ILMU KELAUTAN *September 2017 Vol 22(3):137-146* ISSN 0853-7291

Nutrient Condition of Kampar Big River Estuary: Distribution of N and P Concentrations Drifted by Tidal Bore "Bono"

Ulung Jantama Wisha[1]* and Lilik Maslukah[2]

[1]*Research Institute for Coastal Resources and Vulnerability, Ministry of Marine Affairs and Fisheries*
Jl. Raya Padang-Painan km. 16, Komp. PPS Bungus, Padang Sumatera Barat, Indonesia 25625
[2]*Oceanography Department, Faculty of Fisheries and Marine Science, Diponegoro University*
Jl. Prof. H. Soedarto, S.H., Tembalang Semarang, Indonesia 50275
Email: ulungjantama@gmail.com

Abstract

Due to accelerated anthropogenic activity, a significant amount of pollutants has been directly or indirectly discharged into coastal estuaries of Kampar. Nutrient pollution along the river to the estuary that adversely affects coastal and estuary ecosystem mainly originates from inland such as industrial effluent, household, and agricultural waste as well as a naturally derived pollutant from biogeochemical cycle, which is controlled by the propagation of undular bore (Bono). The purpose of this study is to determine the environmental impact of distribution of nutrients caused by the mechanism of Bono. This research employed a purposive quantitative method, the concentration of dissolved phosphate, nitrate, nitrite and ammonia was analyzed using a spectrophotometer, tidal data retrieval was measured for 30 days' near the estuarine area, while, current flow was measured for 24 hours' measurement. Phosphate concentrations ranged from 0.02-0.1 mg.L^{-1}, nitrate concentrations ranged from 0.76-5.73 mg.L^{-1}, ammonia concentrations ranged from 0.2-0.41 mg.L^{-1}, nitrate concentrations ranged from 0.001-0.03 mg.L^{-1}. The tidal type is mixed tide prevailing semidiurnal with tidal range reach 4.2 m during spring tide condition. At the time of Bono propagate, drastically enhance the surface elevation and directly increase the drift of velocity with the flow direction from estuary into the river upstream, that mechanism affects the nutrient distribution in Kampar river.

Keywords: *Bono, Fluid dynamics, Nutrient distribution, Tidal bore, Water quality*

Introduction

Kampar River is one of the largest river in Riau Province, which has fundamental role in supporting community and industries activities in Riau. These activities around the watershed of Kampar discharge various kinds of pollutants (waste), both organic and inorganic, that directly or indirectly enter the river and accumulated in estuary. It would threaten the life and diversity of aquatic organisms (Kasry and Nur, 2012).

Nitrogen and phosphorus are types of nutrient that are important in recycling the organic compounds, due to the combination with carbon elements through photosynthesis process. Nutrients are substances that play a significant role in the process and development of living organisms such as phytoplankton, especially nitrate and phosphate. The High and low of autotroph organism's population (phytoplankton) in a body of water depends on the content of nutrients in the waters also including phosphate and nitrate (Arifin *et al*., 2011). Nitrate and phosphate compounds are naturally derived from water itself through processes of decomposition of weathering or decomposition of vegetation. The remains of dead organisms and waste disposal both waste land (domestic, industrial, agricultural, animal husbandry) are decomposed by bacteria into substances nutrients in the waters (Li *et al.,* 2011).

In most estuaries, a number of nutrients supplied by external sources (e.g. atmospheric deposition, river runoff, and nitrogen fixation) which has consistently been identified to supply less than the amount required by primary producers. Nitrate and phosphate which are naturally derived from the water itself through processes of decomposition of weathering or decomposition of vegetation. The remains of dead organisms and waste disposal both wasteland (domestic, industrial, agricultural, animal husbandry) are decomposed by bacteria into nutrients in the waters. The source of these nutrients derived from in situ regeneration and recycling of organic matter. Furthermore, this organic matter will experience the remineralization process into an organic nutrient such as phosphate and nitrate.

The impact of the organic waste influx from the land that empties into the river Kampar make these waters are becoming increasingly fertile, even too fertile, called the hypereutrophic (Makmur *et al.,* 2012). It is identified that the water around the mouth of the river and along the river Kampar has extremely high fertility rate. Given these conditions, unusual autotroph organism will be bloom (Dzialowski *et al*., 2008) resulting toxic conditions. It can cause mass organisms death such as fishes and other heterotrophic biotas (de Jonge *et al*., 2002; Khaliq *et al.*, 2006).

The distribution of nutrients in the Kampar river is predominantly caused by the phenomenon of Tidal Bore (Bono). It is formed by the convergence of tidal currents and river flow, so as to form a wave undular bore that is destructive and a major factor in the mechanism transport materials organic and inorganic in the river Kampar up to the mouth (Yulistiyanto, 2009). The research regarding the effect of current toward the nutrient distribution has not been done, especially with respect to the consequence of tidal bore toward the distribution of nutrients in the river Kampar. The purpose of this study is to determine the environmental impact of nutrients distribution caused by the mechanism of the tidal bore (Bono).

Materials and Methods

The primary data in this study consist of nutrient concentration (Phosphate, Nitrate, Ammonia and nitrate) that was obtained through measurement in the laboratory. In addition, water quality data, Tide and current were measured directly in the field. The secondary data used, on the other hand, consist of tide forecasting data by Naotide and digital topography map of Indonesia.

The sampling point covers 18 observation stations (Figure 1) conducted on April 24-26th, 2016. The water sampling was accomplished by using rosette sampler equipped with niskin bottles. Due to relatively shallow water, the sample of water only been taken just on the surface of the Kampar river. However, it sufficiently represents the whole properties of water. The sampling points spread out from the mouth of the river to the upstream, which are still affected by the wave propagation of Bono. The research that was conducted at Mendol Island to Tanjung Mentangor (Figure 1) employed purposive quantitative sampling as the sampling method.

After the water sample was collected, it was put into sample bottles that had been labeled. Preservation of nitrate was done by adding a solution of four drops concentrated H2SO4, then the bottled samples were wrapped in aluminum foil and put into a cool box. Preservation of phosphate samples is similar to the preservation samples of nitrate. However, in phosphates sample, the preservation is done without using sulfuric acid pickling (Zulkarnaen *et al*., 2012). Then, the sample was filtered using a nitrocellulose membrane filter with pore size of 0.45 µm and a diameter of 47 mm that further was stored in a refrigerator (Risamasu and Hanif, 2011). Meanwhile, the concentration of dissolved nitrate was analyzed using the spectrophotometric device which is ranging from 0.1-2 mg.L^{-1} with a brusin at a wavelength of 410 nm.

Determination of phosphate concentration was also completed by employing *spectrophotometer method* as ascorbic acid levels in the range of 0.0 mg.L^{-1} up to 1 mg.L^{-1}, the principle of the method is based on the formation of complex compounds fosfomolibdat blue, then the compound is reduced with ascorbic acid, to form molybdenum blue color complex. The intensity of the color which is formed is proportional to the concentration of phosphorus and measured with a wavelength of 700-880 nm (Grasshoff *et al*., 1999; Ulqodry *et al*., 2010).

Determination of the ammonia concentration was performed by a spectrophotometer as phenate in the range of 0.1 to 0.6 mg.L^{-1} NH_3-N with a wavelength of 640 nm. Meanwhile, the determination of nitrite was performed in the range of 0.01 to 1 mg.L^{-1}, under acidic (pH 2-2.5), in which nitrite reacts with sulfanilamide (SA) and N-(1-naphthyl) ethylene diamine dihydrochloride (NED dihydrochloride) formed azo compounds and the scarlet measured at a wavelength of 543 nm.

Water quality that was measured by using *TOA DKK water Quality Checker Multi-parameter* was conducted simultaneously as the sampling of nutrients, in the exactly same station. In order to obtain reliable data, sampling was conducted on the condition of low tide towards the high tide. Therefore, it can be seen the influence of the wave bono to the distribution of nutrients into the river can be examined. The Tidal pattern was forecasted by using NAOtide software at the coordinates of 103.22603 N and 0.5354 E. The sampling duration was around four hours from 13:00 to 17:00 pm on 26th April 2016. The sampling time during the low tide and the high tide condition can be seen in Figure 2.

The measurement of the tide data using *Automatic Tide Gauge Valeport* was employed from April 23rd to May 23rd, 2016 in the south of the Mendol Island (Figure 1). The data obtained were analyzed using ErgTide software based on admiralty method, while, the tidal range was analyzed, according to Indian Spring Low Water (ISLW) (Adibrata, 2007). In order to calculate a tidal range, the difference between high tide and low tide of 29 days' measurement must be obtained as well as the value of the amplitude and the phase delay (Wisha and Heriati, 2016).

The sea current measurement, at the time of Bono propagate, was done by installing and observing the ADCP *(Aquadopp Profiler -NORTEK)* (Table 1) in the region Tanjung Tersendu–sendu

Table 1. *Acoustic Doppler Current Profiler Specification*

Acoustic Frequency	0,6 MHz
Max Profile range	30-40 m
Cell Size	1-4 m
Minimum Blanking	0,5 m
Max Cell	128
Velocity Range	± 10 $m.s^{-1}$
Accuracy	1 % of measured value ± 0,5 $cm.s^{-1}$
Max Sampling Range	1 Hz

(Figure 1). Furthermore, the river flow measurement was accomplished by adapting the rules of euler in which the measurement relies on one point of observation (Wisha *et al*., 2016). In addition, the current data recording was performed vertically at a depth of one to two meters as it was attached to the MSL of Kampar estuary.

Results and Discussion

According to spectrophotometry analysis, the result obtained in conjunction with phosphate concentrations is around 0.02 to 0.1 $mg.L^{-1}$ (Figure 3). The highest phosphate concentrations are identified in station 2 and 15 with phosphate values of 0.1 $mg.L^{-1}$ and 0.09 $mg.L^{-1}$ respectively. Those stations are located at the Muda Island where the undular bore Bono is generated. It is also known as an accumulation area of dissolved organic and inorganic substances in Kampar River. According to Patty *et al.* (2015), the phosphate value which is high particularly in territorial has a great potential of the blooming algae (eutrophication). It is proved by

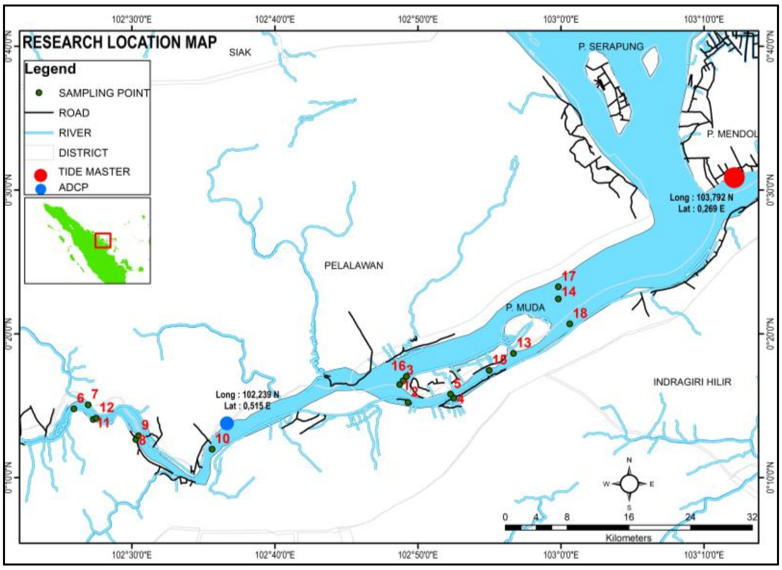

Figure 1. Research location map

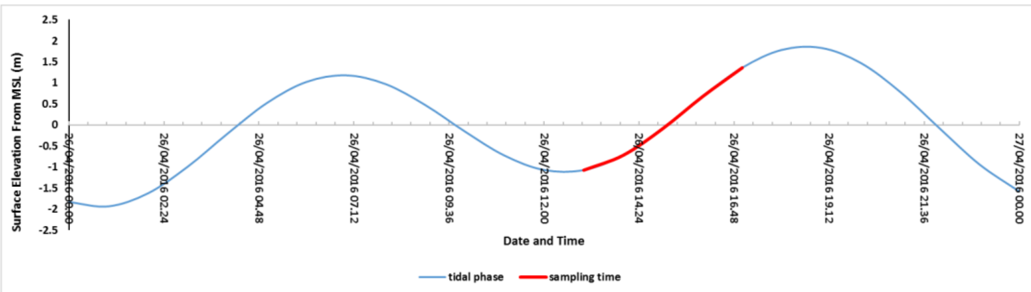

Figure 2. Tide forecasting using NAO tide Software

the finding of hyacin that the surface area of the river in which the populations are growing and expanding rapidly (Ferianita *et al*., 2005).

It has also been examined that the stations with the highest concentration of phosphate are located on the ecosystem of mangrove, which is generally dominated by *Avicennia* sp. Thus, it supports the fertility of water by a constant supply of the debris of mangrove, which further is broken down by bacteria and fungi as the main source of detritus. It is also by the decomposer organism into nutrients such as phosphate, nitrate, sulfur and other elements (Mustofa, 2015). Other than that, in the Muda Island region there are many settlements contributed much phosphate from waste waters such as soaps, detergents and other household waste (WHO & European Commission, 2002).

The phosphate concentration was also influenced by the diffusion of phosphate from the sediment, the sediment is the main storage place of phosphorus cycle that occurs in the waters (Patty *et al*., 2015), which is typically in the form of particulates that binds to the compound hydroxides and oxides of iron. Phosphorus compounds that bind into the sediment can be decomposed with the help of bacteria. It is also possible through the abiotic processes producing soluble phosphate compound that can undergo re-diffusion into the water column (Paytan and McLaughlin, 2007).

The concentration of dissolved nitrogen in the estuary Kampar varies from one station to the others. The concentrations of nitrate is ranging from 0.76 to 5.73 mg.L^{-1}, ammonia (0.2 to 0.41 mg.L^{-1}) and nitrite (0,01- 0,03 mg.L^{-1}) (Figure 4). The highest concentration of nitrate is located at station 2, 6 and 11. The station 2 is nearby Muda Island, while the station 6 and 11 are in the upstream water of Tanjung Mentangor. It is almost certain that the high concentration of nitrate is caused by the accumulation of nutrients (nitrate) that are distributed by Bono wave propagation and accumulate in the upstream. Moreover, nitrate is constantly supplied by the nutrient inputs of waste land due to its location nearby the municipal area (Hendrawati *et al.,* 2008).

The highest concentration of ammonia is observed existing at the same station with the highest concentration of nitrate. Meanwhile, nitrite concentration is almost uniform in all stations. The upstream water is relatively shallow also identified as a settling area of solutes and suspended materials from the Malacca Strait. Those compounds are deposited in sediments and further carried away by undular bore propagation to the upstream resulting in the concentration of nitrate in the upstream becomes higher. Sediment is also known as the main storage nitrate in biogeochemical cycles in aquatic (Santos *et al*., 2008). Nitrates, which are settled in the sediment, are produced from biodegradable organic materials that converted into ammonia and further oxidized to nitrate (Patty *et al*., 2015).

Ammonia levels are extremely high in the Kampar River, it exceeds the standard levels of ammonia in the water (>0.016 mg.L^{-1}) (Wardoyo, 1982). It can promote the massive growth of phytoplankton known as blooming followed by the mass death of phytoplankton. It even can be worse due to low water quality in the Kampar River.

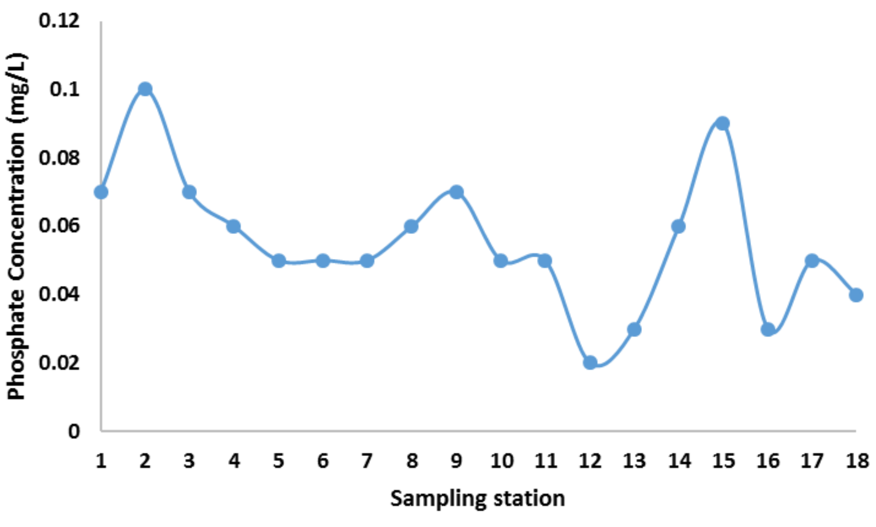

Figure 3. Phosphate concentration along Kampar River Estuary

Nitrite levels are also relatively high (> 0,008 mg.L^{-1}) (Risamasu and Hanif, 2011). High level of nitrite is caused by the low of dissolved oxygen concentration (Table 3), therefore the bacteria which oxidize nitrite to nitrate cannot work optimally due to the lack of oxygen. It causes the levels of nitrite and nitrate become difficult to decrease and accumulated that is transported by Bono wave.

US-EPA (Environmental Protection Agency of America) recommends a limit of NH_3 both in the freshwater and marine environments around 0.02 ppm. In conjunction with nitrite level, the concentration that is considered as an ideal for marine fishis between 0.01 and 0.04 ppm. If the level of nitrite-nitrogen exceeds 0.55 ppm, it potentially can cause a disease called 'brown-blood' in finfish. As for nitrates, at a level of 0.1-0.2 mg.L^{-1} is considered ideal. However, the results show that the concentrations of DIN and DIP Kampar river estuary are still in the range of quality standards established by Ministery of the Environment (KLH, 2004) (Tabel 2).

Nitrate concentrations are very high and dangerous for the survival of the organism. According Hutagalung and Rozak (1997) that the vertical distribution of nitrite is higher with the increasing the water depth and low oxygen, while horizontally the distribution of the higher nitrite headed towards the coast and estuaries (Wankel *et al*., 2006).

Nitrate concentrations are proportional with the phosphate, but the scale and the standard are different (Figure 3 & 4), both in a pernicious level for the waters. It input from the land as well as nutrients transport from the ocean leading to higher deposition of nutrients in the upstream river (Howarth and Marino, 2006). Furthermore, Figure 5 illustrates that the ratio of DIN and DIP is significantly high. This figure reflects the high rate of nutrient input from the mainland (Mukhopadhyay *et al*., 2006). Anthropogenic activities cause the ratio of N/P becomes unbalanced (Purwiyanto *et al.*, 2013) and they are stirred in the water column.

Moreover, the levels of dissolved oxygen (DO) that are ranging from 3.95 to 4.51 mg.L^{-1} (Table 3) are included in the category of medium polluted waters (Lee *et al*., 1978). Extremely low levels of dissolved oxygen in the Kampar River is most likely caused by turbidity as well assignificant activities of microorganisms utilizing oxygen in breaking down organic matter into inorganic substances. According to Young *et al.* (2008) in the bottom layer of the waters, there is accumulation area of organic matter that requires oxygen in order to breakdown. Moreover, the organic waste material is in the water which is the less residual oxygen content dissolved therein.

The other factors also affecting the dissolved oxygen concentration are temperature, salinity, respiration, as well as the layer above the water surface that easily oxidizes the compounds due to its atmospheric pressure (Simanjuntak, 2007). The low dissolved oxygen is caused by a decline in the decomposition of organic material that is hindering the process of the biogeochemical cycle in the Kampar River, it will also directly affect the fertility of the waters (Patty *et al*., 2015).

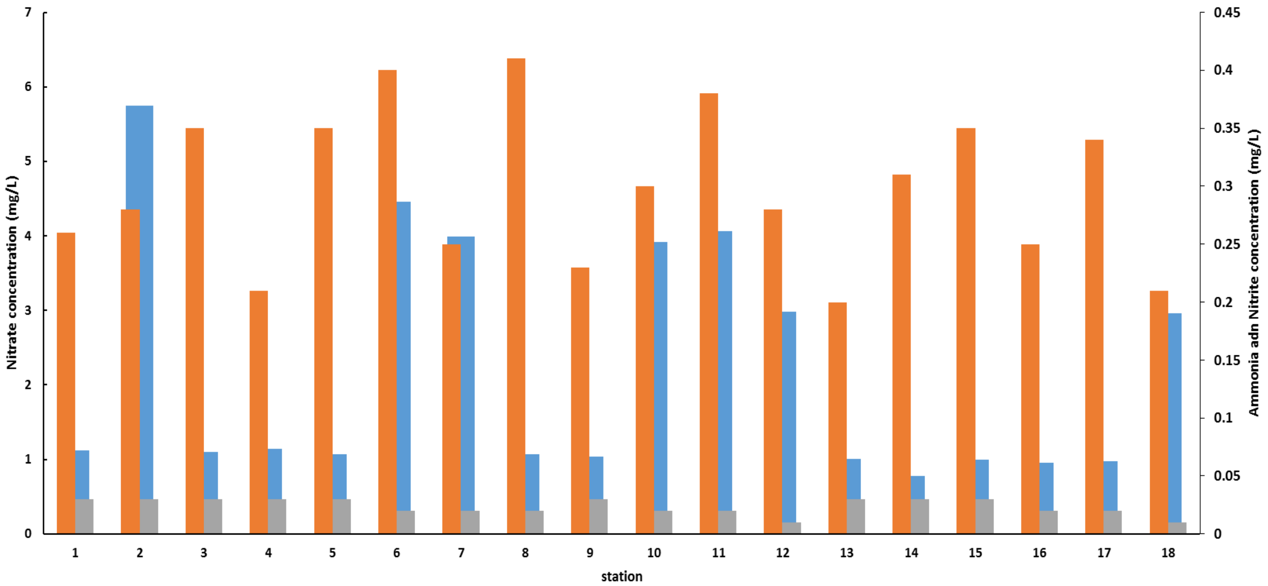

Figure 4. Comparison between Nitrate, Nitrite and Ammonia along Kampar River Estuary
Note. ■ : nitrate, ■ : Ammonia, ■ : Nitrite

Table 2. The results summary of the monitoring of nitrate, nitrite, and ammonia in Kampar estuary compared to the quality standard of KLH (2004)

No	Dissolved Inorganic Nitrogen	River ($mg.L^{-1}$)	Marine ($mg.L^{-1}$)	Muara Kampar ($mg.L^{-1}$)
1	Nitrite	1	0.015	0,01- 0,03
2	Nitrate	10	0.008	0.76 - 5.73
3	Ammonia	2	0.3	0.2 - 0.41

The low salinity in the Kampar River causes the enhancement of nutrient concentration. Scuderi *et al*. (2011) explain that the nutrient concentration will increase in the low salinity of waters, as well as the temperature, which is one the very important physical parameter in the aquatic environment. Changes in water temperature will have an impact on the physical and chemical conditions of the waters and on marine life (Hala *et al*., 2013). It also enhances the nutrient compounds that have been transported by Bono.

The pH value, on the other hand, varies from neutral to slightly alkaline. The pH of the water can still be categorized as a normal. According to Wahab and Mutmainnah (2005), the pH value is said to be in normal condition ranged from 5.6 to 8.3. pH conditions in the Kampar river affect the deposition of nutrient compounds in the sediment. It is known that the pH positively correlates with the speed of nutrients accumulation in the water.

Total dissolved solid (TDS) is identified between 0 to 7.4 $g.L^{-1}$. The concentration of TDS is highly associated with the level of solid content in the water, which will indirectly inhibit the penetration of light entering the water column. Therefore, the use of nutrients for photosynthesis by phytoplankton is reduced, resulting in higher concentration of nutrients in the river (Donnelly and Chanson, 2002).

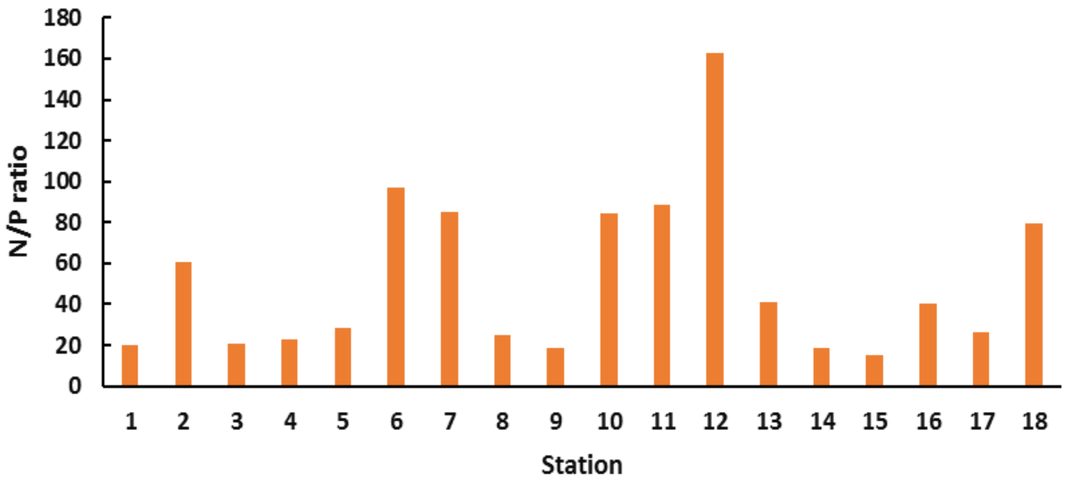

Figure 5. Comparison between total dissolve nitrogen (N) and dissolved inorganic phosphate (P) along Kampar River Estuary
Note. ■ : ratio n/p

Table 3. Descriptive statistic of water quality parameters in Kampar River Estuary

No	Parameters	Min	Max	Mean	ST Dev
1	pH	5.24	7.56	6.58	0.82
2	Salinity (%)	0.1	5.3	1.04	1.49
3	DO ($mg.L^{-1}$)	3.955	4.512	4.29	0.14
4	Temperature (°C)	30.3	32.7	30.92	0.69
5	TDS ($g.L^{-1}$)	0	7.4	1.66	2.19

Table 4. Tidal constituents from admiralty result in Kampar River Estuary

Constanta	M2	S2	N2	K2	K1	O1	P1	M4	MS4	SO
Amplitude	1.13	0.34	0.23	0.24	0.39	0.24	0.13	0.16	0.14	2.59
Phase delay	193.49	40.62	184.77	97.12	89.55	41.19	-68.88	-13.19	178.17	

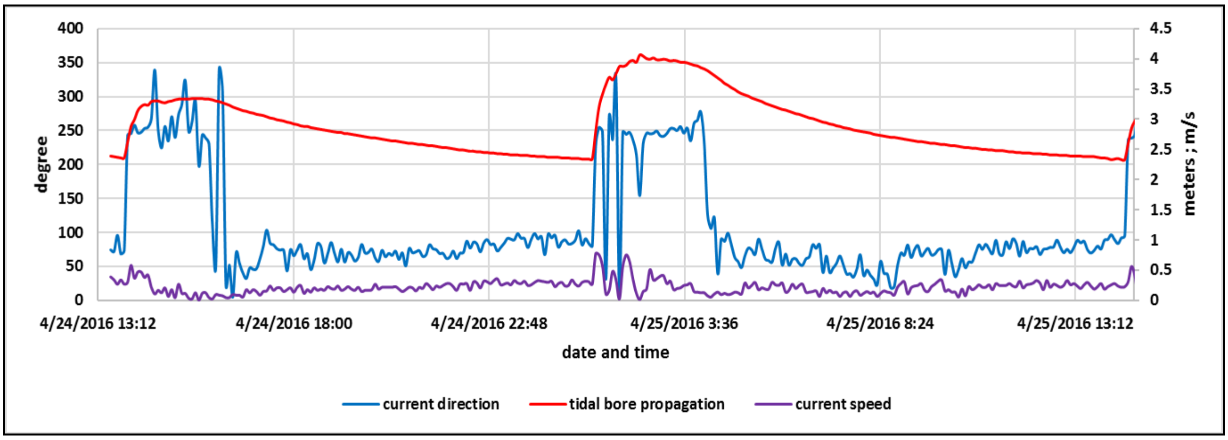

Figure 6. Tidal dynamic, current speed and direction changes in undular bore Bono propagation

Table 5. Tidal type and tidal range in Kampar Estuary

F	tidal range	
0.4286	0.78	4.2
Mixed tide prevailing semidiurnal	Neap	Spring

Based on ISLW analysis (Table 4), it shows that the mean sea level (MSL) of Kampar estuary waters is 2.59 meters, with a maximum tidal range is 4.2 m and the tidal type is mixed tide prevailing semidiurnal (Table 5). A tidal bore is formed due to the very high of the tidal range. According to the Chanson (2009), the tidal can be categorized as a tidal bore if it has a tidal range more than 4 meters. Physical processes occurring in the Malacca Strait, as well as the shape of Kampar River which is divergent, affect the dynamics of the estuary. The shape enhances the height and the speed of the tidal wave. It is supported by decreasing the depth and cross-sectional area (Chanson *et al*., 2010). Kampar River conditions are unstable or frequently change according to the seasons and the wind direction. It causes a different volume of nutrient (N and P) that carried in by a tidal bore during high tide and low tide (Chanson, 2011).

Turbulence in the sediments causing more nutrient being transported and accumulated is highly depends on the undular bore activities (Chanson, 2011). It deposits nutrients in the upstream when energy transport of tidal bore becomes weaker (Chanson, 2004). Seabed erosion occurs on every wave crest that extends, with ripples that follow behind the first undular bore resulting in the turbulence of nutrients, which is generated in the sediment become stronger (Koch and Chanson, 2008).

The mechanism of the tidal bore that influences on the concentration of nutrients in the estuary during the high tide (tidal bore creeping into the river are very significant with regard to the input of the source that comes from the land and from the sea) (Chanson, 2009). According to Magni *et al.* (2005), the variations in the concentrationof N and P in waters are affected by the dynamics of water masses and resuspension processes that increase nutrient in the water. It Linkages the spreading out of tidal currents, the organic material, nitrate, and phosphate (Maslukah *et al.*, 2014). The concentration increases after the tidal wave flow into the river that carries organic and inorganic materials which are further are accumulated in the upstream. This process, unfortunately, can endanger the biota in the upstream, because of the high levels of nutrients concentrated in the water column (Domingues *et al*., 2011).

Hydro-oceanographic factors such as currents that are generated by the tidal wave (undular bore) (Figure 6) directly affect the pattern of the spread of nitrates and phosphates from one place to another. During the high tide, currents will transform the mass of seawater from the open sea towards the upstream, and at low tide, currents will transform the mass of water from the upstream to the open sea (Utami *et al*., 2016). Given these conditions, the material deposition will occur in the upstream, due to the resuspension of nutrient compounds that are derived from the estuary (Chanson, 2004).

At the time of Bono propagating, it changes the water level drastically which is around two meters. Then, it directly alters the current direction and velocity entering the Kampar River. It reaches 0.85 $m.s^{-1}$. On the condition of transport and turbulence occurs rapidly is followed by the higher of scour volume (Wisha *et al*., 2015). Therefore, the nutrients at the bottom will be suspended and carried up to the upstream (Chanson, 2001).

Conclusion

Nutrients condition in the Kampar River that includes nitrate, nitrite, ammonia, and phosphate are categorized in high concentrations. It potentially endangers the microbial life in the Kampar River. Its distribution is volatile due to the transport and mixing caused by wave propagation of Bono. Organic and inorganic substances which are initially deposited in the bottom of the river is accumulated in the upstream area. It tremendously causes the high nutrient concentration in the upstream. Supported by the poor of water quality conditions, it also causes the biodegradation process to be blocked. Kampar Estuary is dominated by tidal oscillation which is much difficult to obtain the sample in the normal condition due to the oscillation. Authors suggest to the other reasearcher who will continue this study, to develop the simualtion of ecology model and study in biological impacts sophisticatedly. This study can be useful as a basis for the assessment of the current environmental conditions of Kampar River for the local government by which dumping waste activities can be severe controlled.

Acknowledgement

Acknowledgements are given to the Research Institute for Coastal Resources and Vulnerability (LPSDKP), the Oceanography Department, Faculty of fisheries and Marine Science Diponegoro University, Didi Adhi Saputra, S.Kel., and all those who support the implementation of this study.

References

Adibrata, Sudirman. 2007. Analisis pasang surut di Pulau Karampuang, Provinsi Sulawesi Barat. *J. Akuatik*. 1(1): 1-6.

Arifin, Taslim, Yulius & Irma, S.A. 2011. Pola sebaran spasial dan karakteristik nitrat-fosfat-oksigen terlarut di perairan pesisir Makassar. *J. Segara*. 7(2): 88-96. doi: 10.15578/segara.v7i2.52.

Chanson, H. 2001. Flow Field in A Tidal Bore: A physical Model. Proc. 29th IAHR Congress, Beijing, Theme E, Tsinghua University. Beijing. pp: 365-373.

Chanson, H. 2004. Mixing and Dispersion Role of Tidal bores. Fluvial, Environmental and Coastal Developments in Hydraulic Engineering Mossa, Yasuda & Chanson (Eds), Taylor & Francis Group. London. pp: 223-232.

Chanson, H. 2009. Environmental, ecological and Cultural Impacts of Tidal Bores, Benaks, Bonos and Burros. IWEH, International Workshop on Environmental Hydraulics Theoretical, Experimental and Computational Solutions. Valencia, 29th, 30th, October 2009.

Chanson, H., Lubin, P., Simon, B. & Reungoat, D. 2010. Turbulence and sediment processes in the tidal bore of the Garonne River: First observations. *Hydraulic Model Report* CH79/10. University of Queensland. Australia.

Chanson, H. 2011. Current knowledge in tidal bores and their environmental, ecological and cultural impacts. *Environ. Fluid. Mech*. 11: 7-98. doi: 10.1007/s10652-009-9160-5.

De Jonge, V.N, Elliott, M. & Orive, E. 2002. Causes, historical development, effects and future challenges of a common environmental problem: Eutrophications. *Hydrobiologia*, 475/476:1-19.

Domingues, R.B., Anselmo, T.P. & Barbosa, A.B. 2011. Nutrient limitation of phytoplankton growth in the freshwater tidal zone o a turbid, Mediteranean estuary. *Est. Coast. Shelf. Sci*. 91(2): 282-297. doi: 10.1016/j.ecss.2010.10.033.

Donnelly, C. & Chanson, H. 2002. Environmental Impact of Tidal Bores in Tropical Rivers. Proc. 5th International River Management Symposium, Brisbane, Australia, September 2002.

Dzialowski, A.R., Dzialowski, W., Shih-Hsien, L., Niang-Choo, J.H. & Huggins, D.G. 2008. Effects of sediment resuspension on nutrient consentrations and algal biomass in reservoir of the Central Plains. *Lake Reservoir Manag*. 24:313-320. doi: 10.1080/07438140809354841.

Ferianita, F., Fachrul, M., Haeruman, H. & Sitepu, L.C. 2005. Komunitas fitoplankton sebagai bio-indikator kualitas perairan Teluk Jakarta. Seminar Nasional MIPA 2005. FMIPA Universitas Indonesia, 24-26 November 2005. Jakarta.

Grasshoff, K, Ehrhardt, M., Kremling, K. & Anderson, L.G. 1999. Methods of Sea Water Analysis. Wiley-VCH. New York.

Hala, Y., Syahrul, M., Suryanti, E., Taba, P. & Soekamto, N.H. 2013. Bioasorpsion of Zn^{2+} and

Cd^{2+} in a two-metal system by *Nannochloropsis salina. Eur. Chem. Bull*. 2(5): 238-241.

Hendrawati, H., Tri, H.P. & Nuni, N.R. 2008. Analisis kadar phosfat dan N-nitrogen (amonia, nitrat, nitrit) pada tambak air payau akibat rembesan lumpur Lapindo di Sidoarjo, Jawa Timur. *J. Kimia Valensi.* 1(3): 135-143
.

Howarth, R.W. & Marino, R. 2006. Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: evolving views over three decades. *Limnol. Oceanogr.* 51 (1 part 2) 364-376. doi: 10.4319/lo.2006. 51.1_part_2.0364

Hutagalung, H.P. & Rozak, A. 1997. Metode Analisis Air Laut, Sedimen dan Biota. Buku 2. Pusat Penelitian dan Pengembangan Oseanolgi LIPI. Jakarta.

Kasry, A. & Nur, E.F. 2012. Kualitas perairan muara sungai Siak ditinjau dari parameter fisik-kimia dan organisme plankton. *Berkala Perikanan Terubuk*. 40(2): 96-113.

Khaliq, A., Abbasi, M.K. & Hussain, T. 2006. Effects of integrated use of organic and inorganic nutrient sources with effective microorganisms (EM) on seed cotton yield in Pakistan. *Bioresource Technol.* 97(8): 967-972. doi: 10.1016/j.biortech.2005.05.002.

Koch, C. & Chanson, H. 2008. Turbulent mixing beneath an undular bore front. *J. Coast. Res*. 24(4): 999-1007. doi: 10.2112/66-0688.1.

Lee, G. F, Jones, R., Saleh, F., Mariani, G., Homer, D., Butler, J. & Bandyopadhyay, P. 1978. Evaluation of the Elutriate Test as a Method of Predicting Contaminant Release During Open Water Disposal of Dredged Sediment and Environmental Impact of Open Water Dredged Disposal. Vol II: data report. Technical Report D-78-45, US Army Corps of Engineers WES. Vicksburg. MS.

Li, Y., Cao, W., Su, C. & Hong, H. 2011. Nutrient sources and composition of recent algal blooms and eutrophication in the northern Jiulong River, Southeast China. *Marine pollution bulletin*. *63*(5): 249-254. doi: 10.1016/j.mar polbul.2011.02.021.

Magni, P., Como, S. & Motani, S. 2005. Interlinked Temporal Changes in Environmental Conditions, Chemical Characteristics of Sediments and Macrofaunal Assemblages in an Estuarine Intertidal Sandflat (Seto Inland Sea, Japan). *J. Mar. Ecol*. 149:1185-1197. doi: 10. 1007/s00227-006-0298-0.

Makmur, M., Haryoto, K., Setyo, S.M. & Djarot, S. W. 2012. Pengaruh Limbah Organik dan Rasio N/P terhadap Kelimpahan Fitoplanktonn di Kawasan Budidaya Kerang Hijau Cilincing. *J. Teknol. Pengelolaan Limbah*. 15(2): 51-64.

Maslukah, L., Indrayanti, E. & Rifai, A. 2014. The distribution of organic matter and nutrients by tidal current at Demaan estuary, Jepara. *Ilmu Kelautan*. 19(4): 189-194. doi: 10.14710/ik. ijms.19.4.189-194.

Mukhopadhyay, S.K., Biswas, H., De, T.K. & Jana, T.K. 2006. Fluxes of nutrients from the tropical River Hooghly at the land–ocean boundary of Sundarbans, NE Coast of Bay of Bengal, India. *J. Mar. Syst.*. 62:9–21.

Mustofa, A. 2015. Kandungan Nitrat dan Pospat sebagai factor tingkat kesuburan perairan pantai. *J. Disprotek*. 6(1):13-19.

Patty, S.I., Arfah, H., Abdul, M.S. 2015. Nutrients (Phosphate, Nitrate), Dissolved Oxygen and Dissolved pH and They Relation to Productivity of Jikumerasa Waters, Buru Island. *J. Pesisir dan laut Tropis*. 1(1): 43- 50.

Paytan, A. & McLaughlin, K. 2007. The Oceanic Phosporus Cycle. *Chem. Rev*. 107(2): 563-576. doi: 10.1021/cr0503613.

Purwiyanto, A.I.S., Prartono, T. and Koropitan, A.F., 2013. Vertical distribution and flux of nutrients in the sediments of the mangrove reclamation region of Muara Angke Kapuk, Jakarta. *Makara J. Sci.* pp.197-202. doi: 10.7454/mss.v16i3.1 482

Risamasu, F.J.L. & Hanif, B.P. 2011. Kajian zat hara fosfat, nitrit, nitrat dan silikat di perairan Kepulauan Matasiri, Kalimantan Selatan. *Ilmu Kelautan*. 16(3):135-142. doi: 10.14710/ik. ijms.16.3.135-142.

Santos, I.R., Burret, W.C., Chanton, J., Mwashote, B., Suryaputra, I.G.N.A. & Dittmar, T. 2008. Nutrient biogeochemistry in a Gulf of Mexico Subterranean Estuary and Groundwater-Derived Fluxes to the Coastal Ocean. *Limnol. Oceanogr*. 53(2):705-718. doi : 10.4319/lo. 2008.53.2.0705.

Scuderi, D., Restuccia, C., Chisari, M., Barbagallo, R.N., Caggia, C., & Giuffrida, F. 2011. Salinity of nutrient solution influences the shelf-life of fresh-cut lettuce grown in floating system. *Postharvest Biol. Technol.* 59(2): 132-137. doi: 10.1016/j.postharvbio.2010. 08.016.

Simanjuntak, M. 2007. Oksigen terlarut dan apparent oxygen utilization di Perairan Teluk Klabat, Pulau Bangka. *Ilmu Kelautan*. 12(2): 702-724.DOI: 10.14710/ik.ijms.12.2.59-66.

Ulqodry, T.Z., Yulisman, Y., Muhammad, S. & Santoso, S. 2010. Karakteristik dan sebaran nitrat, fosfat dan oksigen terlarut di Perairan Karimunjawa, Jawa Tengah. *J. Penelitian Sains*. 13(1D):35-41.

Utami, T.M.R., Maslukah, L. & Yusuf, M. 2016. Sebaran nitrat (NO_3) dan fosfat (PO_4) di Perairan Karangsong, Kabupaten Indramayu. *Buletin Oseanografi Marina*. 5(1): 31-37.

Wahab, A.W. & Mutmainnah, M. 2005. Analisis kandungan logam berat timbal dan seng di sekitar perairan pelabuhan Pare-pare dengan Metode Adisi standar. *J. Marina Chimica Acta*. 6(2):21-24.

Wankel, S.D., Kendall, C., Francis, C.A. & Paytan, A. 2006. Nitrogen sources and cycling in the San Francisco bay Estuary: A nitrate dual isotopic composition approach. *Limnol. Oceanogr*. 1(4): 1654-1664. doi: 10.4319/lo.2006.51.4.1654.

Wardoyo, S.T.H. 1982. Water Analysis Manual Tropical Aquatic Biology Program. Biotrop. SEAMEO. Bogor. 81 p.

Wisha, U.J., Husrin, S. & Prihantono, J. 2015. Hydrodynamics Banten bay during transitional seasons (August-September). *Ilmu Kelautan*. 20(2):101-112. doi: 10.14710/ik.ijms.20.2.10 1-112.

Wisha, U.J., Husrin, S. & Prasetyo, G.S. 2016. Hydrodynamics of Bontang seawaters: its effects on the distribution of water quality parameters. *Ilmu Kelautan*. 21(3): 123-134. doi: 10.14710/ik.ijms.21.3.123-134.

Wisha, U.J. & Heriati, A. 2016. Analysis of tidal range and its effect on distribution of total suspended solid (TSS) in the Pare Bay Waters. *J. Mar. Sci. Technol.* 9(1):23-31. doi: 10.21107/jk.v9i1.10 66.

World Health Organization (WHO) and European Commission. 2002. Eutrophication and Health. Edited by K. Pond. Luxembourg: Office for Official Publication of European Communities. 28 pp.

Young, R.G., Matthaei, C.D. & Townsend, C.R. 2008. Organic matter breakdown and ecosystem metabolism: functional indicators for assessing river ecosystem health. *Journal of the North American Benthological Soc.* 27(3): 605-625. doi: 10.1899/07-121.1.

Yulistiyanto, B., 2009. The phenomenon of bono rising wave in Kampar River Estuary. *Dinamika Teknik Sipil,* 9(1):19-26.

Zulkarnaen, I., Syahril, N. & Irvina, N. 2012. Analysis increases waters fertility at Rokan's River Estuary sighted from nitrate, phosphate, and profusion at diatom. *J. Kelautan Universitas Riau*. 14 pp.