Monitoring Mercury (Hg) Pollution at Ambon Bay: the Use of *Apogon beauforti* as Bioindicator

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Abstract

Contamination of mercury (Hg) in the sea is one of global issues, including the waters of bay inside the Ambon Island. This research was conducted to monitor heavy metal pollution (Hg) in Ambon bay using Apogon beauforti. This study was conducted by using exploratory survey on physical-chemical environmental factors (temperature, salinity, pH, DO). Hg levels in water, sediments, and A. beauforti were measured, as well as the differences in the morphology of the gills of fish. The sampling technique used in this research was a purposive sampling technique. The environmental factor data were collected in-situ during east and the west season in year 2013 and 2014. The levels of mercury were measured by Atomic Absorbsion Spectrophotometer (AAS). Data were analysed by descriptive statistics. The results showed increasing temperature, salinity and pH within one year (2013-2014) at four different stations. There was a decrease in the levels of Hg concentration in sea water, sediments and A. beauforti at four stations, even though it still remained above the Threshold Limit Value (TLV). The gills of A. beauforti showed dark red, pale and blackish colors indicating the accumulation of heavy metals Hg.

Keywords: *monitoring, marine pollution, heavy metals Hg, Apogon beauforti, Ambon*

Introduction

Mercury (Hg) is one the most dangerous elements and can be life-threatening (Hammond, 1971) if it accumulates and affect the aquatic food chain because it cannot be broken down into organic compounds. Moreover, the main way for the mercury to get to humans is from fish consumption. If the mercury accumulates continuously, it will be able to affect the reproductive, respiratory, and nervous system, both in humans and in animals (Azimi and Moghaddam, 2013). According to Lovelt and Tear (2008) mercury could enter the sea water due to the bad drainage system and poor waste management of industrial activities and transportation. Lacerda and Malm (2008) stated that mercury pollute the water through the process of methylation by bacteria, becoming a form of divalent inorganic metal, and in a relatively high concentration, it can be easily absorbed by biological membranes and by the digestive system in almost all of the food chain. Thus, it facilitates the accumulation of the mercury in tissues and organs of organisms. Therefore, the mercury is one of the biggest pollution problems in the world.

One of the coastal areas in Indonesia, which has relatively high potential for sea water, is Ambon bay which is located in Maluku Province. Based on Maluku development in 2010-2014, the decline of water quality was due to the heavy metals mercury contamination. The contamination was likely caused by industrial activities and an increase of sea transportation and household waste. Therefore, an action research and monitoring (biological monitoring) is necessary (Li *et al.,* 2010). Previously, Sexton *et al.* (2004) stated that biomonitoring is necessary to measure, mark, evaluate and define the status of an environment that affected the lives of living things related to presence of particular physical and chemical elements in the environment.

Bio-indicators, species of particular organisms that can be the object of monitoring, are required for the biomonitoring activity. Therefore, bio-indicator is defined as biological indicators of environment quality and the characteristics of environmental conditions. According to Gadzala-Kopciuch *et al.* (2004) that a species or communities can be a bio-indicator with the criteria that its presence remains in an environment, that it has extensive distribution, and that it has a high tolerance to pollutants analyzed, and that the population is stable. The use of *Apogon beauforti* in this study is based on a broad distribution in areas with depressed environmental conditions and can be sampled in all types of season (Chakrabortty and Paratkar, 2006). Based

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on those criteria, it was found that the most potential organisms as bio-indicators of mercury in the waters of the bay in Ambon Island were the fish 'gete-gete' *(Apogon beauforti)* which belong to family Apogonidae, class Actinopterygii and phylum Chordata (Fraser and Ernest, 1985). In the water of Ambon Island, *A. beauforti* was found, and spreading evenly in the bay of Ambon Island and it could be found in areas of the harbor.

By monitoring the mercury in the waters of bay of Ambon Island, it was expected that the results of this research were helpful as assessment tools in the coastal areas development, so that the economy of the coastal communities in bay of Ambon Island can improve steady.

Materials and Methods

This research was an exploratory survey to uncover the physical-chemical environmental factors (temperature, salinity, pH, dissolved oxygen), Hg levels in water, sediments, and *A. beauforti* in the water of Ambon Island. In addition, this research was also conducted to reveal the differences in the morphology of the gills of fish which was exposed to mercury at 4 (four) stations of data collection. This research was conducted in two different period, namely in east season in 2013 and in west season 2014. The samples were taken by using purposive sampling technique, simultaneously for the samples of sediment, seawater and *A. beauforti.* The measurement of the physical-chemical environmental factors was also carried out simultaneously with the sampling of sediment, seawater, and *A. beauforti.* The samples were collected during the east season, particularly on April, May, June, and July 2013.The samples were also collected during the west season in August and September in 2014.

Data collection environmental factors and heavy metal concentration

The data collection of environmental factors (temperature, pH, salinity, and dissolved oxygen) in-situ was done by considering two periods of the season in Maluku, which were east season and west season at four different research stations. The samples used in the research were sea water, sediment, and *A. beauforti.* The sample collection in year I was carried out in April, May, June, and July 2013, and the sample collection in year II was carried out in August, September, October, and November 2014. The sample was collected using *purposive sampling* technique at four different stations, namely Station 1 in Yos Sudarso Harbor, Station 2 in the Ferry Galala harbor, Station 3 in the coastal waters of Passo village, and Station 4 in the coastal waters village Waiyame (Figure 1).

The data collection about the levels of Hg in water, sediment, and *A. beauforti* at the four stations in bay of Ambon Island was carried out by picking out a small portion. The sample collection of sea water at the bottom of the sea used a bottle with the volume of 3 liters (Ratmini, 2009). The samples of *A. beauforti* were collected using nets had mesh size 1cm, 50 individuals were caught, 50g of sediment was collected using *Eckman*

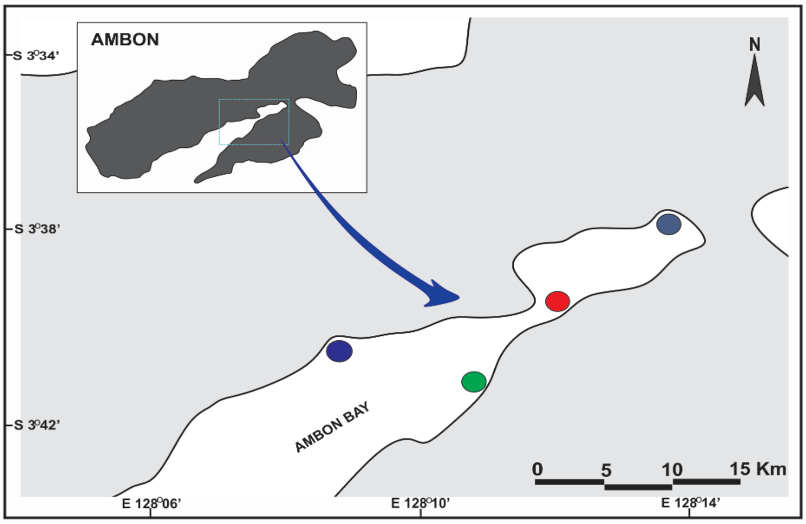

Figure 1. Map of research location
Note: St.1 ● = Yos Sudarso Harbor, St.2 ● =Ferry Galala Harbor,
St.3 ● = Coastal area of Passo, and St.4 ● =Coastal waters of Waiyame

dredge (Leksono, 2007). Each activity of picking out a small amount of the samples was repeated 3 times in the east season and 3 times in the west season. The collected samples were then burnt into ash and then its heavy metal mercury level was analyzed using *Absorbsion Atomic Spectrophotometer* (AAS) (Bielmyer, 2005) .

Data collection of the morphology of the gills of A. beauforti

The data collection of the morphology of the gills of fish was carried out following the steps. 1) Picking out a number of *A. beauforti* which was carried out using nets 1x1 cm, 40 individuals (10 individuals per station) and then the individuals were placed into four plastic containers (buckets). 2) The collected fish were then taken to the laboratory for morphological observation which focused on the gills of *A. beauforti.* 3) The head of the fish was dissected to remove the gills. 4) Next, the gills were morphologically observed using microscopes. 5) The observation was focused on the difference of each organ of the gills of *A. beauforti* based on the patterns of the gills that accumulated heavy metals. The characteristics of the gills of *A. beauforti* that accumulated heavy metals in general were that the color of the lamella were pale dark and blackish.

Results and Discussion

Monitoring the physical-chemical environmental factors and Hg concentration

Physical-chemical environmental factors analyzed in this research included temperature, salinity, pH, dissolved oxygen (DO) (Table 1) and the levels of heavy metal particularly Hg (Table 2).

The monitoring results of the temperature of the waters in bay of Ambon Island (Table 1) in 2013 were 27.3°C to 28.0°C at all four measurement stations, while in 2014 the average temperature ranged between 29.5°C and 30.5 °C at the four measurement stations. The four measurement stations in 2014 were similar to those in 2013. These results indicated that there was an increase in the water temperature of the bay in Ambon Island within one year period, which was an increase of 2.5°C when viewed from the average measurement. This temperature increase might have occurred because the water temperature was influenced by the heat supply from the ocean floor, the family waste decomposition, and the intense penetration of the sun due to season changes. According to Pennington and Chaves (2000) the increase in sea water temperature was influenced by the period of the season, upwelling, and the flow of water currents.

The results of the salinity measurements in the waters of bay of Ambon island (Table 1) in 2013 showed that the average salinity in the four stations was quite similar, which was only in the range of 29.0 ‰ up to 30.0 ‰, while in 2014 it ranged between 30.0 ‰ and 30.5 ‰. This happened because the four stations were still in the same water which was equally located on the waters of bay of Ambon Island. As stated by Patty (2013), the salinity of sea water which was located in the coastal water tended to be similar and lower as it was close to the mainland. Whereas, the salinity of the sea water which was located further out to sea would be higher.

The average value of pH (Table 1) at the four stations showed that the pH value in 2013 ranged between 6.91 and 7.31. While in 2014 the average value of pH at four stations ranged between 7.71 and 7.79. The data showed the pH value increased, so that the condition of the sea water was under alkaline conditions. Based on the established Threshold Limit Values (TLV) by the Ministry of Environment, the suitable pH value should be between 6.5 and 8.5. Thus, the water of bay of Ambon island was still in a good condition, but due to an increase within the one year period, the control efforts was very essential to do.

The results of the measurement of dissolved oxygen (Table 1) showed that in 2013 the value of DO ranged from 7.5 to 9.4, whereas in 2014, the Levels of DO in sea water of Ambon Island decreased in the range of 7.6-7.7. The levels of the dissolved water decreased, as the increase of organic waste in the water. This happened because the available oxygen was used by the bacteria to decompose the organic substances into inorganic substance (Simanjuntak, 2012).

Beside the analysis of Physical-Chemical environment factor, the analysis of Hg content in the sediment, seawater, and *A. beauforti*, it was observed that the levels of mercury at each station varied widely (Table 2). The Hg level of the sample of sediment at stations 1, 2, 3, and 4 appear higher than the samples of sea water and the sample *A. beauforti* in 2013. But in 2014, the mercury levels of the samples in sediment and seawater at stations 1, 2, 3, and 4 decreased. Similarly, the levels of mercury of sample *A. beauforti* at station 2, 3, and 4 also decreased, while at station 1, the mercury levels of sample *A. beauforti* increased. The increase of the

Table 1. Measurements of physical-chemical environment in the water of Ambon Island

Parameters	Stations							
	Yos Sudarso Harbor		Very Galala Harbor		Coastal area of Passo		Coastal area of Waiyame	
	2013	2014	2013	2014	2013	2014	2013	2014
Temperature (°C)	27.60±2.31	29.50±0.71	28.30±2.89	30.00±0.00	27.30±3.06	30.00±0.00	28.00±3.00	30.5±0.71
Salinity (‰)	30.00±0.00	30.50±.071	29.30±1.15	30.00±0.00	30.00±1.00	30.50±0.71	29.00±1.73	30.5±0.71
pH	6.93±0.65	7.71±0.07	7.31±0.52	7,77±0.01	7.15±0.57	7.79±0.02	6.91±0.78	7.78±0.00
DO (ppm)	7.50±2.69	7.65±0.21	8.20±4.92	7.70±0.00	9.40±5.82	7.60±0.00	7.90±4.31	7.70±0.00

Table 2. Measurement of Heavy Metals Hg (ppm) in the Water of Ambon Island

Station	Sediment		Water		*A.* beauforti	
	2013	2014	2013	2014	2013	2014
Yos Sudarso Harbor	24.80±0.72	6.81±0.74	11.10±0.24	2.27±0.11	16.10±1.14	18.74±1.02
Very Galala Harbor	94.20±0.81	15.95±0.8	12.80±0.28	2.18±0.11	19.80±0.94	14.01±0.64
Coastal area of Passo	37.90±0.92	9.01±0.90	13.40±0.47	2.20±0.14	35.10±1.93	19.73±1.13
Coastal area of Waiyame	78.50±1.59	15.03±0.83	10.20±0.42	1.88±0.11	37.70±1.50	18.67±0.40

levels of mercury that occurred in sample *A. beauforti* in station 1 might have been caused by the levels of mercury in the form of methyl mercury which were quite big. In addition, the data collection of Hg at the four stations in the west season led to an influx of Hg content into bay of Ambon Island along with currents and waves and anthropogenic activity. According to Lacerda and Malm (2008), in the form of methyl mercury, the mercury would be liposoluble, that is easily absorbed by the cell membranes of biological organisms in general. The increases and decreases in the level of mercury were very dependent on anthropogenic activities that may affect the environment.

Monitoring individual level environmental based on the morphology of gills

In Table 2, the results of the observations of gill colorof *A. beauforti* in 2013 shows that in stations 1, 2, and 4, 30 individuals had dark red gills, while at station 3, all fish samples had bright red gills. In 2014, the color of the gills of the in stations 1, 2, and 3 were all dark red, while in station 4 all fish samples had bright red gills. Thus, based on the monitoring results there are differences in the color of the gills of *A. beauforti* collected in 2013 and in those collected in 2014 at station 3 and station 4. In 2013, the color of the gills at station 3 was bright red indicating that *A. beauforti* at station 3 had not been exposed to mercury, whereas in 2014, the color of the gills was dark red indicating that *A. beauforti* had been contaminated with mercury. The opposite case occurred at station 4, at station 4 in 2013 the color of the gills was dark red, while those at 2014 were bright red. It indicated that the mercury exposure to *A. beauforti* in 2014 at station 3 increased, and that at station 4 decreased. Even so, the results of the measurement showed that the levels of mercury in *A. beauforti* had gone far beyond the threshold determined by EPA, 0,001 mg.L^{-1}. This is in line with the opinion of Fardiaz (1992), which stated that all fish that were not contaminated with mercury during its growth process would still contain mercury but in low concentrations i.e 0.005 to 0.075 ppm.

Under normal circumstances, the gills of fish are generally bright red. According to Taher (2010), the fresh and healthy fish have bright red gills, without mucus, and does not stink. If it is associated with the results of the analysis of mercury content, which was quite high, the dark red color on the gills of *A. beauforti* was likely caused by an accumulation of mercury in the gills. Mercury may decrease the hemoglobin, red blood cells, and hematocrit, thus it can damage organs such as gills exposed with mercury could change into a darker color because of the accumulation of solid red blood cells in the blood vessels in the gills (Nirmala *et al.,* 2013).

Although the content of mercury in *A. beauforti* was quite high, but *A. beauforti* could still survive. It indicated that *A. beauforti* was able to adapt and survive in waters with relatively high levels of contamination. Ishikawa *et al.* (2007), stated that the concentration of mercury in the form of $HgCl_2$ of 0.005 and 0.01 mg/L could cause changes in hematological conditions on certain

Table 3. the results of *Apogon beauforti* gill color observations in 2013 and 2014

Gills's Color of A. beauforti	Year 2013				Year 2014			
	Yos Sudarso Harbor	Very Galala Harbor	Coastal area of Passo	Coastal area of Waiyame	Yos Sudarso Harbor	Very Galala Harbor	Coastal area of Passo	Coastal area of Waiyame
Vermilion	-	-	10 ind.	-	-	-	-	10 ind
dark red	10 ind	10 ind	-	10 ind	10 ind	10 ind	10 ind	-
bluish red	-	-	-	-	-	-	-	-
Blackish red	-	-	-	-	-	-	-	-
other colors	-	-	-	-	-	-	-	-

Note: ind=individuals

types of fish, and if the concentration was bigger, it can cause death. However, there were also certain types of fish which was not affected by such conditions. Therefore, the fish "gete-gete" or *A. beauforti* can be used as bio-indicators because it is tolerant of heavy metal contamination in marine waters (Bonardi *et al.,* 2010).

According to Purwani *et al.* (2014), in order to be a bio-indicator, species should ideally have several criteria such as, already identified, widely distributed, easy to find in a given environment, easy to analyze in a laboratory, and can live more than one year. Furthermore, Holt and Miller (2011), stated that bio-indicator species was effective to indicate environmental conditions because it is able to tolerate the variability of environments. It showed that *A.beauforti* was a bioindicator species in a polluted environment, which can be proved by using research results, in which *A. beauforti* can survive in all seasons and in areas contaminated with Hg.

Conclusion

There was a rise in temperature, salinity, and pH at four stations measurements in 2013 and 2014, while dissolved oxygen occurs in to four measurement stations also in 2013 and 2014. The levels of mercury in sediments and seawater in 2013 was higher 2014, which means that the mercury levels in sediment and seawater declined in 2014 in all of the measurement stations. As for the sample, *A. beauforti* at station 1, the levels of my house in 2014, higher than he levels of mercury in 2013. The observation of the color of the gills of *A. beauforti* revealed that on the average, the gills color is dark red both in 2013 and in 2014. There is a difference in station 3 and the station 4 between 2013 and 2014. *A. beauforti* can be used as bio-indicators because it is able to tolerate the Hg content which was sufficiently high.

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