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WATER QUALITY STATUS OF KALIMANTAN WATER BODIES BASED ON THE POLLUTION INDEX

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ABSTRACT

These days, the quality of water bodies is a growing environmental concern, so the studies of water quality are extremely important. The aim of this paper is to determine the water quality status of Kalimantan water bodies, using some physical, biological, and chemical parameters. The samples for characterization were collected from 29 water bodies in Kalimantan, which have been divided into 80 different monitoring stations. The water bodies consisted of rivers and lakes that spread to all provinces in Kalimantan. In order to determine the status of water quality, collected samples were analyzed, using the Nemerow pollution index as a comprehensive index method. The results that were obtained show the average water pollution index of Kalimantan was 5.35, where it can be categorized as moderately polluted water. Based on the pollution parameters observed, the main sources of pollutants were domestic wastes, agricultural wastes, mining activities, deforestation, and forest fires.

KEY WORDS : Water quality, Kalimantan, Pollution index

INTRODUCTION

Kalimantan (Borneo) Island is the third biggest island on the Earth. There are many flood-plain lakes and rivers that meander through the rainforest (Ishikawa *et al.,* 2006). In this area, most of the watershed is heavy rainforest which is rich in humic substance, and at high concentration, it causes dark brown color in the water ponds and rivers (Dolmaa *et al.*, 2014).

Rivers and freshwater lakes are very important multi-usage components since they are the source of drinking water, agriculture, fishery, and energy generation (Hacigolu and Dulger, 2009). These sources, especially in developing countries, are endangered to a wide range of pollutants caused by diffuse nonpoint (such as agricultural land, urban development and atmosphere) and point (such as discharges of sewage and industrial waste) sources which are difficult to be monitored, evaluated, and controlled (Ahuja, 2013). In addition, natural processes like precipitation, erosion, weathering of crustal materials and water surface degradation also contribute to exploiting water resources (Agbaire and Obi, 2009). Therefore, proper management of water is needed to conserve the functions of water, because water quality management has a huge impact on the flow and quality of rivers and lakes.

The use of water in Kalimantan, besides as drinking water, is important as it is used for transportation and economic activities (Waguna *et al.*, 2016). Indigenous people of Kalimantan usually characterized by their practice of living along riverbanks. Rapid urbanization in Kalimantan creates some negative effects on people's health and the environment. Elson (2012) found that local

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residents in Southern Kalimantan were frequently using water in the rivers directly for domestic needs, such as bathing, washing and disposing of waste. These activities might increase the contamination of microbes and decrease water quality (Gichana *et al.*, 2014). Furthermore, Shi *et al.,* (2017) found that the urban and farmland lowered water quality, whereas forest and grassland had positive effects on water quality.

The water quality of water bodies is a growing environmental concern. Therefore, studies of water quality are important. The water quality is defined by its physical, chemical and microbiological characteristics. In order to assess water quality for different uses, a variety of indices are used. A general description of the water bodies quality can be described by a Nemerow pollution index (NPI). The Nemerow pollution index is a water pollution index that takes extreme values into account using a weighted environmental quantity index and frequently used in water quality assessments around the world (Ji *et al.*, 2016). The NPI assessment has the advantages of easy processing, simple calculation and clear physical concept (Chen *et al.*, 2016). The assessment method of NPI combines the average value of pollutants with that of maximum value relative to their objective levels (Liu *et al.*, 2007). NPI accumulates numerous of water quality parameters and defines the water quality into a simple manner such as "meeting standard quality", "slightly polluted", "moderately polluted", etc.

Water quality evaluation of rivers and lakes in Kalimantan is very important, in order to know the possibility of using the water as the main source for various necessities. In this study, we evaluated the water quality status of Kalimantan through several physicals, biologicals and chemicals analysis using Nemerow's pollution index.

METHODS

Research areas

This study area was in Indonesian territory of Kalimantan (approximately 73% of the island), it was not included in Brunei and East Malaysia as it is the non-Indonesian parts. Kalimantan, the third-largest island in the world, is one of the important tropical islands. It is in the equatorial region of the Pacific Ocean. Head waters of Borneo's major rivers are located in the center of the highlands. The three longest rivers in Indonesia are in Kalimantan, which are the Kapuas (1,143 km), the Barito (900 km) and the Mahakam (775 km) (Rautner *et al.*, 2005). In addition, there are many lakes in the area, including two of the biggest lakes in Indonesia, which are the Jempang (14,600 ha) and the Semayang (10,300 ha) (Sarwono, 1989). Kalimantan is divided into the five provinces, namely East Kalimantan, South Kalimantan, Central Kalimantan, West Kalimantan, and North Kalimantan. North Kalimantan, the newest province in Indonesia (formed on 25 October 2012), was once part of East Kalimantan.

Sampling and analysis

Water samples from chosen rivers and lakes were monitored twice or three times a year varies at different locations. Data collection was done at 29 water bodies in Kalimantan, which were divided into 80 different monitoring stations (Fig. 1). Rivers and lakes were chosen based on the criteria that the rivers or lakes are cross-province and as the priority of pollution control.

Samples were preserved and analyzed using pollution index method, according to the Ministry of Environment and Forestry Republic of Indonesia standard (Indonesian Ministry of Environment Decree No. 115/2003). The freshwater pollution index in this research was assigned by physical, chemical and microbiological parameters. TSS (total suspended solids), DO (dissolved oxygen), BOD (biochemical oxygen demand), COD (chemical oxygen demand), phosphate, fecal coliform and

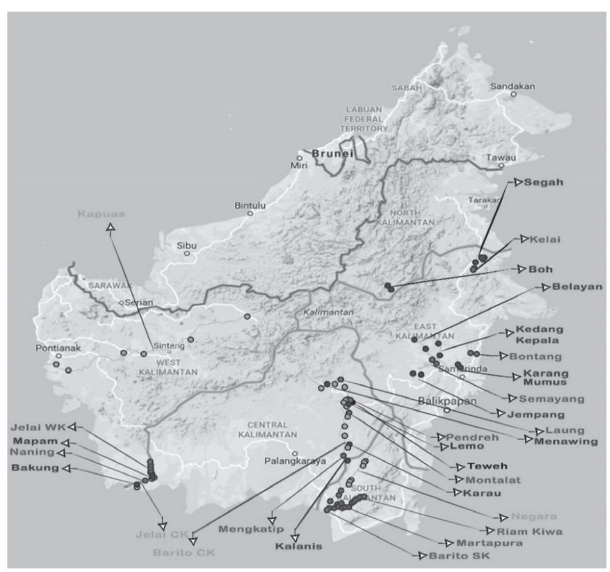

Fig. 1. Map of sampling location with investigated rivers and lakes

total coliform were parameters that applied to identify the level of pollution occurred.

The Indonesian government has established water quality standards for individual water systems or part of the rivers that can be changed depending on the enhancement of water quality. It is classified into four classes (Asian Development Bank, 2016). In this research, each parameter was adjusted to the class II water quality, which commonly used for water resources that the class has not been set. Based on Indonesian Government Regulation No. 82/2001, class II is for water that can be used for water recreation, fresh fish preservation, livestock, water for irrigation, and other usages requiring the similar quality (Indonesian Government Regulation No. 82/ 2001).

Water quality status

In this research, TSS, DO, BOD, COD, phosphate, fecal and total coliform were used to assess the water quality status of water resources in 80 monitoring stations. Water quality status was calculated using the Nemerow pollution index (NPI) method which was developed by Sumitomo and Nemerow (1970). This index is mentioned as the pollution index, which is used for determining the level of pollution relative to allowed water quality parameter (Nemerow, 1974). The calculation of this index takes three steps as follows: (i) correlate the classification of each parameter based on the national water quality standards, (ii) determine the corresponding pollution index for each classification, and (iii) determine the water quality classification by calculating the Nemerow comprehensive index. The evaluation of the pollution level is based on water standard quality divided into four categories in Table 1. The great NPI_{avg} should be less than or equal to one.

Table 1. Water quality classification based on NPI value

NPI	Water quality
$0 < NPI_{avg} < 1.0$	Meeting standard quality
$1.0 < NPI_{avg} < 5.0$	Slightly polluted
$5.0 < NPI_{avg} < 10$	Moderately polluted
$NPI_{avg} > 10$	Heavily polluted

The NPI is a simplified pollution index and it is given as-

$$NPI = \sqrt{\frac{(C_i/L_i)_M^2 + (C_i/L_i)_A^2}{2}} \quad .. (1)$$

with the note that

$$(C_i/L_i) = \begin{cases} (C_i/L_i), & (C_i/L_i) \leq 1 \\ 1 + P.\log(C_i/L_i), & (C_i/L_i) > 1 \end{cases} \quad .. (2)$$

where NPI is the Nemerow pollution index, C_i is the measured value of parameter i, L_i is the desired water quality standard value of parameter i, $(C_i/L_i)_M$ is the maximum value of C_i/L_i, $(C_i/L_i)_A$ is the average value of C_i/L_i, and P is a constant that adjusted to the environmental observation and desired requirements of water quality class (usually is 5). Li values for different water quality parameters studied in this research refer to permissible values of each parameter for water class II in Indonesia (Table 2).

Table 2. Class II water criteria

Parameters	Permissible Values (Water Class II) L_i
TSS	50 mg/L
DO	4 mg/L
BOD	3 mg/L
COD	25 mg/L
PO_4	0.2 mg/L
Fecal Coli	1000 cells/100 mL
Total-Coliform	5000 cells /100 mL

As to DO, which the value decreases if the level of pollution increase, then apply

$$(Ci/Li)_{new} = \frac{C_{im} - C_i}{C_{im} - L_i} \quad .. (3)$$

$(C_i/L_i)_{new}$ is the new value of C_i/L_i from measurement and C_{im} is the saturated dissolved oxygen concentration.

RESULTS AND DISCUSSION

Water Quality Data

Water pollution index monitoring was conducted in 29 water bodies in Kalimantan. Those were 9 in the East and North Kalimantan, 4 in South Kalimantan, 14 in Central Kalimantan and 2 in West Kalimantan. In this study, 7 important indicators related to water quality were monitored in determining the water pollution index, TSS for the physical parameter; DO, BOD, COD, and phosphate for chemical parameters; fecal and total coliform as biological parameters. The calculation results of the pollution index of each parameter are presented in Table 3.

The details of the water pollution index of each

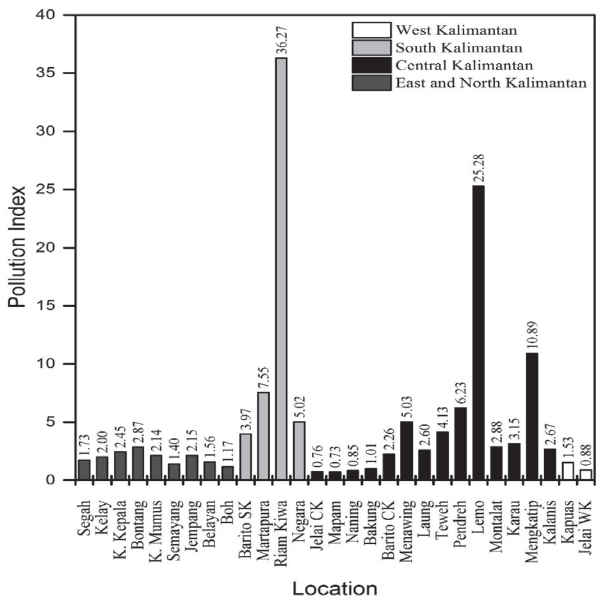

Fig. 2. Water pollution indexes of water bodies in Kalimantan

monitoring location is shown in Fig. 2. Based on the figure, Riam Kiwa river in South Kalimantan had the highest pollution index, calculated as 36.27 with the heavily polluted category. The other rivers, Martapura and Negara were categorized as moderately polluted rivers, while Barito in South Kalimantan was included in the slightly polluted category. The major pollutants in South Kalimantan were fecal coli, total-coliform, phosphate, and BOD, wherein all those pollution indexes at all monitored rivers in South Kalimantan were greater than 1. Hence, it can be said that these parameters exceed the permissible values of class II water criteria.

Heavily polluted Rivers were also found in Central Kalimantan province, that were Lemo and Mengkatip with pollution indexes 25.28 and 10.89 respectively. Besides DO, all indicators on both rivers exceeded the quality standard. However, there were three rivers in Central Kalimantan that have a low pollution index for all parameters,

Table 3. Pollution indexes of each parameter in Kalimantan

Province	Rivers and Lakes	Pollution index of parameters (C_i/L_i)-						
		TSS	DO	BOD	COD	Phosphate	Fecal Coli	Total-Coli
	Segah	0.26	0.38	2.40	0.48	0.01	0.00	0.02
	Kelay	0.17	0.35	2.77	0.58	0.00	0.01	0.01
	KedangKepala	0.62	0.03	3.37	0.73	0.32	0.27	0.09
East and North	Bontang	0.08	0.32	3.98	0.97	0.10	0.01	0.08
Kalimantan	KarangMumus	1.39	0.28	2.88	1.03	0.33	0.41	0.19
	Semayang	0.28	0.18	1.91	0.73	0.27	0.01	0.08
	Jempang	0.21	0.19	2.99	0.61	0.05	0.01	0.01
	Belayan	0.50	0.13	2.14	0.62	0.03	0.24	0.17
	Boh	0.63	0.12	1.59	0.46	0.38	0.02	0.03
South Kalimantan	Barito	1.30	0.18	4.39	1.33	1.09	5.20	1.32
	Martapura	1.26	0.01	4.48	1.36	1.35	10.02	3.53
	RiamKiwa	1.48	0.02	2.50	0.78	2.06	49.80	29.37
	Negara	0.62	0.17	3.07	0.89	1.70	6.64	4.30
Central Kalimantan	Jelai	0.59	0.28	0.91	0.94	0.46	0.20	0.12
	Mapam	0.19	0.30	0.86	0.87	0.70	0.65	0.28
	Naning	1.10	0.33	0.72	0.80	0.36	0.09	0.06
	Bakung	1.28	0.27	1.02	1.07	0.29	0.14	0.28
	Barito	0.59	0.10	2.40	2.93	2.07	0.67	0.15
	Menawing	1.26	0.01	1.43	2.55	0.88	6.80	1.62
	Laung	0.28	0.05	2.72	3.49	0.65	0.71	0.14
	Teweh	5.28	0.11	4.60	4.12	0.38	2.57	0.51
	Pendreh	3.53	0.07	3.47	5.95	0.28	8.18	1.64
	Lemo	34.64	0.12	7.52	6.29	3.60	8.11	1.76
	Montalat	1.29	0.08	3.32	3.77	1.95	0.19	0.18
	Karau	0.49	0.24	0.35	0.85	4.25	0.99	2.23
	Mengkatip	1.07	0.20	4.42	3.91	1.70	14.80	3.66
	Kalanis	0.43	0.22	0.87	1.03	0.73	2.22	3.54
West Kalimantan	Kapuas	1.49	0.16	0.44	0.30	2.06	0.001	0.19
	Jelai	0.09	0.13	1.17	0.54	1.04	0.001	0.02

namely Jelai, Mapam and Naning which are located in the western part of Central Kalimantan province. All pollution indices on the three rivers were within the permissible limit for class II water, except for the Naning River with pollution index for TSS was 1.10 that exceeded class II water quality standard. Kalanis, Karau, Montalat, Teweh, Laung, Bakung and Barito in Central Kalimantan were categorized as slightly polluted, while the rest, Pendreh and Menawing were categorized as moderately polluted rivers. Kapuas and Jelai Rivers became monitoring points of the water pollution index in West Kalimantan and were classified as the category of slightly polluted and meeting standard quality respectively. TSS and phosphate parameters in the Kapuas River exceeded the standard value of permissible pollution index, while in Jelai the exceeding parameters were BOD. The main pollutant parameters in rivers and lakes in East Kalimantan were BOD, whereat all the observed locations indicate that the BOD exceeded class II water criteria. The Karang Mumus River, which is located in the capital of East Kalimantan province, had three pollution parameters that exceeded the standard value, which were TSS, BOD, and COD. Two national priority lakes of East Kalimantan, Semayang, and Jempang, had BOD parameter that exceeded the standard quality of water class II. Overall, all the rivers and lakes monitored in East Kalimantan had pollution indexes were included in the category of slightly polluted water.

Microbiological pollutants, total and fecal coliform were the biggest polluter in several river systems in Kalimantan. A total 10 rivers in South and Central Kalimantan had pollution index greater than 1, where 5 of them fell into the category of heavily polluted and 3 were included in moderately polluted when observed from fecal coli parameter. The lifestyle of local people is the main triggers of biological pollution indicators. Bathing, washing, defecating and disposing of wastewater activities of local residents in South Kalimantan still depend on stream (Elson, 2012), while these activities increase the contamination of microbes and as a result increase the pollution indexes of microbiological parameters.

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen required for aerobic biological organisms in a water body to break the organic components available in a given water sample at a certain temperature over a particular time period (Ahmed and Shah, 2015). BOD indicates the quantity of putrescible organic matter present in a water sample (Zare Abyaneh, 2014). Therefore, low BOD is an indicator of good quality water. Almost in all of the monitoring locations, index pollution of the BOD was higher than 1, except Jelai, Mapam, Naning, Karau in Central Kalimantan and Kapuas in West Kalimantan. Lemo had the highest pollution index of BOD, which was 7.52. The high BOD might due to the decomposition process of organic matter by microbes that consumed oxygen.

Chemical Oxygen Demand (COD) did not meet the quality standard (class II) in some monitored location, such as Karang Mumus in East Kalimantan, Barito, and Maratapura in South Kalimantan, and also all monitored rivers in Central Kalimantan besides Jelai, Mapam, Naning, and Karau. COD in Pendreh and Lemo in Central Kalimantan categorized as moderately polluted. This was most likely caused by the decomposition of organic matter in the form of leaves, trunks, etc., that consumed much oxygen, and also the lack of sewerage systems (Kido *et al.*, 2009; Effendi *et al.*, 2015). Rivers that contained high COD is not suitable for fisheries and agriculture.

Phosphate was one of the major pollutants in Kalimantan, although in the limit of slight contamination. It happened in around 11 monitored rivers in Kalimantan. Phosphate concentration signifies the nutrient levels and eutrophication of the river. Discharge this nutrient into rivers leads to eutrophication by stimulating the growth of undesired plants such as algae and aquatic macrophytes (Abdel-Raouf *et al.*, 2012). This pollutant is mainly originated from high-phosphate household dishwasher detergent, industrial and domestic wastewater and agricultural wastewater (Haji Gholizadeh *et al.*, 2016; Cohen and Keiser, 2017).

Total Suspended Solid (TSS) was categorized as a slight polluter in Naning, Bakung, Menawing, Pendreh, Montalat and Mengkatip in Central Kalimantan, and also Barito, Martapura and Riam Kiwa in South Kalimantan. However, only Karang Mumus in East Kalimantan and Kapuas in West Kalimantan were categorized as moderately polluted, and then Lemo and Teweh in Central Kalimantan were categorized as heavily polluted based on TSS pollution indexes. A high concentration of TSS reduces water clarity and increases the temperature of water since solid materials absorb heat from sunlight (Marinez and Galera, 2011). High TSS might be due to the clearing of peat swamp forest for agricultural purposes, oil palm plantations, logging and drainage, local roads and mining activities which have been widespread throughout Kalimantan area (Larsen *et al.*, 2013; Medrilzam *et al.*, 2017). These activities cause erosion in the topsoil and soft river banks. As a result, it increases the concentration of suspended particles in water. In addition, any potentially harmful substance that is added by residing in the water body also contributes to the TSS concentration.

Regardless of the parameters described above, Dissolve Oxygen (DO) of rivers in Kalimantan ranging from 0.01 – 0.38 was meeting the standard quality. DO is the concentration of dissolved oxygen in thewater. DO concentrations determine ecosystems and habitats in water, and also affect metabolic rates of aquatic organisms, predation risk, and inuence organism behavior and fish community structure (Null *et al.*, 2017).

Jong *et al.* (2015) found that the pollution of water in Kalimantan can be attributed to the extensive forest fires that raged in Kalimantan. The fires possibly result in an addition of nutrients and organic substances into water bodies, explaining the high levels of phosphate, TSS and COD. Forest fires also result in an increase in phosphate availability entering the water system through runoff and deposition. The increase of phosphate and ash particles generates higher levels of COD and low transparency of water. Moreover, the high level of TSS in water is also caused by the ash input from fires.

Water Quality Status of Kalimantan

Fig. 3 shows the classification of water quality based on the Nemerow pollution Index (NPI). NPI calculation results show that there are samples from 4 locations that meet the standard quality, 18 locations have slightly polluted water, 4 locations have moderate pollution water quality and 3 locations are heavily polluted. The variation of water qualities is caused by pollution in some sites, a fact which might be due to the differences in activities being conducted near the sites in different locations. Based on analyzing water qualities in each water body, the average value of pollution indexes in Kalimantan was 5.34. This can be categorized as moderately polluted water.

Water quality of Kalimantan in this research was lower when compared with the previous years (Ministry of Environment and Forestry Republic of Indonesia, 2011-2014). Decreased water quality in Kalimantan requires effective control strategies form local governments in preventing and mitigating water pollution and restoring water quality so that the quality of water is maintained in accordance with its designation.

The results of water quality monitoring in Kalimantan with some pollutant parameters, which were TSS, DO, BOD, COD, phosphate, fecal coliform and total coliform, especially in heavily polluted rivers, indicate that the main sources of organic waste and river sediments are domestic waste, agricultural waste like palm plantations, gold and coal mining and washing activities. In addition to natural factors, the increase of organic and chemical waste is mainly due to the population growth rate in all provinces in Kalimantan, whereas the increase of solid in water is mainly due to the increase in clearing forest and mining activities in Kalimantan.

CONCLUSION

Water quality conditions in Kalimantan was classified as moderately polluted water based on the pollution index. Microbe pollutants were one of the main pollutants of water bodies in Kalimantan that was signified by pollution indexes of total and fecal coliform. In most of rivers, BOD, COD and TSS exceeded standard values of class II water criteria, in which some rivers in Central Kalimantan were categorized as moderately and heavily polluted water. Pollution by phosphate was also suffered by almost all ofthe rivers, nevertheless, all of those were within the limit of lightly polluted category. This

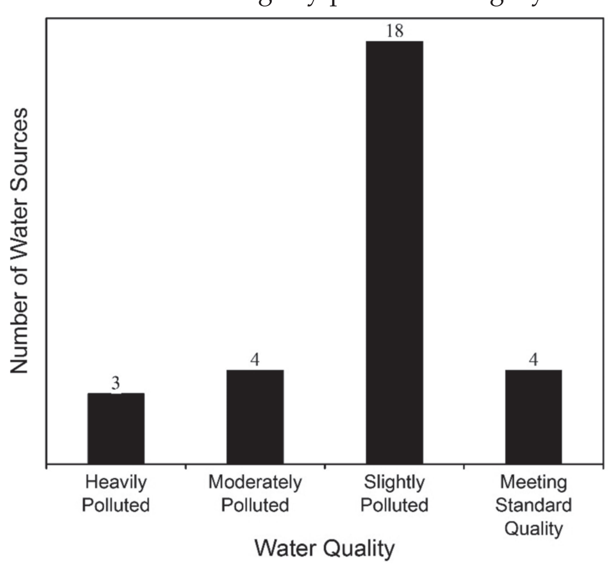

Fig. 3. Water quality based on NPI

condition might be mainly due to the population growth rate, destruction of forest, and the increase of mining activities in Kalimantan.

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