

**SPATIAL DISTRIBUTIONS OF NUTRIENTS AND CHLOROPHYLL-A:  
A POSSIBLE OCCURRENCE OF PHOSPHORUS AS A EUTROPHICATION  
DETERMINANT OF THE JAKARTA BAY**

***SEBARAN SPASIAL ZAT HARA DAN KLOOROFIL-A: POTENSI FOSFOR SEBAGAI  
FAKTOR PENENTU EUTROFIKASI DI TELUK JAKARTA***

**Hanif Budi Prayitno\* and Afdal**

Pusat Penelitian Oseanografi LIPI, Jl. Pasir Putih I, Ancol Timur, Jakarta 14430 Indonesia

\*E-mail: [hani007@lipi.go.id](mailto:hani007@lipi.go.id)

**ABSTRACT**

Phytoplankton blooms due to nutrient enrichment (eutrophication) have been considered as the primary factor causing several massive fish kills occurred in the Jakarta Bay. This study aims to determine the spatial variation of phytoplankton abundance based on chlorophyll-a concentration and its relationship with nutrient level and composition. A field observation was conducted in July 2015 measuring chlorophyll-a and nutrient concentrations. Chlorophyll-a was measured using fluorometer Trilogy AU-10 while nutrients was using spectrophotometer Shimadzu UV-1800. The result showed that chlorophyll-a concentration was relatively higher in the western compared to the eastern region of the Jakarta Bay. In addition, the western region was high in orthophosphate, nitrate and silicate while the eastern region was high in ammonium and nitrate. Statistical analysis shows that chlorophyll-a had the highest significant correlation against orthophosphate in the western region and chlorophyll-a had no significant correlation with nutrients in the eastern region. It seems that phosphorus was the primary determinant of chlorophyll-a variability with a concentration of orthophosphate of more than 0.028 mg P/L is required to increase chlorophyll-a concentration. In addition, low orthophosphate concentration (0.014 mg P/L) below its minimum requirement for maximum phytoplankton growth was likely the factor causing the absence of chlorophyll-a and nutrients relationship in the eastern region. In summary, phosphorus is seemingly the primary eutrophication determinant in the Jakarta Bay.

**Keywords:** Jakarta Bay, nutrients, chlorophyll-a, phosphorus

**ABSTRAK**

*Pertumbuhan fitoplankton yang sangat pesat akibat pengkayaan zat hara (eutrofikasi) dianggap sebagai penyebab utama beberapa kejadian kematian masal ikan di Teluk Jakarta. Studi ini bertujuan menjelaskan variasi spasial kelimpahan fitoplankton berdasarkan konsentrasi klorofil-a di Teluk Jakarta dan keterkaitannya dengan komposisi dan kelimpahan zat hara. Pengamatan lapangan dilakukan pada bulan Juli 2015 dengan mengukur konsentrasi klorofil-a dan zat hara. Klorofil-a diukur dengan fluorometer Trilogy AU-10, sedangkan zat hara dengan spektrofotometer Shimadzu UV-1800. Hasilnya menunjukkan bahwa konsentrasi klorofil-a relatif tinggi di wilayah barat dibandingkan dengan di wilayah timur Teluk Jakarta. Selain itu, wilayah barat tinggi akan senyawa ortofosfat, nitrat dan silikat, sedangkan wilayah timur tinggi akan ammonium dan nitrat. Analisis statistik menunjukkan bahwa klorofil-a memiliki hubungan yang paling signifikan dengan ortofosfat di wilayah barat, sedangkan klorofil-a tidak memiliki hubungan yang signifikan dengan zat hara di wilayah timur. Sepertinya fosfor adalah penentu variabilitas klorofil-a dengan konsentrasi ortofosfat lebih dari 0,028 mg P/L dibutuhkan untuk meningkatkan konsentrasi klorofil-a. Selain itu, konsentrasi ortofosfat yang rendah (0,014 mg P/L) di bawah konsentrasi minimum yang diperlukan untuk pertumbuhan maksimum fitoplankton adalah faktor yang menyebabkan tidak adanya hubungan yang signifikan antara klorofil-a dan zat hara di wilayah timur. Kesimpulannya, fosfor sepertinya adalah penentu utama eutrofikasi di Teluk Jakarta.*

**Kata kunci:** Teluk Jakarta, zat hara, klorofil-a, fosfor

## I. INTRODUCTION

Coastal areas have been inhabited by about one third of the world's population (Martinez *et al.*, 2007). Many coastal people obtain their incomes and improve their quality of lives by exploiting coastal resources through fisheries, tourisms and aquaculture. Therefore, preservation of coastal zones and their resources is very important for a stable socio-economic development. However, it will face a big challenge of dealing with human-induced pressures on coastal waters as a result of population growth and human activities, in particular those of elevated loading of anthropogenic nutrients (nitrogen and phosphorous compounds).

Dissolved inorganic nitrogen (DIN) and phosphorous (DIP) are the two principal nutrients controlling or limiting aquatic plant primary production (Downing, 1997; Ptacnik *et al.*, 2010) which serve as the base of the marine food web. Consequently, sufficient supply of DIN and DIP will maintain the productivity leading to a healthy, productive and resourceful aquatic ecosystem (Paerl, 2009). However, their excessive enrichment may promote overgrowth of phytoplankton (Vuorio *et al.*, 2005; Wang *et al.*, 2016) referred to as eutrophication (Karydis, 2009).

The overgrowth of phytoplankton dominated by diatoms does not always give undesirable impacts since productive coastal fisheries are mostly supported by diatoms (Armbrust, 2009). However, phytoplankton blooms dominated by harmful dinoflagellates may lead to ecological and economic losses (Smith *et al.*, 1999; Lewitus *et al.*, 2012). Domination of these two bloom-forming species in a phytoplankton structure is determined by the composition of nutrients. For instance, diatoms grow well under high concentration of nitrogen (N) compounds while dinoflagellates growth and biomass are stimulated by increasing levels of phosphorus (P) compounds (Hlaili *et al.*,

2006). In other words, dinoflagellates are strong competitors for diatoms under P limitation (Hu *et al.*, 2011). In addition, a shift in dominance from diatoms to non-siliceous taxa such as dinoflagellates may occur under dissolved silicon (DSi) deficiency (Justić *et al.*, 1995; Roberts *et al.*, 2003).

The phytoplankton blooms have occurred several times in Jakarta Bay, Indonesia causing massive fish kills (Azanza and Taylor, 2001; Thoha *et al.*, 2007). Interestingly, orthophosphate and nitrate concentration as well as phytoplankton data published by Thoha *et al.* (2007) show no linear correlation between nutrient concentration and phytoplankton abundance. It seems that in addition to orthophosphate and nitrate more nutrient data are probably required to understand the cause of phytoplankton abundance. For instance, silicate and ammonium should also be considered since silicate and ammonium are essential silicon (Si) and nitrogen (N) sources for phyto-plankton. In addition, some diatom species can grow faster by using ammonium compared to nitrate (Tada *et al.*, 2009). Therefore, this study aims to determine the spatial variation of phytoplankton abundance represented by chlorophyll-a concentration and its correlation with nutrient level and composition in Jakarta Bay.

## II. RESEARCH METHODS

### 2.1. Location

Jakarta Bay is located in the north of Jakarta city, the capital of Indonesia. It geographically lies from-5°50' 0.00" S to-6°07' 0.00" S and from 106°42' 0.00" E to 107°5' 0.00" E. The area of about 514 km<sup>2</sup> and average depth of 15 m is bordered by Cape Tanjung Kait to the west and Cape Tanjung Gombong to the east (Lubis *et al.*, 2007). The bottom composition of the Bay consists of mud, coral sand, rubble and coralline algae (Van der Meij *et al.*, 2009).

## 2.2. Sampling and Analytical Method

Surface seawater samples were collected at a constant depth of 1 m from Jakarta Bay (Figure 1) using a niskin sampler. Sample collection was conducted within 4 days (28-31 July 2015) from 10 am to 2 pm local time. Water samples were stored in 1 liter pre-washed (1.2 N HCl) and rinsed (deionized water, DIW) polyethylene bottles and preserved in an iced cool box during transportation. Within less than 6 hours, samples for nutrients and chlorophyll-a determination (n=32) were filtered through cellulose acetate membrane with a porosity of 0.45  $\mu\text{m}$  prior to chemical analysis. Subsequently, nutrients including orthophosphate ( $\text{PO}_4$ ), nitrate ( $\text{NO}_3$ ), ammonium ( $\text{NH}_4$ ) and reactive silicate ( $\text{SiO}_4$ ) were determined using spectrophotometer Shimadzu UV-1800 based on the methods proposed by Strickland and Parsons (1972). On the other hand, chlorophyll-a was determined using fluorometer Turner Trilogy AU-10 based on the method originally introduced by Holm-Hansen *et al.* (1965), as described by Parsons *et al.* (1984).

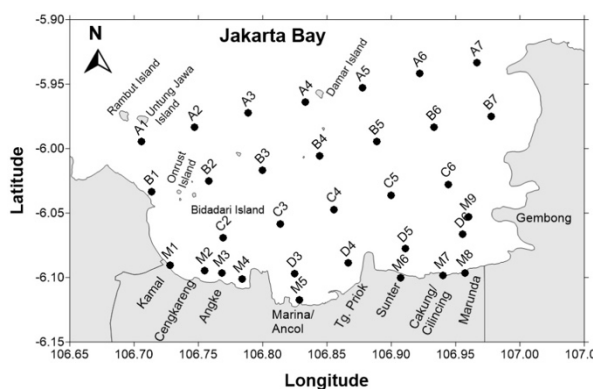


Figure 1. Sampling stations in the Jakarta Bay, July 2015.

## 2.3. Data Analysis

Nutrient ratios (N/P, Si/N and Si/P) are calculated based on dissolved inorganic N, P and Si. Therefore, molar ratios between nitrate+ammonium and orthophosphate, reactive silicate and nitrate+ammonium, and reactive silicate and orthophosphate are

resulting in N/P, Si/N and Si/P respectively. Data obtained from instrumental determination and calculation were subsequently processed using the open source program Ocean View®v4 to provide visualization of spatial distributions of nutrients and chlorophyll-a. Correlation between phytoplankton abundance—which is represented by chlorophyll-a concentration—and nutrients and physical factors such as salinity and light intensity is assessed correlation coefficient using statistical software SPSS v23.

## III. RESULTS AND DISCUSSION

### 3.1. Results

#### 3.1.1. Spatial Variations of Nutrients

Primary producer such as phytoplankton and other aquatic vegetation utilize phosphorus in its dissolved inorganic form referred to as soluble reactive phosphorus (SRP) or orthophosphate ions. In marine environment, orthophosphate occurs predominantly as  $\text{HPO}_4^{2-}$  ion with a small percentage of  $\text{PO}_4^{3-}$  ion. The orthophosphate ( $\text{PO}_4$ ) concentration in the Jakarta Bay ranged from 0.004 mg P/L to 0.383 mg P/L with a mean value of 0.014 mg P/L in the eastern region, 0.028 mg P/L in the middle region and 0.104 mg P/L in the western region. The mean values in the middle and western regions were about twice and seven times higher than the threshold limit value of 0.015 mg P/L respectively. The threshold value is according to Decree of the Minister of Environment of the Republic of Indonesia No. 51 year 2004 about sea water quality standards (Tanjung *et al.*, 2019). The minimum orthophosphate concentrations were found in several stations distributed uniformly among eastern, middle and western part of the Jakarta Bay. On the other hand, the maximum orthophosphate concentrations were found only in one station (M3) in western part of the Jakarta Bay. The high orthophosphate concentrations were generally located in western part of the Jakarta Bay, from which the possible region

contributed the high mean orthophosphate concentration in the Bay.

Nitrate ( $\text{NO}_3$ ) concentration ranged from 0.030 mg N/L to 0.608 mg N/L with a mean value of 0.127 mg N/L in the eastern region, 0.052 mg N/L in the middle region and 0.084 mg N/L in the western region. The mean value for the whole region was more than six times higher than the threshold limit value of 0.008 mg N/L. The minimum concentration was found in the middle part of the Jakarta Bay whereas the maximum concentration was found in the eastern part. In contrast to the orthophosphate, all regions of the Jakarta Bay apparently have contributed to the high mean value of nitrate although the highest nitrate concentration is located in the eastern part of the Jakarta Bay (Station M7).

Ammonium ( $\text{NH}_4$ ) has a different spatial distribution pattern compared to orthophosphate and nitrate. If orthophosphate concentration was relatively higher in the western part of the Jakarta Bay and nitrate concentration was higher in the eastern part, high concentration of ammonium was observed both in the western and the eastern part. However, the highest concentration was observed in Station D6 in the eastern part. Interestingly, the high concentrations of orthophosphate and nitrate were observed close to river mouth or land but the highest ammonium concentration is not simply located close to river mouth or land. It was close to an area in which green mussel farming was located instead. The range of ammonium concentration was 0.017 – 0.280 mg N/L with a mean value of 0.114 mg N/L in the eastern region, 0.045 mg N/L in the

middle region and 0.064 mg N/L in the western region.

Total nitrogen concentrations of ammonium and nitrate referred to as dissolved inorganic nitrogen (DIN) in the eastern, middle and western region of the bay was 0.241 mg/L, 0.097 mg/L and 0.148 mg/L respectively. Since phosphorus (P) and nitrogen (N) mean concentrations in almost all of the regions have exceeded their standard quality value, eutrophication of the bay may have occurred and it can be classified into a eutrophic water. This status was previously studied by Damar (2003) as mentioned by Nugrahadhi *et al.* (2014). He argued that Jakarta Bay had three distinct trophic states: hypereutrophic in the river mouth and inshore waters, eutrophic in the middle part and mesotrophic in outer part.

Soluble reactive silicate ( $\text{SiO}_4$ ) has similar pattern with orthophosphate in term of spatial distribution. Compared to its concentration in the eastern part, the high silicate concentration was found in the western part of the bay. The range of silicate concentration was 0.079 – 5.416 mg Si/L with a mean value of 0.242 mg Si/L in the eastern region, 0.362 mg Si/L in the middle region and 1.846 mg Si/L in the western region. The minimum concentration was observed at Station D4 located in the middle part of the bay whereas the maximum concentration was observed at Station M3 located in the western part close to river mouth. The western part seems to contribute predominantly to the high mean value of silicate. Table 1 and Figure 2 shows the nutrient levels and distributions in the Jakarta Bay in July 2015.

Table 1. Nutrient concentration in the Jakarta Bay, July 2015.

Parts of the Jakarta Bay	$\text{PO}_4$ (mg P/L)		$\text{NO}_3$ (mg N/L)		$\text{NH}_4$ (mg N/L)		DIN(mg N/L)	
	range	ave.	range	Ave.	range	ave.	range	ave.
West	0.004-0.383	0.104	0.036-0.114	0.084	0.017-0.140	0.064	0.053-0.210	0.148

Parts of the Jakarta Bay	PO <sub>4</sub> (mg P/L)		NO <sub>3</sub> (mg N/L)		NH <sub>4</sub> (mg N/L)		DIN(mg N/L)	
	range	ave.	range	Ave.	range	ave.	range	ave.
Middle	0.004-0.248	0.028	0.030-0.109	0.052	0.020-0.070	0.045	0.066-0.175	0.097
East	0.004-0.027	0.014	0.044-0.608	0.127	0.035-0.280	0.114	0.117-0.678	0.241

Parts of the Jakarta Bay	SiO <sub>4</sub> (mg Si/L)		N/P		Si/N		Si/P	
	range	ave.	range	Ave.	range	ave.	range	ave.
West	0.098-5.416	1.846	1.03-30.90	13.76	0.46-17.89	6.02	9.82-84.91	28.16
Middle	0.079-1.753	0.362	1.56-51.12	20.85	0.50-5.00	1.66	7.79-90.70	31.17
East	0.109-0.411	0.242	17.86-64.68	42.00	0.16-1.17	0.62	8.98-46.31	22.25

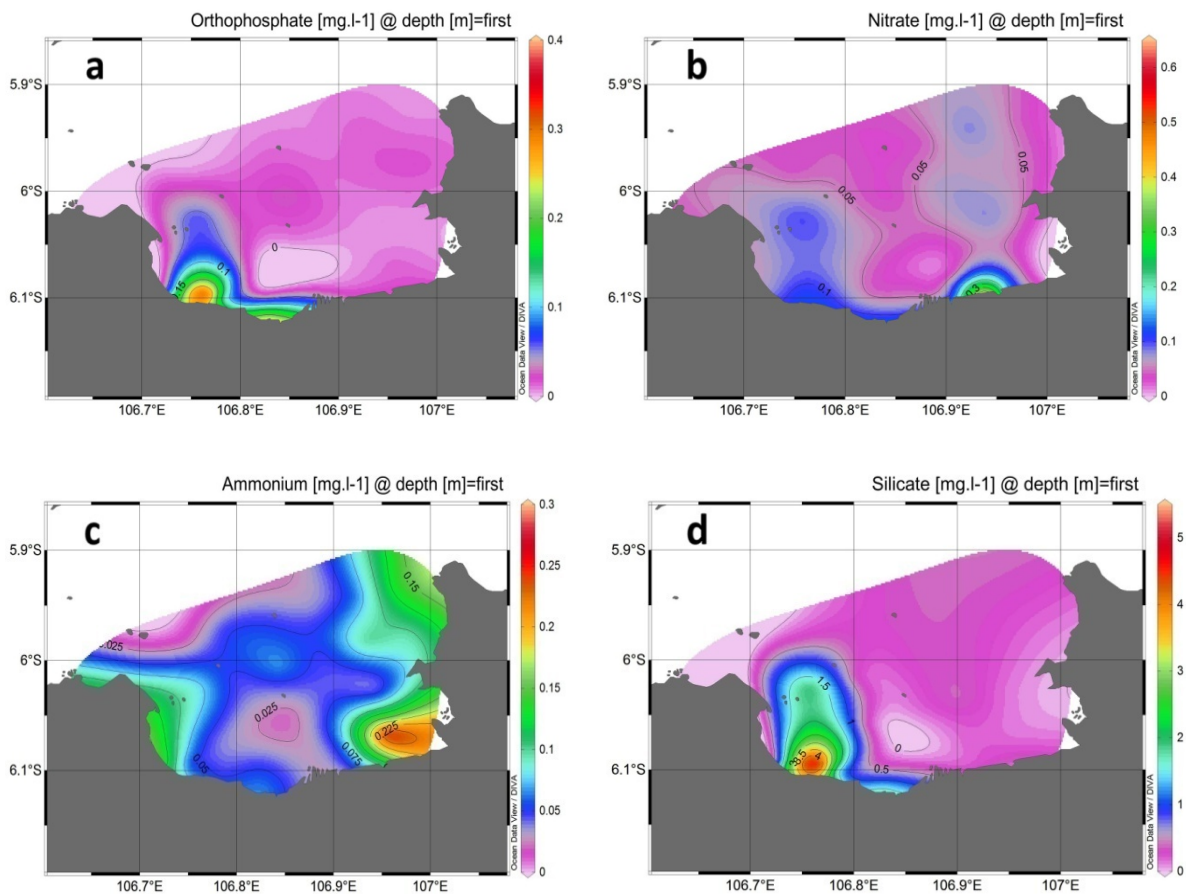


Figure 2. Spatial distribution of orthophosphate (a), nitrate (b), ammonium (c) and reactive silicate (d) in the Jakarta Bay, July 2015.

### 3.1.2. Spatial Variations of Chlorophyll-a

Chlorophyll-a concentration varied from 0.27  $\mu\text{g/L}$  to 19.98  $\mu\text{g/L}$  with a mean value of 3.19  $\mu\text{g/L}$ . Low concentration of chlorophyll-a was generally observed at the most seaward stations (Figure 3). Chlorophyll-a was more concentrated in the eastern and western part of the bay especially close to river mouth where high nutrient levels were supplied. Nevertheless, chlorophyll-a concentration in the western part of the Jakarta Bay was seemingly higher. As the western part of the Bay was rich in phosphate and silicate rather than nitrogen compounds, this could indicate the high chlorophyll-a concentration was coincidence with the high concentrations of phosphate and silicate levels. Generally, siliceous phytoplankton species such as diatoms will dominate the ecological structure of phytoplankton in an aquatic ecosystem with high silicate.

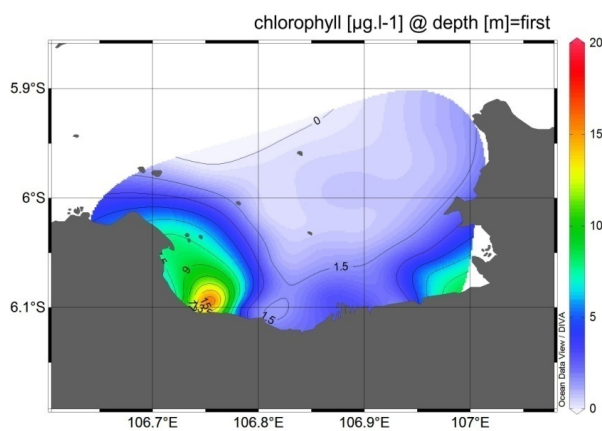


Figure 3. Spatial distribution of chlorophyll-a in the Jakarta Bay, July 2015.

## 3.2. Discussion

### 3.2.1. Spatial Distribution of Nutrients and Chlorophyll-a

Distribution of nutrients in the Jakarta Bay showed different pattern. The different characteristics of nutrient composition between eastern and western part of the Bay may be influenced by the different characteristic of major land use pattern between regions in the east side and west

side of the Bay. According to the Jakarta land use map for 2002 released by the Office of City Planning (Budiyono *et al.*, 2014), the east side is predominated by industrial and commercial warehouse area while the west side is predominated by residential area. The industrial and commercial warehouse may accommodate potential anthropogenic source with high nitrate and ammonium levels to the bay. On the other hand, the residential area may accommodate potential anthropogenic source with high orthophosphate and silicate levels to the bay.

Material containing orthophosphate and silicate from residential area may reach coastal water in the western part of the Bay through river flow. The possible influence of river discharge was visually assessed and confirmed by salinity and total suspended solid (TSS) data (Figure 4). Low salinity and high TDS in the western part of the bay especially opposite to the Cengkareng Drain showed that there was turbid fresh water input from the river. In contrast, river discharge influence to the high nitrate and ammonium concentration at the eastern part of the bay was very low during observation due to high tide event. It was corroborated by high salinity data along the shoreline of the eastern part of the Bay indicating low fresh water input. It seems that the potential source for those nitrogen compounds was mussel farming and fisheries port activity in Cilincing Estuary instead of riverine discharge.

Spatial distributions of orthophosphate which was higher in the western region and ammonium which was higher in the eastern region of the Jakarta Bay are in agreement with the observation conducted by (Putri *et al.*, 2016). In contrast, our observation data show higher nitrate concentrations in the eastern part of the bay while Putri *et al.* (2016) obtained the opposite result. According to Putri *et al.* (2016) nitrate concentration measured in December 2015 was higher in the Western part of the Jakarta Bay specifically at the

mouth of the Kamal River compared to the eastern part. Nitrate concentration at the Kamal Estuary (west) reached 0.389 mg N/L while at the Cilincing Estuary (east) the concentration was 0.268 mg N/L.

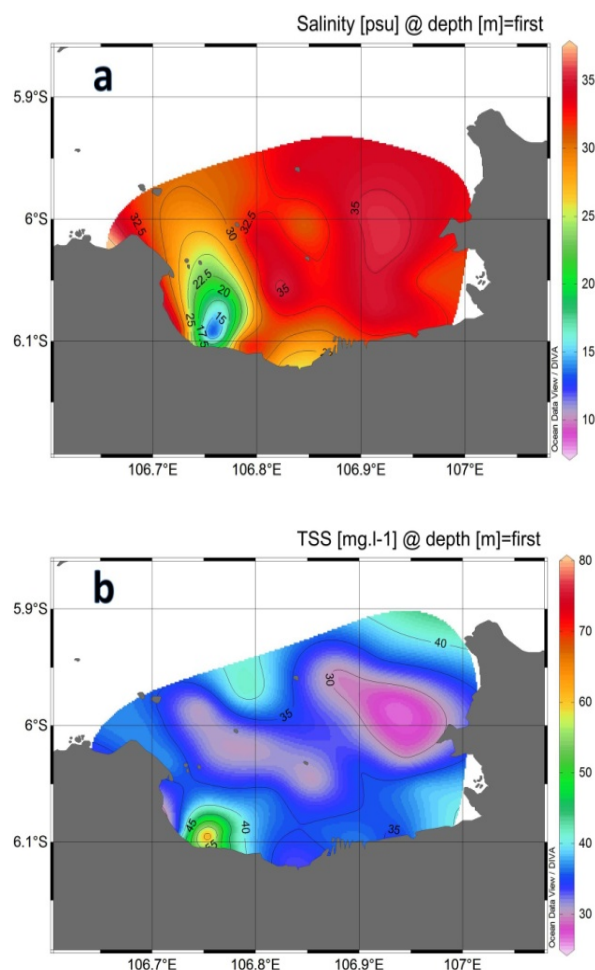


Figure 4. Distribution of salinity (a) and total suspended solid (TSS) (b) in the Jakarta Bay, July 2015.

Similar pattern was also published by Koropitan *et al.* (2009). Western part of the Jakarta Bay seemed to contain higher nitrate compared to the eastern part due to higher outflow and nitrate concentration of the rivers in the western region. In December 2000, the outflow of Angke River (west) was about 38 m<sup>3</sup>/s with a nitrate concentration of 0.105 mg N/L. On the other hand, the outflow of Marunda River (east) was just 17.6 m<sup>3</sup>/s with a nitrate concentration of

0.089 mg N/L. The different result of nitrate spatial distribution pattern from this study and the study conducted by Putri *et al.* and Koropitan *et al.* is likely due to different season of field observation. This study was conducted in the east monsoon (dry season) while their studies were conducted in the peak season of west monsoon (rainy season).

The possibility of water mixing in the water body (rivers and estuaries) during rainy season increases leading to sediment resuspension which in turn releasing nutrients from sediment into water column. Once the resuspension occurs, nutrients are released within minutes. Nitrate are released five times as much as orthophosphate (Prartono and Hasena, 2009). Therefore, it is possible that nitrate concentration in the western region of the Jakarta Bay was higher than that of in the eastern region during west monsoon (rainy season) since the influence of river discharge and water mixing are significant.

Spatial distribution of chlorophyll-a which was more concentrated in the western part of the Jakarta Bay is in contrast to the data published by Palimirmo *et al.* (2016) but similar with the data from Siregar and Koropitan (2013). Palimirmo *et al.* (2016) showed that chlorophyll-a concentration in the mouth of Angke River (western part of the Jakarta Bay) ranged from 1.83 µg/L to 11.45 µg/L. Meanwhile, chlorophyll-a concentration in the mouth of Marunda River (east) was higher with a range of 8.91-135.09 µg/L. Siregar and Koropitan (2013) showed that chlorophyll-a concentration in July 2012 varied between 0.78 and 15.74 µg/L with the highest concentration in Sunter Estuary (middle part of the Jakarta Bay). However, compared to the eastern part, chlorophyll-a concentration in the western part was higher. It seems that chlorophyll-a concentration which was relatively higher in the west than those observed in the east was influenced by sufficient levels of nutrient including orthophosphate, nitrate and silicate as shown on PCA chart (Figure 5).

### 3.2.2. Correlation between Chlorophyll-a and Nutrients

Correlation analysis were carried out between chlorophyll-a, nutrients and physical factors (salinity and light intensity) to investigate the possible eutrophication or phytoplankton abundance determinant. Chlorophyll-a is often used as an estimate of phytoplankton biomass as it is the major photosynthetic pigment in many phytoplankton. PCA chart on Figure 5 shows that chlorophyll-a was not strongly associated with salinity and light intensity in

any part of the Jakarta Bay. Figure 5 and Table 2 shows that chlorophyll-a is uncorrelated with any nutrient in the eastern region of the Jakarta Bay. In the middle region, chlorophyll-a is only significantly correlated with Si/P by negative relationship ( $r = -0.503$ ,  $P < 0.05$ ). Some significant correlations exist in western region. In this region, chlorophyll-a is positively correlated with phosphate ( $r = 0.803$ ,  $P < 0.05$ ), nitrate ( $r = 0.673$ ,  $P < 0.05$ ) and silicate ( $r = 0.666$ ,  $P < 0.05$ ) and negatively correlated with N/P ratio ( $r = -0.684$ ,  $P < 0.05$ ).

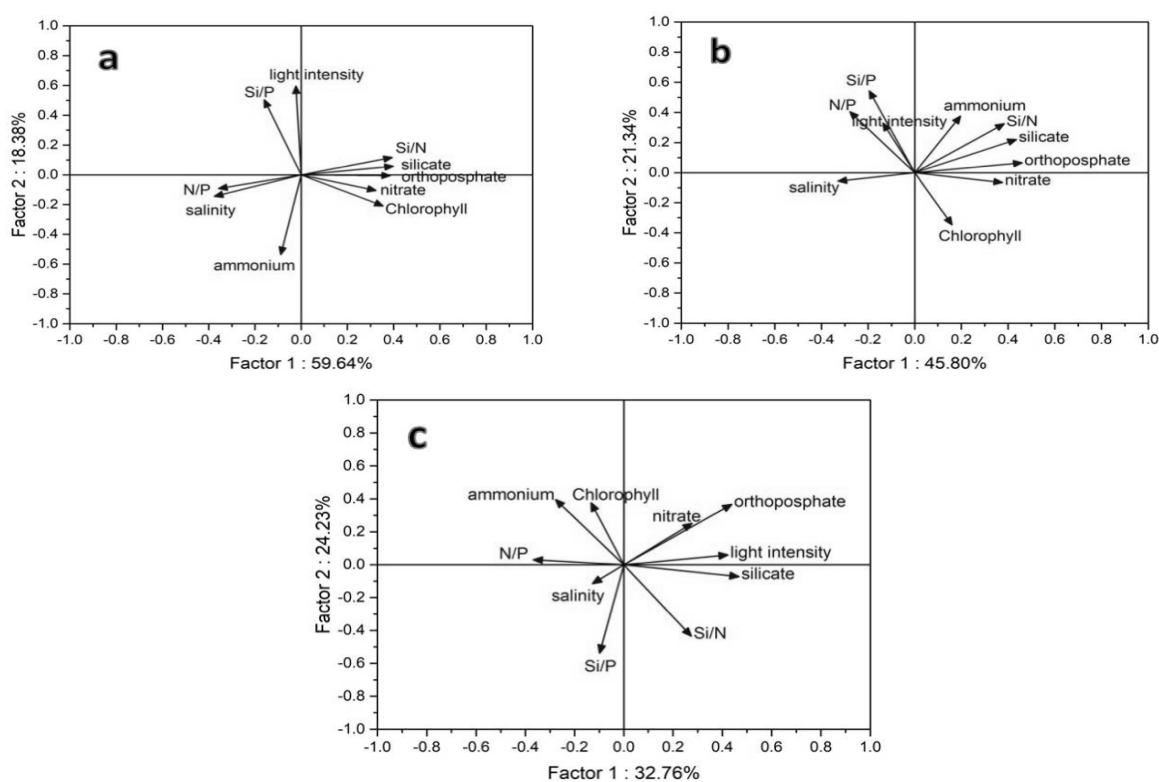


Figure 5. PCA of chlorophyll-a, nutrients and physical factor in the (a) western, (b) middle and (c) eastern part of the Jakarta Bay.

Table 2. Pearson rank correlation coefficient between chlorophyll-a and nutrients.

r	N/P	Si/N	Si/P	PO <sub>4</sub>	NO <sub>3</sub>	NH <sub>4</sub>	Si(OH) <sub>4</sub>
Chlorophyll-a (West)	-0.684 <sup>a</sup>	0.486	-0.343	0.803 <sup>a</sup>	0.673 <sup>a</sup>	0.495	0.666 <sup>a</sup>
Chlorophyll-a (Middle)	-0.281	-0.299	-0.503 <sup>a</sup>	0.291	0.409	-0.150	-0.158
Chlorophyll-a (East)	0.125	-0.409	-0.368	0.052	-0.144	0.554	-0.334

<sup>a</sup>Pearson correlation is significant at  $P < 0.05$ .



As the biggest correlation occurs between chlorophyll-a and orthophosphate, it is likely that eutrophication in the Jakarta Bay is mainly determined by phosphorus level. The role of phosphorus as the primary determinant for eutrophication is corroborated by the negative correlation between chlorophyll-a and N/P ratio in the western region, the negative correlation between chlorophyll-a and Si/P ratio in the middle region as well as the absence of significant correlation coefficient between chlorophyll-a and nutrients in the eastern region of the Jakarta Bay. The lower the N/P or Si/P ratio, the higher the chlorophyll-a concentration is. The N/P or Si/P ratio decreases as phosphorus concentration increases. Therefore, the degree of eutrophication represented by chlorophyll-a concentration will increase if phosphorus concentration increases.

The absence of chlorophyll-a and nutrient relationship in the eastern region of the Jakarta Bay does not mean that chlorophyll-a concentration in this region simply not affected by phosphorus. Orthophosphate level which was relatively low in the eastern region (0.014 mg P/L in average) may be insufficient to accelerate the growth of phytoplankton so that changes in any nutrient levels will not necessarily change the chlorophyll-a concentration resulting in the missing chlorophyll-a and nutrients relationship. In other word, variation of any nutrient levels will not influence chlorophyll-a concentration as long as the orthophosphate level is still below the minimum concentration required by phytoplankton to grow. Ly *et al.* (2014) reported that orthophosphate concentrations of 0.001-0.046 mg P/L were not sufficient to support maximum growth of the phytoplankton community in the western part of the Dutch Wadden Sea. Phytoplankton growth was not limited by P anymore when orthophosphate concentration reached 0.062 mg P/L. In addition, Hodgkiss and Ho (1997) informed that the probability of phyto-

plankton blooms in Hongkong were high when dissolved P levels were greater than 0.020 mg/L.

Aside from the magnitude of correlation coefficient, the role of phosphorus as the primary determinant of eutrophication in the Jakarta Bay can be seen from the orthophosphate and chlorophyll-a spatial distribution patterns (Figure 2 and Figure 3). Chlorophyll-a concentration was high when orthophosphate level was also high. However, chlorophyll-a showed a significant correlation just in the western part of the Bay when the mean concentration of orthophosphate was 0.104 mg P/L. Meanwhile, there were no significant correlations between chlorophyll-a and orthophosphate in the eastern and middle part of the Bay which were having mean concentrations of 0.014 mg P/L and 0.028 mg P/L respectively. Therefore, it is seemingly that orthophosphate concentration of more than 0.028 mg P/L is required to increase chlorophyll-a concentration.

It should be noted that the highest chlorophyll-a concentration was also located in the region with high nitrate and silicate concentrations. It is an indication that phosphorus, nitrogen and silicone all together determined phytoplankton abundance even though phosphorus has the major influence. Similar result was obtained from laboratory experiment conducted. The highest increase of phytoplankton biomass occurred during incubation with enrichment of ammonium, nitrate, orthophosphate and silicate. Significant correlation between chlorophyll-a and silicate indicates that phytoplankton abundance in July 2015 might be dominated by siliceous phytoplankton species such as diatoms.

#### IV. CONCLUSION

Chlorophyll-a concentration as well as orthophosphate, nitrate and silicate concentrations were relatively high in the western part of the Jakarta Bay. Statistical

analysis shows that chlorophyll-a had a strong relationship with orthophosphate, nitrate and silicate. However, chlorophyll-a had the biggest correlation coefficient against orthophosphate indicating that phosphorus was the primary determinant of chlorophyll-a variability. It is seemingly that orthophosphate concentration of more than 0.028 mg P/L is required to increase chlorophyll-a concentration. In contrast, chlorophyll-a concentration was low in the eastern region. There was also no significant correlation between chlorophyll-a and nutrients. Even though the concentrations of nitrate and ammonium were high, orthophosphate concentration was low (0.014 mg P/L in average). It seems that the absence of chlorophyll-a and nutrient correlation was due to the low concentration of orthophosphate. As a consequence, any changes in the level of nutrients other than orthophosphate will not influence chlorophyll-a as long as the orthophosphate level is still below the minimum requirement for phytoplankton to grow. In other word, phosphorus was the limiting element in the eastern region. Thus, spatial distribution of chlorophyll-a and nutrient both in the eastern and western regions of the Jakarta Bay showed that phosphorus was the primary determinant of eutrophication.

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