Plankton And Heavy Metal Correlation From Commercial Vessels In Port Of Tanjung Emas Semarang

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E3S Web of Conferences 31, 06004 (2018) https://doi.org/10.1051/e3sconf/20183106004
ICENIS 2017

Plankton And Heavy Metal Correlation From Commercial Vessels In Port Of Tanjung Emas Semarang

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Abstract. The commercial vessels activity have a big role to increase the flow of number of cargoes from a port to another port. However , the impact of these activities are the disposal of ballast water from port area to the destination port. The purpose of this research was to analyze the correlation of phytoplankton, zooplankton, and heavy metal which were contained inside the ballast water of commercial vessel towards in waters of the port of Tanjung Emas Semarang. The concentration of heavy metal either from commercial vessels or the waters in port area analyzed by Atomic Absorption Spectrophotometer (AAS). The result showed that the correlation of zooplankton and phytoplankton in the water ballast at commercial vessels have a medium correlation to zooplankton and phytoplankton in waters of Port of Tanjung Emas Semarang (PTES) were 48.9% and 58.3%. Correlation of heavy metal Cd, Zn, Cu, Zn and Pb in ballast water of commercial vessel toward each metal in waters of PTES area has a strong correlation in contribution were 76.7%, 75.6%, 71.4% and 73.8%. It showed us that the loading activity of commercial vessels in port are contributed towards the pollution in waters.

1 Introduction

Commercial vessels play an important role in cargoes distribution around the world that more than 80% of the global trade volumes are carried out by sea transportation [1]. On the other hand, developing countries are positioned as the global trade booster [2]. In two decades, the centre of global economy and industry gradually has been moved from Northern Atlantic to Asia. Thus, the change definitely influences the role of Asia in the world trade [3].

The rise of world trade increases the demands of means of transportation one of which is commercial vessel. On one side, the use of commercial vessels can be use as the useful transportation. However, on the other hand, negative impacts are also resulted one of which is ballast water disposal. Ballast water is carried in vessel's ballast tanks to improve stability, balance, and trim which will be discharged when the cargoes are loaded. In Asia, as the effect of ballast water disposal, predatory fish *Scieanops occellatus* emerges [4]. Blenny and Goby fish are also found around the waters of Port Baltimore, Norfolk, and Maryland caused by the commercial vessels activities. These predatory gobies threaten the existance of endemic fish [5, 6].

Port's activities are also considered as the source of metal pollutants [7]. Moreover, this heavy metal pollutants can also be induced by industry and domestic activities which correlate positively to the marine organisms [8,9]. These pollutants increase the Pb content in scallop shells *Amusium pleuronectes* and red fish *Lutjanus erythropterus*, Chromium content in blood clams *Anadara granosa* [10,11,12,13]. The pollutants also affect tape seagrass, *Enhalus acoroides* which live in the waters which has been contaminated by Pb and Cd [14].

Port of Tanjung Emas Semarang (PTES) has been used as a location where both domestic and foreign commercial vessels berth and execute their port activities. The activities more or less give some effects to the port besides their domestic activities and dockyard. Moreover, within the port, we can also find Kali Baru estuary which is the accumulation of domestic activities and industry. This research was aimed to analyze the correlation of ballast water brought by commercial vessels toward the PTES waters.

2 Experimental details

The research was conducted in the PTES, Cetral Java, Indonesia. It was located in the northern coastline 6°53' South and 110°24' East. The sample was collected from the commercial vessels in PTES waters from December 18, 2014 until October 21, 2015. The sample was taken twice from a tank of ballast water on a vessel with DWT (Dead Weight Ton) over 400 tons. Purposive random

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sampling was applied to port's six piers : Pusri (*Pupuk Sriwijaya*) and oil, passengers, domestic, wheat, container and LPG (Liquid Petroleum Gas).

The sample of ballast water was collected by putting a hose into the sounding pipe. A portable pump and suction hose were needed to take the sample [15]. The researcher used portable pump Sanyo, P-WH137C, with voltage source of 220 V~50 Hz, output power of 125 W, and maximum water flow capacity of 30 litre/minutes. The diameter of the suction hose was 0.019 m and it was 10 m length. A valve was installed at the end of the hose. The sample was taken from both surface and base of the ballast tank. The surface water sample was obtained by raising the end of the suction hose while the bottom water sample was obtained by lowering the end of the suction hose.

The sample water of the surface of the tank can also be obtained by opening the manhole on the ballast tank. The sample water of the bottom of tank was taken by using a ten litre bucket.

The sample water was then filtered with filter paper Whatman 40 (0,40 µm) and washed with HNO_3 with pH < 2. The water was then put into water sampler with 5 litres of volume and brought into the laboratory. The water (100 ml) was blended and put into a beaker. After that, 5 ml of citric acid was poured into the mixture and heated up. Then, 50ml of the distilled water was poured. The mixture was then put into a 100 ml graduated flask [16, 17,18,19]. The content of Pb, Cd, Cu, Cd in the ballast water depended on the AAS (Atomic Absorption Spectroscopy) of Shimadzu AA-6300 by using the flame-mixed of air acetylene.

The water sample for the plankton was collected through filtration by using a plankton net with a diameter of 30 cm and mesh of 20 µm. In order to take the water sample from the base of the tank, a bucket was used. The water was then filtered into the plankton net [15,20]. Next, the water sample was put into a 50 ml bottle and a drop of lugol was added. Then, the water sample was filtered into a counting chamber (1 ml). It was important to make sure that there was no air bubbles inside. The water was then observed using a microscope with low magnification in order to obtain the general description. The plankton was counted using 5 field of view (5 columns). Last, genuses on the field of view was identified and counted.

Statistical analysis using SPSS for Windows (Versi 22.0) was applied. Correlation analysis was used to compare the phytoplankton abundance in PTES waters and within the ballast water of commercial vessels in PTES in October 2015.

3 Result and discussion

During the High Tide Level (HTL), the concentration of Cd reached 0.0432-0.0513 mg/litre, the highest concentration in Kali Baru estuary which was from the domestic disposal. On the other hand, the lowest concentration was found in the petroleum pier. The concentration of Cu was about 0.0555-0.066 mg/l, the highest concentration was found in Kali Baru estuary and the lowest was found in the outer area of port waters. Based on the finding, the farther the water were from the estuary, the lower the concentration of Cu would be. The concentration of Pb reached 0.627-0.8417 mg/l.The highest concentration was found in Kali Baru estuary and the lowest was found in the passenger pier. The concentration of Pb in all station had exceeded quality standard. It showed that PTES has been polluted by oil. The concentration of Zn reached 0.0483-0.0783 mg/litre in which the highest concentration was found in Kali Baru estuary and the lowest was found in the cargo vessel's pier. Concentration of heavy metals are in order Cd, Cu, Pb, and Zn were found during the HTL (Figure 1).

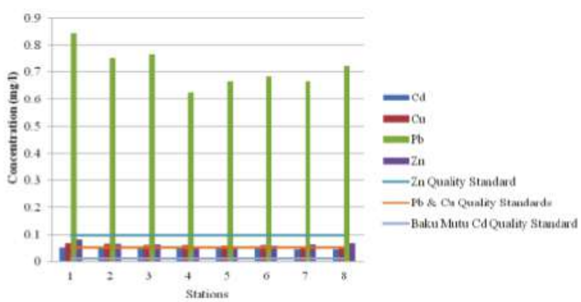

Fig. 1. Concentration of heavy metal during the HTL in October until December 2015 in PTES waters.

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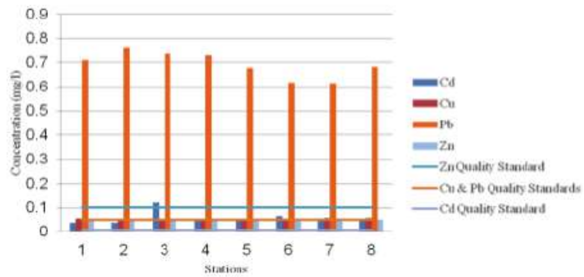

Fig. 2. Concentration of heavy metal during the LTL from October until December 2015 in PTES waters.

Based on the research, it was found that tidal range affects to the concentration of heavy metal. During the Low Tide Level (LTL), water flows from the river into the sea. Thus, the concentration of Cd ranged from 0.039 up to 0.119 mg/l. The maximum concentration occurred in bulk grain pier and the lowest concentration occurred in Kali Baru estuary. The concentration of copper ranged from 0.048-0.059 mg/l, the highest concentration was found in the middle position between container and petroleum piers whereas the lowest was found in bulk grain pier. The concentration of lead (Pb) ranged from 0.615 and 0.763 mg/l, the highest concentration was found in the fertilizer pier and the lowest was found in the middle between container and LPG piers. The concentration of zinc ranged from 0.045-0.057 mg/l, the highest concentration was found in the middle between container and LPG piers and the lowest was found in the bulk grain pier. Those metal concentrations was found in the estuary during the LTL. Based on the data, highest concentration metal was Pb followed by Cu, Zn, and Cd (Figure 2).

The ballast water within the commercial vessels in PTES contained heavy metal pollutants are Pb 0.37192 mg/l, Cd 0.001-0.46 mg/l and Zn reaching 0.001-2.464 mg/l [21,22]. Based on the identification of phytoplankton the HTL of October, it was found that there were 27 genuses of class *Baccilariophyceae, Dinophyceae, Chrysophyceae* and *Cyanophyceae*. During the LTL, there were 30 genuses which included the classes of *Bacillariophyceae, Dinophyceae, Chrysophyceae* and *Cyanophyceae*. The occurance of *Skeletonema* was the highest of all during the HTL followed by *Thalassionema, Thalassiothrix dan Asteroinella*. On the other hand, *Skeletonema, Thalassiothrix, Chaetoceros* and *Asteroinella* was those whose occurance were high during the LTL (Figure 3).

Based on its genus, Skeletonema was identified as phytoplankton with the highest level of occurance during both HTL and LTL in the eight stations [23]. The most dominant genus in PTES waters belongs to class *Baccilariophyceae.* It was also found that there was genus *Chaetoceros* which reached 3,535 individual/l during the HTL and 4,873 individual/l during the LTL. Moreover, genus *Ceratium* was also identified. *Algae* from genus *Chaetoceros* and *Ceratium* can possibly lead to blooming which is definitely dangerous for the fish [24].

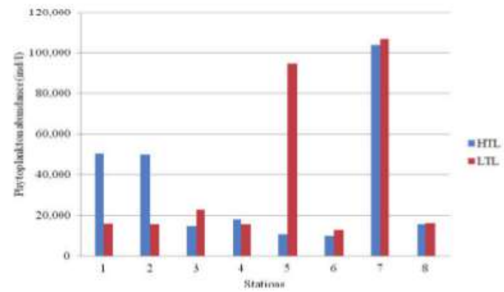

Fig. 3. The Histogram of Phytoplankton abundance in PTES waters during HTL and LTL in October 2015

Phytoplankton abundance during the HTL reached 9,655-104,319 individual/l and 12,318-10,7229 individual/l during the low tidal level, phytoplankton and genus abundance found during the LTL were higher than the HTL. It was because of the fact that the LTL occurs during daytime that the sunlight can easily shine through the waters which leads to the high numbers of phytoplanktons. In the eight research locations, the highest phytoplankton abundance was found in the middle of port waterways which is located between container and petroleum piers. It was due the fact that within this area waters, pollutants were less than some other area of the port. On the other hand, the least numbers of phytoplankton can be found in the container pier (Figure 3).

During the LTL, genus *Gyrosigma* of class *Bacillariophyceae* and *Ornithocercus* of class *Dinophyceae* were found. On the other hand, they were not found during the HTL. Moreover, *Pyrocytis* of class *Chrysophyceae* was also identified during the HTL.

Based on the identification within the ballast water tank of commercial vessels, eight classes were found *Bacillariophyceae, Dinophyceae, Euglenoidea, Conjugatophyceae, Cyanophyceae, Charophyceae, Chrysophyceae, Conjugatophyceae* and *Chlorophyceae. Skeletonema* occurance dominated within the commercial vessels followed by *Chaetoceros* and *Nizschia*. Phytoplankton abundance within the commercial vessels in PTES was about 0.32 -412 individual/l. The highest phytoplankton abundance was found in GW vessel in petroleum pier which was from Situbondo in the ballast tank no 4 port and starboard side. Sample was also taken from drain pipe of Ballast

Pump in JM vessel from Palembang waters. The lowest phytoplankton abundance were found in the A, DF2, MP, and PI vessels. *Skletonema* was frequently found within the ballast tank of GW reaching 412 individual/l and J reaching 206 individual/l (Table 1).

Within commercial vessels, some different genus/species were found in PTES waters including *Gyrosigma* (class of *Bacillariophyceae*) within the SR 68 vessel, *Diatoma vulgare* (class of *Bacillariophyceae*) within the HS vessel, *Pinnularia tabellaria* within C 8 vessel, *Euglena acus ehenberg* (class of *Euglenoidea*) and *Spirotaenia condensata* (class of *Conjugatophyceae*) within the L vessel, *Lyngbya* (class of *Cyanophyceae*) within S, A dan SB vessels; *Oscillatoria* (class of *Cyanophyceae*) within C 8, BC S, GD, GNA and OK vessels; *Gonatozygon* (class of *Charophyceae*) within A, DF,C 8, BC S and GNA vessels; *Ankistrodesmus* (class of Chrysophyceae) within BC S vessel, *Tetmemorus laevis* (class of *Conjugatophyceae*) within GD. In a series, the SR 68, HS, C8, L, S, A, SB, BC S, GD, GNA, and OK vessels were from Jakarta, Tuban, Dumai, Jakarta, Cilacap, Jakarta, Singapore, Singapore, Sorong, Jakarta and Palembang.

The genus/species and the vessel's origin, in which *Oscillatoria* and *Euglena* were found, can possibly cause eutrophication to the new coastal waters. These genus were frequently used as an indicator of organic pollutant in ballast water within commercial vessels (Table 2). The toxic substance within these genus may threaten the organisms as they are consumed. Then, within a food chain, a bigger bioaccumulation may take place. *Oscillatoria* which belongs to genus Cyanobacterium is able to carry out a fermentation (producing energy in an anaerobic condition) in a dark environment and potentially produce toxin [25].

Gyrosigma is a unicelulular diatom which belongs to *Chromophyta* division of class Bacillariophyceae and ordo *Bacillariales* (pennate Diatom), family of *Naviculaceae* [26, 27]. These pennate diatoms of ordo *Bacillariales* has upper valve epitheca and lower valve hypotheca. Some of diatom pennates have raphe and some others do not. Some have *pseudoraphe*, a small axial area on the valve. Some species of diatom pennates have apical pore fiel on their valve but do not possess any raphe.

Most of diatoms are in form of diatom pennate. In both freshwater and seawater, diatoms form colonies into substrate. Diatoms and bacteria form biofilms with some organisms and build a colony. Diatoms also grow in a living substract such as plants and algae. Diatom's growth can possibly produce dark brown liquid [28]. Diatoms which grow in a polluted waters show that these organisms are pollutant tolerant which are mostly dominated by *Navicula*, *Nitzchia*, *Pinnularia* and *Eunotia*. These genuses can be used in an experiment of ecosystem's improvement [29]. Euglena shows some animal's characteristics including having no sellulose cell wall. Its outer membrane is flexible. Some species have a clear eyespot. Inside its cell, it has contractile vacuole and fibrils/microtubules. Yet, Euglena is able to make its own food by photosynthesis since it has chloroplast and is an facultative autotrophic [30].

Table 2. Genus/species, vessel's origin and port of origin

No	Genus/Spesies	Vessels	Port of origin
1	*Gyrosigma*	SR 68	Jakarta
2	*Diatomae vulgare*	HS	Tuban
3	*Pinnularia tabellaria*	C 8	Dumai
4	*Euglena acus ehrenberg*	L	Jakarta
5	*Spirotaenia condensata*	L	Cilacap
6	*Lyngbya*	S, SA, SB	Cilacap, Jakarta, Singapore
7	*Oscillatoria*	C 8, BC S, GD, GNA, OK	Dumai, Singapore, Sorong, Jakarta, Palembang
8	*Gonatozygon*	A, DF, C 8, BC S, GNA	Jakarta, Dumai, Singapore, Jakarta
9	*Ankistrodesmus*	BC S	Singapore
10	*Tetmemorus laevis*	GD	Sorong

Genus *Okeania, Lyngbya, Simploa, Phormidium, Oscillatoria* and *Sprirulina* belong to cynobacteria. This cynobacteria causes bloom that have occured in Old Providence Island, 300 km from shore of Mosquito, Nicaraguay. It depresses coral reef community in the island. It was caused by overbalanced nutrient and global warming [31]. In Roebuck bay in which nutrients was overbalanced, biodiversity has been significantly changed. Therefore, it increases cynobacteria abundance such as *Lynbia* which causes anoxia and hypoxia. It also impacts to the decrease of benthic invertebrate [32].

Some pollution-tolerant genuses were also found including *Navicula, Nitzschia, Scenedesmus, Coscinodiscus, Ankistrodesmus, Chhlorella, Oscillatoria, Phormidium.* Those genuses dominated four research stations of seafood factory waste. Those genuses caused eutrophication [33].

Some microalgae including *Euglena, Navicula, Nitzschia, Ankitrodesmus* and *Scenedesmus* were identified as tolerant toward organic tolerant [34]. It showed that algae found in ballast tank of commercial vessels were pollution tolerant organisms.

Chlorophyll of Genus *Ankistrodesmus* can be significantly produced by adding CO_2 and controlling its value on 10.7 mg/l, 10.57 mg/l and 7.84 mg/l [35]. It shows that genus *Ankitrodesmus* is tolerant to enclosed space inside the ballast tank of the commercial vessels

https://doi.org/10.1051/e3sconf/20183106004

Table 1. Composition and phytoplankton abundance within ballast water in commercial vessels

No.	Class/Genus	L	S B	C 1	JM	GW	HS	A	MB2	BM79	DF2	M	C8	MP	GD	OK	P I
	BACILLARIOPHYCEAE																
1	*Nizschia vermicularis*	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	*Hemialus sp.*	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	*Nizschia curvula*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	*Skeletonema sp.*	-	+	-	++++	++++	-	-	-	-	-	-	-	-	-	-	-
5	*Rhizosolenia sp.*	-	+	+	+	-	-	-	+	-	-	+	-	+	-	+	+
6	*Coscinodiscus sp.*	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
7	*Pleurosygma sp.*	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	+
8	*Ceratium sp.*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-
9	*Chaetoceros sp.*	-	-	-	+	++++	-	-	-	-	-	-	-	-	-	-	-
10	*Thallaxiothrix sp.*	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
11	*Navicula sp.*	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
12	*Gyrosygma sp*	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-
13	*Nitzschia sp.*	-	-	-	-	-	-	-	-	+	+	+	+	-	+	-	-
14	*Diatoma vulgare*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
15	*Synedra sp.*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-
16	*Pinnularia tabellaria*	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
	DINOPHYCEAE																
17	*Peridinium sp.*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
18	EUGLENOIDA																
19	*Euglena acus Ehrbg.*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CONJUGATOPHYCEAE																
20	*Spirotaenia condensata*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	*Tetmemorus leavis*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
	CYANOPHYCEAE																
22	*Lyngbya*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
23	*Oscillatoria sp.*	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	-
	CHAROPHYCEAE																
24	*Gonatozygon sp.*	-	-	-	-	-	-	+	-	-	+	-	+	-	-	-	-
	Total	157	11	8	219	703	0.3	3	0.3	2	1	8	4	1	6	6	1

Note : + 0-50, ++ 51-100, +++ 101-150, ++++ > 151 ind/l.

Based on the research, planktons which cause *red tide* in Indonesia were found. Within SB, JM and GW vessels, *Skletonema sp.* was found up to 2.55 sel/l, 206.4 sel/l and 412 sel/l. Moreover, plankton *Chaetoceros sp.*, which also causes red tide, was also found inside the ballast water of JM and GM vessels reaching 3.82 sel/l and 282.8 sel/l. *Red tide* is defined as a phenomenon in which plankton population (plankton bloom) increases significantly [36]. This phenomenon causes the rising of mass fish and biota die-off due to the sudden decrease of DO content. Thus, red tide is also known as Paralytic Shellfish Poisoning (PSP), a kind of disease brought by poisonous seafood which was contaminated by microorganisms in which red tide takes place. This phenomena once occured in Ancol in May 2004 as *Skletonema sp., Thalassiosira sp.* and *Chaetoceros sp.* were found [37].

In June and September 2011, four genuses which cause *red tide* were found in the estuary of Cisadane and Untung Jawa Island. The genuses were *Ceratium, Pseudonitzshia, Dinophysis dan Chaetoceros.* Plankton which causes *red tide* was also found in the C1 vessel which was from Pontianak whose numbers up to 1.275 sel/l [38].

Red tide occured in Kao Bay in 1994 was resulted by the decrease of DO or exotic species such as *Phyrodinium* (class of *Dinofragellate)* [39]. There was also found in the ballast tank of a commercial vessel from Palembang, OK vessel, reaching 0.955 sel/l. Genus *Nitzschia spp.* which causes red tide was also found in the L vessel. The species were *Nitzshia vermicularis* (124 cell/l) and *Nitzshia curvula* (29.3 cell/l). Genus *Nitzshia sp.* was found in the RB, S, BM 79, DF, M, C, BC S, GD and GNA vessels whose numbers reached 1.275 cell/l, 0.32 cell/l, 1.6 cell/l, 0.32 cell/l, 3.505 cell/l, 1.595 cell/l, 0.32 cell/l, 3.505 cell/l and 8,6 cell/l. Species that can cause Diarrhetic Shellfish Poisoning (DSP) are *Nitzschia pungens* which can cause the effects of Amnesic Shellfish Poisoning (ASP) [40].

Zooplankton found within the ballast water in the commercial vessels have a moderate level of correlation to zooplankton found in PTES waters. The correlation reaches 0.489 or 48.9%. Moreover, phytoplankton found within the ballast water in the commercial vessels also have a moderate level of correlation to phytoplankton found in PTES waters reaching 0.583 or 58.3% (Table 3).

Table 3. the Correlation between phytoplankton and zooplankton in ptes waters and phytoplankton and zooplankton within ballast water of commercial vessels

Biota	Phytoplankton (coastal waters)	Zooplankton (coastal waters)
$Phytoplankton_{vessel}$	0.489*	
$Zooplankton_{vessel}$		0.583*

* Significant correlation $p < 0.01$ (2-tailed)

The hypothesis of heavy metal in PTES waters and heavy metal within ballast water of commercial vessels stated that H_1 : there is a correlation between heavy meatal in PTES waters and heavy metal found in the ballast water of the commercial vessels. The correlation of Cd, Zn, Cu, Zn dan Pb found in PTES waters and those which were found in the ballast water was high up to 0.776 (76.6%), 0.756 (75.6), 0.714 (71.4%) and 0.738 (73.8%) (Table 4).

Table 4. The correlation between heavy metal in PTES waters and in ballast water of commercial vessels

Eleme nt	$Cd_{coastal}$ waters	$Cu_{coastal}$ waters	$Zn_{coastal}$ waters	$Pb_{coastal}$ waters
Cd_{vessel}	0.776*			
Cu_{vessel}		0.756*		
Zn_{vessel}			0.714*	
Pb_{vessel}				0.738*

* Significant correlation p=0.05 (2-tailed)

Lead (Pb) can possibly give bad impacts to the mangrove *Avicennia marina*. The highest content of lead was found within mangrove's stems (5.89 ppm). Lead also damaged mangrove's cells within leaf and fruit [41]. The effect of copper (Cu) exposure to *Moerella iridescens* in Maluan Bay has correlated positively to the dissolved particle of the sediment. It also contributed to the metal content within the shells [42]. Metal exposure on gastropod has greater effect than the exposure on crustacean and fish due to its lower tropical nature. On the other hand, metal content within fish liver is greater than what has been found in its gills and muscles tissue [43].

4 Conclusion

Within the commercial vessels, some different genus/species were found including Gyrosigma (class of Bacillariophyceae), Diatom vulgare (class of Bacillariophyceae), Pinnularia tabellaria, Euglena *acus ehenberg* (class of *Euglenoidea*) and *Spirotaenia condensata* (class of *Conjugatophyceae*), *Lyngbya* (class of *Cyanophyceae*), *Oscillatoria* (class of *Cyanophyceae*), *Gonatozygon* (class of *Charophyceae*), *Ankistrodesmus* (class of Chrysophyceae), *Tetmemorus laevis* (class of *Conjugatophyceae*). These genus/spesies were brought from various ports that they can possibly influence the organisms of PTES waters.

Zooplankton within the ballast water of commercial vessels has a moderate level of correlation with zooplankton found in PTES waters which number reaches 0.489 or 48.9%. Phytoplankton within ballast water of commercial vessels has a moderate level of correlation to phytoplankton found in PTES waters which number reaches 0.583 or 58.3%. There is a moderate level of correlation between phytoplankton in PTES waters and those found in the commercial vessels.

Metal Cd, Zn, Cu, Zn and Pb within ballast water of commercial vessels have a high level of correlation to each metal found in PTES waters. The correlation of Cd, Zn, Cu and Pb to the heavy metal in PTES waters reach 0.776 (76.6%), 0.756 (75.6), 0.714 (71.4%) and 0.738 (73.8%).

It is concluded that it is better for the commercial vessels to discharge their ballast water offshore before they reach PTES waters in order to prevent and minimize the emerge of some alien species in the port waters. A useful ballast water management is definitely needed.

5 Appreciation

We would like to thank the following people for their support, without whose help this work would never been possible: Port Authority and Harbormaster Office Head of Tanjung Emas Semarang, officers of commercial vessels for permitting us to take research sample of ballast water. Faculty of Fisheries and Marine Science staffs at Diponegoro University; Mr. Andreas, Sigit, and Vian who helped to identify phytoplankton of both PTES waters and ballast water of commercial vessels.

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