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Preliminary rapid fishing port water quality assessment with pollution index

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Abstract. The fishing port of Tasikagung is one of the largest ports in Rembang, Central Java. Fishing port is surrounded by densily populated thereby affecting the quality of sea water. This study was conducted in 13 stations, representing the entire port area. Based on grab sampling, preliminary rapid assessment sea water quality for port purposes denoted that lightly pollution has occurred in this area. In addition, if sea water qualities were compared with marine biota water quality purpose, pollution index indicated moderately pollution. However further frequent sampling representing monsoon season needs to be pursued in order to obtain series of water quality data.
Key Words: pollution index, sea water, moderately pollution, fishing industry.

Introduction. Tasikagung is the largest fishing port in Rembang and the backbone of the economy in the District of Rembang, Central Java, Indonesia. Fishing port Tasikagung as a provider of operational facilities of fishing vessel has a significant role in supporting marine fisheries (Marine and fisheries department profile Rembang 2013). Ports usually serve one or more of the four main types of businesses including fisheries development equipped with a breakwater, channel port, processing plant, fishing vessel, and other facilities (Clark 1995).

Port activities such as fish auctions, food stall, selling frozen and fresh fish, Saroyo Mina diesel cooperation shop, workshop, and public toilets produce wastewater. The fishing industry problems also produce waste. Basically the fishing industry generally produces wastewater which is dominated by organic materials (Riani 2012). Therefore, it is needed waste reduction and recycling of waste (Kuznetsov et al 2015). Port is the center of economic development but its activities create negative impact, and affect the surrounding habitat as well (Puig et al 2015). Port environmental management is an important aspect including waste management from vessel operations (Jaccoud & Magrini 2014).

The negative impacts of pollution in the sea are causing unexpected death of fish and nutrition enrichment that can cause excessive growth of algae, the increase of metabolism, and the changes of community structure, which is known as eutrophication (Day et al 1989; Riani et al 2014). Hence, the application of wastewater discharge regulation is the key element to prevent, control and reduce the input of dangerous substances, nutrients and other water pollutants from water sources point into the ecosystem (Helmer & Hespanhol 1997).

A rapid assessment of sea water quality is required to determine the sea water quality status. Usage of water quality index or pollution index is worthwhile in providing instant description of seawater quality status. A water quality index provides a single number (like a grade) that expresses overall water quality at a certain location and time based on several water quality parameters. The objective of an index is to turn complex water quality data into information that is understandable and useable by the public.

Pollution index method and Storet is popular for practitioners and researchers in water quality assessment used in Indonesia (Saraswati et al 2014). This research used the pollution index to preliminary determine the pollution status of water quality in coastal fishing port of Tasikagung.

Material and Method. The study was conducted at the Fishing Port Tasikagung, Rembang, Central Java Province, January - February 2015. Purposive sampling based on predetermined locations with the consideration that the activity nearby seawater sampling sites were likely influenced sea water quality. Hence, 13 stations were selected, grouped into 5 namely Group A (river mouth), group B (fish auction), group C (port midlle part), group D (port end part), group 5 (control, relatively away from port) (Figure 1). All 13 sampling points represented the whole fishing port area. Seawater samples were analyzed according to APHA (2005).

Figure 1. Water quality sampling site at Fishing Port, Tasikagung (Map source, Google earth).

Determination of water quality status with pollution index. Water parameters were assessed by the method of pollution index referring to the Minister of Environment Decree (MoED) No. 115 of 2003 on Guidelines for Determination of Water Quality Status. Port water quality was compared with marine water quality standard for sea port water quality purpose and marine biota water quality purpose, issued by Minister of Environment Decree No. 51 of 2004. WQI is one of the methods to evaluate water quality in an ecosystem. The WQI is a function of Ci/Lj, where Ci represents the concentration of parameter i and Lj represents the concentration permissible value (PV) of parameter (Jubaedah et al 2015). Pollution index can be determined by the following measures:

1. select the parameters that exist in the sea water quality standard;
2. calculate Ci/Li for each parameter for each sampling location. Ci is measured water quality parameter. Li is standard water quality for each parameter;
3. the use of value $(Ci/Li)_{measurement}$ if the value is smaller than 1.0, and the use of $(Ci/Li)_{new}$ if the value of $(Ci/Li)_{measurement}$ greater than 1.0
   $(Ci/Li)_{new} = 1.0 + P \log (Ci/Li)_{measurement}$
4. determine the average value and the maximum value of the overall Ci/Li [(Ci/Li)R and (Ci/Li)M];
5. determine water pollution index (Hammer & Harper 2006):

$$Pij = \sqrt{\frac{(\frac{Ci}{Lij})^2_M + (\frac{Ci}{Lij})^2_R}{2}}$$

where: Pij = Pollution Index for a specified water quality purpose (j),
Ci = Measured water quality parameters,
Lij = Standard water quality parameter for each parameter at specified water quality purpose (j),
(Cij/Lij)M = Cij/Lij maximum,
(Cij/Lij)R = Cij/Lij average;

6. PiJ was then compared with the criteria shown in Table 1.

Table 1

Pollution index and water quality status

Pollution Index	*Water quality*
$0 \le Pij \le 1.0$	Meet quality standards (good condition)
$1.0 < Pij \le 5.0$	Lightly polluted
$5.0 < Pij \le 10$	Moderately polluted
$Pij \ge 10$	Heavily polluted

Source: Minister of Environment Decree No. 115 of 2003 on Guidelines for Determination of Water Quality Status.

Results and Discussion. Pollution index was applied to determine the contamination level relative to water quality parameters standard stipulated by the government regulation. Example of pollution index calculation (Group A) is elaborated at Figure 2. Pollution Index (Pij) for marine biota water quality purpose at each sampling point was Group A (9.6964), group B (7.8309), group C (8.8005), group D (6.9008), and group E (7.1545) pointing out moderately polluted. Meanwhile pollution index for port water quality purpose for each station was group A (2.8485), group B (1.3285), group C (1.6582), and group D (0.4941) indicating lightly polluted. Group E (0.5647) met quality standards (good condition) (Table 2).

Based on grab sampling, preliminary assessment of fishing port water quality pointed out that lightly and moderately contamination has occurred in this area. However further frequent sampling representing monsoon season needs to be pursued in order to obtain series of water quality data. Therefore a comprehensive conclusion can be well withdrawal. Xu et al (2004) stated that port activities and the flow of surface water from the mainland (run off) influenced on changes in physical chemical parameters of waters. Most of the synthetic organic materials can not be broken down by bacteria, only a small fraction can be described with a slow rate of decomposition (Gray 2004). Poor water quality in the waters of coastal fishing port affected by domestic sewage and port waste.

Table 2

Tasikagung port water quality parameters

No	Parameters	Standard for marine biota*	Standard for sea port*	Unit	Group A			Average	Group B			Average
					1	2	3		4	5	6	
1	Temperature	28-32	-	^oC	29.4	32.2	30	29.7	37.5	31.6	29.5	32.867
2	TSS	80	80	mg L^{-1}	149.8	507.33	139.83	265.65	178.21	101	48.8	109.337
3	Turbidity	< 5	-	NTU	197	2170	129	832	30.2	32.5	11.3	24.667
4	pH	6.5–8.5	6.5–8.5	-	7.6	8.08	7.82	7.83	7.72	8.03	8.11	7.953
5	BOD	20	-	mg L^{-1}	301.58	822.48	73.11	399.06	708.25	891.02	799.63	799.633
6	COD	-	-	mg L^{-1}	472.04	1294.2	114.71	626.98	1066.56	1395.66	1250.14	1237.45
7	DO	>5	-	mg L^{-1}	2.28	5.94	2.9	3.71	3.71	4.11	2.96	3.393
8	Ammonia (NH_3)	0.3	0.3	mg L^{-1}	0.4694	0.2538	0.3845	0.3692	0.3972	0.168	0.1179	0.228
9	Nitrite (NO_2)	-	-	mg L^{-1}	0.665	0.1517	0.536	0.45	0.246	0.0243	0.0106	0.094
10	Nitrate (NO_3)	0.008	-	mg L^{-1}	1.7166	1.7976	1.5142	1.68	0.6154	0.6397	0.4737	0.576
11	Total nitrogen	-	-	mg L^{-1}	0.9095	1.8725	0.7064	1.16	0.6787	0.3355	0.336	0.45
12	Sulphate (SO_4)	-	-	mg L^{-1}	230.46	2868.4	573.68	1224.18	1848.5	1039.15	2971.6	1953.08
13	Orthophosphate (PO_4)	0.015	-	mg L^{-1}	0.6668	0.2162	0.4236	0.436	0.5450	0.3809	0.0961	0.341
	Pollution Index for Marine Biota							9.6964				7.8309
	Pollution Index for Sea Port							2.8485				1.3285

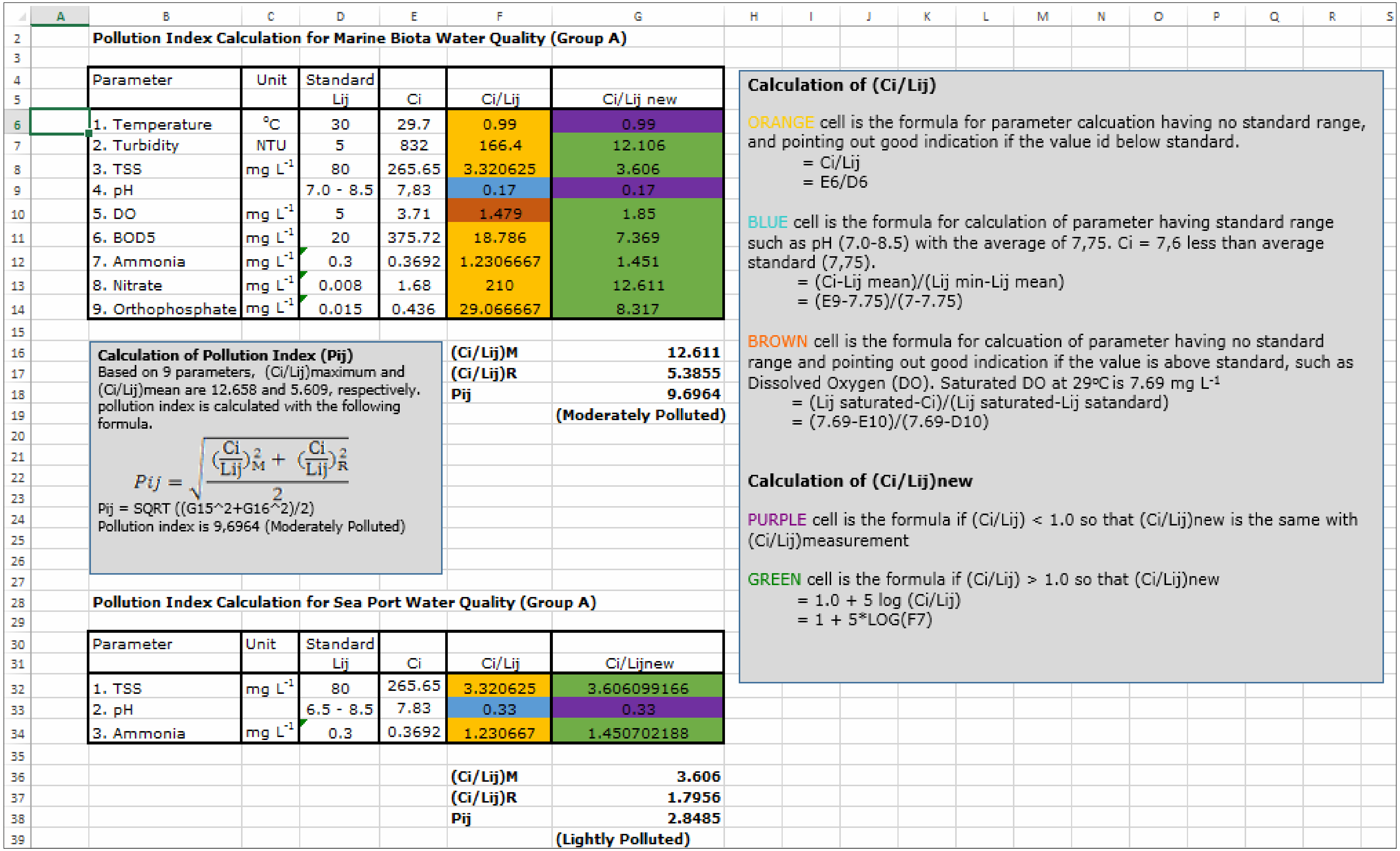
*Minister of Environment Decree No. 51 of 2004 on Marine Water Quality Standard.

Table 2. Continued

Tasikagung port water quality parameters

No	Parameters	Standard for marine biota*	Standard for sea port*	Unit	Group C			Average	Group D			Average	Group E
					7	8	9		10	11	12		13
1	Temperature	28-32	-	^oC	30.3	27.9	31	29.733	29.4	29.5	30.3	29.733	27.9
2	TSS	80	80	mg L^{-1}	45.1	35.17	35.13	38.467	15.4	33.9	20.15	23.15	40.93
3	Turbidity	< 5	-	NTU	33.3	17.3	24.8	25.133	1.9	3.8	2	2.567	5.2
4	pH	6.5 – 8.5	6.5 – 8.5	-	7.36	7.92	7.75	7.677	8.12	8	8.2	8.107	8.12
5	BOD	20	-	mg L^{-1}	731.09	845.33	776.79	784.403	1050.95	868.17	708.25	875.79	753.94
6	COD	-	-	mg L^{-1}	1152.7	1301.88	1197.18	1217.23	1627.59	1345.54	1090.42	1354.52	1169.28
7	DO	>5	-	mg L^{-1}	1.96	2.32	3.1	2.46	3.61	3.75	4.13	3.83	3.71
8	Ammonia (NH_3)	0.3	0.3	mg L^{-1}	0.9615	0.3017	0.2404	0.501	0.1309	0.1475	0.1124	0.13	0.1136
9	Nitrite (NO_2)	-	-	mg L^{-1}	0.546	0.0419	0.2325	0.273	0.0018	0.0043	0.0042	0.003	0.0032
10	Nitrate (NO_3)	0.008	-	mg L^{-1}	0.668	0.6073	0.4211	0.565	0.3846	0.3765	0.3482	0.37	0.4494
11	Total nitrogen	-	-	mg L^{-1}	1.2873	0.5472	0.5264	0.787	0.5499	0.3172	0.2926	0.387	0.2121
12	Sulphate (SO_4)	-	-	mg L^{-1}	4169.9	4261	3460.6	3963.83	2725.6	8640.9	8321.25	6562.58	8534.1
13	Orthophosphate (PO_4)	0.015	-	mg L^{-1}	5.076	0.1027	0.6549	1.945	0.0418	0.0136	0.0306	0.029	0.0018
	Pollution Index for Marine Biota							8.8005				6.9008	7.1545
	Pollution Index for Sea Port							1.6582				0.4941	0.5647

*Minister of Environment Decree No. 51 of 2004 on Marine Water Quality Standard.



Pollution Index Calculation for Marine Biota Water Quality (Group A)

Parameter	Unit	Standard Lij	Ci	Ci/Lij	Ci/Lij new
1. Temperature	°C	30	29.7	0.99	0.99
2. Turbidity	NTU	5	832	166.4	12.106
3. TSS	mg L^{-1}	80	265.65	3.320625	3.606
4. pH		7.0 - 8.5	7,83	0.17	0.17
5. DO	mg L^{-1}	5	3.71	1.479	1.85
6. BOD5	mg L^{-1}	20	375.72	18.786	7.369
7. Ammonia	mg L^{-1}	0.3	0.3692	1.2306667	1.451
8. Nitrate	mg L^{-1}	0.008	1.68	210	12.611
9. Orthophosphate	mg L^{-1}	0.015	0.436	29.066667	8.317

(Ci/Lij)M	**12.611**
(Ci/Lij)R	**5.3855**
Pij	**9.6964**
	(Moderately Polluted)

Calculation of Pollution Index (Pij)

Based on 9 parameters, (Ci/Lij)maximum and (Ci/Lij)mean are 12.658 and 5.609, respectively. pollution index is calculated with the following formula.

$$Pij = \sqrt{\frac{(\frac{Ci}{Lij})_M^2 + (\frac{Ci}{Lij})_R^2}{2}}$$

Pij = SQRT ((G15^2+G16^2)/2)

Pollution index is 9,6964 (Moderately Polluted)

Pollution Index Calculation for Sea Port Water Quality (Group A)

Parameter	Unit	Standard Lij	Ci	Ci/Lij	Ci/Lijnew
1. TSS	mg L^{-1}	80	265.65	3.320625	3.606099166
2. pH		6.5 - 8.5	7.83	0.33	0.33
3. Ammonia	mg L^{-1}	0.3	0.3692	1.230667	1.450702188

(Ci/Lij)M	**3.606**
(Ci/Lij)R	**1.7956**
Pij	**2.8485**
	(Lightly Polluted)

Calculation of (Ci/Lij)

ORANGE cell is the formula for parameter calcuation having no standard range, and pointing out good indication if the value id below standard.
= Ci/Lij
= E6/D6

BLUE cell is the formula for calculation of parameter having standard range such as pH (7.0-8.5) with the average of 7,75. Ci = 7,6 less than average standard (7,75).
= (Ci-Lij mean)/(Lij min-Lij mean)
= (E9-7.75)/(7-7.75)

BROWN cell is the formula for calcuation of parameter having no standard range and pointing out good indication if the value is above standard, such as Dissolved Oxygen (DO). Saturated DO at 29ºC is 7.69 mg L^{-1}
= (Lij saturated-Ci)/(Lij saturated-Lij satandard)
= (7.69-E10)/(7.69-D10)

Calculation of (Ci/Lij)new

PURPLE cell is the formula if (Ci/Lij) < 1.0 so that (Ci/Lij)new is the same with (Ci/Lij)measurement

GREEN cell is the formula if (Ci/Lij) > 1.0 so that (Ci/Lij)new
= 1.0 + 5 log (Ci/Lij)
= 1 + 5*LOG(F7)

Figure 2. Example of pollution index calculation.

Human activities nearby the fishing port of Tasikagung contribute both directly and indirectly to increased organic matter in sea waters. The port does not have wastewater treatment plants. Lee & Lee (2015) divided the sources of water pollution in fishing ports into: industry, domestic/urban, aquaculture, shipping, and tourism. Dura et al (2005) stated that pollution of specific organic substances e.g. polyhalogenated and polycyclic aromatic hydrocarbons is substantially differences in various regions depending on population density and the local industry structure, proportion of wastewater treated, agriculture and its intensity in pertinent rivers' watersheds. To ensure accurate assessment of water quality, significant attention had to be paid to analytical method development of water quality and standard criteria (Wang et al 2015).

Water Quality Index (WQI) or pollution index as a water quality aggregation was useful in identifying anthropogenic impacts in the area (Lobato et al 2015). Pollution Index is a comprehensive index that includes more water quality constituents. WQI utilizes the water quality data and helps in the modification of the policies, which are formulated by various environmental monitoring agencies (Liu et al 2011; Tyagi et al 2013). Comparison of water quality parameters using the concept of WQI with regulatory standards in providing a source of water quality values can be seen in the list of constituents and concentrations in the sample (Abukila 2015).

WQI makes it easier to define abstract numerical values of a single water sample. WQI can be used in monitoring, comparison and control of water quality, for example WQI in the program reduce pollution and inform residents (Abbassi & Abbassi 2012; Alves et al 2014). Water quality index proved to be very efficient in informing water quality to decision makers and to the public, it is because WQI obtained by combining several single water quality measurements for simplified expression of a complex set of variables (Helmer & Hespanhol 1997). Water quality management based Pollution Index can provide input to the decision in assessing the quality of water, take action to improve the quality if there is a loss of quality due to pollution compounds. Pollution Index includes a diverse group of independent and meaningful quality parameters (Sahabuddin et al 2014; Brraich & Jangu 2015).

The National Water-Quality Assessment Program (NAWQA) of the U.S. Geological Survey (USGS), part of the Department of the Interior has involved the collection and analysis of water quality data in over 50 major river basins and aquifer systems in nearly all 50 states. The program has encompassed three principal categories of investigation: (1) the current conditions of surface water; (2) changes in those conditions over time; and (3) major factors such as climate that affect water quality (Calhoun 2005). Taiwan Environmental Protection Administration (TEPA) has developed a River Pollution Index (RPI) classification system for river water quality evaluation based on the purpose of water usage and degree of protection for each stream section (Lai et al 2013).

Basic requirements are that monitoring data have to provide a reliable assessment of status of all water bodies; this implies that networks have to consider the representativeness of monitoring points as well as frequency. In addition, monitoring has to be designed in such a way that long-term pollution trends may be detected (Gonzalez et al 2009). Time and space scales of observation are very important for analyzing the stochastic characteristics of hydrodynamic and water quality phenomena (Ganoulis 2009).

Pollution index is concentration aggregation of several water quality parameters into a single quantity to indicate the general status of pollution in the region. Pollution simplified index could be useful in assessing the quality of the environment and are used to set priorities in environmental management by decision-makers. People will get information about the status of the environment. In addition, the environmental conditions in different areas can be compared and temporal changes in environmental quality in a particular location can be followed (Golge et al 2013). WQI denotes direct comparison of the overall quality of different waters even though the concentration ranges of the individual constituents may be very different, allow the user to examine waters and view them in terms of ranked for example; bad, poor, good, better, best. The WQI is a method of providing water-quality information that can be more readily used by planners, managers, and other non-technical people (Stoner 1978). WQI can also be used to calculate the level of heavy metal contamination in the sample (Al Obaidy et al 2015).

WQI value is a combined physical-chemical index which makes it possible to compare the water quality of various water bodies. Therefore, it has wide application and it is used as the indicator of the quality of sea, river, and water as well as of drinking water (Milijasevic et al 2011). WQI is one of the methods to evaluate water quality in an ecosystem.

***Temperature*, *pH*, *TSS*, *and turbidity*.** Water temperature ranged from 27.5 to 37.5°C (Table 2). Range of pH 7.36-8.20 met the quality standard (MoED No. 51 of 2004 on marine water quality standard) which is 6.5 to 8.5. Sea water temperature at each sampling point supported the life in it. At station 1 low seawater temperature (29.4^{o}C) was recorded since close to the mouth of the river. It is in line with report of Sembiring et al (2012) that influence from the rivers and lands can lower the temperature of the seawater at the mouth of the river and surrounding areas.

Total Suspended Solid (TSS) causing turbidity in the water due to undissolved solids and cannot directly precipitate. TSS consists of particles whose size and weighs less than the sediment, such as clay, certain organic materials, cells of microorganisms, and so on (Thomas & Pouet 2005).

TSS at the sampling point 1 (149.8 mg L^{-1}), 2 (507.33 mg L^{-1}), 3 (139.83 mg L^{-1}), 4 (178.21 mg L^{-1}), and 5 (101 mg L^{-1}) exceeded the quality standard (80 mg L^{-1}).

Turbidity was above quality standards according Minister of Environment Decree No. 51 of 2004 (< 5 NTU) namely 197 NTU, 2170 NTU, 129 NTU, 30.2 NTU, and 32.5 NTU for sampling points 1, 2, 3, 4, and 5, respectively. Anthropogenic activities (household, market, etc.) around the fishing port and beach produced waste presumably in part dumped directly into the water body and wastewater from fish auction market, flowing into the waters of the Fishing Port, might cause high TSS and turbidity. No wastewater treatment existed at this site. According to Ferry et al (2015) solid waste from households also must be managed well be shared responsibility and supported by relevant stakeholders either community or government.

***BOD*, *COD*, *DO*, *ammonia*, *nitrate*, *total nitrogen*, *and orthophosphate*.** Chemical Oxygen Demand (COD) is a measure of water pollution by organic substances that can not be oxidized through a microbiological process and result in reduced dissolved oxygen in the water. BOD (Biochemical Oxygen Demand) is a measure of oxygen consumed during decomposition of organic matter. High BOD and COD denote water quality deterioration. At all sampling points, BOD and COD were high (822.48 mg L^{-1}, and 1294.2 mg L^{-1}, respectively) and beyond the quality standards. While at the sampling point 3 low BOD (73.11 mg L^{-1}) and low DO (2.9 mgL^{-1}) were recorded.

Dissolved Oxygen (DO) at almost all sampling points did not meet the quality standard namely < 5 mg L^{-1}. The lower the oxygen concentration, the greater the stress of aquatic biota. Consequently, species sensitive to low levels of dissolved oxygen was replaced by species more tolerant to adverse conditions, significantly reduces the diversity of aquatic life (Patty 2014). At the sampling point 2 close to the river, DO (5.98 mg L^{-1}) meet the quality standard. Mouth of the river, in general has a relatively high DO content compared to other waters (Day et al 1989).

High ammonia concentration might correlate with high content of organic matter, it is seen in the high BOD and COD. This condition subsequently brings about low DO concentration. Lowest nitrite levels (0.0018 mg L^{-1}) existed at station 13 and the highest nitrite (0.665 mg L^{-1}) at station 1. Increased levels of nitrite in marine waters are closely related to the inclusion of the biodegradable organic matter. Decomposition of organic matter containing nitrogen will produce nitrate compounds, nitrites or ammonia. The massive amounts of nutrients in sewage serve as an ideal fertilizer for planktons and algae to flourish and enhance the productivity of the aquatic ecosystem (Al-Ghais 2013).

Nitrogen is one of the substances needed by phytoplankton for photosynthesis. Nitrogen in the sea consists of several forms, including: organic bond, ammonia, nitrites, nitrogen oxides, and in the form of free molecular (gas). Fluctuations in distribution of nitrate in the ocean depend on the season. Iizumi et al (1980) added that the concentration of ammonia in seawater is basically low and utilized by phytoplankton resulting in oxidation of ammonia producing nitrite and nitrate by bacterial nitrification. Sampling point 13 denoted the lowest N total concentration (0.2121 mg L^{-1}), and the highest (1.8725 mg L^{-1}) existed at sampling point 2.

Sulfate concentration in the coastal waters of the fishing port reached 8640.9 mg L^{-1}. According to Sudirman et al (2013) sulfuric compounds derived from plant waste products (waste) paper, textile, and other industries, sulfate were also found as a result of decomposition of organic materials. High levels of sulfate in the water are likely to be affected by the settlement activity on land in coastal fishing ports Tasikagung. Major environmental and ecological issues arising from enhanced sulphate enriched coastal sediments include the accumulation of dissolved sulphide in the sediment (Hyun et al 2013). In eutrophic coastal sediments, sulphate reduction has been regarded as a dominant C oxidation pathway, often responsible for most C oxidation (Hyun et al 2013).

Phosphate levels at station 11 (0.0136 mg L^{-1}) and 13 (0.0018 mg L^{-1}) were below the quality standard namely 0.015 mg L^{-1}. However, at station 11 high phosphate concentrations may be influenced by current and depth. The excessive phosphate in living body will be issued back to nature in the form of urine or feces which are then broken down by bacteria back into inorganic phosphate. Apart from the remains of the body's metabolism, phosphate is also obtained from the decomposition of dead creatures by bacteria. Phosphate in water might originate from phosphate detergents in liquid waste and pesticides and insecticides from agricultural lands (Effendi 2003; Peavy et al 1985).

Conclusions. Based on grab sampling, preliminary rapid assessment sea water quality for port purposes pointed out that Tasikagung port sea water quality underwent lightly pollution. Furthermore, if sea water qualities were compared with marine biota water quality purpose, moderately pollution has occurred. Pollution index is worthwhile to be used as preliminary rapid port water quality assessment. However, further frequent sampling has to be pursued to thoroughly assess port water quality.

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