Inhibition Effects of Jakarta Bay Sediments to the Growth of Marine Diatom (*Chaetoceros Gracilis*)

Pengaruh Inhibisi Sedimen Teluk Jakarta Terhadap Pertumbuhan Diatom Laut (Chaetoceros gracilis)

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ABSTRACT: Jakarta Bay coastal ecosystem is known suffered from water pollution and habitat degradation. Solid and fluid waste from households and several industrial areas flow and ended up in the bay. Ecotoxicological studies are needed to assess the effects of pollutant on marine organism, including phytoplankton as the primary producer. Therefore chemical analysis and toxicity test were performed to investigate the impact of Jakarta Bay Sediments to marine diatoms *Chaetoceros gracilis*. Heavy metals concentration especially Cu, Pb, Cd, and Hg in the sediments were lower than in previous studies. It could be related to the stricter environmental regulations which started enforced at the end of 1990s. Meanwhile, PAH and pesticide were higher than in previous studies. Increasing activities and maritime traffic in surrounding area of Tanjung Priok Port area and most likely comes from other adjacent harbors (Muara Baru, Muara Angke, and Marina Ancol harbor) and the massive usage of the pesticide compound in the households of the Jakarta City area were suspected to be the reasons. Estuaries area and locations <10 km were identified and predicted would produce harmful effects since the concentration of Zn and Hg in those area exceeded Probable Effects Level (PEL) of Sediment Quality Guidelines (SQG). The growth responses of *Chaetoceros gracilis* were varied greatly. Most of the sites (24 from 31 sites) showed inhibition effects on the growth of diatoms, ranged from 1.75-35.33 % (17.75±9.59 %) relative to control, with the highest inhibition value was at Cengkareng Drain estuary (M2). The relationship between the concentration of contaminants and the inhibition response could not be clearly explained, however, there is an assumption that low concentrations of some heavy metals were suspected to give adverse effects on diatom's growth.

Keywords: sediment, toxicity, marine diatoms, *Chaetoceros gracilis*, Jakarta Bay

ABSTRAK: *Ekosistem Teluk Jakarta dikenal mengalami pencemaran air dan degradasi habitat. Limbah cair dan padat berasal dari perumahan dan industri mengalir dan berakhir di teluk tersebut. Kajian ekotoksikologi diperlukan untuk mengetahui pengaruh pencemar terhadap organisme laut termasuk fitoplankton sebagai produsen primer. Analisis kimia dan uji toksisitas dilakukan untuk mengetahui dampak sedimen Teluk Jakarta terhadap diatom laut Chaetoceros gracilis. Konsentrasi logam berat terutama Cu, Pb, Cd, dan Hg dalam sedimen lebih rendah dari penelitian sebelumnya. Hal tersebut berkaitan dengan peraturan lingkungan ketat yang mulai diberlakukan pada akhir 1990-an. Namun demikian, konsentrasi PAH dan pestisida lebih tinggi dari penelitian sebelumnya. Hal tersebut diduga kuat akibat dari peningkatan aktivitas dan lalu lintas maritim di daerah sekitar Pelabuhan Tanjung Priok, juga kemungkinan besar berasal dari pelabuhan lain yang berdekatan (Muara Baru, Muara Angke, dan pelabuhan Marina Ancol) serta akibat penggunaan besar-besaran senyawa pestisida kegiatan rumah tangga di wilayah Kota Jakarta. Daerah dan lokasi estuaria <10 km diidentifikasi dan diprediksi akan menghasilkan efek berbahaya karena konsentrasi Zn dan Hg di area tersebut melebihi Probable Effects Level (PEL) dari Pedoman Kualitas Sedimen (SQG). Respon pertumbuhan diatom laut Chaetoceros gracilis sangat bervariasi. Sebagian besar stasiun (24 dari 31 stasiun) menunjukkan efek penghambatan pada pertumbuhan diatom, berkisar antara 1,75-35,33% (17,75 ± 9,59%) relatif terhadap kontrol, dengan nilai penghambatan tertinggi di muara Sungai Cengkareng (M2). Hubungan antara konsentrasi kontaminan dan respon penghambatan tidak dapat dijelaskan dengan lebih pasti namun terdapat asumsi konsentrasi rendah dari beberapa logam berat diduga memberikan efek buruk pada pertumbuhan diatom.*

Kata Kunci: *sedimen, toksisitas, diatom laut, Chaetoceros gracilis, Teluk Jakarta*

INTRODUCTION

The growth of the Jakarta with more than 10 million inhabitants is giving adverse effects on the Jakarta Bay coastal ecosystem by water pollution and habitat degradation (Dwiyitno *et al.*, 2016). All surrounding rivers and canals are carrying solid and fluid waste from households and several industrial areas into the bay (Siregar *et al.*, 2016). Thirteen smaller rivers with a catchment of ~2000 km^2 contribute 112.7 m^3 s^{-1} discharge into the central part of the bay (Koropitan *et al.*, 2009). Trace metals such as vanadium (V), chrome (Cr), cobalt (Co), and nickel (Ni) are mainly controlled by the abundance of geogenic terrestrial material, whereas copper (Cu), zink (Zn), lead (Pb), and stanum (Sn) are derived from anthropogenic municipal and industrial sources (Williams *et al.*, 2000). The concentrations of metals such as Cr, Cu, and Pb in the Jakarta Bay sediments in 2014 (Siregar *et al.* 2016) increased three to five times higher than in 1996 (Williams *et al.,* 2000). Several types of organic pollutants such as polycyclic aromatic hydrocarbons (PAHs), dichlorodiphenyltrichloroethane (DDT), polychlorinatedbiphenyls (PCBs), tributyltin (TBT), polybrominateddiphenylethers (PBDEs), and hexachlorocyclohexanes (HCHs) were also found in sediments, water, and mussel (Sudaryanto *et al.*, 2007a; 2007b; Williams *et al.*, 2000;). Accumulated pollutants in marine sediments could directly and indirectly disrupt the ecosystem, causing significant contamination and loss of desirable species (Burton, 2002). Characterization of sediments by chemical analysis does not provides sufficient information concerning the toxicity of the sediment-bound contaminants to aquatic organisms (Munawar and Munawar, 1987). Therefore, sediment toxicity tests are the tools to provide information of the toxicity and bioavailability of chemical compounds in the sediment on aquatic organisms (Moreno-Garrido *et al.*, 2003).

Diatoms are the primary producers in water bodies, contributing 40% of the primary productivity of the oceans and contributing approximately 20% of global carbon fixation (Hildebrand, 2008). Diatoms are regularly used for bioassessment and ecotoxicological studies, because they have a cosmopolitan nature, short life span and quick response to environmental and anthropogenic disturbances (Pandey *et al.*, 2017). Previous studies confirmed that diatoms are known to be sensitive to toxic substances, such as metals (Cattaneo *et al.*, 2004; Duong *et al.*, 2008) and organic contaminants (Moisset *et al.*, 2015). Contaminants have given effects on diatoms by the alteration in cells integrity (nuclear anomalies, alterations in the cell membrane and cytoplasmic content), alteration in chloroplasts (shape, size, color and number), lipid bodies, alteration in frustule size, and morphological deformities (Pandey *et al.*, 2017).

Previous studies on sediment toxicity in Indonesia have been carried out using marine diatoms Chaetoceros gracilis as test organism and sediment samples from Klabat Bay, Bangka Island (Hindarti *et al.*, 2008; Puspitasari and Hindarti, 2009); Cirebon coastal area (Puspitasari, 2011) and Semarang coastal area (Puspitasari and Lestari, 2014). More studies are needed to provide sufficient information concerning the toxicity from the locations known as a polluted area in Indonesian marine waters and the usage of *Chaetoceros gracilis* as bioindicator. Therefore, the aim of this study is to assess the sediments toxicity of Jakarta Bay on the growth of marine diatom *Chaetoceros gracilis*.

METHODS

Sediment samples were collected following ASTM (2006a) method from 31 locations located in the Jakarta Bay during dry season, early August 2015 (Figure 1). There are 10 estuaries flow into the bay and potentially carrying solid and fluid waste. Therefore, sampling locations were divided into five areas based on the distance from the estuaries to determine contaminants distribution and toxicity effect. The locations were A (A1-A7) within ±20 km, B (B1-B7) within ±15 km, C (C2-C6) within ±10 km, D (D3-D6) within ±5 km, and M (M1-M9) within <3 km that were close to the estuaries. Analysis of heavy metals (Cu, Pb, Cd, Ni, and Zn) in the sediment was performed using Flame Atomic Absorption Spectrophotometer (Varian SpektrAA-20 plus) following the USEPA method 3050B (USEPA 1996). Analysis of Hg was performed following USEPA method 245.5 (Mercury in Sediment-Manual Cold Vapor Technique) (USEPA 1974).

The concentration of heavy metals were expressed in mg kg^{-1} dry weight (dw). Analysis of PAH and pesticide were performed using GC/MS (Thermo Scientific Trace 1310) following the Schwarzbauer, *et al* (2000) method. The concentration of PAH and pesticide were expressed in mg kg^{-1} dw and µg kg^{-1} dw, respectively. 96-h sediment toxicity test using phytoplankton was carried out following the PSEP (PSEP 1995), Asean-Canada CPMS (1995) and ASTM (2006b). A strain of marine diatom Chaetoceros gracilis was obtained from Mariculture Laboratory, Research Center for Oceanography-Indonesian Institute of Sciences. Cell counts data from phytoplankton growth test were transformed with $\log^{10}$ transformation prior analyses. Analysis of the normality of contaminants data was performed by the Shapiro-Wilks test. Simple linear regression analysis was carried out in order to determine the relationship between concentration of each contaminant and inhibition response in locations close to estuaries (M and D areas). Graphics and

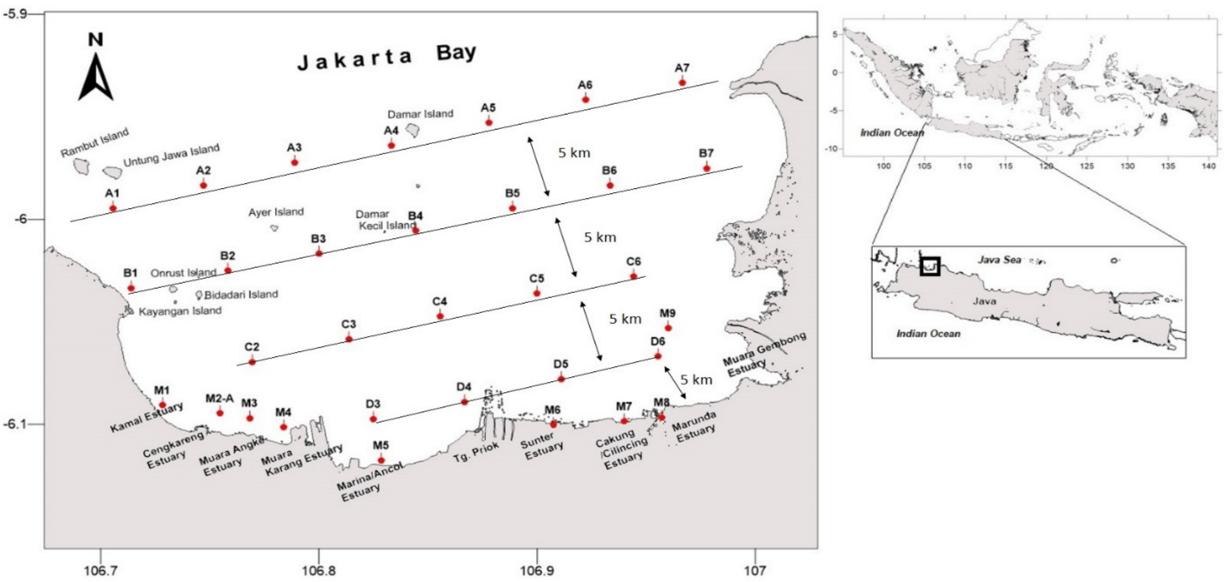

Figure1. Sediment sampling stations in the Jakarta Bay

statistical analysis were performed using Microsoft Excel 2007.

RESULTS

The concentration of contaminants in Jakarta Bay sediments were varied but indicated increasing accumulation trend of heavy metals, especially for Cu, Zn, Pb, and Hg, at the locations close to the estuaries (<3km and 5 km area) (Figure 2). Zn had the highest measured concentration among all the heavy metals followed by Cu, Pb, and Hg. The highest concentration of Zn (1514.5 mg kg^{-1} dw) was found at M4 (Muara Karang estuary), Cu (109.6 mg kg^{-1} dw) and Pb (65.37 mg kg^{-1} dw) at M7 (Cilincing estuary), and Hg (0.86 mg kg^{-1} dw) at M5 (Ancol Estuary).

The concentrations of PAH and pesticide were relatively fluctuated. The highest concentration of PAH (8.26 mg kg^{-1} dw) and Pesticide (88.14 µg kg^{-1} dw) were found at D3 (close to Ancol estuary) and M8 (Marunda estuary), respectively. In this study, the spatial distribution of contaminant did not show clear seaward gradients. This could be due to the re-suspension of surface sediments and transport of suspended particles with the water masses within the Jakarta Bay (Van der Wulp *et al.*, 2016). Surface sediments was dominated by fine-grained sediments (silt and clay) (95.54±9.94%) and there is no significant difference between locations (Figure 3).

The growth responses of C. *gracilis* after being exposed to Jakarta Bay sediments shows no significant difference between areas (Figure 4). The average of cell density in control solution was 247.2 x 10^4 cells ml^{-1} and in sediments exposure were ranged from 159.83 to 314.33 x 10^4 cells ml^{-1} (with average of 217.42±35.14 cells ml^{-1}) . Most of the sites (24 from 31 sites) shows inhibition effects, ranged from 1.75 to 35.33 % (with average of 17.75±9.59 %) relative to control. The highest inhibition value was identified at M2 (Cengkareng Drain estuary). Despite of the difficulties to determine which pollutant influenced the measured toxicity response, we found consistent significant positive relationships ($p<0.05$) between the inhibition response and the concentration of Cd, Pb, Hg, and pesticide in locations closed to estuaries. Similar condition were not found in other areas >5 km from estuaries. However, the variation of the observed response is not solely due to the influence of one type of contaminants. In most cases the stress of pollution on ecosystems is caused by the combined toxicity of many contaminants.

DISCUSSIONS

In this study, heavy metals concentration especially Cu, Pb, Cd, and Hg were lower than those reported in 2014 by Siregar *et al.* (2016). It could be related to the stricter environmental regulations which started to be enforced at the end of 1990s (Hosono *et al.* 2011). In contrast, PAH and pesticide concentrations were higher than those reported in 2012-2013 by Dwiyitno *et al.* (2016). Williams *et al.* (2000) assumed that higher concentrations of PAH in Jakarta Bay could be related to the activities and maritime traffic in surrounding area of Tanjung Priok Port area and other adjacent harbors (Muara Baru, Muara Angke, and Marina Ancol harbor). Meanwhile, pesticide has been intensively used in agriculture and health purposes (malaria eradication) for almost three decades (Sudaryanto *et al.*, 2007). Dwiyitno *et al.* (2016) confirmed that the massive usage of the pesticide

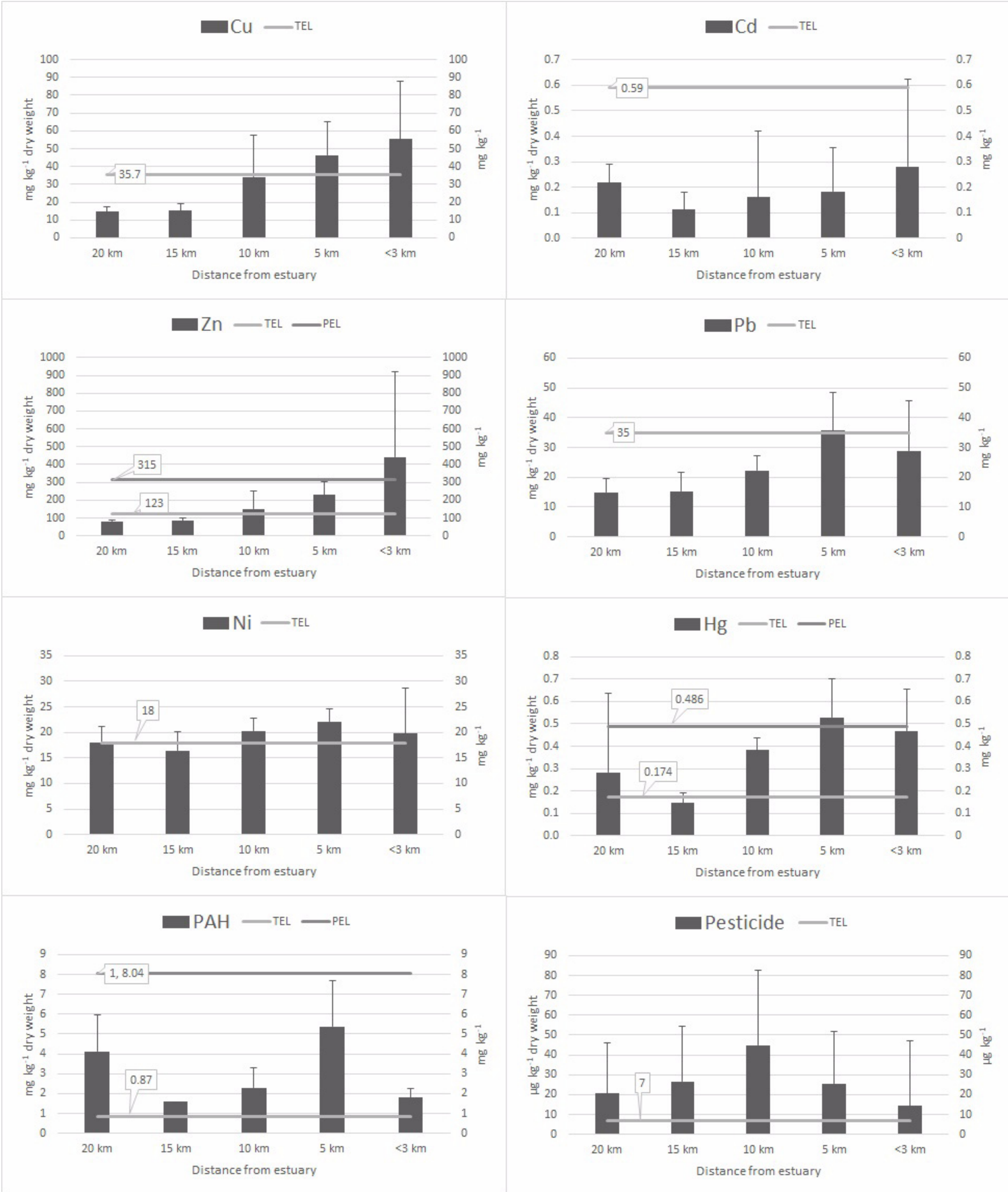

Figure 2. Mean concentration (±SD) of contaminants in Jakarta Bay sediments. Threshold Effect Level (TEL) and Probable Effect Level (PEL) of Sediment Quality Guidelines (SQG) summarized by Burton (2002) are included as threshold value.

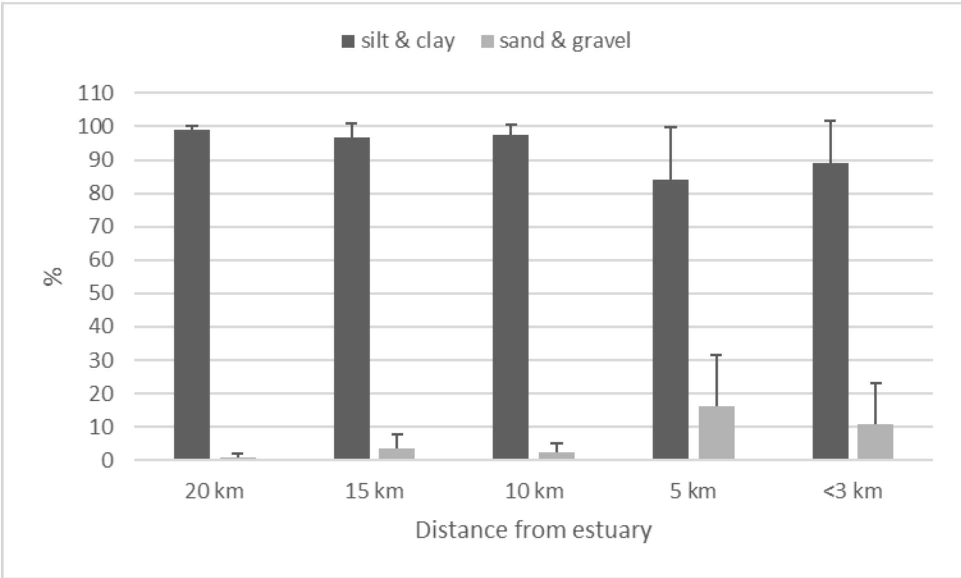

Figure 3. Sediment fractions of Jakarta Bay sediments

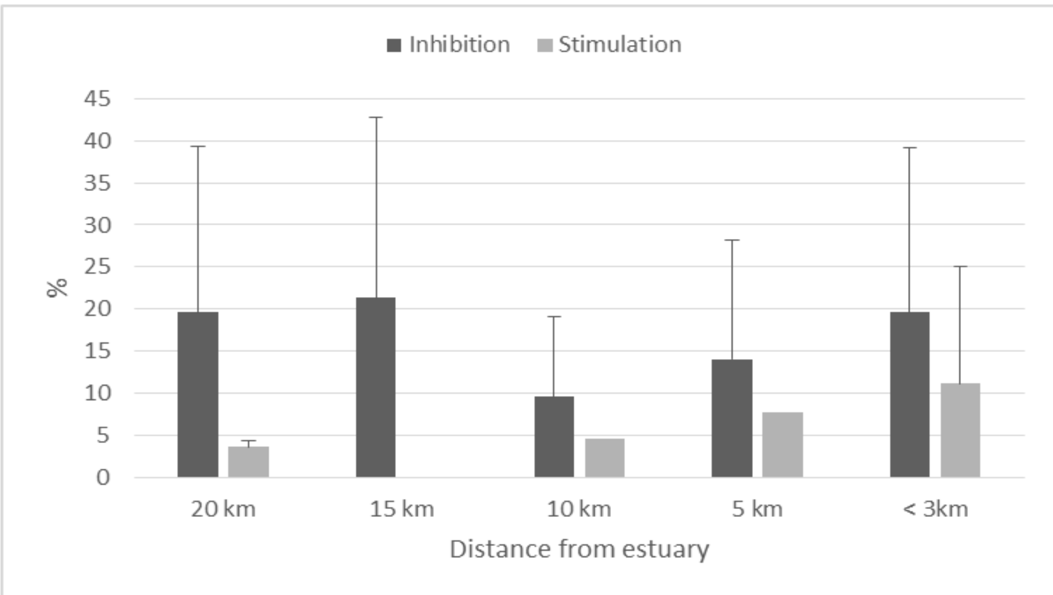

Figure 4. Growth responses of marine diatoms Chaetoceros gracilis after being exposed to Jakarta Bay sediments.

compound in the households of the Jakarta City area increased its concentration in the environment.

To assess the quality of sediments, the concentration of contaminants in the Jakarta Bay sediments were compared to the Threshold Effect Level (TEL) and Probable Effect Level (PEL) reported in the Sediment Quality Guidelines (SQG) summarized by Burton (2002). Long *et al.* (1998) described that TEL represents concentration of contaminant toward the low end of the effects ranges (below) which the toxicity probability and other effects are rarely observed. In contrast, PEL represents concentration of contaminant toward the middle and above of the effects ranges which effects are more flequently observed. The concentration of contaminants that is below TEL would produce less than 10% adverse effects, while concentration that is above PEL would produce 50 % harmful effects. As can be seen in Figure 2, the concentrations of all contaminants (except Cd) in most area, are above TEL value. Previous study by Siregar *et al.* (2016) using ERM (Effects Range Median ~equivalent with PEL) values, mentioned that some elements i.e. Cu, Hg, and Cr in Jakarta Bay sediments exceeded the ERM. According to that, the locations <10 km are identified and predicted could pose a toxicity risks ranged from low risk to a level that further attention are needed.

The effect of Jakarta Bay sediments on the inhibition response of C. gracilis in dry season were also observed in previous study by Hindarti *et al.* (1999) (Table 1). Another previous study confirmed that seasonal variation of growth response on C. gracilis in dry season was dominated by inhibition responses (Puspitasari and Hindarti 2009). The effects on other organisms is also observed in abnormalities and mortality of bivalve and sea urchin larvae (Hindarti *et al.* 1999; Hindarti *et al.* 2008). Low precipitation in dry season (April-October) affect the decrease of river runoff from the mainland, lowering nutrients influx, and increase the concentration of pollutant in sediment (Puspitasari and Hindarti 2009).

Table 1. Effects of contaminated sediments in Indonesian coastal waters to several marine organisms.

Locations, season	Species	Dominant response	References
Jakarta Bay, dry season	Marine diatom (*Chaetoceros gracilis*)	Inhibition, 1.75-35.33 % relative to control	This study
Jakarta Bay, wet and dry season	Marine diatom (*Chaetoceros gracilis*)	• Stimulation (in wet season) • Inhibition (in dry season)	Hindarti *et al.* 1999
	Tetraselmis sp.	Inhibition (in wet and dry season)	
Semarang, Central Java, dry season	Marine diatom (*Chaetoceros gracilis*)	Stimulation, >100 % relative to control	Puspitasari & Lestari 2014
Klabat Bay, Bangka Island, wet and dry season	Marine diatom (*Chaetoceros gracilis*)	• Stimulation (in wet season), 40% relative to control. • Inhibition (in dry season), 60% relative to control	Puspitasari & Hindarti 2009
Jakarta Bay, dry season	Bivalve (*Perna viridis*)	Larvae abnormality, 0-35%	Hindarti *et al.* 1999
Klabat Bay, Bangka Island, wet and dry season	Sea urchin (*Tripneustes gratilla*)	Larvae abnormality, 10.5-59.6 % relative to control	Hindarti *et al.,* 2008

CONCLUSION

Although heavy metals concentration in Jakarta Bay sediments, especially Cu, Pb, Cd, and Hg, were lower than those reported in 2014, there was an indication of increasing spatial concentration of Cu, Zn, Pb, and Hg, at the locations close to the estuaries (<3km and 5 km area). The inhibition response of diatom *Chaetoceros gracilis* is correspond with the toxic effects of contaminant in the sediments from the locations close to the estuaries. Since the adverse effects of Jakarta Bay sediments have been identified and can be expected affects on marine organisms, the waste management in megacity Jakarta should be improved and environmental regulations should be remain enforced.

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