillet samples consist of 18 samples (6 samples with three repetitions). The concentration of mercury in Indian Mackerel can be seen in Figure 4.

![Figure 4. Mercury concentration in Indian Mackerel fish fillet samples.](image)

Six fillet samples are under a safe limit value of mercury contamination from BPOM and SNI. It means that Indian Mackerel fillet samples are safe for consumption. The results of this study are similar to the research about the concentration of mercury in Indian Mackerel from Makassar’s coastal area. The results showed that the concentration of mercury in Indian Mackerel is low or even undetectable [6]. The highest mercury concentrations are generally in fish gills. The meat portion of fish absorbs mercury from the skin respiration process or binding mercury from the waters [12].

Indian Mackerel whole fish samples consist of 24 samples (7 samples of individuals with three repetitions). The concentration of mercury in whole fish samples can be seen in Figure 5.
The highest concentration is 49.965 µg/kg (KW 2) while the lowest concentration is 29.211 µg/kg (KW 5). All mercury concentration values in whole fish samples are in the safe value of mercury contamination limit from BPOM and SNI.

High and low concentrations in fish fillet and whole fish samples are different due to individual weight factor. This study shows that the smaller the size of Indian Mackerel, mercury concentrations are also getting smaller. High and low concentrations of Indian Mackerel also different from concentration on Yellowfin Tuna due to species factors[12]. Mercury concentration in whole fish samples is less than mercury concentration in fish fillet samples. The average mercury concentration in whole fish samples reached 38.35 µg/kg, while the average concentration in fish fillet samples reached 146.35 µg/kg.

Table 4. Comparison of the mean Hg concentrations in Indian Mackerel to other studies.

| No. | Origin                                      | Total Samples | Average/Range of Length (cm) | Average/Range of Weight (kg) | Hg Conc. (µg/kg) | Reference |
|-----|---------------------------------------------|---------------|------------------------------|------------------------------|------------------|-----------|
| 1.  | Fish Landing Station of Digha                | 8             | -                            | -                            | 1220             | [13]      |
| 2.  | Local Fish Market in Suez                   | 10            | 23                           | 0.135                        | ND*              | [14]      |
| 3.  | Karachi Fish Harbour                         | 24            | 21-30                        | 0.099-0.192                  | 0.0415           | [15]      |
| 4.  | Fish Landing Peninsular, Malaysia            | 13            | 13.4-24.3                    | 0.2-0.36                     | 399              | [16]      |
| 5.  | Bitung Fish Auction                          | 13            | 15.5-28.5                    | 0.036-0.09                   | 92.35            | This study |

* Not detected.
4. Conclusions
Based on the research in this study, six frozen samples of Yellowfin Tuna are in high concentrations. Market evaluation is needed related to Tuna catches that have high mercury concentrations. Total mercury concentration in Yellowfin Tuna reached 67.54 µg / kg (fish fillet) and 737.84 µg / kg (frozen fillet) while total mercury concentration in Indian Mackerel reached 146.35 µg / kg (fish fillet) and 38.35 µg / kg (whole fish). Yellowfin Tuna and Indian Mackerel are assumed safe for consumption because the total average mercury concentrations have complied with BPOM and SNI law standards.

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