

Analysis of Surface Water Quality of Four Rivers in Jayapura Regency, Indonesia: CCME-WQI Approach

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ABSTRACT

In Indonesia, the river water quality has been determined based on Government Regulation of the Republic of Indonesia No. 22 of 2021. This study aimed to determine the quality of surface water from the Damsari, Jabawi, Kleblow, and Komba Rivers in Jayapura Regency based on the monitoring data from 2016 to 2019. The CCME-WQI method is used to determine the status of rivers based on river water quality standards (class 1 to class 4). The results of the study showed that the parameters of water temperature, TDS, pH, NH₃, NO₃⁻, SO₄⁻², surfactant, oil/grease, Cr-(IV), Mn, Fe, Fecal Coliform, and Total Coliform were still in accordance with the quality standard. Meanwhile, TSS, COD, BOD, Total Phosphate, Hg, and Ni have exceeded the water quality standard, where the dominant pollutant source is an anthropogenic waste. On the basis of the WQI average value, the four rivers are not suitable as a source of drinking water (Poor-Marginal; 41.33 – 58.25). The Jabawi River can be used as a recreational facility, but it must be under special management (Fair; 69.75), while the other three rivers are not suitable (Marginal; 52.00 – 61.67). The Jabawi and Komba Rivers are in the Fair category (75.50 and 69.33) to support aquatic life, while the Damsari and Kleblow Rivers are in the Marginal category (59.00 and 61.25). The water quality of the four rivers is very good and suitable to be used as a water source for irrigation (Good category; 80.00 – 88.00). The strategies for controlling river water pollution and increasing the role of the government, stakeholders, and the community are needed.

Keywords: CCME-WQI; water quality index; physicochemical; heavy metal; microbiological; Jayapura Regency

INTRODUCTION

Water is an essential natural resource for human life, both for household activities and for certain purposes in the economic sector. In many developing countries, rivers play an important role in society, especially for household needs

[Bytyçi et al., 2018]. However, nowadays, many rivers have experienced water quality degradation and have even been polluted. In general, the quality of fresh water in Indonesia (including rivers, lakes, and groundwater) was determined in Government Regulation of the Republic of Indonesia No. 82 of 2001, then updated in Government

Regulation of the Republic of Indonesia No. 22 of 2021 concerning the implementation of environmental protection and management [Pemerintah Republik Indonesia, 2021]. The regulation states that water quality status is the level of water quality conditions that indicate good or polluted conditions at a certain time compared to the water quality standards. Good category is assigned if it has not exceeded the predetermined threshold for each parameter assessed, otherwise it is categorized as polluted.

River ecosystems have the natural capacity for recovery (purification), assimilating all pollutants that enter the river. However, the purification ability is highly dependent on the intensity of pollutants from the surrounding environment. If the input of pollutants continues, the purification power of a river will not be able to keep up with the rate of pollution load, so that the quality of the river water will continue to deteriorate. River water quality is strongly influenced by the surrounding community environment. Various anthropogenic activities, such as industrial, agricultural, and settlement activities along the riverside will produce the waste that greatly impacts the water quality, where the pollution pressure will be higher towards the downstream of the river [Najah et al., 2009; Pullanikkatil et al., 2015]. Moreover, non-standard management of river water systems can cause water quality problems [Krishnan et al., 2007]. Water pollution caused by various pollutants will not only have an impact on environmental and economic problems but human health will also be affected [Yang and Wang, 2010; Shehu, 2019]. Human health will be at risk if the water in which the concentration of certain parameters exceeds a predetermined threshold is consumed [World Health Organization, 2012]. Therefore, it is necessary to assess and evaluate the quality of river water to minimize its negative impacts. Monitoring water quality is not only in the rivers that are the target of pollution control programs but also in the rivers that have not been polluted, because it will be useful for developing better water quality conservation measures [Saraswati et al., 2019].

The composition of physical, chemical, and microbiological parameters plays an important role in determining river water quality [Barakat et al., 2012; Musliu et al., 2018; Tanjung et al., 2019]. Currently, there have been many studies conducted on river water with the aim of monitoring and controlling water quality, as well as

preventing significant changes from occurring. In addition to comparing with quality standards, determination of river water quality can be done by analyzing the water quality index (WQI) [Javid et al., 2014; Abdel-Satar et al., 2017; Ewaid and Abed, 2017; Musliu et al., 2018]. WQI serves to describe the overall water quality status from a large amount of water quality data to a simpler form [Durmishi et al., 2012; Javid et al., 2014]. One of the methods is CCME-WQI which was developed by CCME (Canadian Council of Ministers of the Environment) [Canadian Council of Ministers of the Environment, 2001]. The CCME-WQI method describes the status of water with transformation techniques and weighting important parameters in determining water quality [Saraswati et al., 2014].

This study aimed to analyze the surface water quality of Damsari, Jabawi, Kleblow, and Komba Rivers in Jayapura Regency, Indonesia. The analysis refers to the water quality standards that have been set based on the Government Regulation of the Republic of Indonesia No. 22 of 2021 [Pemerintah Republik Indonesia, 2021]. Furthermore, an analysis of the status of river water quality was carried out using the CCME-WQI method. The results of this study are very important, because river water quality data is one of the most effective tools for communicating information about the feasibility status of river water to the community and interested stakeholders.

METHODS

Study site

Jayapura Regency is one of the regencies in Papua Province, Indonesia, with an area of 17,516.6 km² which is divided into 19 sub-districts [Badan Pusat Statistik Kabupaten Jayapura, 2020]. There are 23 rivers in the Jayapura Regency, both large and small rivers, of which 14 rivers directly contribute to the water quality of Lake Sentani [Dinas Lingkungan Hidup Kabupaten Jayapura, 2017]. In general, the rivers in Jayapura Regency have shallow depths and have turbid to clear water. Currently, rivers in Jayapura Regency are used to support community activities.

This study is located in four rivers in Jayapura Regency, namely Damsari River (S1), Jabawi River (S2), Kleblow River (S3), and Komba River (S4). Field data collection was carried out

in February 2016, August 2017, August and September 2018, and October 2019. The sampling locations for river surface water in the four rivers are presented in Figure 1.

Water sampling technique and water quality analysis

A sampling of river surface water was carried out twice in each data collection period. Surface water quality including water temperature, DO (dissolved oxygen), and pH (acidity) were determined in-situ using a digital thermometer, DO meter, and pH meter, respectively. The sampling of river water is carried out based on the Indonesian National Standard (Standar Nasional Indonesia; SNI) method No. 6964.8.2015. A 500 mL surface water sample was collected into a sample bottle that had been given a preservative, then stored in a coolbox for analysis at the Regional Health Laboratory, Jayapura City, Papua Province, Indonesia. The concentration data for each parameter were analyzed descriptively, namely by comparing the results of in-situ measurements and conducting a laboratory analysis with river water quality standards based on Government Regulation of the Republic of Indonesia No. 22 of 2021 for drinking water (class 1), recreation (class 2), aquatic life (class 3), and irrigation (class 4) (Table 1) [Pemerintah Republik Indonesia, 2021].

Water quality index analysis

The WQI analysis used refers to the CCME-WQI method which combines three elements for water quality assessment, namely *Scope* (the percentage of variables that exceed the permitted quality standards; F_1), *Frequency* (number of separate tests for the variables that do not reach quality standards; F_2), and *Amplitude* (the extent to which the failed tests exceed the permissible quality standards; F_3). The CCME-WQI equation is as follows [Canadian Council of Ministers of the Environment, 2001]:

$$CCME-WQI = 100 - \sqrt{\frac{F_1^2 + F_2^2 + F_3^2}{1.732}} \quad (1)$$

$$F_1 = \left(\frac{\text{number of failed variables}}{\text{total number of variables}} \right) \times 100 \quad (2)$$

$$F_2 = \left(\frac{\text{number of failed tests}}{\text{total number of tests}} \right) \times 100 \quad (3)$$

$$F_3 = \left(\frac{nse}{0.01nse + 0.01} \right) \quad (4)$$

where: *nse* is the normalized sum of the excursion's obtained based on the equation:

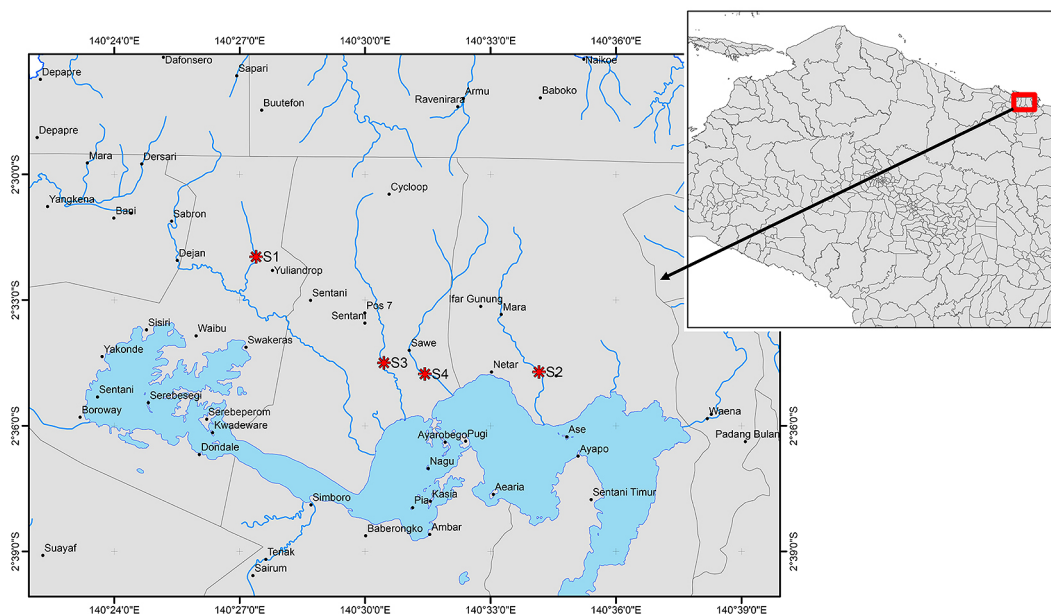


Figure 1. Map of river water sampling sites in Jayapura Regency, Indonesia

Table 1. River water quality standards in Indonesia

Parameters	Unit	Quality standards			
		Class 1	Class 2	Class 3	Class 4
Temperature	°C	Dev 3	Dev 3	Dev 3	Dev 3
Total dissolved solids (TDS)	mg/L	1000	1000	1000	1000
Total suspended solid (TSS)	mg/L	25	50	100	400
Acidity (pH)	–	6 – 9	6 – 9	6 – 9	6 – 9
Dissolved oxygen (DO)	mg/L	6	4	3	1
Chemical oxygen demand (COD)	mg/L	10	25	40	80
Biochemical oxygen demand (BOD ₅)	mg/L	2	3	6	12
Ammonia (NH ₃)	mg/L	0.5	–	–	–
Nitrate (NO ₃ ⁻)	mg/L	10	10	20	20
Total phosphate	mg/L	0.01	0.03	0.1	–
Sulfate (SO ₄ ⁻²)	mg/L	300	300	300	400
Free chlorine (Cl ₂)	mg/L	0.03	0.03	0.03	–
Surfactant/detergent	mg/L	0.2	0.2	0.2	–
Oil and grease	mg/L	1	1	1	10
Mercury (Hg)	mg/L	0.001	0.002	0.002	0.005
Lead (Pb)	mg/L	0.03	0.03	0.03	0.5
Cadmium (Cd)	mg/L	0.01	0.01	0.01	0.01
Hexavalent chromium (Cr-(VI))	mg/L	0.05	0.05	0.05	1
Nickel (Ni)	mg/L	0.05	0.05	0.05	0.1
Copper (Cu)	mg/L	0.02	0.02	0.02	0.2
Mangan (Mn)	mg/L	0.4	0.4	0.5	1.0
Iron (Fe)	mg/L	0.3	–	–	–
Zinc (Zn)	mg/L	0.05	0.05	0.05	2.0
Fecal coliform	MPN/100 mL	100	1000	2000	2000
Total coliform	MPN/100 mL	1000	5000	10000	10000

$$excursions_i = \left(\frac{failed\ tests\ value_i}{objective_j} \right) - 1 \quad (5)$$

or,

$$excursions_i = \left(\frac{objective_j}{failed\ tests\ value_i} \right) - 1 \quad (6)$$

There are five categories of the CCME-WQI index to describe water quality, namely Poor (WQI = 0 – 44), Marginal (WQI = 45 – 64), Fair (WQI = 65 – 79), Good (WQI = 80 – 94), and Excellent (WQI = 95 – 100) [Canadian Council of Ministers of the Environment, 2001].

RESULTS AND DISCUSSION

Physicochemical parameters

The concentrations of physicochemical parameters include water temperature (26.5 – 30.7 °C), TDS (24 – 166 mg/L), pH (6.44 – 8.55), NH₃

(0.16 – 0.41 mg/L), NO₃⁻ (0.1 – 0.8 mg/L), SO₄⁻² (0.01 – 3.0 mg/L), surfactant (0.009 – 0.196 mg/L), and oil/grease (0.113 – 0.861 mg/L) still meet the quality standards for drinking water (class 1), recreation (class 2), aquatic life (class 3), and irrigation (class 4) at all study sites. Likewise, the average concentration of these parameters still meets the quality standards of classes 1 to 4 (Table 2). On the other hand, the concentrations of several physicochemical parameters, including TSS, DO, COD, BOD, Total Phosphate, and Cl₂ have exceeded the class 1 to 3 quality standards in several study sites and even at all study sites.

TSS is an organic and inorganic material in the form of fine sand or mud suspended in the water column. High average concentrations of TSS were found at all study sites that have exceeded the water quality standard of class 1 in Damsari, Jabawi, and Kleblow Rivers, to exceed the quality standard of class 2 in Komba River (Table 2). This can be caused by high community activities and a large number of settlements around the river at all study sites. According to Baharem et al. [2014], the high activity of the community around

Table 2. Summary of concentration (average \pm SD) of river water physicochemical parameters in Jayapura Regency, Indonesia

Parameters	Concentration			
	Damsari	Jabawi	Kleblow	Komba
Temperature	28.333 \pm 2.92	28.275 \pm 1.471	28.525 \pm 0.793	28.1 \pm 2.117
TDS	55.5 \pm 44.548	88.825 \pm 56.44	133.325 \pm 18.83	93.633 \pm 55.378
TSS	34.0 \pm 7.105	38.0 \pm 4.835	49.0 \pm 6.732	58.0 \pm 8.968
pH	6.76 \pm 0.394	7.623 \pm 0.657	7.048 \pm 0.167	6.557 \pm 0.098
DO	6.34 \pm 0.73	7.195 \pm 1.387	6.668 \pm 0.899	6.61 \pm 1.312
COD	17.5 \pm 3.536	14.667 \pm 9.504	25.0 \pm 7.071	12.5 \pm 3.536
BOD ₅	2.84 \pm 0.057	1.75 \pm 0.937	3.34 \pm 0.042	1.7 \pm 1.202
NH ₃	0.2 \pm 0.057	0.31 \pm 0.056	0.365 \pm 0.064	0.26 \pm 0.017
NO ₃ ⁻	0.425 \pm 0.46	0.75 \pm 0.071	0.41 \pm 0.038	0.445 \pm 0.46
Total phosphate	0.897 \pm 0.991	0.2 \pm 0.126	0.725 \pm 0.885	0.41 \pm 0.434
SO ₄ ⁻²	1.0 \pm 0.217	2.5 \pm 0.707	0.505 \pm 0.701	3.0 \pm 0.283
Cl ₂	0.073 \pm 0.071	0.083 \pm 0.12	0.028 \pm 0.005	0.025 \pm 0.021
Surfactant	0.012 \pm 0.009	0.075 \pm 0.072	0.028 \pm 0.026	0.118 \pm 0.111
Oil and grease	0.445 \pm 0.253	0.359 \pm 0.334	0.465 \pm 0.127	0.838 \pm 0.033

the river will tend to increase the concentration of TSS. Likewise, Merchan et al. [2019] found that community activities such as agricultural land use tend to increase the concentration of TSS, although the effect varies greatly depending on local characteristics, whether natural such as river flow or anthropological, e.g. land-use practices.

DO plays an important role in assessing water quality for aquatic biota life [Abdel-Satar et al., 2017], while COD and BOD play an important role in estimating the water pollution from organic matter [Ali et al., 2014]. The DO concentration in the Komba River in 2016 (5.63 mg/L) was found to be lower than the minimum quality standard (class 1) and in the other three rivers in 2017 (5.2 – 5.5 mg/L). However, the average DO concentration at the four study sites is quite high and met the recommended minimum quality standards (Table 2). DO concentrations are usually 80 – 100% oxygen saturation levels in unpolluted rivers [Secchi et al., 2011] and are usually in the surface layer, because they directly diffuse into water bodies [Hamuna et al., 2018]. The COD concentrations were quite high at the four study sites (range 5 – 30 mg/L) and exceeded the quality standard for drinking water (class 1), except for the Jabawi River (in 2017). Overall, the average COD concentration at the four study sites has exceeded the class 1 quality standard (Table 2). The concentration of BOD was found to be quite high in the Kleblow River (range 3.31 – 3.37 mg/L) which has exceeded the quality standards of classes 1 and 2. Likewise, in the Damsari River (range 2.80 – 2.88 mg/L)

it has exceeded the quality standard of class 1. Overall, the average concentration of BOD has exceeded the quality standard for class 1 in the Damsari River and class 2 in the Kleblow River, while in the Jabawi and Komba rivers it is low (Table 2). The waste from agricultural activities and human settlements can cause an increase in COD and BOD concentrations in water bodies, especially the waste that can decomposed and degraded by microorganisms. This condition can be exacerbated if there is industrial activity around the river [Ye et al., 2009; Pratt and Chang, 2012].

The concentration of Total Phosphate found ranged from 0.09 – 2.04 mg/L. The highest average concentration was found in Damsari River, while the lowest was in Jabawi River (Table 2). These results indicate that the concentration of Total Phosphate has exceeded the water quality standard (class 1 to 3) at all study sites, so it is not suitable for drinking, recreation, and supporting aquatic life. Phosphate is a minor element in water, because most inorganic phosphorus compounds have low solubility, usually in the range of 0.01 – 0.1 mg/L [Effendi et al., 2015]. The high concentration of Phosphate in the waters is caused by the decomposition of organic matter, weathering of rock minerals, the use of fertilizers, and household and industrial waste [Christensen et al., 2011; Effendi et al., 2015].

The concentration of Cl₂ at the four study sites ranged from 0.01 – 0.26 mg/L. The average concentration has exceeded the quality standards (class 1 to 3) in Damsari and Jabawi Rivers, making it unfit for drinking water, recreation,

and supporting aquatic life (Table 2). Chlorine in reasonable concentrations is not harmful to humans and is even useful for disinfection of drinking water i.e., the destruction of microbiological pathogens in drinking water [Galal-Gorchev, 1996]. However, chlorine in high concentrations has the potential to cause eye, skin, and upper respiratory tract irritation, as well as long-term effects causing respiratory tract obstruction. Chlorine can also cause a salty taste and odor in water bodies (due to the chlorination process) [Damo and Icka, 2013].

Heavy metal parameters

The concentration of heavy metals (Hg, Pb, Cd, Cr-(VI), Ni, Cu, Mn, Fe, and Zn) dissolved in river water at four study sites (Damsari, Jabawi, Kleblow, and Komba Rivers) ranged from 0.022 – 0.0549 mg/L, 0.002 – 0.096 mg/L, 0.001 – 0.1332 mg/L, 0.002 – 0.018 mg/L, 0.17 – 0.292 mg/L, 0.007 – 0.064 mg/L, 0.01 – 0.09 mg/L, 0.049 – 0.27 mg/L, and 0.02 – 0.225 mg/L, respectively. The average concentrations of these heavy metals are presented in Table 3. The concentrations of Cr-(IV), Mn, and Fe still meet the quality standards set for use for drinking water (class 1), recreation (class 2), aquatic life (class 3), and irrigation (class 4) at all study sites. In contrast, the concentrations of Hg and Ni have exceeded the quality standard (class 1 to 4) at all study sites. Although not all data on Cd concentration have exceeded the quality standard, the average concentration of Cd has exceeded the river water quality standard for classes 1 to 4 at all study sites. The average concentration of Cu and Zn has exceeded the quality standard of classes 1 to 3 in all study sites, while the average concentration of Pb is exceeded only in the Damsari and Kleblow Rivers.

High concentrations of heavy metals are a global problem in various waters in the world. Naturally, the concentration of heavy metals in water bodies is very low and the concentration will increase with the addition of inputs to water bodies such as anthropogenic waste containing heavy metals [Hamuna and Tanjung, 2021], also because of its non-degradable and accumulating nature [Saher and Siddiqui, 2019]. The high concentration of Hg found in this study is thought to be due to traditional gold mining activities in the upper reaches of the river. The high concentration of non-essential heavy metals (Hg, Pb, Ni, and Cd) is very risky to humans, aquatic biota, and aquaculture activities because these heavy metals have a high level of toxic response [Hakanson, 1990]. Although Cu and Zn are included in the category of essential heavy metals (essential micronutrients), they can be toxic and harmful to living things, especially humans and aquatic biota if their concentrations are high (exceed quality standards) [Chen et al., 2016; Rosado et al., 2016].

Microbiological parameters

The concentration of microbiological parameters in four rivers (Damsari, Jabawi, Kleblow, and Komba Rivers) during the observation period still met the quality standards set for use as drinking water (class 1), recreation (class 2), aquatic life (class 3), and irrigation (class 4). The average concentration of Fecal Coliform and Total Coliform is still low compared to the standard quality that has been set (Table 4), where the concentrations of Fecal Coliform and Total Coliform found ranged from 7.0 – 48.0 MPN/100 mL and 13.0 – 390.0 MPN/100 mL, respectively.

Generally, Fecal Coliform and Total Coliform are a group of bacteria in the aquatic environment produced from human waste, animal waste,

Table 3. Summary of heavy metal concentrations (average \pm SD) in river water in Jayapura Regency, Indonesia

Parameters	Concentration			
	Damsari	Jabawi	Kleblow	Komba
Hg	0.022 \pm 0.005	0.044 \pm 0.015	0.055 \pm 0.007	0.044 \pm 0.013
Pb	0.034 \pm 0.012	0.009 \pm 0.006	0.033 \pm 0.042	0.014 \pm 0.017
Cd	0.053 \pm 0.054	0.023 \pm 0.044	0.037 \pm 0.042	0.045 \pm 0.076
Cr-(VI)	0.006 \pm 0.007	0.007 \pm 0.007	0.004 \pm 0.001	0.005 \pm 0.002
Ni	0.258 \pm 0.061	0.17 \pm 0.018	0.251 \pm 0.021	0.292 \pm 0.019
Cu	0.037 \pm 0.038	0.027 \pm 0.022	0.048 \pm 0.019	0.035 \pm 0.023
Mn	0.09 \pm 0.012	0.03 \pm 0.008	0.02 \pm 0.004	0.01 \pm 0.006
Fe	0.18 \pm 0.031	0.13 \pm 0.076	0.16 \pm 0.156	0.14 \pm 0.021
Zn	0.124 \pm 0.121	0.094 \pm 0.11	0.124 \pm 0.102	0.134 \pm 0.129

Table 4. Summary of concentration (average \pm SD) of microbiological parameters in river water in Jayapura Regency, Indonesia

Parameters	Concentration			
	Damsari	Jabawi	Kleblow	Komba
Fecal Coliform	17.0 \pm 21.213	28.667 \pm 19.502	9.0 \pm 2.828	25.5 \pm 4.95
Total Coliform	37.0 \pm 31.113	80.0 \pm 94.43	204.5 \pm 262.337	58.5 \pm 27.577

and anthropogenic waste [Messner et al., 2017]. Increasing its concentration in water bodies can indicate significant pollution from anthropogenic waste; it can be a major indicator of wastewater pollution [Milanović et al., 2011; Brankov et al., 2012], and can have negative effects on human health [Saraswati et al., 2019]. The low concentrations of Fecal Coliform and Total Coliform in all study sites may indicate that the awareness of the local community (around the river) is high enough not to dispose of human and livestock waste into the river.

Water quality index

WQI assessment in the four rivers was carried out to determine the suitability of the surface water of the rivers for drinking water (class 1), recreation (class 2), supporting aquatic life (class 3), and irrigation (class 4). The number of input parameters used is 24, 22, 22, and 19 for class 1, class 2, class 3, and class 4, respectively. This refers to the quality standards set by the Government of the Republic of Indonesia [Pemerintah Republik Indonesia, 2021] and the availability of the amount of data in this study. Generally,

the WQI value of river surface water at the four study sites is in the categories of Poor – Fair for drinking water, Marginal – Good for recreation, Marginal – Good for supporting aquatic life, and Marginal – Excellent for irrigation (Table 5). On the basis of the average WQI value (Figure 2), only the Damsari River is in the Poor category (WQI = 41.33) for drinking water, while the other three rivers are in the Marginal category (WQI = 44.50 – 51.00). The Jabawi River is in the Fair category (WQI = 69.75) for river use as a recreation area, while the other three rivers are in the Marginal category (WQI = 52.00 – 61.67). Furthermore, the Jabawi and Komba rivers are in the Fair category (WQI = 69.33 – 75.50) to support aquatic life, while the Damsari and Kleblow rivers are in the Marginal category (WQI = 59.00 – 61.26). The water quality of the four rivers is in the Good category (WQI = 80.00 – 88.00) for irrigation.

The results of the CCME-WQI analysis can provide flexibility in the number and types of significant parameters in determining the index [Saraswati et al., 2014]. The water quality parameters that exceed quality standards and tend to affect the low WQI values at all study sites are TSS, COD, BOD, Total Phosphate, Cl₂, Hg, Pb, Cd,

Table 5. WQI values for Damsari, Jabawi, Kleblow, and Komba Rivers (2016–2019)

Sites	Purpose of use	WQI	Category
Damsari River	Drinking	40 – 43	Poor
	Recreation	49 – 57	Marginal
	Aquatic life	50 – 65	Marginal-fair
	Irrigation	64 – 96	Marginal-excellent
Jabawi River	Drinking	44 – 72	Poor-fair
	Recreation	51 – 82	Marginal-good
	Aquatic life	51 – 89	Marginal-good
	Irrigation	63 – 98	Marginal-excellent
Kleblow River	Drinking	40 – 55	Poor-marginal
	Recreation	47 – 66	Marginal-fair
	Aquatic life	48 – 83	Marginal-good
	Irrigation	63 – 98	Marginal-excellent
Komba River	Drinking	37 – 66	Poor-fair
	Recreation	42 – 80	Poor-good
	Aquatic life	46 – 88	Marginal-good
	Irrigation	59 – 97	Marginal-excellent

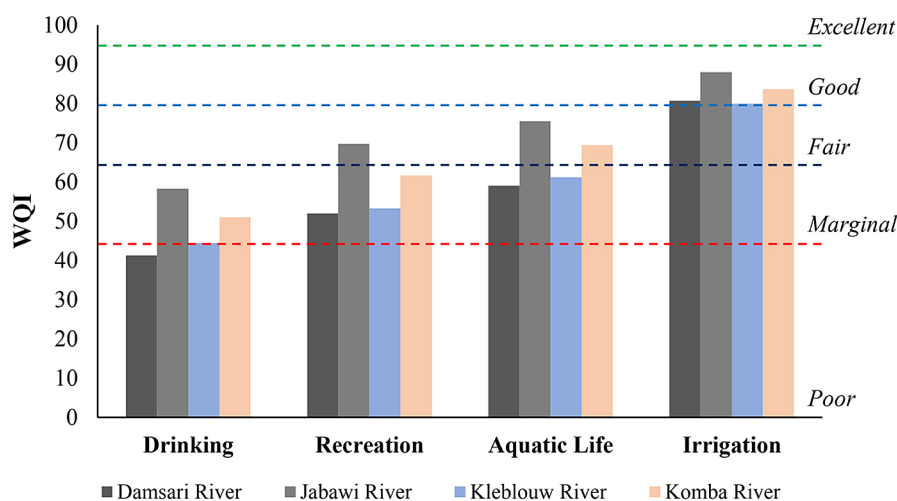


Figure 2. Average WQI values (2016 – 2019) for Damsari, Jabawi, Kleblow, and Komba Rivers in Jayapura Regency, Indonesia

Ni, Cu, and Zn. However, the results of the WQI analysis show that the *nse* values of Total Phosphate and Hg are higher than the other parameters in Damsari and Kleblow Rivers. Meanwhile, the highest *nse* values in Jabawi and Komba Rivers were Total Phosphate, Hg, Cd, and Cu.

Although the WQI values in this study only describe the WQI at one site in each river, the results of this study have provided the information that can describe the water quality in the four rivers. The results of this study conclude that the surface water of the Damsari, Jabawi, Kleblow, and Komba Rivers is not suitable as a source of drinking water. The Jabawi River can be used as a place of recreation, but good regulations are needed for its management, while the other three rivers are not suitable for recreation. Jabawi and Komba Rivers can be used as alternatives to support freshwater fish farming activities, for example as water sources or fish farming locations (but studies on river currents are necessary). The water quality of Damsari, Jabawi, Kleblow, and Komba Rivers is very suitable to be used as a water source for irrigation.

WQI is an important tool that can summarize and simplify different values for accurate, effective water quality determination, and can provide the information on pollutant source indicator parameters in different water bodies [Damo and Icka, 2013; Finotti et al., 2015]. The CCME-WQI method is very objective and sensitive in responding to the dynamics of water quality and local characteristics at each location [Akkoyunlu and Akiner, 2012; Sarasswati et al., 2014]. Therefore, the resulting water quality index information can

be used as an instrument in river management plans to improve river the water quality in this study area, including providing the information to the community about the river water quality in their area.

CONCLUSIONS

The results of this study have provided an overview of water quality in the Damsari, Jabawi, Kleblow, and Komba Rivers in Jayapura Regency, Indonesia. The physicochemical parameters (water temperature, TDS, pH, NH_3 , NO_3^- , SO_4^{2-} , surfactant, and oil/grease), heavy metal parameters (Cr-(IV), Mn, Fe), and microbiological parameters (Fecal Coliform and Total Coliform) still meet the quality standards set for drinking water (class 1), recreation (class 2), to support aquatic life (class 3), and irrigation (class 4) at all study sites. On the other hand, water quality parameters such as TSS, COD, BOD, Total Phosphate, Hg, and Ni have exceeded the quality standards at all study sites. The dominant source of pollutants comes from anthropogenic waste at all study sites. The average WQI value for drinking water is in the Poor category in the Damsari River, while the other three rivers are in the Marginal category, so the four rivers are not suitable as a source of drinking water. Only the Jabawi River is in the Fair category for recreation so that it can be used as a recreational facility but good regulations for its management are needed. In turn, the other three rivers are not suitable for recreation. Jabawi and Komba Rivers are included in the Fair category and can be used

as an alternative to support aquatic life. The water quality of Damsari, Jabawi, Kleblow, and Komba Rivers is very suitable to be used as a water source for irrigation (Good category). The information on water quality and river water quality index can be used as an instrument in river management plans to improve the river water quality at this study site. For future studies, it is possible to observe the water quality from upstream to downstream to determine the water quality ratio and index spatially. The same observations were also made in other rivers in Jayapura Regency.

As a recommendation from this study, to improve the water quality in its natural condition, a strategy for controlling river water pollution is needed. The strategy is focused on increasing the role of the government, stakeholders, and the community in controlling river water pollution in the Jayapura Regency. In addition, it is necessary to integrate the river water pollution control policies in regional spatial planning plans.

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