Current Status and Future Prospect of Marine Pollution Research in the Banda Sea

C Y Manullang[1]

[1]Centre for Deep-Sea Research, Indonesian Institute of Sciences (PPLD LIPI), Jl. Y. Syaranamual, Guru-Guru Poka Ambon 97233, Indonesia.

corry.yanti.manullang@lipi.go.id

Abstract. Anthropogenic pressure can cause serious problem in the marine environment, such as marine pollution. In this paper the existing scientific literatures related to marine pollution study that had been conducted at the Banda Sea were reviewed. There were in total 22 publications found that specifically addressed the marine pollution at the Banda Sea. The majority of case studies were conducted in shallow coastal waters. Few data discussed about deep-sea waters. We highlighted knowledge gaps regarding the information on data from Banda Islands coastal area. The final goal of this paper is to recommend the future studies that need to be conducted in the Banda Sea waters.

Keywords: *marine pollution, Banda Sea, deep sea*

1. Introduction

The Banda Sea is the deepest sea in Indonesia that is connected to the Pacific Ocean and surrounded by hundreds of islands (figure 1). The deepest part is the Weber Trench which is 7 440 meters deep [1]. The Banda Sea is also located at the heart of the Coral Triangle that makes this area the highest marine biodiversity spot in Indonesia. In 2014, Indonesian Ministry of Maritime Affairs and Fisheries estimated that the total capture fisheries production of Maluku waters was at 538 thousand tons [2]. Due to this large potential, the government of the Republic of Indonesia has declared the Moluccas Province to be a "National Fish Barn" since 2014.

However, like in the other part of the world, the Banda Sea could be exposed to anthropogenic activities. One of the anthropogenic stresses that can be a serious problem in the marine environment is marine pollution. The marine pollution occurs when any substances or energy enter the marine environment and bring out the harmful effects upon ecosystems and human health [3].

The marine pollution study provides information about the disturbances of the oceanic environment and its biota, as well as its effects on the environment and human safety. In this paper, we reviewed the marine pollution study conducted in and around the Banda Sea since the first publication in 1987 until 2017. We identified any research gap and propose the next marine pollution research that needs to be done in the Banda Sea.

2. Marine Pollution Investigation in the Banda Sea, 1983-2017

Our understanding of the present status of marine pollution in the Banda Sea is surprisingly limited. Most of the studies that have been conducted were concentrated in Ambon Island that is predominantly shallow with <200 m in depth. There is only one published data about marine pollution in Banda waters. Even though the data was limited, a number of studies on marine pollution have been conducted in Ambon Island. At least, from 1983 to 2017 (table 1), there were 22 publications in the Banda Sea consisting of 17 studies about heavy metals (9 peer-reviewed articles, 7 undergraduate reports, and 1 dissertation), 3 studies on domestic waste (2 journals, one newspaper article) and 2 studies on hydrocarbon (1 peer-reviewed article and 1 undergraduate report).

2.1. Heavy Metals

2.1.1 Sea Water

The Ambon Bay consists of an inner and outer area that is connected by a narrow and shallow threshold with an average depth of about 12 m (figure 1). The outer bay area is less populated than inner area. The inner bay has an average depth of 30 m with about 6 km^2 of area. The outer bay opens into Banda Sea, and has an area of about 100 km^2 with an average depth over 100 m (figure 1).

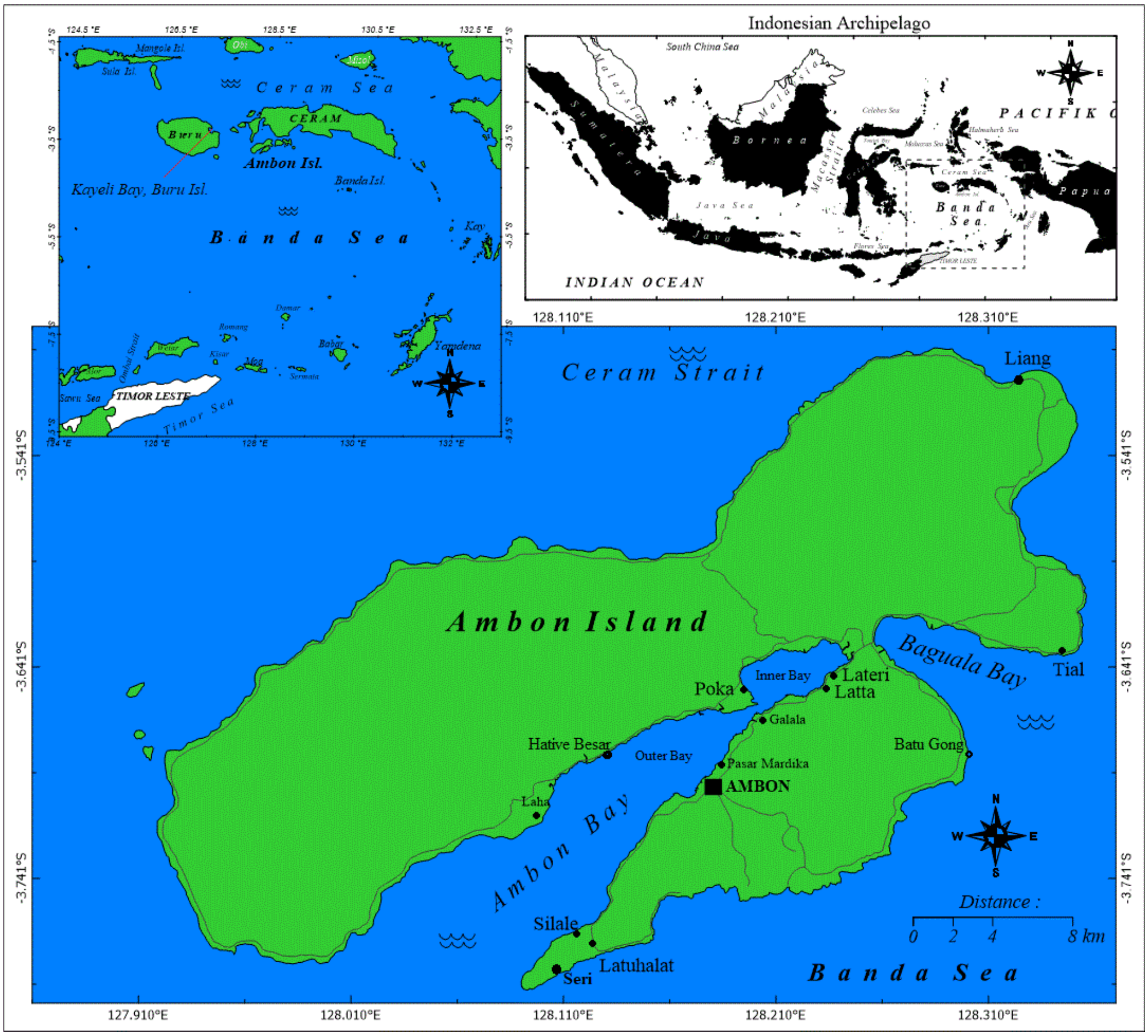

Figure 1. Map of the Banda Sea**.**

Heavy metal studies on sea water have been conducted in the Banda Sea since early 1980s. Two investigations in 1983 and 1987 on sea water found high concentrations of Cu, Zn, Pb and Cd in Ambon Bay [4, 5] (table 1). The range of Cu, Zn and Cd in Ambon Bay has exceeded the limits of the national standard on marine water quality (Decree of the Indonesian Minister of environment no. 51, 2004) [6]. After more than two decades since the first publication about Ambon Bay, the total concentrations of Cu, Zn, Pb, Cd and Hg in seawater from this bay were reported to be below the upper limit [7] than those observed in 1987 irrespective of population density. The decreased trend 1983 to 2009 might be caused by many factors, such as: sampling time (seasons), different procedure in metal determinations and bias in methodological approach. Unfortunately, these studies were difficult to compare due to the lack of methodological details in the published paper and different sampling time for each study.

Table 1. Heavy metals studies in the Banda Sea, 1983-2017 (in $mg.kg^{-1}$, dry weight for sediment and biota, in $mg.l^{-1}$ for sea water). Bolded numbers indicate values exceeding the guideline's upper threshold limit for the specific heavy metal. AIB: Ambon Inner Bay, AOB: Ambon Outer Bay.

No	Location	Cr	Fe	Cu	Zn	Pb	Cd	Hg	Ref
Sea water									
1	Ambon Bay	-	-	**0.008-0.050**	0.02-**0.06**	0.035-0.075	<0.001-**0.05**	<0.001	[4]
2	Ambon Bay	-	-	0.005-**0.058**	0.009-**0.071**	0.004-**0.09**	**0.005-0.065**	-	[5]
3	Ambon Bay	-	-	<0.001	<0.0078-0.0079	<0.001-0.005	<0.001	<0.001	[7]
4	Ambon Island	-	-	-	-	-	**0.01-0.03**	-	[8]
5	AIB	-	-	-	-	**0.05-0.1**	-	-	[9]
Marine Sediment									
6	Ambon Bay	-	-	19.9-27.4	62.1-95.6	10.4-23.1	<1	0.0396-0.1225	[4]
7	Ambon Bay	-	-	0.05-0.216	0.168-10.45	0.17-0.683	0.129-**2.161**	0.05-**0.16**	[11]
8	Ambon Bay	-	-	-	-	9.473-24.901	0.163-0.444	**1.991-4.521**	[12]
9	Ambon Bay	-	-	-	1.258-48.8	1.397-15.280	<0.0013-0.512	<0.0013	[7]
10	Ambon Island	-	-	-	-	-	0.17-0.32	-	[8]
11	AIB	-	-	-	-	5-20	-	-	[9]
12	Ambon Bay	-	27,598–51,716	14.4-24.5	51.3-**163**	14.4-24.5	0.1 – 0.66	0.04–**0.44**	[13]
13	Buru Island	-	-	-	-	-	-	**0.35-0.4**	[14]
14	Buru Island	-	-	-	-	-	-	**8.05-10.23**	[15]
Marine biota: mollusc									
15	Ambon Bay	-	-	<0.001-0.47	0.34-0.77	0.25-0.36	<0.001-0.47	-	[5]
16	Ambon Bay	-	-	-	-	**3.908-5.490**	0.309-0.694	0.196-0.410	[12]
17	AIB	-	11.53-38.96	-	-	0.78-2.36	002-0.046	-	[16]
18	AIB	0.09-0.36	-	0.14-0.51	-	-	0.01	-	[17]
19	AIB	1.415 - **4.250**	-	18.145-48.040	-	-	0.315-1.415	-	[18]
20	Buru Island	-	-	-	-	-	-	0.15-**2.99**	[15]
Marine biota: fish									
27	Buru Island	-	-	-	-	-	-	0.001-**3.44**	[15]
Marine biota: crustacea									
28	Buru Island	-	-	-	-	-	-	0.12-**120.31**	[15]

continued on the next page

Table 1. Continued

No	Location	Cr	Fe	Cu	Zn	Pb	Cd	Hg	Ref
Marine biota: soft coral									
21	AOB	-	-	0.8975-2.7962	6.36-22.8025	1.4612-8.57	-	-	[19]
22	AOB	1.95-2.585	-	-	-	8.2-12	0.755-1.0662	-	[20]
Marine biota: seagrass									
23	Ambon Bay	8.61-18.29	-	-	-	14.2-37.5	13.18-17.43	-	[22]
24	Ambon Bay	15.7-22.65	-	-	-	14.76-20.88	15-27.35	-	[23]
25	AIB	-	-	-	-	2-20	-	-	[9]
Marine biota: sea urchin									
26	Ambon Island	-	-	-	-	-	0.30-1.95	-	[8]
Guidelines									
Sea Water		0.005	-	0.008	0.05	0.008	0.001	0.001	[6]
Marine sediment		81	-	34	150	46.7	1.2	0.15	[10]
Mollusc		2	-	70	1000	2.5	2	1	[5]
Fish and crustacean		-	-	-	-	0.5	-	0.5	[19]

However, the Cd and Pb concentration in Ambon Island tend to increase since 2011 (table 1). The study in 2011 reported the high Cd level was observed in four sites around Ambon Island (Latta, Liang, Latuhalat and Tial) (figure 1) [8]. These sites are less populated in Ambon Island. The study in 2014 also reported the higher Pb in Poka and Lateri [9]. These sites are dense population area in Ambon Inner Bay. These concentrations were above the aforementioned standard.

2.1.2 Marine Sediment

An initial study of heavy metals in marine sediment in Ambon Bay, the Banda Sea, was reported in 1983 [4] (table 1). This study indicated low concentrations of Cu, Zn, Pb, Cd and Hg. The concentrations observed were below the guideline issued by the National Oceanic and Atmospheric Administration Effect Range Low (NOAA ERL) [10]. The second study published in 1987 indicated Cd and Hg concentration increase. However, the concentrations of Cu, Zn, Pb observed were below the aforementioned guideline [11].

Almost two decades after the first publication about heavy metals in marine sediment in the Banda Sea, a study in Batu Gong, Hative Besar, Poka and Seri indicated higher concentrations of Pb (~36 times) and Hg (~28 times) than those reported in 1987 (see table 1) [12]. Pb and Hg levels in 2005 have exceeded the NOAA guideline. In contrast to increasing Pb and Hg concentrations, the level of Cd was lower than those observed in 1987.

An indication of higher Zn concentration (~5 times) than those reported in 1987 was also reported in 2009 [7]. This study also reported a lower Pb and Hg level than those observed in 2005. However, Pb, Zn, Cd and Hg levels found in this 2009 study were below the NOAA guideline. The heavy metal concentrations below the NOAA guideline's upper limit were also observed in Latta, Liang, Latuhalat and Tial [8] and Poka and Lateri [9].

The most updated information regarding heavy metals concentrations in the Ambon Bay was published in 2017. The reference [13] reported the level of Fe, Zn, Cu, Pb, Cd and Hg in marine surface sediment of Ambon Bay were higher than those measured in previous studies. Based on the quality standards for marine sediment under NOAA value, level of certain metals (Cu, Zn, Hg) measured were above the guideline. There was no guideline found for Fe [10]. This study indicated the strong contribution of heavy metals pollution from the urban waste, residential sources, farming industry, shipping activities and ship repair activity from dockyard around the Ambon Bay. The increasing trend of heavy metal on marine sediment on those studies can be expected that many pollutants accumulate in the sediments.

Recent studies [14, 15] reported the Hg contamination in marine sediments offshore Kayeli Bay Buru Island). The Hg concentrations observed on both studies were above the aforementioned standard for marine sediment. This Hg contamination was suspected to be originated from artisanal gold minings operating in this island. These studies were sampled in 2012 and 2013. The interval time between those study was 10-month period, but surprisingly the Hg concentration in 2013 has increased more than 20 times than those sampled in 2012.

2.1.3 Marine Biota

Investigations about heavy metals concentration in marine biota were done mostly on molluscs (6 studies), followed by studies on soft corals (2 studies), seagrass (3 studies), sea urchin (1 study), fish (1 study) and crustacean (1 study). Heavy metal studies on molluscs were done from 1987 to 2012.

The first study reported a low concentration of Pb, Cd, Cu, Zn on molluscs *Chicoreus* sp., *Conus quercinus* and *Strombus tuhuanu* [5] (table 1). The concentrations recorded were below the National Health and Medical Research Council (NHMRC) threshold value [5]. To our knowledge, the NHMRC was the only guideline widely cited for molluscs. However, online tracking of this reference did not yield satisfactory result nor any update of this guideline. The second study reported the Pb, Cd and Hg level on molluscs Neritidae (*Nerita albicilla, N. planospira, N. umlaasiama, N. picea, N. literata, N. maxima*) [12]. The level of Pb found has exceeded the NHMRC limit. However, the Cd and Hg concentration on those molluscs were below the NHMRC value. The third study reported the low concentration of Cd and Pb found on the mollusc *Anadara antiquata* [16]. The Cd and Pb observed were below the aforementioned guideline. In 2007, the level of Cu, Cd and Cr measured on molluscs G*afrarium tumidum* [17] and *Soletellina biradiata* [18]. Higher concentrations of these heavy metals were found on the latter (table 1), notably the Cr has exceeded the NHMRC limit. This study also observed the level of Fe on mollusc *Gafrarium tumidum* but no guidelines exist about Fe concentration [5].

Five of the six previous studies about heavy metal contamination on mollusc were done in Ambon Island. The other one reported the Hg concentration from Kayeli Bay (Buru Island) [15]. The Hg concentration were measured on four mollusks species: *Anadara granosa, Cerethium* sp., *Nerita* sp. and *Terebralia palustris.* The highest Hg concentration was recorded on *Cerethium* sp., followed by *Nerita* sp., *A. Granosa* (raw), *T. palustris*, and *A. granosa* (cooked). The Hg concentration found on *Cerethium* sp. has exceeded the aforementioned guideline. Moreover, this study also reported the Hg concentration on 12 fishes and 3 crustaceans from Buru Island. The higest Hg concentration was found on a freshwater/estuarine species *Channa striata* followed by *Terapon theraps* (omnivorous), *Epinephelus fuscoguttatus* (benthic, carnivorous), *Equulites leuciscus* (benthic, carnivorous), *Lutjanus rufolineatus* (carnivorous), *Upeneus vittatus* (carnivorous), *Dussumieria* sp. (planktivorous), *E. fasciatus* (carnivorous), *Alectis ciliaris* (carnivorous), *Auxis rochei* (carnivorous), *Stolephorus indicus* (planktivorous), *Decapterus macrosoma* (a pelagic schooling fish common in deeper marine waters) [15]. The Hg concentrations on 5 species have exceeded the guideline issued by the Food Standards of Australia and New Zealand (FSANZ) [19]. The Hg concentration on crustacean was recorded on *Metapenaeus lysianassa*, Kepitang bakau (Indonesian name, possibly for *Scylla* spp. a type of crab species that live in the mangrove ecosystem), *Metapenaus* sp. The Hg concentration on the prawn *M. lysianassa* were higher more than 100 times than Hg observed on Kepitang bakau and *Metapenaus* sp. [15] and far exceeded the FSANZ value.

Several heavy metals concentration on soft corals (*Sarcophyton roseum* and *Symphylia agaricia*) were reported in 2007 [20] and 2008 [21]. Compared to other study, the Pb observed on soft coral in AOB were below the Pb observed on soft coral *Sinularia polydactyla* in Sulawesi (eastern Indonesia) [22].

There were three studies about heavy metals on seagrass in the Banda Sea. Two studies were conducted on seagrass *Enhalus acoroides*. The first one reported the Pb, Cd and Cr concentrations on its leaves [23]. The other one observed the Pb, Cd and Cr on roots [24]. The higher concentration of Pb, Cd and Cr were higher in the roots. The third study measured the Pb concentration on leaves, rhizomes and roots of *Thalassia hemprichii* [9]. The results showed a consistent pattern of accumulation (rhizomes> leaves> roots) at all sites [9].

The latest study on heavy metal concentration in the Banda Sea reported the low Cd concentration on sea urchin *Diadema setosum* from Ambon Bay in 2011 [8]. The Cd measured in Ambon Bay was lower than Cd level observed on the same organism sampled in a coral reef area in Singapore [25].

The activity in the harbour area of Ambon Island was reported as the probable cause of distorted growth and reproductive failure (imposex) in some of the gastropods sampled in Ambon Island [26]. These gastropods were taken from 9 out of 24 sampling sites at which whelks were present. The imposex was observed in three gastropods groups (*Thais kieneri*, *T. savignyi* and *Vasum turbinellus*) that were found in harbour area but was absent or in mild stage where there was no harbour related-activity in the sampling area.

2.2. Hydrocarbon

Both studies about hydrocarbon concentrations in the Banda Sea were conducted in Ambon Bay. The first study reported the hydrocarbon concentrations in Ambon Bay were at 22.3-25.9 $mg.l^{-1}$ [27], and these were higher than the limits of the national standard on marine water quality (Decree of the Indonesian Ministry of Environment no. 51/2004) [6]. The second study was conducted in 2009 [28], where it was reported that the hydrocarbon content was ten times lower than those observed in 1991. However, the hydrocarbon level observed in 1991 was above the aforementioned standard. Other than that, an initial study about hydrocarbon-degrading bacteria from Ambon Bay was published in 1997 [29].

2.3. Domestic Waste

The research since 1995 obviously mentioned the high risk of plastic debris in Ambon Island [26]. The study of marine litter along Ambon Island coasts (10 sites in Ambon Bay, 6 sites in South-east waters of Ambon Island and 5 sites in the Northeast area) showed that the mean density of marine litter in Ambon Island was at 4.6 $items.m^{-2}$. Compared to the other countries, the number of mean density of marine litter in Ambon Island is higher than Brazil (0.14 $items.m^{-2}$), Australia (0.04 $items.m^{-2}$), Mexico (1.5 $items.m^{-2}$) and Japan (3.41 $items.m^{-2}$) [30].

The highest density was found in Ambon Bay and the less contaminated was south-east coast sites [26]. There was an assumption that the local human population was the source of marine litter due to the significant correlation of their presence on the shore and the number of population in the adjacent coastal area. In this study, there was also assumption that the domestic waste in Ambon Bay was an indirect cause of heavy loads of the isopod ectoparasite *Renocila* sp. in the coral reef fish, *Abudefduf saxatilis* in Ambon Island. Indeed, it was assumed that there was a positive correlation between the increasing number of parasite load and the increasing number of organic waste in the coastal areas sampled. Furthermore, counting carried out on the floating litter on the surface of Ambon Bay indicated its highest density near the market of Ambon (Pasar Mardika) and Ambon Inner Bay. The density of the beach litter along the strandlines and the upper tidal between Ambon Inner Bay (Poka) and Ambon Outer Bay (Silale) was also compared. The beach litter found in Poka was eight times higher than in outer bay [31]. The density difference was due to the sizes of human population in respective area, where Poka was heavily populated than Silale.

The study of Institute for Marine Research and Observation Denpasar, Indonesian Ministry of Maritime Affairs and Fisheries [32] reported the presence of 5 000-6 000 particles of microplastics per km^2 in the Banda Sea. Compared to the other studies, microplastics density in the Banda Sea was higher than the mean density of floating litter in the North Sea (25-38 $items.km^{-2}$), West Hawaii (0.5

items.km^{-2}) South China Sea (0.3-16.9 items.km^{-2}), North Pacific (459 items.km^{-2}), Strait Malacca (579 items.km^{-2}) and global density of floating marine debris (0 to beyond 600 items.km^{-2}) [33].

3. Future perspective of marine pollution research in the Banda Sea

Nowadays, plastic debris has become a global issue. Plastic debris is one of the most challenging problems for marine environment because slowly degrading plastic wastes generate microplastic (particles smaller than 1 to 5 mm) which can be easily spread over long distances by wind-driven ocean surface layer circulation [34]. This waste is ubiquitous in the ocean remote shorelines, coastal waters, and the seabed of the deep ocean and also floats on the sea surface. The quantity of floating litter (plastic debris) observed in the open ocean in mid-ocean gyres represents a small fraction of the total input [35].

The presence of plastic debris in the marine environment generates ecological and socio-economic impact. Lots of studies have proved that microplastics have entered the organism's body such as on zooplankton [36], tuna [37], whale [38], corals [39], crab [40] by ingestion process. Marine plastic debris could affect also the reputation of the local tourism industry [34]. Due to the potential risk of marine plastic debris and microplastic in the Banda Sea, more studies about plastic and microplastic debris in the Banda Sea is urgently required to investigate the source, distribution, fate and impacts of marine microplastics in the Banda Sea. Adopting the research needs from UNEP program, we suggest conducting these topics for research in the Banda Sea:

a) Sources of plastic and microplastics
  - Source of plastic: research can be conducted to quantify inputs from fisheries sector, aquaculture sector, tourism sector, atmospheric transport.
  - Source of microplastic: research can assess the relative contribution of synthetic fibers; the relative contribution of vehicle tire fragments; the size, shape, and composition (polymer and additives) of microplastics from different sources; the input of resin pellets from the plastics production and river inputs; atmospheric inputs.

b) Distribution and fate
  - Factors controlling degradation
  - Presence, transport, and fate of plastics in the marine environment

c) Impacts
  - Quantifying impacts on biota, especially commercial biota such as tuna
  - Measuring the socio impacts
  - Assessing the economic impact

Acknowledgment

The author is thankful to Johanis Lekalete for generating the maps and both anonymous reviewers for their contributions in improving this paper. The participation of CYM in the ISBSE 2017 was fully funded by Centre for Deep-Sea Research, LIPI.

References

[1] Van Riel P M 1934 The bottom configuration in relation to the flow of the bottom water (*The Snellius Expedition in the Eastern part of the Netherlands East Indies 1929-1930* vol II part 2 Chapter II) (Utrecht: Kemink) 63 p

[2] Ministry of Maritime Affairs and Fisheries 2014 The total capture fisheries production, 2010-2014 *Marine and Fisheries in Figures 2015* [Internet] accessed on Nov 24th, 2017 from http://statistik.kkp.go.id/sidatik-dev/Publikasi/src/kpda2015.pdf

[3] GESAMP (IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution) 1991 Reducing environmental impacts of coastal aquaculture *Rep. Stud. GESAMP* **47** p 35

[4] Thayib S S and Razak H 1988 Observation on the bacteriological indicator, heavy metal and pesticide at Ambon Bay, Banten Bay and Jakarta Bay, *Perairan Indonesia: Biologi,*

Budidaya, Kualitas Perairan dan Oseanografi, pp 124–31 (in Indonesian with English abstract).

[5] Edward and Tarigan 1987 Pengamatan pendahuluan kadar Pb, Cd, Cu dan Zn dalam air dan biota di Teluk Ambon (*Teluk Ambon: Biologi, Perikanan, Oseanografi dan Geologi*) eds S Soemodihardjo, S Birowo and K Romimohtarto (Ambon: LIPI Press) pp 106-11

[6] Kementerian Lingkungan Hidup 2004 *Keputusan Menteri Lingkungan Hidup no. 51/2004 tentang baku mutu air laut* (Jakarta: Kementrian Lingkungan Hidup)

[7] Marasabessy M D, Edward, Valentin F L and Radjab A W 2009 Kandungan logam berat di Teluk Ambon dalam kaitannya dengan kehidupan biota laut *Lingkungan Tropis Edisi Khusus* pp 383 – 92

[8] Rumahlatu D 2011 Konsentrasi logam berat kadmium pada air, sedimen dan *Diadema setosum* (Echinodermata, Echinoidea) di Perairan Pulau Ambon *Jurnal Ilmu Kelautan* **16**(2) 78-85

[9] Tupan C I, Herawati E Y, Arfiati D and Aulanni'am 2014 Profile of Lead (Pb) heavy metal in water, sediment and seagrass (*Thalassia hemprichii*) in Ambon Island, Maluku, Indonesia *J. Bio. Env. Sci.* **5**(4) 65-73

[10] NOAA (National Oceanic and Atmospheric Administration) 1999 *Screening quick reference tables (SquiRTs)* [Internet] accessed Feb 1 2018 from http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html

[11] Edward and Pulumahuny F S 1987 Kandungan Logam Berat Hg, Pb, Cd, Cu dan Zn dalam sedimen di Perairan Teluk Ambon *Jurnal Fakultas Perikanan* **11**(1) 24-30

[12] Leiwakabessy F 2005 *Logam berat di perairan pantai Pulau Ambon dan korelasinya dengan kerusakan cangkang, rasio seks, ukuran cangkang kepada individu dan indeks keragaman jenis siput Nerita (Neritidae: Gastropoda)* Disertation (Surabaya: Airlangga University) 221 p

[13] Manullang C Y, Lestari, Tapilatu Y and Arifin Z 2017 Assessment of Fe, Cu, Zn, Pb, Cd and Hg n Ambon Bay surface sediments *Mar. Res. Indonesia* **42**(2) 77-86

[14] Male Y T, Reichelt-Brushett A J, Pocock M and Nanlohy A 2013 Recent mercury contamination from artisanal gold mining on Buru Island, Indonesia–potential future risks to environmental health and food safety *Mar. Pollut. Bull.* **77**(1–2) 428–33

[15] Reichelt-Brushett A J, Stone J, Howe P, Thomas B, Clark M, Male Y, Nanlohy, Butcher P 2016 Geochemistry and mercury contamination in receiving environments of artisanal mining wastes and identified concerns for food safety *Environ. Res.* **152** 401-18 56

[16] Pentury R 2006 *Analisis Kadar Logam Pb, Cd dan Fe dalam kerang* Anadara antiquata Undergraduate thesis (Ambon: Pattimura University) 56 p

[17] Hattu S 2007 *Analisis Kadar Logam Berat Cu, Cd, Cr dalam daging kerang manis (*Gafrarium tumidum*) pada Perairan Teluk Ambon bagian dalam* Undergraduate thesis (Ambon: Pattimura University) 47 p

[18] Nuniary M J 2007 *Analisa kadar logam Cd, Cr dan Cu dalam daging kerang* Soletellina biradiata *pada perairan Teluk Ambon Dalam* Undergraduate thesis (Ambon: Pattimura University) 57 p

[19] FSANZ (Food Standards Australia and New Zealand) 2015 *Contaminants and Natural Toxicants* [Internet] accessed Jun 26 2018 from https://www.legislation.gov.au/Details/F2015C00052

[20] Manuputty N 2007 *Penggunaan karang lunak (*Sarcophyton roseum*) sebagai indikator pencemaran logam berat Pb, Zn dan Cu di Perairan Teluk Ambon Bagian Luar* Undegraduate thesis (Ambon: Pattimura University) 47 p

[21] Tuwanakotta N 2008 *Kadar logam berat Pb, Cd dan Cr dalam spons (*Symphylia agaricia*) di Perairan Teluk Ambon bagian luar* Undegraduate thesis (Ambon: Pattimura University) 48 p

[22] Kadir H, Samawi M F and Haris A 2013 Akumulasi logam berat Pb pada rangka dan polip karang lunak *Sinularia polydactyla Jurnal Ilmu Kelautan dan Perikanan* **23**(1) pp 1-7

[23] Sipahelut A 2009 *Penentuan kandungan logam berat Pb, Cd dan Cr pada daun lamun* Enhalus

acoroides *di Perairan Teluk Ambon* Undergraduate thesis (Ambon: Pattimura University) 50 p

[24] Laimeheriwa, R S 2009 *Kandungan logam berat Pb, Cd dan Cr pada akar lamun* Enhalus acoroides *di Perairan Teluk Ambon* Undergraduate thesis (Ambon: Pattimura University) 55 p

[25] Flammang P, Warnau M, Temara A, Lane D J W and Jangoux M 1997 Heavy metals in *Diadema setosum* (Echinodermata, Echinoidea) from Singapore coral reefs *J. Sea Res.* **38** 35-45

[26] Evans S M, Dawson M, Day M, Frid C L J, Gill L A and Porter J 1995 Domestic waste and TBT pollution in coastal areas of Ambon Island (eastern Indonesia) *Mar. Pollut. Bull.* **30** 109-15

[27] Edward and Hermiati E 1990 Kandungan Hidrokarbon di Teluk Ambon, Maluku (*Perairan Maluku dan Sekitarnya*) eds D P Praseno (Ambon: LIPI Press) pp 106-11

[28] Dalila S 2009 *Kandungan senyawa Hidrokarbon di Perairan Teluk Ambon* Undergraduate thesis (Ambon: Pattimura University) 57 p

[29] Sutiknowati L I 1997 Sebaran Kepadatan Bakteri Pemecah Minyak di Teluk Ambon *Seminar Kelautan LIPI–UNHAS* (Makassar: LON LIPI–UNHAS) pp 260–64

[30] Pszczol S S O and Creed J C 2007 Quantification and classification of marine litter on beaches along Armação dos Búzios, Rio de Janeiro, Brazil *J. Coast. Res.* **23**(2) 421-28

[31] Uneputty P and Evans S M 1997 The Impact of Plastic Debris on the Biota of Tidal Flats in Ambon Bay (Eastern Indonesia) *Mar. Environ. Res*. **44**(3) 233-42

[32] Yunanto A 2017 *Pencemaran Sampah Plastik Mikro Terus Meluas* [Pollution continue to spread] *Kompas Daily* June 10th 2017 p 14 (in Indonesian)

[33] Galgani F, Hanke G and Maes T 2015 Global Distribution, Composition and Abundance of Marine Litter (*Marine Anthropogenic Litter*) eds M Bergmann, L Gutow and M Klages (Bremerhaven: Springer) pp 29-56 https://doi.org/10.1007/978-3-319-16510-3

[34] Thevenon F, Carroll C and Sousa J 2014 *Plastic debris in the ocean: The characterization of marine plastics and their environmental impacts, situation analysis report*. ed F Thevenon et al (Gland, Switzerland: IUCN) 52 p

[35] UNEP 2016 *Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change* [Internet] accessed on Aug 15 2017 from https://wedocs.unep.org

[36] Cole M, Lindeque P, Fileman E, Halsband C, Goodhead R, Moger J and Galloway T S 2013 Microplastic Ingestion by Zooplankton *Environ. Sci. Technol.* **47**(12) 6646–55. doi: 10.1021/es400663f

[37] Romeo T, Pietro B, Pedà C, Consoli P, Andaloro F and Fossi M C 2015 First evidence of presence of plastic debris in stomach of large pelagic fish in the Mediterranean Sea. *Mar. Pollut. Bull.* **95** 358–61

[38] Besseling E, Foekema E M, Van F J A, Leopold M F, Kühn S, Bravo R E L, Heße E, Mielke L, IJzer J, Kamminga P and Koelmans A A 2015 Microplastic in a macro filter feeder: Humpback whale *Megaptera novaeangliae Mar. Pollut. Bull*. **95** 248–52

[39] Hall N M, Berry K L E, Rintoul L and Hoogenboom M O 2015 Microplastic ingestion by scleractinian corals *Mar. Biol.* **162** 725–32

[40] Watts A J R, Lewis C, Goodhead R M, Beckett S J, Moger J, Tyler C R and Galloway T S 2014 Uptake and retention of microplastics by the Shore Crab *Carcinus maenas Environ. Sci. Technol.* **48**(15) 8823–30 doi: 10.1021/es501090e