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Evaluation of Water Quality of Way Kuripan's River Using Water Quality Index Tool

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Abstract

The aim of this study is to analyze the water quality of the Way Kuripan River based on the Water Quality Index (WQI) calculation method that is developed by the Malaysian Department of Environment (DOE). Water samples were taken from five sample points (SK01, SK02, SK03, SK04 and SK05) in January 2017. WQI was calculated on the basis of six parameters: dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, total suspended solid (TSS) and ammoniac-nitrogen (NH3-N). The calculation procedure consists of three stages. Firstly, identifying the equation of the sub-index (SI) based on the parameter value. Secondly, calculate the sub-index (SI) of each parameter. Last is the calculation of the water quality index. The results show that SK01 and SK04 have WQI values of 70.3 and 70.11. Those values show that water quality of the Way Kuripan river is class III so the water is slightly polluted. Sample points, SK02 (WQI = 55.8) and SK03 (WQI=53.8) are highly polluted. The lowest WQI of the Way Kuripan river is SK05 = 38.3, so it is classified as,Class V (highly polluted). In conclusion, this data confirms that the water quality in the Sungai Kuripan River has been polluted.

Keywords: Way Kuripan's River, Water Quality Index (WQI), water quality parameter

Abstrak (Indonesian)

Penelitian ini bertujuan untuk menganalisa kualitas air Sungai Way Kuripan berdasarkan metode perhitungan Kualitas Air (WQI) yang dikembangkan oleh Department of Environment (DOE) Malaysia. Sampel air diambil dari lima titik sampel (SK01, SK02, SK03, SK04 dan SK05) pada bulan Januari 2017. WQI dihitung berdasarkan enam parameter yaitu dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, total suspended solid (TSS) dan ammoniacal nitrogen (NH_3-N). Prosedur perhitungan terdiri dari tiga tahapan, pertama mengidentifikasi persamaan sub-indeks (SI) berdasarkan nilai parameter; Kedua menghitung sub indeks (SI) dari setiap parameter, dan yang terakhir adalah menghitung indeks kualitas air. Hasil analisis menunjukkan bahwa SK01 dan SK04 memiliki nilai WQI 70.3 dan 70.11, dengan kategori kualitas sungai kelas III (sedikit tercemar). Pada titik sampel SK02 dan SK03 memiliki kualitas air yang sangat tercemar dengan WQI masing-masing 55.8 dan 53.8. Sedangkan SK05 memiliki kualitas air terendah dibandingkan dengan yang lain yaitu sebesar 38.3 (Kelas V, sangat tercemar). Secara keseluruhan menunjukkan bahwa kualitas air di Sungai Way Kuripan telah tercemar.

Katakunci: Sungai Way Kuripan, Index Kualitas Air (WQI), parameter kualitas air

1. Introduction

Over the years of time, river has been subjected to human interference regularly and water quality was to be getting deteriorated profoundly. Major anthropogenic activities practiced in and around the river such as agriculture, abstraction of water for irrigation and drinking, washing cloths and utensils, discharging of sewage waste, sand dredging, boating, and fishing activities along the river were generating serious threat to the biota by altering the physicochemical and biological concentration of the river system [11].

Water quality is one of the most important factors that must be considered when evaluating the sustainable development of region [7]. The most useful tool to monitor and assess the water quality is by using the water Quality Index (WQI) which is a single number like a grade explains the total water quality at a certain area and time based on several water quality parameters [2]. It also assesses the suitability of the quality of the water for a variety uses such as agriculture, aquaculture, and domestic use [5]. WQI was first proposed by Horton 1965, later, numerous of indices have been developed all over the world such as Weight Arithmetic (WA), National Sanitation Foundation (NSF), Canadian Council of Ministers of the Environment (CCME), British Columbia, Oregon etc [4][13][15][17].

Many researches have been conducted to monitor and study water quality, Kim and Cardone created a WQI that evaluates changes in water quality over time and space [1]. Tsegaye developed a chemical WQI based on data from 18 stream in one lake basin in northern Alabama that summed the concentration of seven water quality parameters (total nitrogen, dissolved lead, dissolved oxygen, pH, total particulate and dissolved phosphorus) after standardizing each observations to the maximum concentration for each parameter [19]. Meher et al. (2015) used a total of 14 parameters such as pH, total dissolved solids (TDS), alkalinity, dissolved oxygen (DO), biological oxygen demand (BOD), conductivity, turbidity, and other parameters for developing a water quality index for different sections of the Ganges River [12]. Al-Shujairi (2013)

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Figure 1. Study area locations.

proposed a WQI formula to evaluate water quality in the Tigris and Eupharets Rivers in Iraq that used seven water quality parameters (TDS, total hardness, pH, DO, BOD, Nitrate (NO3), and phosphate [16]. In Taiwan, WQI was developed as an index of river water quality. It is a multiplicative aggregate function of standardized scores for temperature, pH, toxic substances, organics (DO, BOD, ammonia), particulate (suspended solid, turbidity), and microorganisms such as faecal coliforms [17]. Sargaonkar and Deshpande (2003) have developed the Overall Index of Population (OIP) for Indian rivers based on measurements and subsequent classification of pH, turbidity, DO, BOD, hardness, TDS, total coliforms, arsenic, and fluoride [3]. In 1985, Department of Environment Malaysia (DOE) has developed water quality index that used six parameters: BOD, Chemical Oxygen Demand (COD), DO, Suspended Solid (SS), Ammonia-Nitrogen (AN), and pH [6].w The DOE WQI has been practiced in Malaysia for about 32 years [20]. It is a set of water quality guidelines that categorize the water quality class according to water quality for public use, such as recreational purpose, irrigation, and aquaculture. Until today, DOE-WQI has been employed to measure water samples from 902 manual stations in 120 basins (462 rivers) in Malaysia. Each of WQI method have vary parameters depend on the history of manufacture and the geographical situation of the user's country.

DOE-WQI method is quite powerful to measure water quality samples yet the calculation procedure is not quite easy to undertake without computer assistance. In 2011, Susilo and Febrina have developed graphical calculation method in order to find easier procedure of DOE WQI calculation [8]. In this study, we used DOE-WQI method [6] by using graphical calculation [8] to analyze Way Kuripan River.Way Kuripan's River is one of the largest river in Bandar Lampung city. Along the river, there are landfill, industrial, residential and agriculture. The water body of the river practically receives, industrial waste, liquid waste from landfill, domestic wastes and drainage water from the residential area. Water of this river is used for some purposes such as cleaning and sanitizing by the people living in surrounding areas. Based on this condition, it is necessary to know whether the water is qualified enough for domestic used.

2. Experimental Section

2.1. Study area

Way Kuripan's River is created by the confluence of Way Simpang Kiri's River and Way Simpang Kanan's River. The length and the catchment area of the Way Kuripan's River are 9, 6 km and 60,81 km^2.

2.2. Sample collection

The water samples will be collected from five stations. That are SK01 (05˚26.458'S, 105˚15.026'E), SK02 (05˚26.712'S, 105˚15.169'E), SK03 (05˚26.910'S, 105˚15.387'E), SK04 (05˚26.194'S, 105˚15.461'E), SK05 (05˚26.212'S, 105˚15.778'E). The surface water sample was collected about a half of the depth of river because the velocity of water flow less than $5m^3/s$ [9]. Water samples from each station were stored in one liter polyethylene bottles for analysis of selected parameters included: pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolve Oxygen (DO), Ammoniac Nitrogen (NH3-N), Total Suspended Solid (TSS).

2.3. Source of pollution

Based on the investigation of land allocation, it can be identified that the source of pollution on Way Kuripan River's upstream is the result of erosion of vacant land and residential population. In upstream and downstream sections, the source of pollution is dominated by domestic waste derived from the contribution of Karang City Urban Village. While downstream of Way Kuripan River, pollution is caused by Market or Shops (Purwata and Karang City Urban Village), home industry, temporary garbage shelter which is located along the river, and from dense settlement in Purwata Village. Source of pollution on Way Kuripan River can be seen in Figure 2.

2.4. Data Analysis

The formula used for calculating DOE WQI is developed by the Department of Environment of Malaysia. The formula is described as follows [6]:

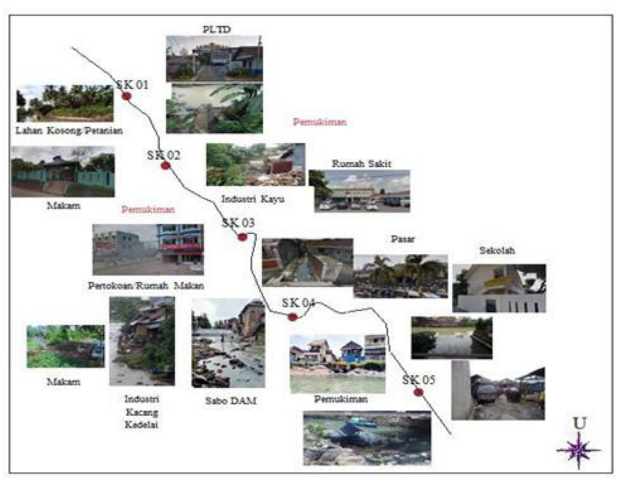

Figure 2. The source of pollution in Way Kuripan River

WQI = (0,22$SIDO$)+(0,19$SIBOD$)+(0.16$SICOD$)+(0.15$SIAN$)+(0.16$SISS$)+(0,12$SIPH$) (1)

Where, WQI = Water Quality Index, $SIDO$ = Sub-index DO, $SIBOD$= Sub-index BOD, $SICOD$ = Sub-index COD, $SIAN$ = Sub-index AN, $SISS$ = Sub-index TSS, $SIpH$ = Sub-index pH.

Every sub-index is calculated based on the equation in certain condition which is:

SIDO

SIDO $= 0$ for $x \leq 8$

SIDO $= 100$ for $x \geq 92$

SIDO $= -0.395 + 0.030x^2 - 0.00020x^3$ for $8 < x < 92$

SIBOD

SIBOD $= 100.4 - 4.23x$ for $x \leq 5$

SIBOD $= 108 * \exp(-0.055x) - 0.1x$ for $x > 5$

SICOD

SICOD $= -1.33x + 99.1$ for $x \leq 20$

SICOD $= 103*\exp(-0.0157x) - 0.04x$ for $x > 20$

SIAN

SIAN $= 100.5 - 105x$ for $x \leq 0.3$

SIAN $= 94*\exp(-0.573x) - 5 * |x - 2|$ for $0.3 < x < 4$;

SIAN $= 0$ for $x \geq 4$

SISS

SISS $= 97.5*\exp(-0.00676x) + 0.05x$ for $x \leq 100$

SISS $= 71*\exp(-0.0061x) - 0.015x$ for $100 < x < 1000$

SISS $= 0$ for $x \geq 1000$

SIpH

SIpH $= 17.2 - 17.2x + 5.02x^2$ for $x < 5.5$

SIpH $= -242 + 95.5x - 6.67x^2$ for $5.5 \leq x < 7$

SIpH $= -181 + 82.4x - 6.05x^2$ for $7 \leq x < 8.75$

SIpH $= 536 - 77.0x + 2.76x^2$ for $x \geq 8.75$.

Graphical method for calculating DOE WQI is derived from general calculation procedures in (1). In the graphical method, the general equation of WQI calculation is changed into:

WQI= SIDO'+SIBOD'+SIOD'+SIAN'+SISS'+SIpH' *(2)*

The value of *SIDO', SIBOD', SICOD', SIAN', SISS', and SIpH'* are derived from the value *SIDO*, *SIBOD, SICOD, SIAN, SISS*, and *SIpH* multiplied by their coefficient. The calculation procedure of *SIDO, SIBOD, SICOD, SIAN, SISS*, and *SIpH* combined with the multiplication with their coefficient is described in the graphical presentation. The graphs are presented in the Fig. 3 to Fig 8. By using the graph of *SIDO', SIBOD', SICOD', SIAN', SISS'*, and *SIpH'*, the calculation procedures of *WQI* can be simplified and furthermore it can be undertaken without the assistance of computer.

General rating scale for the DOE WQI is between 0 and 100. The interpretation of the value applied in some water resources development purposes is described below:

For general use of water:

- $0 \leqslant x < 60$ = very polluted water
- $60 \leqslant x < 80$ = slightly polluted water
- $x > 80$ = clean water.

For classification of water:

- $0 \leqslant x < 40$ = Class V
- $40 \leqslant x < 50$ = Class IV
- $60 \leqslant x < 80$ = Class III
- $80 \leqslant x < 90$ = Class II
- $x > 90$ = Class I.

For public water supply:

- $0 \leqslant x < 40$ = not acceptable for public water supply
- $40 \leqslant x < 50$ = doubtful for public water supply
- $60 \leqslant x < 80$ = needs expensive treatment for public water supply
- $80 \leqslant x < 90$ = needs minor purification for public water supply
- $x > 90$ = no need treatment for public water supply

For recreation water:

- $0 \leqslant x < 20$ = not acceptable for recreation
- $20 \leqslant x < 30$ = obvious pollution appearing, still not acceptable for all recreation
- $30 \leqslant x < 40$ = only for boating
- $40 \leqslant x < 50$ = doubtful for water contact
- $50 \leqslant x < 70$ = acceptable for water contact but needs bacteria count
- $x > 70$ = acceptable for all water sport.

3. Results and Discussion

3.1 Result of Sample Test

The test results of water samples conducted at UPTD Health Laboratory Hall with five parameters are Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia (AN), Suspended Solid (SS) and Degree of Acidity (pH) can be seen in Table 1. The test results of these parameters are then compared with the water quality standard in accordance with Government Regulation of the Republic of Indonesia no. 82, 2001 on the Management of Water Quality and Control of Water Pollution [14].

Table 1 shows the value of Dissolved Oxygen (DO) at sample points SK01, SK02, SK05 is 3.69 mg/l; 3.56 mg/l and 3.05 mg/l included in water quality standard class III [14]. While at the sample points SK03 and SK05 have a DO value of 4.04 mg/l (Class II) and 1.45 mg/l (almost close to Class IV). DO is one of the important

Table 1. Test Result

No.	Parameters	Test Result					Quality Standard				Unit
		SK01	SK02	SK03	SK04	SK05	Class I	Class II	Class III	Class IV	
1	DO	3,69	3,56	4,04	1,45	3,05	6	4	3	0	mg/l
2	BOD	2	30	29	4	131	2	3	6	12	mg/l
3	COD	6	9	32	6	468	10	25	50	100	mg/l
4	AN	0,03	0,03	0,12	0,16	0,03	0,5	-	-	-	mg/l
5	SS	1	1	1	1	1	50	400	400	400	mg/l
6	pH	7,56	7,36	7,20	7,47	7,61	9-Jun	9-Jun	9-Jun	9-May	mg/l

Table 2. Results of *Sub-Indexs* Calculation

No.	Sub-Index	SK 01	SK 02	SK 03	SK 04	SK 05
1	SIDO'	0	0	0	0	0
2	SIBOD'	17.6	14.3	10.9	15.9	11.6
3	SICOD'	3.4	13.9	10.9	15.9	11.7
4	SIAN'	3.6	9.6	12.8	15.9	11.9
5	SISS'	15.7	14.3	12.4	15.9	11.8
6	SipH'	0	0	10.9	15.9	11.5

parameters in water quality analysis. The DO value indicates the amount of oxygen available in a body of water. The greater the DO value on water, indicating the water has good quality. Conversely, if the DO value is low, it can be seen that the water has been contaminated. The value of DO also shows the extent to which the water body is able to accommodate water biota such as fish and microorganisms. From the measurement results show the value of DO increasingly smaller the downstream. As for the BOD value there is an increase from upstream to downstream (Table 1). The increase of BOD value is above the standard of the class IV water quality, this occurred at sample points SK02, SK03 and SK05 30 mg/l, 29 mg/l and 131 mg/l, respectively. The highest BOD value occurred in the downstream area (SK05 = 131 mg/l) while the upstream of the river had a low BOD value of 2 mg/l included in class I water quality standard. The BOD value indicates the amount of oxygen required by microorganisms to decompose dissolved organic substance and some of the organic substances suspended in water. The greater the value of BOD means the process of decomposition of organic substance occurs in large quantities and will absorb oxygen in water thereby reducing the amount of dissolved oxygen (DO) .The increase in BOD value from upstream to downstream indicates the quality of river water has decreased. This is because the source of pollutants is not only from the previous water flow but also from the surrounding settlements that dispose of domestic waste directly into the river. In addition, the activities of ships entering the estuary by disposing of waste from ships such as engine oil and others also increase the source of pollutan to downstream areas. Furthermore, the result of measurement of COD value (Table 1) shows at sample point SK01, SK02, SK04 is 6 mg/l, 9 mg/l and 6 mg/l are included in the standard of water quality class I. COD value at sample point SK03 32 mg / l is almost close to the standard of water quality class III. While the COD value for the downstream area (SK05) is very high that is equal to 468 mg/l far exceeds the water quality standard required by the government. The downstream region requires the greatest amount of oxygen compared to other regions for chemical reaction processes to decompose the contaminants. Level of ammonia (AN) at sample point SK 02 to SK 04 has increased with highest AN concentration occurring at sample point SK 04 = 0,16 mg/l but not exceeding recommended quality standard based on PP. 82, 2001 that is equal to 0,5 mg/l. In this area the dominant activity is the settlements whose effluents are directly discharged into river bodies and poor sanitation of the people. This is in accordance with the statement of Effendi (2003) which states that high ammonia level is an indication of the contamination of organic materials derived from domestic waste, industries and run-off agricultural fertilizers [9]. SS (Suspended Solid) parameter of Way Kuripan River at sample point SK01 up to SK05 sample point has the same value that is 1 mg/l. Concentrations of SS from upstream to downstream enter the water quality standard of class I and Class II based on PP no. 82, 2001 so that suspended solids content of river water of Way Kuripan not affect the allocation of raw water, facilities / infrastructure of recreational water, animal husbandry and fishery interests. Although SS is not toxic but with the increasing value of SS means increasingly penetration of light obstructed into the river. For the result of measurement of pH parameter of river water of Way Kuripan is classified as normal, indicated life of aquatic biota still in good enough condition.From the overall examination of water quality of Way River Kuripan, there are examination that do not meet the criteria of quality standard according to Government Regulation of Republic of Indonesia no. 82, 2001 on the Management of Water Quality and Control of Water Pollution [14].

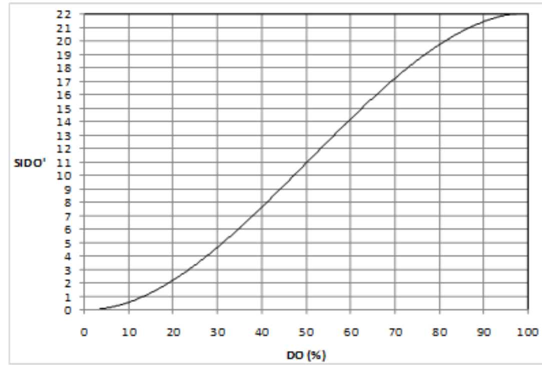

Figure 3. *SIDO*' graph

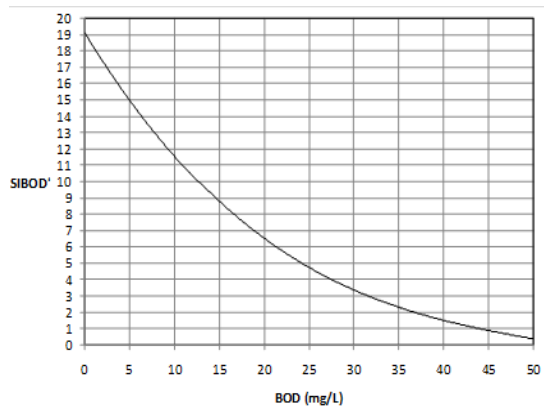

Figure 4. *SIBOD*' graph

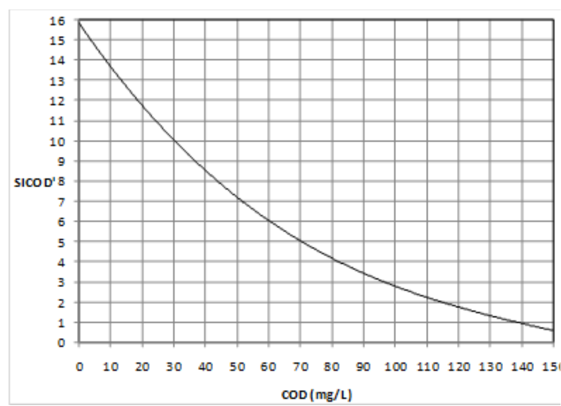

Figure 5. *SICOD*' graph

3.2 Analysis of DOE-Water Quality Index (DOE-WQI)

Based on the analysis of Way Kuripan River water samples (Table 1), it can be calculated the sub-index value of each parameter using graphic (Fig.3 – Fig.8). The results of the calculation of sub-index

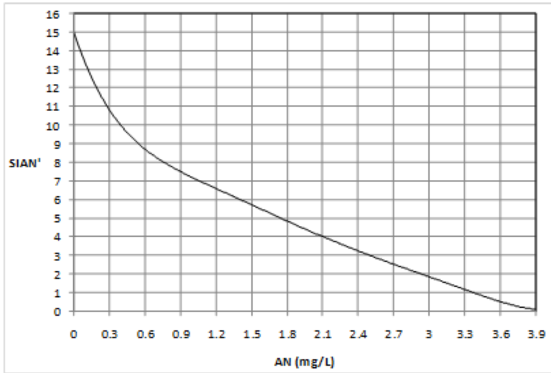

Figure 6.*SIAN*' graph

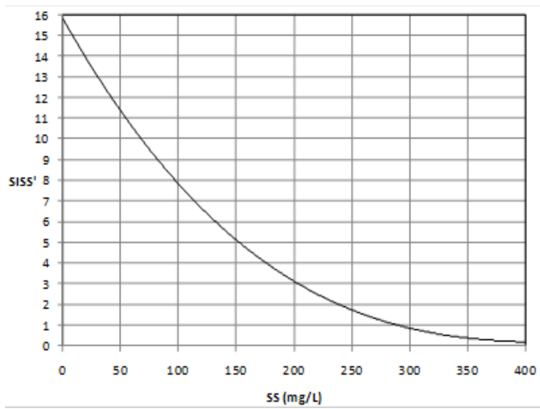

Figure 7. *SISS*' graph

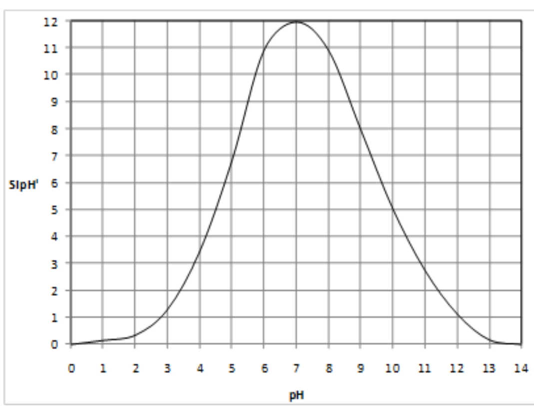

Figure 8. *SIpH'* graph

values can be seen in Table 2.

Furthermore, to analyze the water quality used DOE-WQI method using equation (2). The results of DOE-WQI calculations are presented in Table 3.

The result of water quality analysis with WQI method shows decreasing value from upstream to downstream, it is related to the contamination level. At the sample point SK01 the WQI value is 70.3, this means that the water quality in upper river area is slightly polluted. Based on the result of investigation of pollution source in upstream area occured due to erosion of vacant land and residential area. Upstream water can be used for drinking water needs, although it requires processing first, it is safe to use for fisheries of all types of fish and is suitable for all types of water sports, shipping and water transportation. The areas between upstream

Table 3. WQI Value of Way Kuripan River

No.	Sample Location	WQI	Class
1	SK01	70.3	III (Slightly Polluted)
2	SK02	55.8	IV (Polluted)
3	SK03	53.8	IV (Polluted)
4	SK04	70.11	III (Slightly Polluted)
5	SK05	38.3	V (Highly Polluted)

and downstream at the sample points of SK02, SK03, SK04 have WQI values of 55.8, 53.8 and 70.11. The source of pollution is dominated by domestic and household wastes generated from the contribution of Karang City urban village with dense population. The water quality at the sample points of SK02 and SK03 is worse with SK04, this is the case of SABO DAM between sample points SK03 and SK04. The high concentration of contaminants from the previous water flow (SK02 and SK03) became lower when through SABO DAM due to an increase in water discharge. Water discharge gives a significant influence on the improvement of water quality level. Water quality on SK02 and SK03 is doubtful if it is used for drinking water because the pollution level is higher than that of SK01. The class category for this area is Class IV (polluted), there is a need for routine bacterial control if it is to be used for the sport in contact with water. While for fisheries only allowed for fish that are cultivated but still doubtful for more sensitive fish but permitted for shipping and water transportation. As for SK04 has a value approaching SK01. While the downstream of Way Kuripan River (SK05) has a WQI value of 38.3, including in the highly polluted category (Class V). The source of pollution is caused by market or shops (Purwata and Karang City urban village), home industry, temporary shelter which is widely located along the river flow, the flow of in and out of traditional fishing boats and from dense settlements in Purwata Village. River water in the downstream area can not be used for drinking water, whereas for fisheries only fish can live in permissible dirty water. Sailing and water transportation are permitted even though there is still pollution. Overall the Way Kuripan River condition from upstream to downstream has been contaminated with varying levels of pollution.

4. Conclusion

In general, the water quality of Way Kuripan River is in contaminated status with varying level of pollution. The results of the analysis show that SK01 and SK04 have WQI values of 70.3 and 70.11, with the category of river water quality of class III (slightly contaminated). At the sample points of SK02 and SK03 have WQI values of 55.8 and 53.8. The water quality at the sample points is included in polluted category (Class IV). The value of WQI at the sample point of SK05 is 38.3 with the status of highly polluted water quality (Class V). The results of this study can be used as a reference by the local government to overcome the contamination of Way Kuripan River water with water pollution control strategy, utilization, monitoring and maintenance of water resources in DAS Way Kuripan .

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