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Research Article

Palm oil industry effect on water quality status of Pawan and Jelai Rivers in Ketapang Regency in 2012-2016

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Abstract: Pawan and Jelai Rivers are two of the three main rivers in Ketapang Regency, West Kalimantan. The extensive growth of palm oil industry in Ketapang might affect the aquatic environment, especially the rivers, due to excessive uses of water. Therefore, the aims of this study were to examine the effect of palm oil industry on the changes in water quality status of Pawan and Jelai Rivers in Ketapang regency during 2012-2016 and to identify critical parameters that might determine the water quality status in the two rivers. This study used the laboratory testing results of Pawan and Jelai Rivers, which were carried out periodically by various companies/institutions. There were 24 physical, chemical, and microbiological parameters that were analyzed to determine the water quality status using STORET method. Critical parameters were determined by comparing parameters analyzed with their threshold values. The results revealed that Pawan and Jelai Rivers passing through oil palm plantations and palm oil mills were moderately to highly polluted in 2012, 2014 and 2016. Critical parameters of the river water quality are BOD, COD, Cl_2, phenol, Fe, and total *Coliform*.

Keywords*: Jelai River, Pawan River, STORET method, water quality status*

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Introduction

Ketapang is the largest regency, compared to 14 other regencies/cities, in West Kalimantan Province. The area of Ketapang is 31,588 km^2, or around 21.28 % of the total area of West Kalimantan which is 146,807 km^2. The regency has many large and small rivers. The main rivers are Pawan, Jelai, and Kendawangan (BPS of West Kalimantan, 2017). Rivers that spread in this region have very important roles for the social and economy of the local communities.

One of the activities that is highly dependent on the rivers in Ketapang is plantations. Oil palm commodities in Ketapang contributed 90.39 % to the total plantation products in 2016, with total production reaching 360,201 tons (BPS of Ketapang, 2017). Furthermore, Ketapang also has the largest number of palm processing plants in West Kalimantan. There are 16 palm oil mills in Ketapang from a total of 64 factories in West Kalimantan (GAPKI, 2017).

Nowadays, the rapid growth of the palm oil industry has become a major concern due to its effects on the environment, including river water quality. The pollutants could come from the wastewater of palm oil factories that is not well managed, as well as from the plantations that have bad land management. Several studies have been conducted to find out the possible effects of palm oil mill effluents (POME) on river water quality in Indonesia. A study by Zahara et al. (2016) discovered that the disposal of POME by palm oil mills have an adverse effect on water river quality in Mabat River on Bangka regency. In addition, research by Muliari and Zulfahmi (2016) showed that POME disrupted the phytoplankton structure in Krung Mane River, North Aceh Regency.

Considering the issues of palm oil industries in the past few years, it is necessary to study the

possible effects of the oil palm industry on the river water quality in various regions in Indonesia, including in Ketapang. Therefore, the aims of this study were to examine the changes in the water quality status of Pawan and Jelai Rivers in Ketapang regency during 2012-2016, and to identify critical parameters that might determine the water quality status in both rivers.

Materials and Methods

This study employed secondary data from the Institute for Industrial Research and Standardization of Pontianak. The data selected were the results of laboratory testing on the water quality of Pawan and Jelai Rivers (Figure 1). The testing was carried out periodically by various companies/institutions. Only data from sampling sites passing through oil palm plantations/palm oil mills were used to ensure that the river water quality in those sites was strongly affected by oil palm activities.

In total, there were 24 physical, chemical, and microbiological parameters that were analyzed. All the parameters, methods used, and other information are listed in Table 1. River water quality analysis refers to the Indonesian Government Regulation Standards in PP No. 82 of 2001. Meanwhile, the status of water quality was determined by using the Storage and Retrieval of Water Quality Data System (STORET) method according to KepMenLH No. 115 of 2003. STORET was used since the method has been known to be more sensitive compared to the Pollution Index method which is also suggested by KepMenLH No. 115 of 2003 (Barokah et al., 2017). STORET is a method that could be used to determine water quality status using time series data comprising at least two water quality observation data. The STORET method compares water quality data with water quality standards to determine water quality status. In this study, the measured values were compared with water quality class II thresholds. If the measured values exceeded the threshold, a negative score was given. The total score obtained will determine the classification status of river water quality. The water quality classification status in this method is divided into four groups:

1. Class A: very good (meeting the requirements). score= 0
2. Class B: good (lightly polluted), score= -1 to -10
3. Class C: fair (moderately polluted), score= -11 to -30
4. Class D: bad (heavily polluted), score= ≥ -31

After comparing various parameters with their quality standards, critical parameters on the water quality of the Pawan and Jelai Rivers were selected. Critical parameters are parameters that often exceed the quality standard threshold or get the most negative values from the STORET analysis. Additional data from other sampling sites of Pawan and Jelai Rivers were used to confirm these critical parameters.

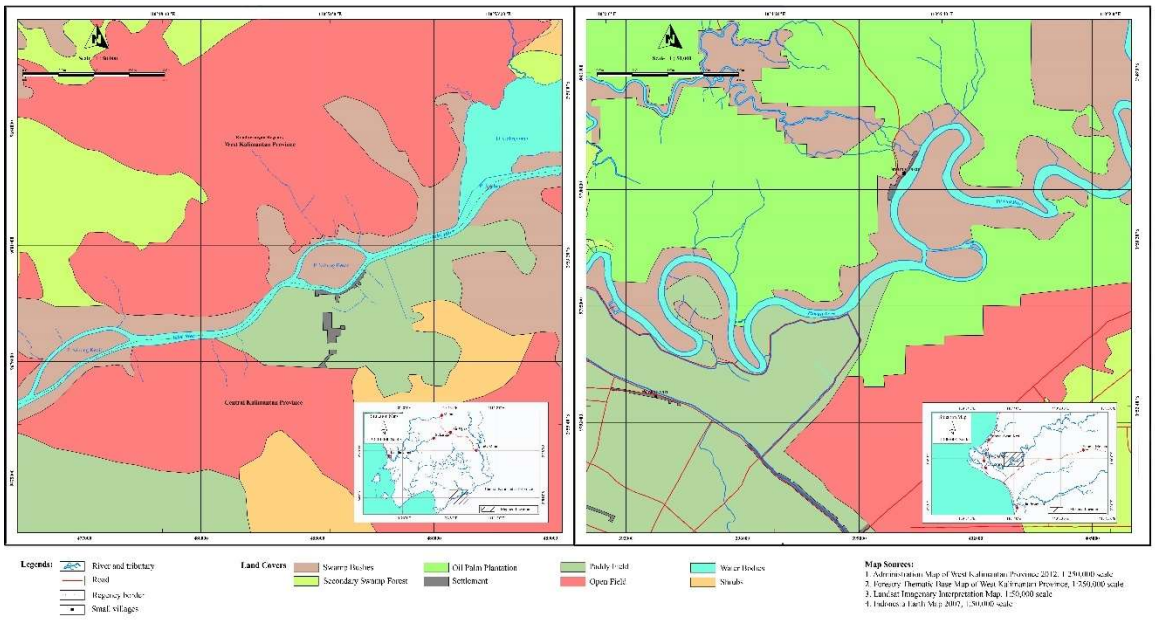

Figure 1. The study area of Pawan (right) and Jelai (left) Rivers and oil palm plantation distribution in Ketapang regency.

Table 1. Parameters and methods used for water quality testing of Pawan and Jelai Rivers according to PP No. 82 of 2001.

No.	Parameters	Units	Threshold Values		Methods
			Water Quality Class I*	Water Quality Class II*	
	Physical				
1	TDS	mg/L	1,000	1,000	SNI 06-6989.27-2005
2	TSS	mg/L	50	50	SNI 06-6989.3-2004
	Chemical				
3	pH	-	6 – 9	6 – 9	SNI 06-6989.11-2004
4	BOD_5	mg/L	2	3	IK 5.4.2.11.02
5	COD	mg/L	10	25	SNI 06-6989.2-2004
6	DO	mg/L	6	4	APHA 4500-OB: 1998
7	P Total	mg/L	0.2	0.2	SNI 06-6989.31-2005
8	NO_3-N	mg/L	10	10	SNI 06-2480-1991
9	NO_2-N	mg/L	0.06	0.06	SNI 06-6989.9-2004
10	NH_3-N	mg/L	0.5	(-)	SNI 06-6989.30-2005
11	Fe	mg/L	0.3	(-)	SNI 6989.4:2009
12	Zn	mg/L	0.05	0.05	SNI 6989.7:2009
13	Cu	mg/L	0.02	0.02	SNI 6989.6:2009
14	Pb	mg/L	0.03	0.03	SNI 6989.8:2009
15	Cl	mg/L	600	600	SNI 6989.19:2009
16	CN	mg/L	0.02	0.02	SNI 6989.76:2011
17	Cl_2	mg/L	0.03	0.03	HACH Method 8021
18	SO_4	mg/L	400	(-)	SNI 6989.20:2009
19	Hg	mg/L	0.001	0.002	SNI 06-2462-1991
20	Fats and oils	mg/L	1	1	SNI 06-6989.10-2004
21	Detergent as MBAS	mg/L	0.2	0.2	SNI 06-6989.51-2005
22	Phenol	mg/L	0.001	0.001	SNI 06-6989.21-2004
	Microbiological				
23	Fecal *Coliform*	colony/100 mL	100	1000	SNI 19-2897-1992 point 2
24	Total *Coliform*	colony/100 mL	1,000	5,000	SNI 19-2897-1992 point 3

*Water quality class I: water for raw water of drinking water
Water quality class II: water for fisheries/infrastructures/water recreational purpose

Results and Discussion

Water quality changes in Pawan and Jelai Rivers

STORET analysis result showed that the water quality status of Pawan and Jelai Rivers fluctuated in 2012, 2014, and 2016. Pawan River was found to be moderately polluted in 2012 and 2014, and heavily polluted in 2016 (Table 2). Increased negative scores indicate that river water quality is likely to get worse each year. Meanwhile, Jelai River was found to be moderately polluted in 2012 and 2016; and heavily polluted in 2014 (Table 2).

Such changes in the water quality status of Jelai River indicate that the water quality of the river might be highly affected by the amount of rainfall in those years. It was found that the water quality status of the Jelai River appears to be directly proportional to the amount of rainfall in Ketapang Regency. Weather data show that the amount of rainfall in Ketapang was 2,645.2 mm in 2012; 2,016 mm in 2014; and 2,731.1 mm in 2016. (BMKG, 2017). Unlike Jelai River, the water quality of Pawan River does not appear to be affected by the amount of rainfall. The water quality of the river seems to be affected by other factors, including river length, water discharge, and watershed area. It is known that the length of the Pawan River is 197 km, with a watershed area of 13,400 km^2; while the length of the Jelai River is 135 km, with a watershed area of only 5,400 km^2 (BPS of West Kalimantan). Although the status of the two rivers was classified as moderate and heavy polluted, it is important to acknowledge that the sampling sites were taken out on part of rivers that pass/close to palm oil mills or oil palm plantations.

Table 2. Water quality status of Pawan and Jelai River in 2012, 2014, and 2016.

River	2012		2014		2016	
	Score	Water Quality Classification	Score	Water Quality Classification	Score	Water Quality Classification
Pawan	-8	Class C (moderately polluted)	-20	Class C (moderately polluted)	-36	Class D (heavily polluted)
Jelai	-24	Class C (moderately polluted)	-60	Class D (heavily polluted)	-16	Class C (moderately polluted)

That may not represent the overall reflection of water quality in the two rivers. The quality of river water in other areas might be different, considering the length of the two rivers. Nevertheless, the low quality of water in both rivers still needs to be considered by related parties because of the important role of Jelai and Pawan Rivers. Immediate actions were required to reduce river water pollutions, especially those related to the palm oil industry.

Critical Parameters of Pawan and Jelai Rivers' Water Quality

The low water quality of both rivers was the accumulation of various pollutants that come from many tributaries. Therefore, to determine the main pollutant sources in Jelai and Pawan Rivers, critical parameters need to be specified. The critical parameters obtained in this study were determined from two sampling sites in Pawan River, and three sampling sites in Jelai River. After the critical parameters are known, it is expected that the main pollutant sources could be identified for immediate corrective actions. The critical parameters obtained in this study were BOD, COD, free chloride (Cl_2), phenol, iron (Fe), and total *Coliform*.

BOD and COD

BOD (Biological Oxygen Demand) is the amount of oxygen required by microorganisms to oxidize organic substances in water. Meanwhile, COD (Chemical Oxygen Demand) shows the need for chemical oxygen for oxidation of organic compounds in water. The measurements of BOD and COD from several sites on the Jelai and Pawan Rivers during 2012-2016 revealed that these two parameters often exceeded the water quality class II threshold, occasionally exceeding the water quality class I threshold (Figures 2 and 3).

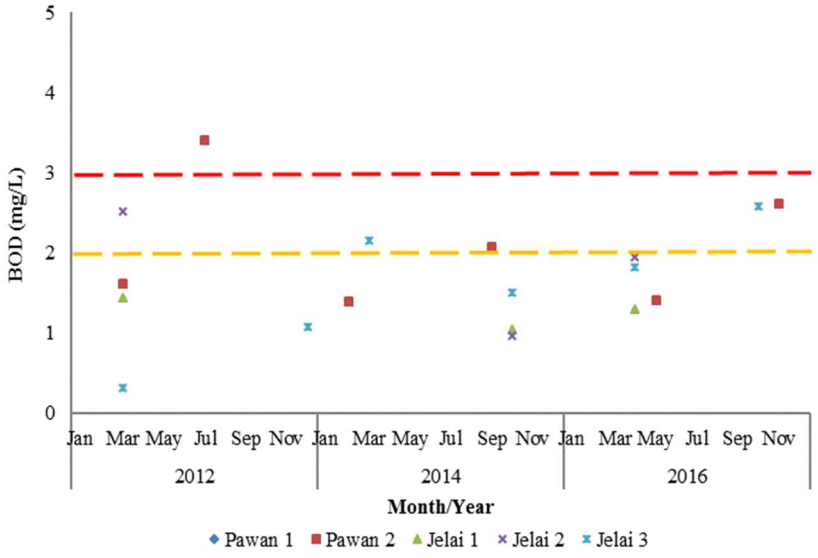

Figure 2. BOD values of Pawan and Jelai Rivers in 2012, 2014, and 2016.
(red dashed line is threshold value for water quality class I, yellow dashed line is threshold value for water quality class I).

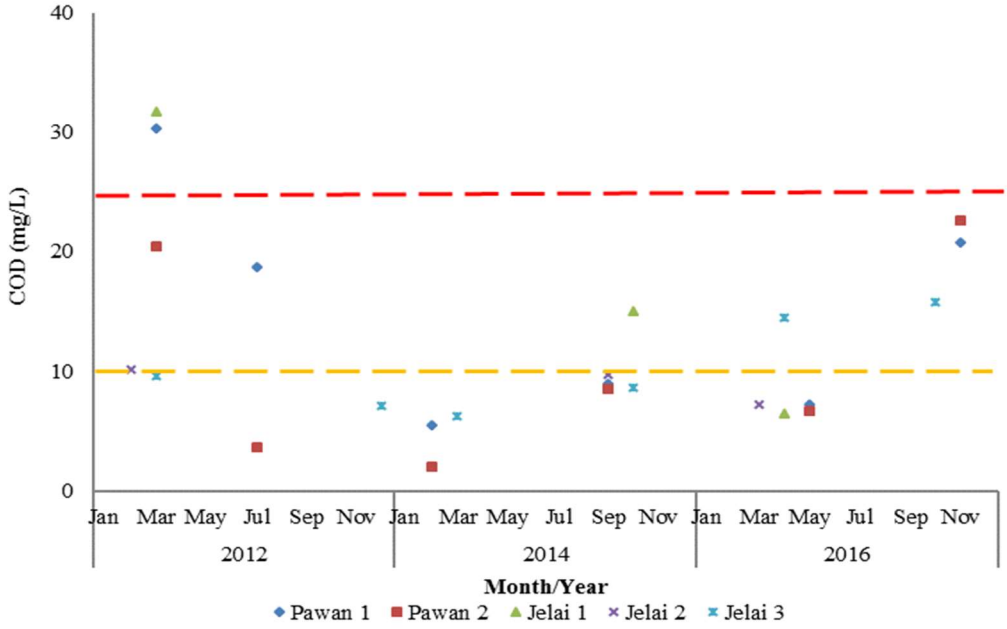

Figure 3. COD values of Pawan and Jelai Rivers in 2012, 2014, and 2016.
(red dashed line is threshold value for water quality class I, yellow dashed line is threshold value for water quality class II).

High levels of BOD and COD indicate the high levels of suspended organic pollutants and dissolved substances in both rivers.The main pollutant that causes high levels of BOD and COD in river water usually comes from the disposal of industrial wastewater. Considering that most palm oil mills are located near to rivers, it could be presumed that high levels of BOD and COD are likely to come from those mills. It is known that palm oil mill effluent (POME) has BOD of 25,000 ppm and COD of around 60,000 ppm (Comte et al, 2012). The high levels of BOD and COD in river water could also indicate that the POME produced by palm oil mills along the Jelai and Pawan Rivers and their tributaries were not well managed.

The high levels of BOD and COD in the river water due to palm oil mills are also supported by Edward et al. (2015) study which monitored the water quality of the Anyanyan River in Nigeria which passes palm oil mills. The BOD and COD levels in the river exceeded the specified threshold values. Meanwhile, a study by Nadzir et al (2019) showed that COD level in Pahang River in Malaysia was below the specified threshold value as the river only passes oil palm plantations.

Free Chlorine (Cl_2)

The free chlorine concentration in Pawan and Jelai Rivers often exceeded the water quality class I and II thresholds set by the Government through PP No.82 2001 (Figure 4). This condition needs serious attention because high chlorine concentrations in the aquatic environment can endanger the lives of various aquatic organisms. Many studies have been conducted to examine the lethal and sub lethal effects of chlorine compounds on aquatic animals, including invertebrates and fishes. Wan et al. (2000) found that 50% mortality (LC_{50}) in the population of Daphnia magna was caused by 0.017 mg/L exposure to inorganic chloramines over 48 hours. Another study by Williams et al. (2003) showed that benthic macro invertebrate community structure (abundance and number of taxa) substantially decreased (sometimes to zero) in river sites exposed to chlorinated sewage.

Most chlorine comes from wastewater treatment and water purification plants. Chlorine compounds have been used as disinfectants in those systems for years because they are effective, inexpensive, and remain active within the systems for a considerable period (Lee and Westerhoff, 2009). Water purification plants in palm oil mills should be the sources of the chlorines. Chlorines are used for disinfecting raw water obtained from the river that is collected in water tanks. This raw water then could be used for washing and boiling process, and for factory domestic needs. Therefore, discharging this chlorinated water into water stream in a long time would make chlorine concentration in the river higher.

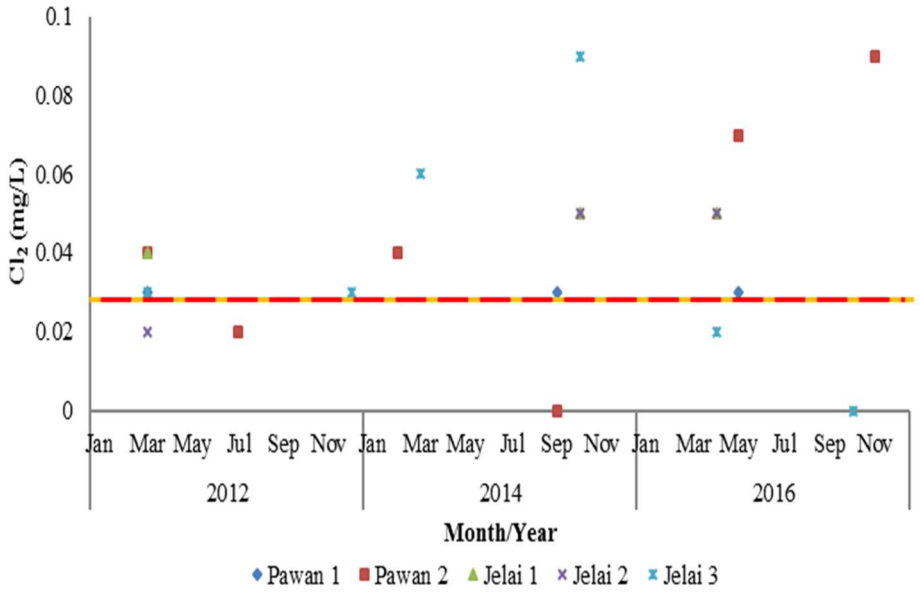

Figure 4. Free chlorine (Cl_2) concentration of Pawan and Jelai Rivers in 2012, 2014, and 2016. (red dashed line is a threshold value for water quality class I, the yellow dashed line is a threshold value for water quality class II).

Phenol

Phenol compounds are chemicals listed as pollutants with a priority interest by the United States Environmental Protection Agency (USEPA) and European Union (EU) (Anku et al., 2017). Consequently, high phenol concentrations in the aquatic environment should be a concern because of the toxicity and long-term accumulations. Similar to Cl_2 parameter, phenol concentration in Pawan and Jelai Rivers also often exceeded the water quality class I and II thresholds in 2012, 2014, and 2016 (Figure 5).

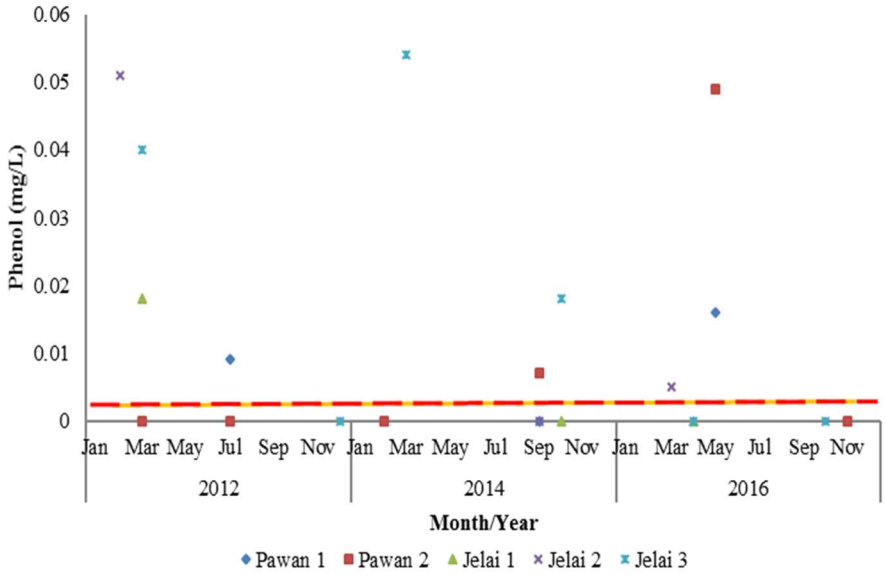

Figure 5. Phenol concentration of Pawan and Jelai Rivers in 2012, 2014, and 2016. (red dashed line is a threshold value for water quality class I, the yellow dashed line is a threshold value for water quality class II).

Natural sources of phenol in water bodies are generally produced through the decomposition of animals and plants in water, including through synthesis by microorganisms and aquatic plants. Phenol due to anthropogenic factors is mostly produced by industrial and agricultural/plantation activities (Anku et al., 2017; Pal and Chakraborty, 2017). It is predicted that the phenol in Pawan and Jelai Rivers come from the excessive application of pesticides, insecticides, or herbicides containing phenol compounds in the oil palm plantations (Anku et al., 2017). Utilization of excessive pesticides and herbicides could contaminate the rivers due to the leaching process of pollutants by rainwater. Therefore, due to the wide area of oil palm plantations in Ketapang, further surveys and monitoring of Pawan and Jelai tributaries passing the oil palm plantations are required to find the main area and sources of this phenol pollutant.

Iron (Fe)

Iron (Fe) is one of heavy metals that also acts as a micronutrient. The United States Environmental Protection Agency (USEPA) classifies Fe in water as a secondary contaminant, which means that Fe does not have a direct impact on health. In Indonesia, Fe concentration in the water used as raw water for drinking water is set at a maximum of 0.3 mg/L; there is no threshold value for Fe concentration in water that is used for recreational facilities or fisheries purposes (Table 1). Based on the monitoring of water quality in Pawan and Jelai Rivers during 2012-2016, it is found that Fe levels are rarely below the water quality class I threshold value of 0.3 mg/L (Figure 6). Therefore, the data suggest that Pawan and Jelai Rivers should never be used as drinking water sources.

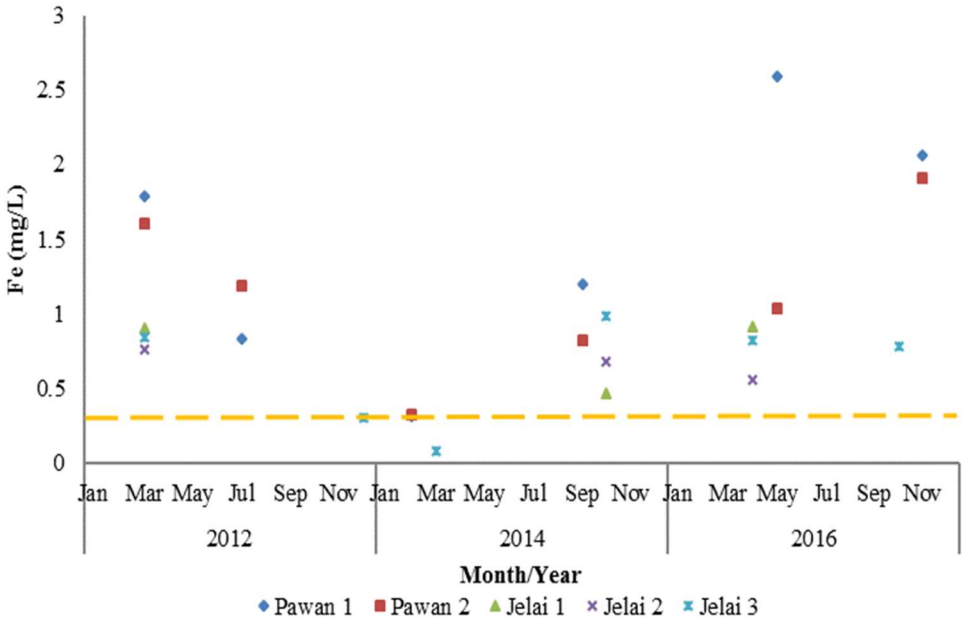

Figure 6. Iron concentration of Pawan and Jelai Rivers in 2012, 2014, and 2016. (yellow dashed line is a threshold value for water quality class II).

The relatively high levels of Fe in both rivers are suspected to come from the peatlands widely distributed in various areas of West Kalimantan, including in Ketapang Regency. One of the characteristics of tropical peat is high Fe concentration (Noor et al., 2014). A high concentration of Fe in other regions of West Kalimantan was also reported in groundwaters in Singkawang City (Aisyah et al., 2017) and peat water in Pontianak City and Kubu Raya regency (A'idah et al., 2018).

Total Coliform

Coliform is a group of Gram-negative rod-shaped bacteria, oxidase-negative, aerobic to facultative anaerobes, not forming spores, able to grow aerobically on agar media containing bile salts, and able to ferment lactose by forming gases and acids

within 48 hours at a temperature of 37 °C. *Coliform* bacteria include the genera of *Citrobacter, Enterobacter, Escherichia, Hafnia, Klebsiella, Serratia*, and *Yersinia*. Total *Coliform* in water could be used as an indicator of contamination of pathogenic bacteria from human and animal faeces (Horan, 2013).

The microbiological parameters in the Pawan and Jelai Rivers are crucial because these parameters have the highest multiplier factor in the STORET method. Microbiological parameters could also directly reflect the quality of river water and have a direct impact on aquatic and human life. Therefore, even though this parameter exceeded the water quality class II threshold value on the Jelai River once (Figure 7), these parameters gave high negative scores in the STORET analysis.

The *Coliform* bacteria in Pawan and Jelai Rivers might come from oil palm plantations that use organic fertilizers or manures since the use of those fertilizers are common in the area. The excessive use of organic fertilizers could pollute the rivers if the organic fertilizers are carried away by rainfall (Pradipa and Widyastuti, 2018). Pollutant sources from human faeces are very unlikely, considering the sampling sites that were far from the settlement.

In addition to human and animal faecal contamination, *Coliform* concentration in river water could be influenced by other factors. Rahmawati et al. (2017) concluded that total *Coliform* parameters in Jawi River, Pontianak city were positively correlated with BOD and pH parameters. On the other hand, Pradipa and Widyastuti (2018) showed that total *Coliform* positively correlated with rainfall and river flow rate in Pindul Watershed, Gunung Kidul Regency, Yogyakarta.

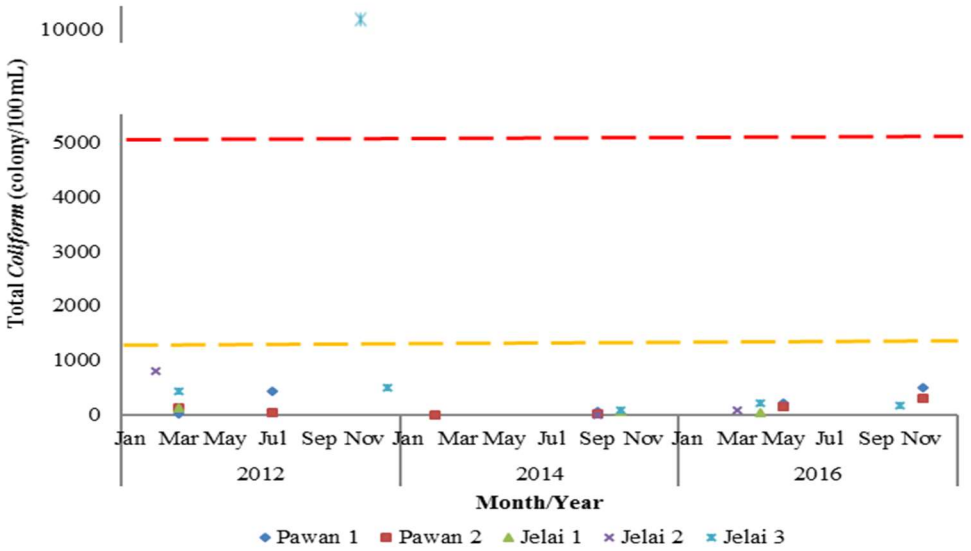

Figure 7. Total *Coliform* concentration of Pawan and Jelai Rivers in 2012, 2014, and 2016. (red dashed line is a threshold value for water quality class I, the yellow dashed line is a threshold value for water quality class II).

Conclusion

Pawan and Jelai Rivers in Ketapang Regency, passing through oil palm plantations and palm oil mills, were found to be moderately to highly polluted in 2012, 2014 and 2016. Critical parameters of Pawan and Jelai Rivers' water quality are BOD, COD, Cl_2, phenol, Fe, and total *Coliform*. The parameters of BOD, COD, and Cl_2 might be affected by the activities of palm oil mills. Phenol and total *Coliform* parameters might be affected by activities in oil palm plantations. Meanwhile, the high Fe content in Pawan and Jelai Rivers is a natural condition in the area.

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References

A'idah, E., Destiarti, L. and Idiawati, N. 2018. Determination of peat water characteristics in Pontianak City and Kubu Raya District. *Jurnal Kimia Khatulistiwa* 7(3):91-96 (*in Indonesian*).

Aisyah, A.N. 2017. Analysis and identification of groundwater quality status in Singkawang City: a case study in North Singkawang District. *Jurnal Teknologi Lingkungan Lahan Basah* 5(1) (*in Indonesian*).

Anku, W.W., Mamo, M.A. and Govender, P.P. 2017. Phenolic compounds in water: sources, reactivity, toxicity and treatment methods. In Phenolic compounds-natural sources, importance and applications. *IntechOpen*. http://dx.doi.org/10.5772/66927.

Barokah, G.R., Ariyani, F. and Siregar, T.H., 2017. Comparison of STORET and pollution index method to assess the environmental pollution status: a case study from Lampung Bay, Indonesia. *Squalen Bulletin of Marine and Fisheries Postharvest and Biotechnology* 12(2): 67-74.

BPS-Statistics of West Kalimantan. 2017. *West Kalimantan in Figures 2017*. BPS-Statistics of West Kalimantan, Pontianak, 503 pp.

BPS-Statistics of Ketapang. 2017. *Ketapang in Figures 2017*. BPS-Statistics of Ketapang, Ketapang, 504 pp.

Comte, I., Colin, F., Whalen, J.K., Grünberger, O. and Caliman, J.P. 2012. Agricultural practices in oil palm plantations and their impact on hydrological changes, nutrient fluxes and water quality in Indonesia: a review. In *Advances in Agronomy* 116:71-124.

Edward, J.B., Idowu, E.O. and Oyebola, O.E. 2015. Impact of palm oil mill effluent on physic-chemical parameters of a southwestern River, Ekiti state, Nigeria. *Journal of Natural Sciences Research* 4(14):26-30.

Horan, N.J. 2003. Faecal indicator organisms. *The Handbook of Water and Wastewater Microbiology*, pp.105-112.

Indonesian Palm Oil Association (GAPKI) of Kalimantan Barat. 2017. Palm Oil Processing Plants in West Kalimantan Province. http://www.gapki-kalbar.or.id/laporan.php [accessed 8-12-2017] (*in Indonesian*).

Lee, W. and Westerhoff, P. 2009. Formation of organic chloramines during water disinfection–chlorination versus chloramination. *Water Research* 43(8): 2233-2239.

Meteorological, Climatological, and Geophysical Agency (BMKG). 2017. Ketapang Regency Daily Climate Data in 2012, 2014 and 2016. http://dataonline.bmkg.go.id [accessed 14-3-2017] (*in Indonesian*).

Muliari, M. and Zulfahmi, I. 2016. Impact of palm oil mill effluent towards phytoplankton community in Krueng Mane River, North Aceh. *Jurnal Perikanan dan Kelautan* 6(2): 137-146.

Nadzir, N.S.C., Abdullah, M.Z. and Sulaiman, F.R. 2019. Surface water quality in palm oil plantation. *Malaysian Journal of Fundamental and Applied Sciences* 15(1): 85-87.

Noor M., Masganti, and Agus, F. 2014. *Formation and Characteristics of Indonesian Tropical Peat*. Jakarta: IAARD Press (*in Indonesian*).

Pal, S. and Chakraborty, K. 2017. Different Aspects of Chloride in Freshwater: A Review. *International Journal of Current Trends in Science and Technology* 7 (8): 20295-20303.

Pradipa, H. and Widyastuti, M. 2018. Temporal variability of *Coliform* bacteria as an indicator of pollution in the surface river system of the Pindul Catchment Area. *Jurnal Bumi Indonesia* 7(3) (*in Indonesian*).

Rahmawati, R., Fitria, L. and Syafitri, L. 2017. Correlation of Physical-chemical parameters to total *Coliform* value in Jawi River, Pontianak, West Kalimantan. Biosaintifika: *Journal of Biology & Biology Education* 9(2): 370-379.

Williams, M.L., Palmer, C.G. and Gordon, A.K. 2003. Riverine macroinvertebrate responses to chlorine and chlorinated sewage effluents-Acute chlorine tolerances of *Baetis harrisoni* (Ephemeroptera) from two rivers in KwaZulu-Natal, South Africa. *Water SA* 29(4): 483-488.

Wan, M.T., Van Aggelen, G., Cheng, W. and Buday, C. 2000. Validation of the acute toxicity of inorganic chloramines to the fresh water invertebrate *Daphnia magna*. *Bulletin of Environmental Contamination and Toxicology* 64(2): 213-220.

Zahara, S., Umroh, U. and Utami, E. 2016. Effect of palm oil mill liquid waste disposal on Mabat River Bangka River water quality. *Akuatik: Jurnal Sumberdaya Perairan* 10(1): 21-25 (*in Indonesian*).