Investigating the Availability of Domestic Wastewater Pollution Load Capacity in Brantas River, Malang

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Abstract. The riverine system can recover itself to its balance once pollutant enters the water body. Nonetheless, this self-purification capability only applies when the concentration and magnitude of the pollutant do not exceed the pollution load capacity. As the main river in Malang, the Brantas River receives most of the pollutants from anthropogenic activities, especially domestic wastewater. A study was conducted to uncover the capacity of the pollution load of the Brantas River. Samples were obtained from surface water in five stations along the river and analysed according to the domestic wastewater parameters in the Permen LHK No. P.68/2016 against river water quality for Class II limit. A model was then constructed using QUAL2Kw software. The analysis showed that Brantas River does not have sufficient allocation for COD and BOD at all stations, and NH_3 at downstream stations. In contrast, the river remains able to accept TSS and coliform inputs. The model showed that only coliform contaminants can be self-purified despite all citizens discharging domestic wastewater containing coliform at the maximum concentration and flow. It is clear that to make the pollution load for domestic wastewater available in Malang, river quality must be managed before the stream enters the city.

1 Introduction

In the last decade, 494 million people have been still practising open defecation, even though in the last five years, there has been a 20% increase in the proportion of the global population using safely managed sanitation [1]. This problem also occurs in big cities in Indonesia, for instance, the Malang agglomeration area. With a population of nearly 1 million people, Malang struggles with safely managed sanitation implementation since 17% of the population still practices open defecation [2]. There is indeed a proportion that small and decentralised sewage treatment facilities cover. Nonetheless, only 14% of these facilities are in acceptable performance [3]. This makes a significant amount of excreta in the form of untreated blackwater channelled directly to the main river passing the city, the Brantas River.

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It is indeed that river has the ability to self-purify itself from pollutants entering its body. Oxidation reactions mainly carry out this self-purification mechanism where pollutants decompose [4]. A river which flows on the mountain, such as the upstream part of Brantas, has a higher capacity to do self-purification since it has a higher flow rate, oxidation, and nitrification rate. Nonetheless, given that the pollutant load is vast enough to deplete the dissolved oxygen significantly, the river could not recover the condition and become polluted [5]. Because such an amount of untreated blackwater enters the Brantas River regularly, it is essential to understand whether the pollutant load exceeding the river's self-purification capacity needs to be uncovered. This is also connected to the health risk as Brantas River serves as the primary drinking water supply for the whole province [6].

Modelling has been preferred to understand the capacity of self-purification of a river. QUAL2Kw for instance, has been used to determine the carrying capacity of the pollution load of a river and can recommend the availability level of the river in receiving incoming pollutant load [7]. This method was used in several studies to understand the pollution load capacity in the Brantas River. These studies were mainly focused on pollution load related to industrial and agricultural sources. They showed that N is the major pollutant related to the activities and became higher along the stream [8,9].

On the other hand, domestic wastewater contributes to the availability of pollution load capacity of such rivers more than industrial and agricultural do. Domestic wastewater contributes up to 83.5% of the total pollutant that enters the river body [10]. A study recently discovered that the pollution load related to domestic activity in the Brantas River has surpassed its carrying capacity for COD and BOD parameters [11]. However, there has not been a study that measures domestic wastewater quality from its source and is modelled to clearly understand the pollution load capacity for domestic wastewater inputs in Malang.
Hence, this study was conducted with two objectives, i.e., 1) to inspect if the pollution load carrying capacity for domestic wastewater parameters in the upstream Brantas River is still available, and 2) to understand the self-purification capacity availability of domestic wastewater parameters by simulating domestic wastewater input into the water body. The scope of this study limits several variables, i.e., the river segment was located within Malang City, branches were not taken into calculation, and fluctuation of precipitation and river flow rate was considered negligible.

2 Materials and Methods

2.1 Location Segmentation and Sampling

The upstream part of the Brantas River with a length of 25.245 km crossing the city was divided into four segments. Each segment was capped with a sampling station identified (from upstream to downstream) as Pendem Bridge (PEN-1), Begawan Bridge (BEG-1), Kadalpang Dam (DAM-1), Muharto Alley (MUH-1), and Kendalpayak-Tambakrejo area (BUM-1). In addition, domestic wastewater was sampled in two communities around Dam Kadalpang (DAM-2) and Muharto Alley (MUH-2) that did not own sufficient wastewater treatment facilities to illustrate the untreated domestic wastewater quality. Sampling was done for each station's river and domestic wastewater. The details of river segments and sampling stations can be seen in Table and Figure 1

Table 1. Sampling Stations

Segment	Length (km)	Upstream Coordinate	Downstream Coordinate
A	5.413	PEN-1 7°54'10.09"S 112°34'31.02"E	BEG-1 7°55'32.82"S 112°36'8.16"E
B	4.972	BEG-1 7°55'32.82"S 112°36'8.16"E	DAM-1 7°57'28.38"S 112°37'27.31"E
C	5.888	DAM-1 7°57'28.38"S 112°37'27.31"E	MUH-1 7°59'26.95"S 112°38'22.71"E
D	8.972	MUH-1 7°59'26.95"S 112°38'22.71"E	BUM-1 8° 3'26.52"S 112°37'47.70"E

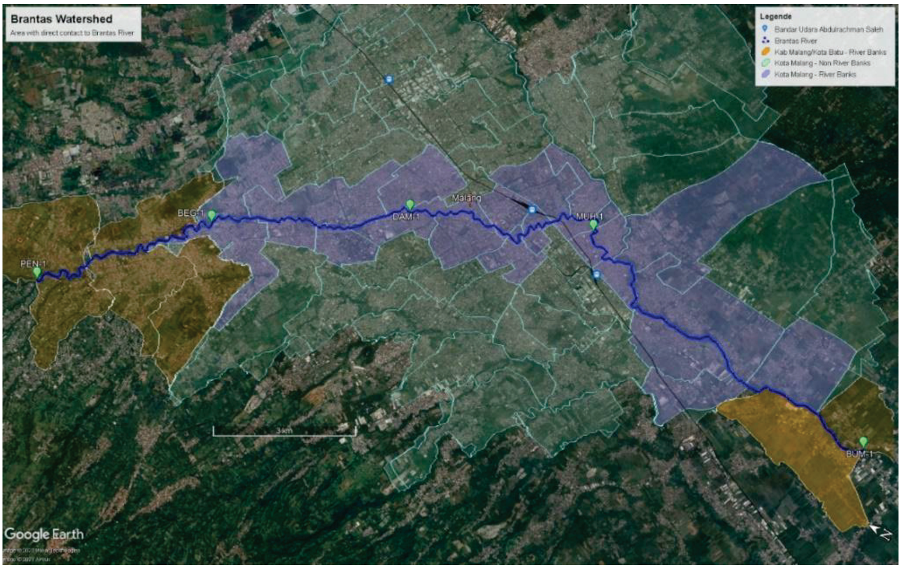


Fig. 1. Upstream part of Brantas River crossing the Malang City used in this study. The coloured area shows villages with a direct border to the Brantas River.

2.2 Wastewater Analysis and Evaluation

River and domestic wastewater were analysed to obtain domestic wastewater parameter values according to Permen LHK No. P.68/2016, i.e., pH, COD, BOD, TSS, oil and grease, NH_3, and total coliform. The analysis was conducted in the laboratory following SNI 6989.11:2019 and the APHA standard method for examining water and wastewater [12]. The result of river water analysis was compared to the limit of Class II rivers according to PP No. 21/2021 meanwhile, the result of domestic wastewater analysis was compared to the limit according to Permen LHK No. P.68/2016.

2.3 Water Quality Modelling

Parameters from river water that were still within the legal specification were modelled using QUAL2Kw ver. 5.1. Parameter variables involved in the modelling were inorganic solids, CBODfast, NH_4-Nitrogen, Pathogen, Generic constituent, and pH. Headwater flow data was obtained from Perum Jasa Tirta I. Channel slope, bottom width, and side slope were estimated using GIS software. The model was constructed according to auto-calibration genetic algorithm control [13]. Each generated model was evaluated using the Nash-Sutcliffe Efficiency (NSE) according to Equation (1):

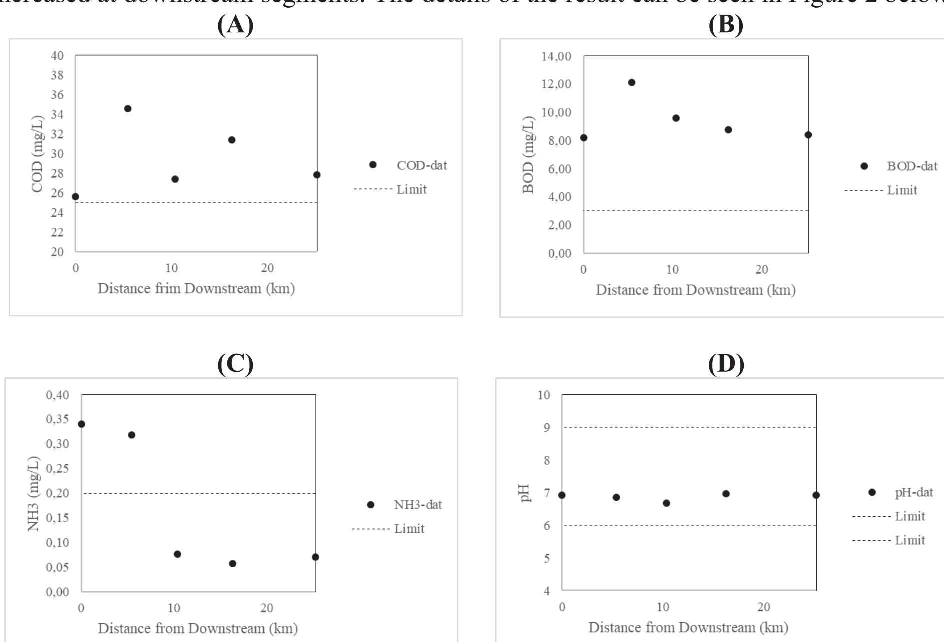
$$NSE = \frac{\sum_{i=1}^{n}(X_i{}^{obs} - X_i{}^{sim})^2}{\sum_{i=1}^{n}(X_i{}^{obs} - X_i{}^{mean})^2} \tag{1}$$

where X_i^{obs} is the ith observation for the parameter being evaluated, X_i^{sim} is the ith simulated value of the parameter being evaluated, X^{mean} is the mean of observed data for the parameter being evaluated, and n is the number of observations [14].
The model with a sufficient evaluation score (ranging between 0.0 and 1.0) was then used to forecast the self-purification capacity using respective domestic wastewater parameter values obtained from the previous step. The domestic wastewater flow rate was estimated from the maximum flow rate in Permen LHK No. P.68/2016 and the population of Malang City, proportional to the length of the river segment with a direct border to residential areas. This scenario can inform if the load of such parameters will likely affect the availability of self-purification capacity of the river.

3 Result and Discussion

3.1 Brantas River Water Quality

The laboratory analysis showed that COD and BOD surpassed the Class II water quality limit from all sampling stations. Meanwhile, parameter NH_3 only surpassed the limit in the two most downstream sampling stations. Parameter TSS, pH, and total coliform were within the Class II water quality specification at all sampling stations. The finding indicated that the domestic wastewater as pollutant input has occurred along the river and accumulated and increased at downstream segments. The details of the result can be seen in Figure 2 below.



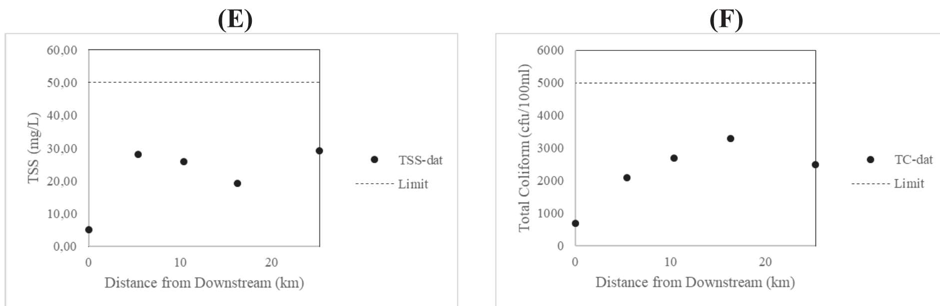


Fig. 2. The domestic wastewater parameter value compared to Class II water quality for (A) COD, (B) BOD, (C) NH_3, (D) pH, (E) TSS, and (F) Total Coliform

The finding was in line with previous studies that found that most parameters of domestic wastewater in Brantas River have exceeded Class II river quality due to the input of up to 500 kg-BOD/d and 1,000 kg-COD/d within the city border [15]. According to previous studies, COD and BOD were parameters that constantly exceeded the limit. The pattern of such parameter fluctuation is consistent with previous studies where COD and BOD were getting more significant in downstream segments [9,11]. The increasing concentration of TSS did not follow the increasing concentration of COD and BOD. This may indicate that the pollutant was significant enough to deplete the dissolved oxygen. This condition makes the organic substances unable to decompose into inorganic substances since the oxidant is the limiting unit [16]. At this point, it can be concluded that the capacity for COD and BOD pollution load in the river has reached its limit. No domestic wastewater containing COD and BOD may enter the water body as the water needs to have Class II water quality.

Even though NH_3 was within the limit in the first three sampling stations, it showed a significant increase in the two most downstream stations. This may result from a significant pollutant load between DAM-1 and MUH-1 stations, where the population is at its highest density, making the domestic wastewater channelled into the river higher. In addition, many agricultural areas, particularly rice fields and sugarcane yards, between MUH-1 and BUM-1, make N concentration in the river even higher. The high nitrogen constituents in the river relate to pesticides and fertilisers used in agriculture. The leach of pesticides and agriculture can get into the river via irrigation and rainwater runoff [8]. This condition is likely to occur since wastewater treatment plant has rarely been used in agricultural settings in Malang.

On the other hand, pH, TSS, and total coliform were within the specification of Class II river quality. This indicated that the self-purification mechanism for these constituents was working. The river's high flow rate and step-side slope may affect TSS behaviour. Meanwhile, total coliform may stabilise due to the disinfection mechanism of ultraviolet irradiation from the sunshine [17].

3.2 Pollution Load of Domestic Wastewater

From the water quality evaluation, it was clearly understood that the pollution load capacity of COD, BOD, and, to a certain degree, NH_3, has been filled. This made modelling for pollution load was done for pH, TSS, and total coliform only. The QUAL2Kw modelling with fitness value equal 0.5985 generated results which can be seen in Figure 3 below.

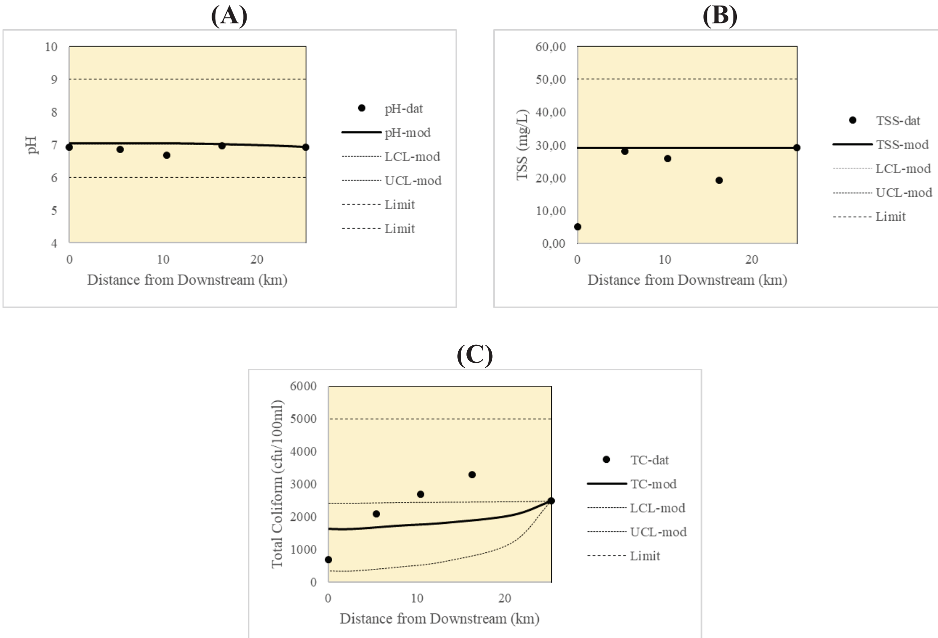


Fig. 3. The river quality modelling of the parameters (A) pH, (B) TSS, and (C) total coliform. Note that the suffix -dat and -mod refers to measured and modelled value, respectively

The three models showed different patterns. The model for the pH parameter showed a relatively flat with a slight increase towards the downstream. The TSS parameter model showed a flat pattern despite the distance from the upstream. The model for the total coliform parameter showed a tendency to decrease along the distance from the upstream. The measured values, especially for pH and total coliform, were consistent with the modelled values.

The models were then evaluated using the NSE equation and generated values of -2.230, -0.742, and 0.024 for parameter pH, TSS, and total coliform. Since the accepted NSE value must be between 0.00 and 1.00, the satisfactory result model was only for the total coliform parameter. The positive NSE value of total coliform indicated that the mean of the simulated value was a more appropriate predictor than the mean of the measured value [14]. Therefore, the model eligible for observing the pollution load capacity was the model for total coliform.

3.3 Self-Purification Capacity of Upstream Brantas River

The analysis of domestic wastewater samples showed that water quality was within the specification of Permen LHK No. P.68/2016 as can be seen in Table 2 below.

Table 2. Domestic Wastewater Quality

Parameter	Unit	Limit	Sampling Stations	
			DAM-2	MUH-2
NH3	mg/L	10	0.1267	0.2954
Total Coliform	cfu/100mL	3,000	2,880	1,480
pH	-	6-9	6.92	6.93
Oil & Grease	mg/L	5	1.5	1
COD	mg/L	100	27.5	23.9

BOD	mg/L	30	9.87	7.54
TSS	mg/L	30	21.2	8.8

Hence, the measured values of total coliform were involved in QUAL2Kw modelling as a baseline to understand if its load will affect the self-purification capacity of the river (Scenario 1). The contaminant was considered a diffused source in the simulation since domestic wastewater is discharged along the river. The proportional number of populations based on the length of the river with a direct border to residential areas was calculated to anticipate the value. The result showed no significant difference in pollution load capacity when total coliform is channelled to the river body with the maximum load following Scenario 1 (M = 2,180; SD = 990), $t(6) = -1.77$; $p = 0.138$. This indicated that the 1,000,000 citizens of Malang channelled domestic wastewater with a flow of 100 L/person.d, self-purification did still occur. On the other hand, the capacity of total coliform load in Brantas River was still available.

Nonetheless, as a product of domestic wastewater, it was clearly understood that Brantas River lacked its capacity for self-purification for some parameters. This was observed in the most upstream sampling station, PEN-1. Therefore, water quality management must be followed even when the stream has not reached the city area. There must be a buffer zone to ensure that diffuse domestic wastewater sources do not enter the water body freely. Or, in other words, it is recommended for the city to have some municipal wastewater treatment so that the pollution load can be controlled more.

4 Conclusions

From the perspective of domestic wastewater discharging, the Brantas River did not have enough capacity to receive COD and BOD pollutants from Pendem Bridge Station until the Kendalpayak area and NH_3 from Dam Kadalpang to Kendalpayak area. Brantas River may receive TSS and total coliform load from Pendem Bridge to the Kendalpayak area. This study has generated a model that can foresee the self-purification of total coliform regarding domestic wastewater intake. The model showed that self-purification of total coliform still occurs even if the maximum load of the entire population of Malang discharges such contaminants to the river body. Despite its ability to self-purify, it is clear that the water quality of the Brantas River must be managed before the stream enters the city. This can be achieved by limiting the diffuse source of contaminants such as agricultural wastewater containing pesticides and fertiliser in the more upstream area of Malang city and providing municipal wastewater treatment plant within the city border.

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