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Water Quality Index Score in River Water Treatment Plant at Upper Klang and Gombak River Catchment

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Abstract: National River Water Plants are located along upper Klang and Gombak river catchment to purify the polluted river using direct contact methods. As the current water quality situation in the study area is poor due to the contribution of anthropogenic activities on the water quality degradation in these urban rivers, the investigation was performed using the Water Quality Index. This paper gives the overall performance of RWTP using Water Quality Index (WQI) calculation methods. The WQI act as the basis of environment assessment towards to river water quality classification under Malaysia National Water Quality Standards. As an overall result, 57 percent from the total effluents achieve target Class II and above and another 43 percent achieve Class III and below regardless of two (2) RWTPs are under target from the average monitoring; RWTP Sg Gisir and RWTP Sg Sentul. However, the result for RWTP Sg Sentul is not yet conclusive since the monitoring duration is less than 2 years. Certainly, RWTP Sg Gisir needs to be taken into consideration for more frequent maintenance of the RWTP or upgrading of the RWTP oxidation tank as suggested in several MBBR/IFAS operation. As to improve the RWTP performance to score higher WQI, the introduction of recycling sludge in the biological tank so it will be a shorter reaction time. Additionally, the RWTP owner should implement a frequent maintenance work into RWTP component especially clarifier, sludge collector, biological oxidation tank and rubbish trap collector.

Keywords: Catchment, River, Treatment Plant, Water quality index

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I. INTRODUCTION

Over the past decades, river water quality in major Klang valley area has deteriorated in most of the major river due to anthropogenic factors; urbanization, industrialization and population growth[1].

Sedimentation also becomes the main problem to the river caused by rain wash and slope collapse during seasonal variation of flow which is due to hydrological and geological characteristics of river basins

[1-2], [11-12], [3-10]. Many studies have qualified the effect of population increase the land use and will associate to anthropogenic activities finally reflect to river water quality [13-21].

Pollutant from the various sources of the catchment will leak and gather with sediment in river beds[22]. Therefore, river water quality degradation problems become even worse. Instead of that, during the rainy season may worsen this problem and finally, ecosystems will meet the huge impacts. Water pollution is a crucial problem in the Kuala Lumpur Metropolitan City (our study area) because many developments happen as well as squatter's population are located along the river as well as frequent transportation of pollutants in the river [23-26]. The accumulation of pollutants will deteriorate river water quality and deplete dissolved oxygen in the river [27].

Malaysian government applied direct river water treatment plant (RWTP) as an alternative for reducing river pollution in Klang river catchment. This project is one of the River of Life (ROL) Project to upgrade the Upper Klang and Gombak river and its tributaries from polluted to clean and suitable for recreational activities [28]. Klang River originates from Ulu Gombak Forest Reserve located in central Peninsular Malaysia and it is a combination of 13 major tributaries and covers about 1,288 km^2 of the catchment area. Klang river encompasses two main territory area; Kuala Lumpur and Selangor State. The climate of the region is generally categorized as humid tropic and peak rainfall in September to December [29].

RWTPs are operated as same as wastewater treatment plant technology applying Integrated Fixed Activated Sludge (IFAS) system consist of multiple types of the biological carrier in the biological oxidation tank [18], [30]. Influent (Inf) and effluent (Eff) of the RWTP are recorded monthly to evaluate the river water improvement capacity.

RWTP practically use the concept of Integrated Fixed Activated Sludge (IFAS) which is commonly applied in the domestic and industrial wastewater system.[31-36]. RWTP operationally starts from water intake collection with trash screening and rubber dam. Then, the primary process is introduced with stabilization flow tank to reduce the hydrological surge of flowing river water followed by the grit removal process. Next, the secondary process started with hybrid attached and suspended culture in the biological oxidation tank. The attached growth will be acclimatized on the biological carrier to form a bio film colony. Bio film will use the nutrient (organic and inorganic) in the river water [10], [37]. Suspended biomass will grow in the existing culture tank with the supply of dissolved oxygen. After purifying process with four-hour hydraulic retention time, clarifier is introduced to the river water before finally release back to the river water [38]. The target effluent is to achieve the Water Quality Index (WQI) class II [39].The location of sampling RWTP stations in upper Klang river catchment is shown in Figure 1

Table. 1 General rating scale for the Water Quality Index [40]

WQI	Status	Class	Uses
80-100	Clean	I	Conservation of natural environment Water Supply I – Practically no treatment necessary Fishery I – Very sensitive aquatic species
		II	Water Supply II – Conventional treatment Fishery II – Sensitive aquatic species Recreational use body contact
60-79	Slightly Polluted	III	Water Supply III – Extensive treatment required Fishery III – Common of economic value and tolerant species; livestock drinking
0-59	Very Polluted	IV	Irrigation
		V	None of the above

The Water Quality Index (WQI) is often applied as a mathematical model for evaluating the status of river and lake water all over the world. The status of all rivers in Malaysia is monitored by the Department of Environment (DOE) as in Table 1. Department of Irrigation and Drainage (DID) monitor WQI for the Upper Klang and Gombak river and its tributaries for ROL projects [39].

The WQI act as the basis of environment assessment towards to river water quality classification under Malaysia National Water Quality Standards (NWQS). It expresses the quality of river water by a unit less single number varies from index 0 to index 100. The highest index value represents the best water quality and vice versa. This index number is a combination measurement of physical, chemical and biological parameters. Finally, the index number is classified into five classes from (I to V). The top class is the highest beneficial uses. [40]. Accordance ROL project target, the effluent of RWTP must achieve Class II which is suitable for the recreational purpose [39].

As current water quality situation in the study area is poor due to the contribution of anthropogenic activities on the water quality degradation in these urban rivers, the investigation was performed using WQI Index score analysis in this study. As regard, a suite of selected water quality indices is attempted to discover the water quality trend and the ability of ROL RWTP in reducing the Klang and Gombak river water from polluted into WQI Class II as targeted in ROL project's aim. The present study is the first of its kind in Klang and Gombak river including its tributaries and will contribute to the baseline information for future water local water quality studies.

II. METHODOLOGY

Currently, as for 2018, there are seven (7) full operational RWTPs that available for water quality sampling. Two (2) representative samples of RWTP for both influent and effluent once per month starting 2013 to 2017 are collected. The detailed duration and data size for analysis for RWTP station are shown in Table 2.

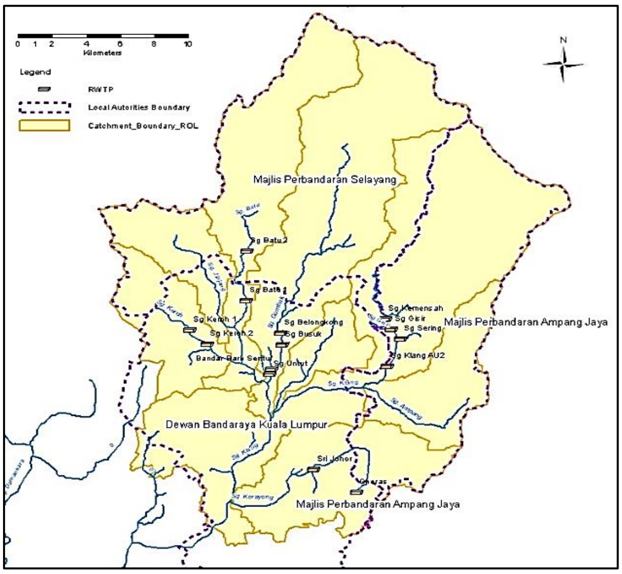

Fig. 1 Location of RWTPs and plan view of selected RWTP

The parameter testing for each influent and effluent are Dissolved Oxygen (DO in unit mg/L), Temperature (°C), pH (unit less), Biochemical Oxygen Demand (BOD in unit mg/L), Chemical Oxygen Demand (COD in mg/L), Total Suspended Solid (TSS in unit mg/L), Ammonia cal Nitrogen (AN in unit mg/L) and Escherichia-Coli (E-coli in unit Most Probable Number; MPN).

The sample is stored in a sterile 1500 ml polyethylene bottle before instantly transfer to the analytical laboratory for water quality parameters according to standard methods [41].

The detailed RWTP operation and data collection can be referred to from a previous publication [42]. The most essential method to classify the river water quality is the WQI index and National Water Quality Standards (NWQS). These are the common regulation for all common water guideline in Malaysia. The NWQS defined classes I to V, referred to the classification of rivers or river segments based on the descending order of water quality: Class I being the best and Class V being the worst [40].

The WQI is calculated using six parameters WQI: DO, BOD, COD, TSS, AN and pH with the inclusion of intermediate sub-indices. Calculations are performed on the water quality parameters to find individual sub-indices. The sub-indices are named SIDO, SIBOD, SICOD, SIAN, SISS and SIPH. The best-fit equations used for the assessment of the six sub-indices are shown below [43].

Table. 2 RWTP sampling duration and sampling size

RWTP Station	Catchment	Duration	Sample size	
			Influent	Effluent
Klang	Upper Klang river	January 2015 to December 2017	33	32
Sering	Upper Klang river	January 2015 to December 2017	32	27
Kemensah	Upper Klang river	January 2015 to December 2017	35	35
Gisir	Upper Klang river	January 2015 to December 2017	34	34
Belongkong	Gombak river	February 2015 to December 2017	33	30
Kemunsing	Gombak river	April 2016 to December 2017	19	19
Sentul	Gombak river	May 2016 to December 2017	19	19

Table. 3 Water quality index classification [40]

Parameters	Unit	Classes				
		I	II	III	IV	V
pH	-	>7	6-7	5-6	<5	>5
DO	mg/L	>7	6-7	5-6	1-3	<1
BOD	mg/L	<1	1-3	3-6	6-12	>12
COD	mg/L	<10	10-25	25-50	50-100	>100
TSS	mg/L	<25	25-50	50-150	150-300	>300
AN	mg/L	<0.1	0.1-0.3	0.3-0.9	0.9-2.7	>2.7
WQI	mg/L	>92.7	76.5-92.7	51.9-76.5	31.0-51.9	<31.0

(a) Sub-index for DO (in % saturation): SIDO

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

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

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

(b) Sub-index for BOD: SIBOD

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

$SIBOD = 108e^{-0.085x} - 0.1$ for $x > 5$

(c) Sub-index for COD: SICOD

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

$SICOD = 103\, e^{-0.0157x} - 0.04x$ for $x \geq 20$

(d) Sub-index AN: SIAN

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

$SIAN = 94^{-0.573x} - 5|x\text{-}2|$ for $0.3 < x < 4$

(e) Sub-index for TSS: SISS

$SISS = 97.5e^{-0.00676x} = 0.05x$ for $x \leq 100$

$SISS = 71e^{-0.0016x} - 0.015x$ for $100 < x < 1000$

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

(f) Sub-index for pH: 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 $x \geq 8.75$

Where x is the concentration in mg/L for all parameters except pH. Once the respective sub-indices have been calculated, the WQI can be calculated using Eq. (1).

$$WQI = (0.2 \times SIDO) + (.19 \times SIBOD) + (0.16 \times SICOD) + (0.15 \times SIAN) + (0.16 \times SISS) + (0.12 \times SIPH) \quad (1)$$

Table. 4 Water quality classification based on WQI

Parameters	Index Range		
	Clean	Slightly polluted	Polluted
SIBOD	91-100	80-90	0-79
SIAN	92-100	71-91	0-70
SISS	76-100	70-75	0-69
WQI	81-100	60-80	0-59

The summation of the weights for all the sub-indices must have a value of unity. The respective class designed for WQI Score is shown in Table 3 and 4.

III. RESULTS AND DISCUSSIONS

Results

Table 5 provides the total number of occurrences of water quality for all RWTPs. It has been observed from the number of occurrences, water quality for influent for every station majority belong to Class III (48 percent) and Class IV (27 percent). Additionally, water quality for effluent for every station belongs to Class II (53 percent) and Class III (40 percent). The most polluted influent, which is categorized under Class V that contributes to 8 percent from the total influent. There are RWTP Sg Gisir with 9 times occurrence followed by RWTP Belongkong (5 times occurrence), RWTP Sentul (2 times occurrence) and RWTP Sg Kemunsing (1-time occurrence). The most effective RWTP which able to purify the influent up to Class I is RWTP Klang with 3 times occurrence. It followed by RWTP Belongkong and RWTP Sentul with 2 times occurrence. However, the observed difference between influent and effluent in this analysis was not significant because there is still a plenty number of effluents from all station did not achieve the project target.

A number of occurrences in each RWTP effluent. RWTP Belongkong effluent achieves 2 times Class I, 16 occurrences of Class II, 11 times for Class III and only 1 time for Class I. RWTP Gisir achieve 8 times Class II, 22 times Class and 4 times Class IV. As depicted in Figure 2, almost recorded influent under Gombak river catchment are classified as polluted as referred from the WQI score (less than 59) in Table 2. Despite that matter, RWTPs still effectively treat the polluted water using IFAS which are proven to provides best resistance against influent shock loading; besides, it has higher efficacy than conventional activated sludge processes[44], [45].

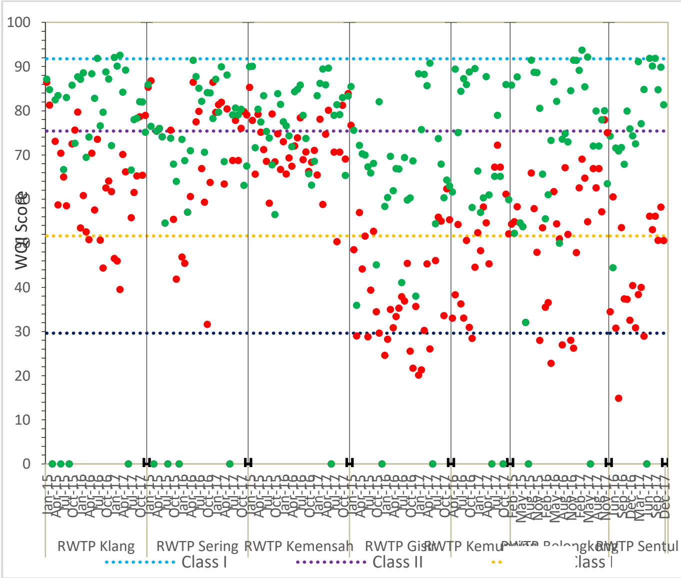

Fig. 2 RWTP influent and effluent WQI score

The main factor in this tributary, Gisir River received polluted influent from three of non-upgraded sewage treatment plant in the upstream. This RWTP located at the end of Gisir river stem before the effluent of RWTP Gisir enters into the main river (Klang River) [44], [45]. RWTP Kemensah achieves excellent target effluent with 23 times Class II and only 12 times Class III. RWTP Kemunsing although still new in water quality monitoring analysis but can achieve 9 class II followed by 10 times Class III.

Effluent in RWTP Sg Klang achieves the maximum 22 times Class I, only 3 times in Class I- and 7-times class III. Effluent RWTP Sg Sentul achieves 2 times Class I and 1-time Class I and the other is Class II and III. Meantime, effluent for RWTP Sering achieves target 17 times while 10 times under target.

Table. 5 Number of occurrences for WQI Class

Station	Class I	Class II	Class III	Class IV	Class V
Inf Belongkong		1	21	6	5
Inf Gisir		1	6	18	9
Inf Kemensah		9	25	1	
Inf Kemunsing			9	9	1
Inf Klang		6	21	6	
Inf Sentul			6	11	2
Inf Sering		17	11	4	
Eff Belongkong	2	16	11	1	
Eff Gisir		8	22	4	
Eff Kemensah		23	12		
Eff Kemunsing		9	10		
Eff Klang	3	22	7		
Eff Sentul	2	9	7	1	
Eff Sering		17	10		

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Table. 6 Average water quality values in RWTP

Station	Average DO %	Average pH	Average BOD	Average COD	Average SS	Average AN
Inf Klang	53.28	6.86	8.32	29.70	22.09	3.43
Eff Klang	81.56	6.88	3.83	15.66	13.91	1.11
Inf Sering	70.70	6.83	10.13	33.01	32.44	2.45
Eff Sering	72.43	6.78	5.34	16.75	14.56	1.32
Inf Kemensah	63.57	6.79	6.36	30.64	15.30	1.79
Eff Kemensah	76.74	6.97	4.71	18.61	43.67	1.13
Inf Gisir	15.71	6.91	22.10	69.76	17.74	6.26
Eff Gisir	60.96	7.05	8.34	29.82	10.56	4.58
Inf Belongkong	42.16	7.04	20.59	57.28	34.73	5.37
Eff Belongkong	71.09	7.14	5.31	17.19	7.04	1.49
Inf Kemunsing	32.87	7.15	14.67	51.05	21.30	5.24
Eff Kemunsing	62.99	7.11	7.11	36.43	241.87	1.94
Inf Sentul	37.05	6.99	14.79	48.59	25.21	3.08
Eff Sentul	62.35	7.13	11.44	30.80	26.47	2.70

As an overall result, 57 percent from the total effluents achieve target Class II and above and another 43 percent achieve Class III and below. In spite of these results, there two RWTP are under target from the average monitoring; RWTP Gisir and RWTP Sg Sentul based on Table 5. However, the result for RWTP Sg Sentul is not yet conclusive since the monitoring duration is less than 2 years as shown in Figure 2. Certainly, RWTP Gisir is necessary to be taken into consideration for upgrading or frequent maintenance of the RWTP as suggested in several Moving Bed Biological Reactor (MBBR) or IFAS operation [48]–[50].

RWTP using IFAS technology a water superstructure according to novel compact design space treatment technology. The problem formulation was done during design and commissioning phase so that the comprehensive system for the existing primary and secondary process with no recycle sludge system. As an alternative, introduction a new task responsible for recycling sludge so it will be shorter reaction time [49], [51].

RWTP owner should also implement a frequent maintenance work into RWTP component especially clarifier, sludge collector, biological oxidation tank and rubbish trap collector. Plus, replacing the biological carrier infrequent will reduce fouling in the oxidation tank [52]. The addition of the maintenance period will increase the capacity of bio film performance in RWTP. Bączyk, *et al.* (2018) report that the recurrence maintenance work is improving the capacity and workability of any river structures. Clifford *et al.* (2013) state that a robust bio film water system (e.g. IFAS) will lessen maintenance cost and operational issues.

IV. CONCLUSIONS

This RWTP using IFAS technology has satisfactory achieve ROL project objective with more than half of RWTP in Klang river in all monitored effluent achieve a clean river water into WQI Class II and above. RWTP Gisir need to have their facilities frequent maintenance as 75 percent of the effluent are under WQI Class III and IV and didn't achieve WQI Class II. This is caused by high

Ammonia concentration from domestic wastewater at Sg. Gisir and contribute to higher value of WQI. This study also suggests the requirement to have RWTP in any future river restoration project for the river water pollution control besides other approaches e.g gross trap, log boom etc whereas having a frequent maintenance to achieve satisfactory project target. RWTP Sg Sentul still need more longer observation period for a conclusive result. These advanced technologies should be employed has become important, not only due mitigation for improving the river deterioration but also due to the sustainable development:

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