INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 10, No. 1, p. 80-89, 2017
http://www.innspub.net

RESEARCH PAPER

OPEN ACCESS

The impact of ballast water disposal of commercial vessels, diversity of species and tide time in the west monsoon in port of Tanjung Emas Semarang

Agus Tjahjono*[1,2], Azis Nur Bambang[3], Sutrisno Anggoro[3]

[1]*Graduate Program on Environmental Science, School of Postgraduate Studies Diponegoro University, Semarang, Central Java, Indonesia*

[2]*Engineering Department, Semarang Merchant Marine Polytechnic, Semarang, Central Java, Indonesia*

[3]*Departement of Environmental Sciences, School of Postgraduate Studies Diponegoro University, Semarang, Central Java, , Indonesia*

Article published on January 20, 2017

Key words: Ballast Water, PTES, West Monsoon, Pb

Abstract

The disposal of ballast water impacted to the aquatic ecosystem. Certain plankton species are able to survive in polluted conditions in the sea water of the Port of Tanjung Emas Semarang (PTES). This study aimed to assess the quality of the sea water as a result of ballast water discharge in the west monsoon against species phytoplankton diversity. Plankton was used as a bioindicator in the changes in water quality when HTL (High Tide Level) and LTL (Low Tide Level) occurred in the west monsoon of the ecosystem. The concentration of heavy metals in some commercial vessels were above the maximum limit, which resulted in the extinction of plankton organisms; it was possibly caused by the entry of these vessels in PTES waters. In the west monsoon, the Pb concentrations in the 8 stations are above the prescribed maximum limit that affected the marine environment, however the Total Dissolved Solid (TDS) were still in the low range for the waters. The test samples of heavy metals was done by spectrophotometry. The results demonstrated the diversity of the genus Bacillariophyceae mostly found increasing in station II, and decreasing in the station IV with number, 3.83, and 3,395 species/l respectively. The adaptability of plankton was evident in *Skeletonema, Synedra, Thalassiothrix, Thalassionema, Ceratium, Peridium, Ornithocercus* and *Anabaenopsis*. Determination of ballast water exchange in the ocean was one alternative to prevent a decline in species diversity.

***Corresponding Author:** Agus Tjahjono ✉ a_agus_tjahjono70@yahoo.co.id

Introduction

Sea transportation method has been increasing because it was supported by merchant vessels which acted as a driver in global trade. Commercial vessels utilize seawater in ballast tank to maintain the stability of the vessels, which functions to lower the ship with a draft. This would allow the ship's propeller to be aligned perfectly thus perfecting the rate of submerged ship, hence the pace of the ship can be maintained, also keeping it trim for good sailing stability.

The ballast water disposal from commercial vessels cause negative effect to the environment, it was discovered 139 alien species and fish ruffee into species that are harmful (Mills *et al.,* 1994), 58 species are introduced in eight ports, 49 species of which are dominated by species from tropical areas (Hewitt, 2002), declining abundance mesozooplankton species was due to the invasion of *Mnemiopsis Leidyyi*, decreasing kilka fish to three times as much (Roohi *et al.*, 2010), and impacted in economics (Lovell *et al.*, 2006; Lin *et al.*, 2007).

Ballast water management in accordance with the regulations may only be discharged with less than 10 living organisms per m^3 with size of more than or equal to 50 µm.

The ship also may only be issued organism in the ballast tank with microbes indicator in accordance with the standards of human health such as *Vibrio cholerae* (O1 and O139) were less than one colony per 100 ml, *Escherichia coli* less than 250 colonies per 100 ml, and *Enterecocci* less than 100 colonies per 100 ml (IMO, 2005).

Objective assessment of the water quality of the effluent water ballast when HTL and LTL in the west monsoon is one of the evaluations Pb contents in ballast water of commercial vessles and the diversity of phytoplankton in PTES waters, will became the foundation for the model management policy for littoral waters.

Material and methods

Field of study

The determination of selected research sites in the PTES, Central Java province, Indonesia. This was due to discharge of ballast water carried by commercial vessels had impacted the harbor waters and environment as presented in Figure 2 (the site of study).

The research location is situated on the northern coast of Central Java province, at position 6° 53' South and 110° 24' East. Sampling is done at station 1 (Kali Baru estuary) on 6° 57.059' South and 110° 25.150' East, 2nd station (fertilizer pier) on 6° 56.911' South and 110° 25.271' East, 3rd station (wheat pier) on 6° 57.030' South and 110° 25,458' East, 4th station (passenger pier) on 6° 56.957' South and 110° 25.505' East, 5th station (cargo pier) on 6° 56.615' South and 110° 25.379' East, 6th station (container pier) on 6° 56.305' South and 110°25. 383' East, 7th station (middle point between LPG and container pier) on 6° 56.408' South and 110°25.337' East, 8th station (LPG jetty) on 6° 56.464' South and 110° 25.213' East.

Analysis of physics, chemistry of water

The physics and chemistry water was taken from the PTES waters, and then analyzed in the Health Service Central Laboratory Health Semarang. The plankton analysis was conducted in the laboratory resources management of the Faculty of Fisheries and Marine Science Diponegoro University.

Analysis diversity indices

The diversity indices was determined from the results of the Shannon-Wiener,1949 (Wibisono, 2005 & Effendi, 2007) :

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

(1)

Description :

H = Shannon's diversity indices

S = total number of species in the community (richness)

p_i = Proportion of S made up of the ith species.

Procedure for applying the method

The water samples were taken in the west monsoon period from October to December 2015 during HTL and LTL, a sample of 50 ml was taken, then be given 20 drops of Lugol, then whipped, then be put in a ice box. Checks on Sedwich Rafter was made, observed with a microscope. Yamaji (1980) used to identify the biota, and plankton were found.

The water sample in ballast tank of commercial vessels was collected by using the method conducted by putting sound meter in ballast water tank through sounding pipes. Portable pump and suction hoses were used to collect the water sample (Garret *et al.*, 2011). The portable pump was Sanyo brand, model P-WH137C, 220 V~50 Hz of voltage, 125 W of output power, 30 liters/minute of maximum water capacity. The suction hose had 0.019 m width of diameter and 10 m in length.

The end of suction hose was completed with a foot valve. The water sample of the ballast water in the surface of the tank could be collected by rising the end of suction hose, while the water sample from bottom of the tank could be collected by lowering the end of the suction hose. Sample of the ballast water that is on the surface of the tank could also be collected by opening manhole in the ballast tank of commercial vessels. Sample of water, in the bottom of the tank, was collected by using 10 liters bucket.

The water sample was filtered using 40 (0,42 µm) whatman filter paper and washed using HNO_3 concentrated to pH < 2. Then, it is placed in water sampler of 5 liter volume. The water sample was then brought to the laboratory.

The water (100 ml) was mixed thoroughly and put in the beaker. Then, it was added by 5 ml of citric acid and heated, 50 ml of distilled water is added, and the mixture was put in 100 ml of graduated flask and then taken to a chemical laboratory for analysis by spectrophotometric method, SNI06-6989, 14-2004, SNI 06-6989.51-2005, and AAS (Atomic Absorption Spectrofotometry) .

Statistical analysis

The SPSS® for Windows (Ver 22.0) statistical software was used for analysis. Correlation analysis used to correlate between abundance of phytoplankton in November 2015 and psysicochemical parameters in PTES waters.

Results and discussion

The commercial vessels had an important role in the distribution of goods brought by sea transportation. The ballast tanks acted as stability maintainer of the ship, when the cargoes is empty, the sea water would be uptaken and stored in a ballast tank. When the vessel reaches its next port, ballast water would be discharged to port waters.

Based on the analysis in passenger ships owned by Pelni Lines, L, S, and B found to contain high levels in some parameters in the ballast tank .

The TDS (Total Disolved Solid), TSS (Total Suspended Solid), H_2S, phenol compounds; heavy metal content Zn is above the standard quality according to the Decree of the Minister of Environment No. 51 of 2004 on the Sea Water Quality Standards for Harbour Waters were determined to be about 2000 to 4000 mg/l. Commercial vessels MP, GW and GNA with domestic route had Pb contents that exceeded the quality standards, caused by regions of origin waters have been polluted (Table 1).

The ongoing ballast water discharge influenced the diversity. Identification of phytoplankton at HTL in October was conducted related to adaptability of *Baccilariophyceae, Dinophyceae, Chrysophyceae* and *Cyanophyceae* as many as 27 generas, 30 generas were found at lowest tide.

The species commonly found during HTL were *Skeletonema, Thalassionema, Thalassiomthrix* and *Asteroinella,* LTL with *Skeletonema*, *Thalassiothrix, Chaetoceros* and *Asteroinella* genus (Figure 1).

Table 1. Analysis results parameters in the ballast tank in the commercial vessels.

No	Name of vessels	Parameter	Unit	Result	Port of origin	Quality standards
1.	L	TDS	mg/l	23,924	Pontianak	2,000-4,000
2.	S	TSS	mg/l	1,336	Jakarta	80
		H_2S	mg/l	4.8		0.03
		Phenol	mg/l	2.8		0.002
		Pb	mg/l	0.03		0.05
3.	B	Phenol	mg/l	0.008	Sampit	0.002
		Zn	mg/l	0.498		0.1
		Pb	mg/l	0.03		0.05
4.	L	Pb	mg/l	0.03	Pontianak	0.05
5.	Ce I	Pb	mg/l	0.04	Pontianak	0.05
6.	Domestic vessels : Y, SB, Ok, PI, IZ, C 8 ,S	Pb	mg/l	0.05-0.63	Palembang	0.05
	MP	Pb	mg/l	14 times more than the standard	Palembang	0.05
7.	GW	Pb	mg/l	0.07 -0.12	Banyuwangi	
8	- A - MB - DF 2	Pb	mg/l	0.031-0.71	Jakarta	0.05
9	GNA	Pb	mg/l	11.6	Jakarta	
10	Foreign vessels: PA & SB	Pb	mg/l	0.04-1.12	New Orleans & Singapore	0.05

The changes of biota affected by Pb in HTL on October, November and December respectively ranging from 0.605 to 0.65 mg/l, 0.27 to 0.67 mg/l, and 0.56 to 1.215 mg/l., also TDS , pH (at the station 5), BOD_5.

The occurrence of an increase in heavy metal affected the growth of plankton, it was associated with tidal patterns, migration, deployment, and therefore contributed to saprobity (Suryanti, 2008).

Table 2. Analysis results of multiple parameters of water quality at HTL conditions in the western monsoon at PTES waters.

Parameter	St.1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8
DO (mg/l)	5.57	6.44	5.9	6.44	6.08	6.79	6.73	6.62
Ph	7.93	8	7.96	8.01	8	7.97	8	8.02
Salinity (‰)	33.34	34.3	33.7	34.37	33.78	32.92	34.45	34.08
Nitrate (mg/l)	0.35	0.23	0.28	0.2	0.15	0.36	0.24	0.18
Phosphate (mg/l)	0.58	0.51	0.66	0.48	0.57	0.86	0.57	0.89
TSS (mg/l)	4.33	78.17	51.5	33.33	55.33	89.83	83	151.83
Temp. (°C)	27.82	26.43	26.53	26.33	26.45	6.72	26.93	27.27
Depth (m)	6.51	8.37	8.18	8.09	11.03	10.62	10.69	7.9
Brightness (m)	1.08	1.05	1.08	1.20	1.14	1.10	1.18	1.12
BOD_5 (mg/l)	1.63	1.57	1.73	1.59	1.56	1.6	1.5	1.65
Sulfide (mg/l)	0.07	0.06	0.08	0.05	0.07	0.07	0.07	0.1
Phenol (mg/l)	0.02	0.05	0.03	0.02	0.01	0.03	0.02	0.04
Turbidity (NTU)	28.31	105.6	38.54	27.09	54.9	141.25	78.01	152.59
TDS (mg/l)	303.67	337	345	332.33	417.67	435.83	467.17	475.17

The highest concentration of several parameters are presented in Table 1. Among these contents when discharged into the waters of the PTES affect the quality of the physical, chemical and biological.

The tidal patterns had strongly influenced the biota that inhabits in the zone, in addition to additional activity in the area of the PTES, which could result in changes to physical factors of chemical waters.

Table 3. Analysis results of multiple parameters of water quality at LTL of western monsoon at PTES waters.

Parameter	St.1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8
DO (mg/l)	4.23	5.07	4.59	4.47	5.22	5.14	5.25	4.95
Ph (mg/l)	7.81	7.94	7.91	7.93	7.96	7.94	7.94	7.93
Salinity (‰)	33.2	33.15	33.17	33.08	33.18	32.7	32.9	32.27
Nitrate (mg/l)	0.14	0.18	0.26	0.24	0.29	0.21	0.25	0.16
Phosphate (mg/l)	0.46	0.71	0.65	0.45	0.46	0.62	0.66	0.56
TSS (mg/l)	27	92.5	101.33	42	124.5	58.17	64.33	59.5
Temp. (^oC)	30.18	30	30.43	30.93	30.33	31.52	30.55	33
Depth (m)	6.3	7.36	9.32	7.37	8.18	9.84	10.22	4.6
Brightness (m)	1.27	1.27	1.27	0.99	1.17	1.21	1.02	1.14
BOD_5	1,61	1.37	1.11	1.41	1.18	1.14	1.04	1.42
Sulfide (mg/l)	0.09	0.13	0.14	0,11	0.16	0.23	1.54	0.2
Phenol (mg/l)	0.02	0.04	0.04	0	0.03	0.03	0.02	0.03
Turbidity (NTU)	36.88	117.37	83.32	52.47	102.47	66.28	82.48	72.36
TDS (mg/l)	505.5	536.33	475.33	351.5	463	445.83	464.33	503.67

The results of measurements of water quality parameters in the PTES during the HTL and LTL of October-December 2015 with the optimum range is presented in Table 2 and 3. Overall Pb concentration at all stations on the condition of tidal waters was above the maximum limit of 0.05 mg/l, this indicated that the PTES waters had faced pollution as presented in Figure 3.

The natural sources of Pb was derived from the beach (sourced from rivers, coastal erosion by wave activity), so that the levels and the toxicity of lead is influenced by hardness, pH, alkalinity and oxygen levels. Pb-containing waste material discharged into waters contribute to the pollution of the waters, but the toxicity of lead was reduced if an increase in the hardness and dissolved oxygen (Effendi, 2007).

Table 4. Pearson's correlation coefficients (r) for abudance phytoplankton in November 2015 and physicochemical parameters in PTES waters.

	Abudance Phytoplankton	
	HTL	LTL
DO	-0.197	-0.541
Ph	-0.115	-0.821[a]
Sal	0.191	0.457
Nitrate	0.069	-0.0296
Phosphate	-0.501	0.102
TSS	-0.269	-0.279
Temp.	0.139	-0.509
Depth	-0.221	0.165
Brightness	-0.569	0.503
BOD5	0.104	0.164
Sulfite	-0.452	0.084
Phenol	0.525	0.214
Turbidity	-0.174	-0.363
TDS	-0.115	0.365

[a] Correlation is significant at the 0.05 level (two-tailed).

Water bodies contained in excess of the Pb ion compound concentrations can cause death to aquatic biota, where the concentration of 188 mg /l can kill fish.

The pollution that occurred when the ballast water discharges from commercial vessels to the waters would disturb the ecological balance, the species is not native, crytogenic species (Arenas *et al.*, 2006). The impact occurred in countries outside their foreign organisms alter ecosystems, for example the invasion of tree fastener-nitrogen *Myrica faya* to the Volcano National Park Hawaii, thus reducing biodiversity (Vitousek *et al.*, 1996), the frequency of the phylum phyla foreign mollusk, arthropods, chordates, and Rhodophyta with alien species in littoral regions, sub-littoral benthic or demersal species (Galil, 2008), alien species *Neogobius* (round goby *N.melanostomus*, racer goby *N.gymnotrachelus* and monkey goby *N.fluviatilis*), amur sleeper *Perccottus glenii* and topmouth gudgeon *Pseudorasbora parva* (Grabowska *et al.*, 2010).

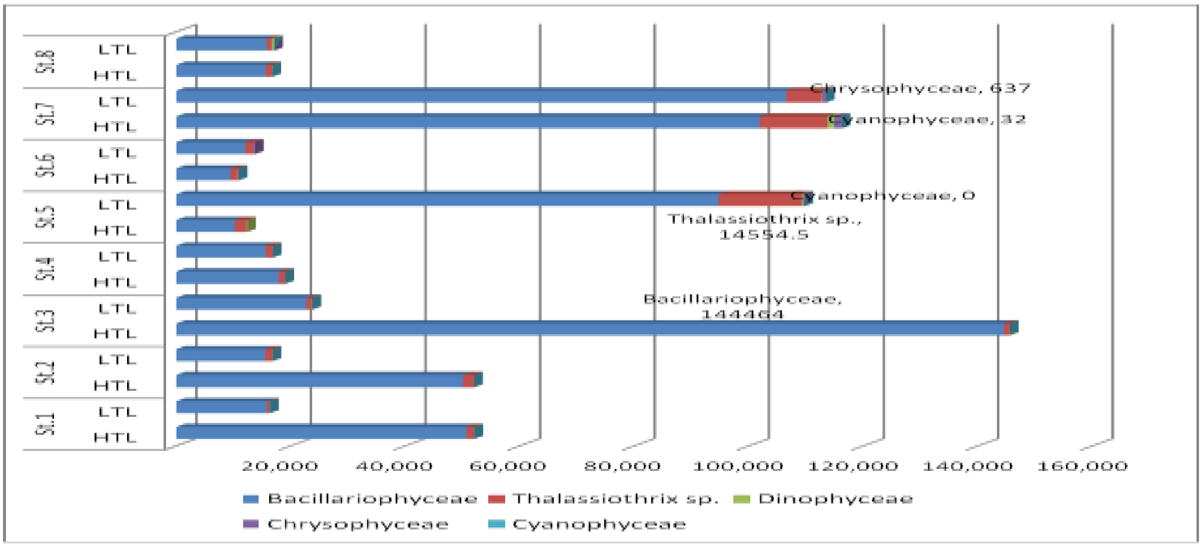

Fig. 1. Diversity Phytoplankton (ind/l) in the PTES waters in October 2015.

The season is the environmental factors that affect the distribution of diatomaceous on waters (Wu and Chou, 1998). So the presence of phytoplankton affect aquatic life. This was because phytoplankton played an important role as primary producers to marine organisms. Given its location between the estuary and the sea, it influenced by the characteristics of fresh and marine waters, where the water was fluctuating in physics and chemistry (Nybakken, 1988). These relationships affect the adaptability of biota on water quality.

The biodiversity was the degree of stability of the structure of the communities inhabited by organisms, so it was used to assess the quality of the waters in various designation. Value index of diversity (H') of phytoplankton during the HTL was ranged from 0.6 to 1.455 with the maximum value at station 6 and the minimum at station 4, whereas when LTL ranged from 0.63 to 1.19 were categorized of carring H' value was less than one classified polluted heavy, genus groups that often appears both HTL and LTL at the 8th station (LPG pier) is *Skeletonema*, which dominated the genus came from *Baccilariophyceae* class. The genus *Chaetoceros* ranged from 3,535 to 4,873 individuals/liter, and the genus *Ceratium*. The two genera could cause the blooming of which may be harmful to fisheries (Rompas, 2010). The findings by Hartoko (2013) confirmed that 11 genera have been found on the coast of Semarang and Mangkang Kulon where *Skeletonema* dominate these waters. Odum (1993) explains that the pollution is able to change the structure of the ecosystem as well as reducing the number of species/genus in the community.

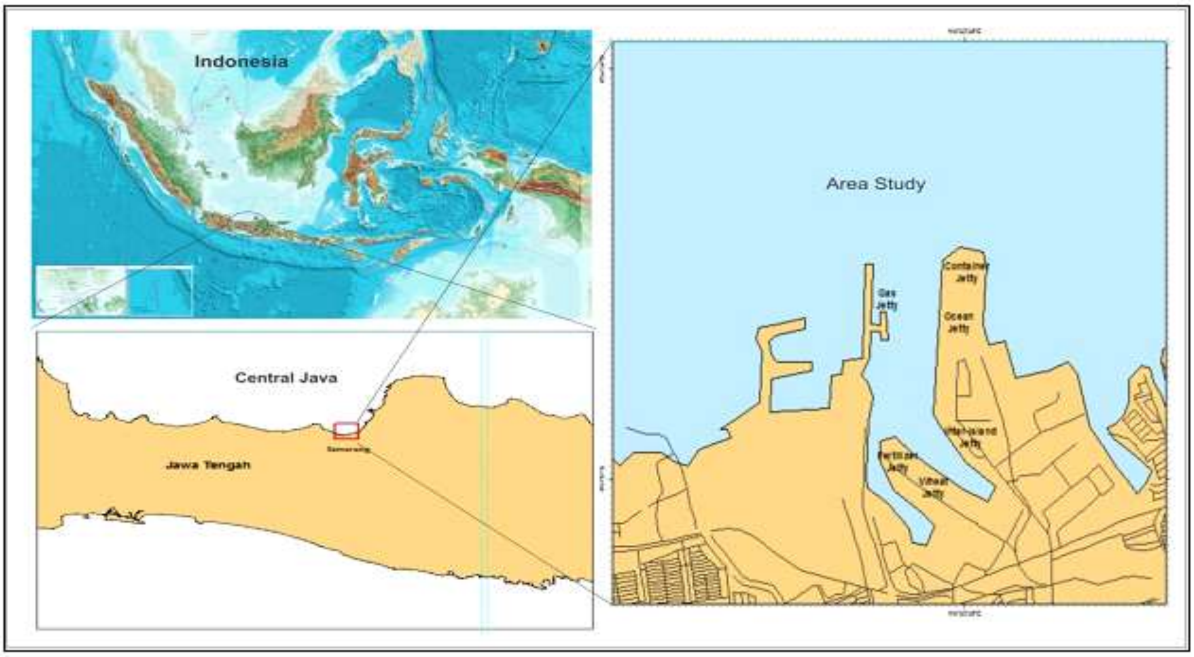

Fig. 2. Research location.

The condition is supported by the value of TDS at HTL ranged from 303.67 to 475.17 mg/l with the lowest score at the estuary of the Kali Baru and the highest score in the container pier, while the value ranges at LTL from 351.5 to 536.33 mg/l with the lowest at the passenger pier and the highest value at the fertilizer pier.

The abundance of phytoplankton at HTL ranged 933-42,631 individu/liters while at LTL ranged 3,659-18,6774 individu/liters. The abundance of phytoplankton at HTL found at highest value at the fertilizer pier and the lowest value at the container piers. When LTL the abundance of phytoplankton reached at the highest in Kali Baru estuaries and the lowest at container piers.

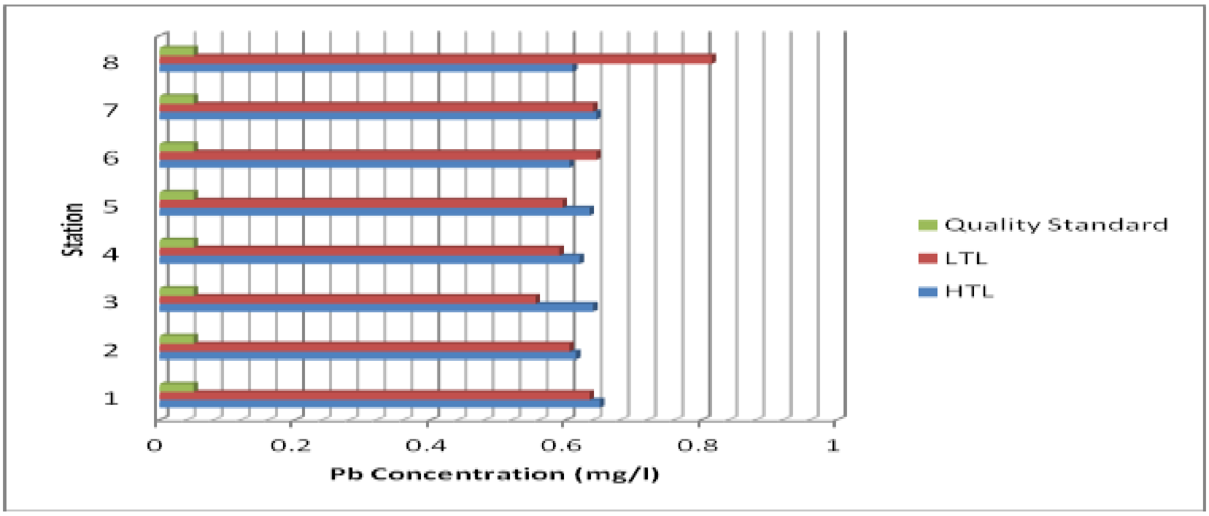

Fig. 3. Average concentrations of Pb (mg/l) in HTL and LTL of western monsoon at the PTES.

The lowest condition of abundance of phytoplankton found either at HTL and LTL at container piers. The condition above was caused by west monsoon, the condition of wind and current tend to go ashore so that phytoplankton which has floating characteristics were gathered in estuary area (Figure 4 & 5).

Similarly, on December 2015 during the HTL was found 18 genera with 5 classes including *Bacillariophyceae, Dinophyceae, Chrysophyceae, Chyanophyceae* and *Chlorophyceae*, while during LTL was found 19 genus with 4 classes. *Skeletonema, Chaetoceros* and *Chyclotella* are the genus most commonly found in the HTL and LTL in west monsoon.

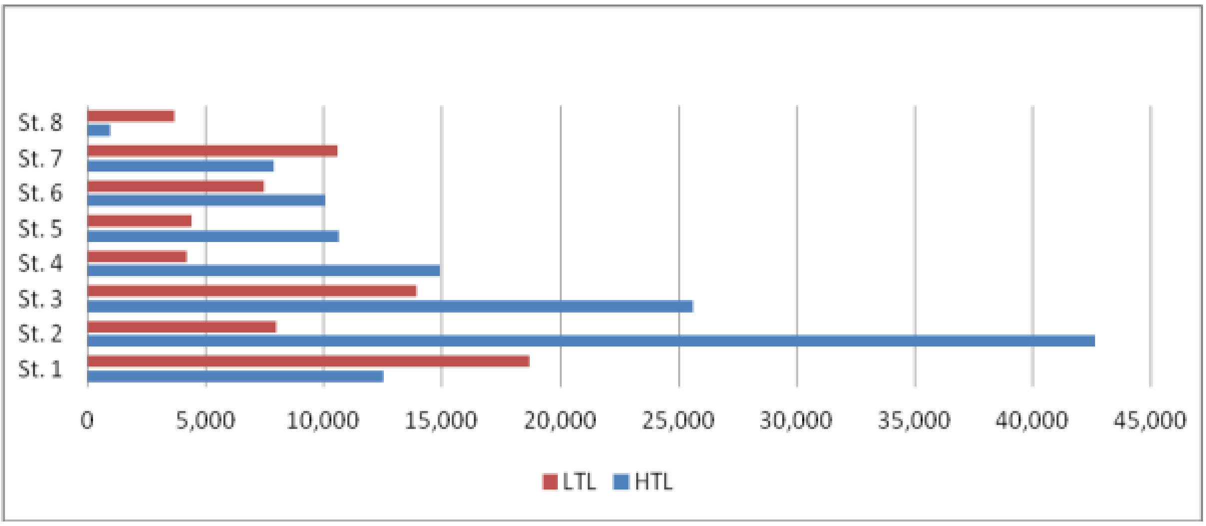

Fig. 4. Total abudance of phytoplankton (individu/l) in November 2015.

The value of BOD_5 in the HTL (1.5 to 1.73 mg/l) were the highest in the grain pier and for LTL it was in the middle point between gas and container pier, when LTL was ranged from 1.04 to 1.61 mg/l highest in Kali Baru estuaries, also the lowest was in the middle point between LPG and container piers. The values of BOD_5, TSS, Pb and other parameters as well as the patterns of tidal influenced the deployment and migration of plankton that affect the organism saprobity.

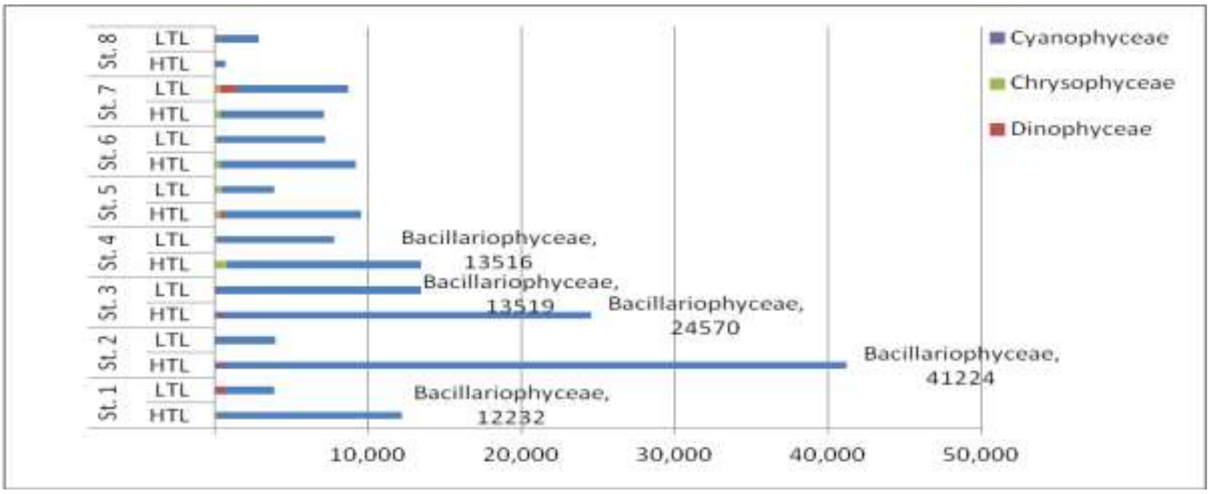

Fig. 5. Genus group Phytoplankton are found in November 2015.

The impact displacement of the organism through the mediation of ballast water of commercial vessels needed one attempt for rescue of the existence of phytoplankton to the sustainability of aquatic ecosystems. Table 4 showed the coefficient of correlation between the abundance of phytoplankton and physical and chemical content of parameters in PTES waters. The correlation of abundance of phytoplankton with physical and chemical content of the parameters ranged at middle point towards phenol (r = 0,525, $P < 0.05$) at HTL also affected very low at temperature (r = 0.139, $P < 0.05$). The significant correlation towards Ph obtained at LTL (r = - 0.821, $P < 0.05$), the middle correlation towards brightness obtained (r = 0.503, $P < 0.05$).

These observations suggest that the pH condition has been associated and played an important role on the abundance and distribution of phytoplankton. The increasing pH value will be affect the microorganisms waters where phytoplankton photosynthesis process will be hampered (Handayani & Patria, 2009).

Conclusion

The ballast water discharged into the waters of PTES changed the water quality through physical, chemical and biological means. Some commercial vessels with domestic route had Pb contents that exceeded the quality standards, caused by regions of origin waters have been polluted. This emphasized their *Skeletonema* phytoplankton that survived well in the conditions of HTL and LTL. Efforts zoning discharge ballast water location and mid ocean exchange are alternative to prevent a decline in species diversity.

Acknowledgement

The authors want to show his deepest gratitude to whose have helped in this research. They are Office of Harbour Master and Port Authorities of Tanjung Emas Semarang, the ship's officers who give permission to the technicians on board, staffs of faculty of Fisheries and Marine Science Diponegoro University, and the staffs of Regional Health Laboratories Semarang in analyzing the samples.

References

Arenas F, Bishop JD, Carlton JT, Dyrynda PJ, Farnham WF, Gonzales DJ, Jacobs MW, Lambert C, Lambert G, Nielsen SE, Pederson JA, Porter JS, Ward S, Wood CA. 2006. Alien species and other notable records from a rapid assessment survey of marinas on the south coast of England. Journal of Marine Biological Association of The United Kingdom **86,** 1329-1337.

Effendi H. 2007. Telaah kualitas air bagi pengelolaan sumber daya dan lingkungan perairan. Yogyakarta, Penerbit Kanisius.

Galil BS. 2008. Alien spesies in the Mediterranean sea-which, when, where, why? Hydrobiologia **606**,105-116.

Garret MJ, Wolny JL, Williams BJ, Dirks MD, Brame JA, Richardson RW. 2011. Methods for sampling and analysis of marine microalgae in ship ballast tanks : a case study from Tampa Bay, Florida, USA, Journal Algae **26(2),** 181-192.

Grabowska J, Kotusz J, Witkowski A. 2010. Alien fish in Polish waters: an overview. Folia Zoology **59(1),** 73-85.

Handayani S, Patria MP. 2005. Komunitas phytoplankton di perairan waduk Krenceng, Cilegon Banten. Makara Sains **9(2),** 75-80.

Hewitt CL. 2002. Distribution and biodiversity of Australian tropical marine bioinvasions. Pacific Science **56(2),** 213-222.

IMO (International Maritime Organization). 2005. International convention for the control and management of ship's ballast water and sediment 2004. London, International Martime Organization, 36 p.

Isamu Y. 1980. Illustrations of the marine plankton of Japan. Osaka, Hoikusha Publishing Co, Ltd, 1-537 p.

Lovell SJ, Stone SF, Fernandez L. 2006. The economic impacts of aquatic invasive species: a review of the literature, agricultural and resource economics review. Agricultural and Resource Economics **35(1),** 195-208.

Lin W, Zhou G, Cheng X, Xu R. 2007. Fast economic develoment accelerates biological invasions in China. PloS One Journal **2(11),** 1-6.

Mills EL, Leach JH, Carlton JT, Secor CL. 1994. Exotic species and the integrity of the great lakes lessons from the past. Journal BioScience **44(10),** 666-676.

Nybakken JW. 1988. Biologi laut: suatu pendekatan ekologis. Jakarta, Gramedia.

Oethe R, Haste, Erik ES. 1998. Identifying marine phytoplankton. London, Academic Press, Inc.

Odum EP. 1993. Dasar-dasar ekologi terjemahan Tjahjono Samingan edisi ketiga. Yogyakarta, UGM Press.

Roohi A, Kideys AE, Sajjadi A, Hashemian A, Pourgholam R, Fazli H, Khanari AG, Eker-Develi E. 2010. Changes in biodeversity of phytoplankton, zooplankton, fishes and macrobenthos in the Southern Caspia Sea after the invasion of the Ctenophore Mnemiopsis Leidyi. Biological Invasions **12,** 2342-2361.

Rompas RM. 2010. Toksikologi kelautan. Jakarta, Sekretariat Dewan Kelautan Indonesia.

Suryanti. 2008. Kajian tingkat saprobitas di muara sungai Morodemak pada saat pasang dan surut. Jurnal Saintek Perikanan **4(1),** 76-83.

Vitousek PM, D'Antonia CM, Loope LL, Wesbrooks R. 1996. Biological Invasions as Global Environmental Change, American Scientist **84,** 18-224.

Wartiniyati, Anggoro S, Hendrarto B, Sunoko HR. 2016. Assessment of leachate quality by comparing WQI to saprobic index in plankton. Journal of Biodiversity and Environmental Science (JBES) **8(3),** 96-106.

Wibisono MS. 2005. Pengantar ilmu kelautan. Jakarta, Gramedia Widiasarana Indonesia (Grasindo).

Wu JT, Chou JW. 1998. Dinoflagellate Associations in Fetsui Reservoir. Taiwan Botanical Bulletin of Academia Sinica **39,** 137-145.