Pollution Model of Batik and Domestic Wastewater on River Water Quality

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Abstract. Human activities create waste that can affect the river's water quality physically, chemically, and biologically. Waste pollution from non-point sources is difficult to control where it spreads with a fairly even flow of discharge. Some watersheds in Indonesia have specific non-point source sources of pollution such as batik waste originating from Small and Medium Enterprises (SMEs). The research case study is in an urban area in the segment of the Premulung river segment of Solo City. This study aims to explain the effects of various pollutants on water quality, such as batik waste and domestic waste. Premulung River water samples were taken at 13 points from non-point sources and 10-point sources. The prediction model uses Qual2kw software. The results showed that the flow of batik waste from SMEs affected water quality in the COD parameters and the colour changed temporarily and quickly along the river channel. Rivers which is polluted by batik waste have the characteristics of dark water with high organic matter content. At the downstream river, water quality improves because batik waste will settle to the bottom of the river at a certain distance.

1. Introduction

Land use, lithology, time, rainfall and human activities cause changes in river water quality physically, chemically or biologically. Kinds of human activities in fulfilling their needs of life that come from industrial activities, households, and agriculture will create waste that gives a contribution to the decreasing of river water quality [1]. Wastewater that enters the river becomes a pollutant [2]. Water pollution in the river is a complex process a representation of the effects of interaction between pollutant substances, river hydrogeomorphology and human activities [1]. Water quality parameters in the Upper Manyame River are associated with increases in pollution load from settlements and agriculture activities [3]. Urban landuses had stronger impacts on water quality in the Dongjiang River [4]. Water quality measurements results in several rivers showed that the level of BOD, COD and coliform that have far exceeded the quality standard.

Several recent studies have used this model [5]. Qual2KW able to stimulate some water parameters like temperature, Conductivity, Inorganic Solids, Dissolved Oxygen, CBOD slow, CBOD fast, Organic Nitrogen, NH4-Nitrogen, NO3-Nitrogen [6]. In Araguaia river (Amazon region, Brazil) using Qual2kw to set hydraulic parameters [7]. Rio Blanco watershed in Jalisco, Mexico. Using the Qual2kw model for the distribution of pollutant sources in watersheds located in Northern Lombardy,
Italy [8]. Qual2kw model can be used in the simulation of reducing the load of river pollutants [9]. Using of Qual2kw programme can estimate pollution load values on each river segment. First, did the segment division (reach), distance and river boundary [10].

But research on this topic in Indonesia is still rare. Qual2kw is used to assess the carrying capacity of pollutants in the Bedog river [12]. The research also explained that Qual2kw was used for numerical modelling of river water quality [13]. In addition, there are several other studies in Indonesia that use Qual2kw, in the research of Dyah et al. Qual2kw is used to determine strategies for overcoming the Gajahwong river water pollution caused by organic matter [14]. Whereas in the study of Marlina et al. Qual2Kw was used to evaluate the capacity of the pollutant load n the Winongo river [15]. And in the study of Febriyana, Qual2Kw is used to determine the capacity of the Surabaya river segment of Cangkir [16]. Total Suspended Solids (TSS) is suspended materials that consist of mud and soft sand and microorganism especially caused by soil erosion that carried over to water bodies.

Some watersheds in Indonesia have non-point sources of pollution caused by high human activity around rivers and specific sources such as batik waste originating from Small and Medium Enterprises. The case study is in the Premulung River Surakarta City as a densely populated urban area. The majority of social activities in Surakarta are trader, office space, and industry. Premulung river is Bengawan Solo tributaries which are located in the west side, upstream of the river at the foot of Mount Merbabu. While Bengawan Solo River is the longest river in Java island (600 km) that pass two provinces, they are Central Java and East Java with a drainage area of 16.000 km². The Bengawan Solo River Region is located at 110 ° 18' East to 112 ° 45' East and 6 ° 49' East to 8 ° 08' East, tropical with high temperatures and humidity [17]. Recorded about 15.2 million inhabitants society life in river area units of Bengawan Solo [9]. In previous studies according to Arya [18] based on the results of laboratory tests the value of COD, Nitrate, Phosphate or copper (Cu), almost the entire Premulung River segment is still below the Class IV of the quality standard according to Republic of Indonesia Regulation No. 82 of 2001. The results of the model show that spatial planning has a very close correlation to the amount of pollution load entering the river. Non-centralized source pollutant load will be directly related to the area and are built [18].

This water quality is based on water quality standard appropriate river class based on Government Regulation [19] about management water quality and water pollution control. These are in line with the report result of the Environmental Status of Indonesia that most rivers in a densely populated area in all region of Indonesia are polluted. The load value will be calculated to be pollutant sources spread only when load sources transported into the water flow if there is no runoff, the load of non-point source in water bodies locked from human or animal population size [20]. The study aims to determine the effects of pollutant sources on water quality, such as batik waste and domestic waste. The results of modelling can be useful in managing non-point source pollution in urban areas.

2. Methodology

The Premulung watershed includes the Premulung River, Brojo River, Wingko River and Tanggul River. The Premulung River is a tributary of the Bengawan Solo River on the west side, upstream at the foot of Mount Merbabu. Passing through the area of agriculture, settlements and several industries that enter the Sukoharjo and Surakarta regencies. The study was conducted in the dry season of 2017.

The research location is in the stream of the Premulung River, upstream at the foot of Mount Merbabu and spins in Boyolali and Sukoharjo. Along the Premulung River, there are no available runoff discharge data or water level measurements. So, the calculation of the mainstay discharge uses a mathematical model of Thornwithe runoff through the conversion of rain and climate data. Then the evaporation calculation uses the Penman method. Climatology data used in this study were taken from Surakarta Airport Station in 2015 - 2017 consisting of temperature, humidity, wind speed, duration of sun exposure.

Determination of segmentation based on watershed land use to represent the potential sources of existing pollutants. Segments are needed to identify whether there are inputs (assumed all point
source) into a segment that can change water flow and quality. In this study, the Premulung river as the main river is divided into 6 (six) segments which are further divided into 17 sections or reach and the Brojo River as a tributary [6]. Determination of sampling locations guided by SNI 03-7016-2004[21]. Premulung River water samples are taken using the Grab Sample method at 13 points of non-point source and 10 points of the source of human activities such as settlements and Small, Medium Enterprises or the Batik industry.

Water quality change prediction model uses Qual2kw method with water quality parameters including DO, COD, BOD. The QUAL2Kw model splits the river into segments which are then divided into small subsections known as computational elements [22]. In the analysis of the data, several analyses were carried out, including hydrological analysis, analysis of space utilization patterns in the Premulung River, Analysis of the Pollution Source of the Premulung River and the Pollution Load of the Premulung River. Analysis of the effect of land use on the level of water quality is based on water quality in each segment that has been obtained.

![Figure 1. Premulung River sampling point](image)

Qual2Kw is a one-dimensional river quality and flow model which is an upgraded version of the QUAL2E model. Qual2Kw was developed by the US Environmental Protection Agency which can simulate migration and transportation of conventional pollutants. Qual2Kw can simulate migration and transportation of various constituents.
\[
\frac{dC_i}{dt} = \frac{Q_{i-1}}{V_i} C_{i-1} - \frac{Q_1}{V_i} C_i - \frac{Q_{ab,i}}{V_i} C_i + \frac{E_{i-1}}{V_i} (C_{i-1} - C_i) + \frac{E_i}{V_i} (C_{i+1} - C_i) + \frac{W_i}{V_i} + S \quad (1)
\]

Where,
- \(Q_i\) = Flow (m\(^3\)/s)
- \(Ab\) = Abstraction
- \(V_i\) = Volume (m\(^3\))
- \(E_i\) = mass dispersion coefficient between reach i and i + 1 (m\(^3\)/d)
- \(Wi\) = external loading parameter di reach i (g/d)
- \(Si\) = increasing and decreasing constituents due to reaction and mass transfer mechanism (g/m\(^3\)/d)
- \(Ci\) = concentration of constituents

The prediction of the type and number of sources of pollution is calculated based on the analysis of the digitized story maps and field reviews. The gross domestic pollution burden is the multiplication of the population by the factor of waste generation per capita per day of waste production by the transmission factor. The analytical method uses the descriptive method which explains the land use and human activities in the Premulung River, which can affect water quality.

3. Results and discussion

The results of calculations with the Thornthwaite Method in the form of an average debit flow monthly. In figure 2 concluded the average peak of the rainy season occurs in February and November and the peak of dry season occurs in July until August. Flow in February reaches 10.14 m\(^3\)/second, while peak flow on dry season occurs in August 0.78 m\(^3\)/second, for a confidence level of 50%.

![Figure 2. Monthly Q\(_p\) of Premulung watershed method thornwhaite](image)

The sampling process is carried out in July, the measured flow is predicted according to figure 3. At the upstream location, the flow is estimated to reach 0.38 m\(^3\)/second and then increase to 0.8 m\(^3\)/second downstream by the Bengawan Solo River. Increased flow at the meeting of the Brojo river at a distance of 4.5 km. Flow along with the flow of more than non-point source waste around the area.
The water quality of Premulung River is included in the class IV. Based on Republic of Indonesia Regulation No. 82 of 2001[23], class IV river water quality has a designation as a flow for agriculture. The morphological condition of the Premulung River has a fairly good flow, but some locations are still unorganized and closed by plants so that sun penetration is very poor and there is a lack of oxygen in the water [24]. The stream of the Premulung River divides the City of Surakarta in the Laweyan District, the Serengan District and also a part of the Pasar Kliwon District. The banks of the Premulung River are areas with high population density with domestic and non-domestic wastewater flows which directly lead to river flows [18] and as a place for industrial waste disposal, thus making the river polluted [25]. Various industrial waste flows result in the colour of river water being blackish-brown and having copper (Cu) metal content that exceeds quality standards. Premulung River has a colour condition that tends to be blackish brown due to the disposal of batik industry waste. The textile industry produces wastewater containing high organic concentrations and colour insensitivity.

Based on the results of laboratory testing at the point source, it was found that several parameters exceeded the quality standard in accordance with Central Java Province Regulation No. 5 of 2012 concerning Wastewater Quality Standards.
| Parameter | Unit | Central Java Regulation No. 5 of 2012 | Sample Code |
|-----------|------|--------------------------------------|--------------|
| Temperature | °C  | Batik A 26,6 | 25,5 | 26,8 | 26,9 | 26,8 |
| pH         | 6 – 9 | 6,82 | 6,95 | 9,27 | 9,02 | 7,43 |
| DO         | mg/L | 6,4 | 4,2 | 6,8 | 6,5 | 2,5 |
| TSS        | mg/L | 50 | 224 | 200 | 138 | 642 | 1224 |
| COD        | mg/L | 150 | 140,41 | 140,41 | 417,81 | 164,38 | 318,49 |
| BOD        | mg/L | 60 | 45,94 | 43,64 | 126,33 | 52,83 | 84 |
| Cu         | mg/L | 1 | 0,07 | 0,1 | 0,02 | 0,52 | 0,05 |

Based on survey results like Table 1, the results of laboratory test parameters are temperature, pH, DO, COD, BOD. Based on the results of laboratory tests, it is known that TSS levels from all batik waste samples exceed the quality standards. In the COD parameter, for waste C batik, batik X and Y batik exceeded 150 mgL and passed the quality standard while the A batik waste and B batik were below the quality standard. COD is an important parameter that shows the quality of health in freshwater bodies (Suthar et al. 2010). Then for BOD parameters of waste that exceed 60 mgL or quality standards, namely C batik and Y batik. Higher BOD values cause the depletion of dissolved oxygen in water[26]. The parameters of temperature, pH, DO, and copper are below the quality standard for all samples. The source of pollution in Laweyan District is 55 boarding houses, 32 hotels, and 81 Batik Small and Medium Enterprises. In addition to these three sources, in Laweyan District, there are also the hospital and other industrial activities. Waste generated from these businesses and/or activities is channelled to the Premulung River and Brojo River. Other businesses and/or activities located in Serengan District are ten boarding houses, six hotels, and eight batik Small Medium Enterprises. Waste generated from these businesses and/or activities is channelled to the Premulung River, and part of the Jenes River.
In Figure 5 it is known that a decrease in DO starts from km 5. This is due to the presence of waste input from the batik industry that has not been or has not been processed before. The results of DO measurements in Table 1 from the Small Medium Enterprises batik show a high enough value because the waste that was sampled was fresh waste that had just come out of the dyeing process. Untreated textile waste can contaminate groundwater and water, reducing dissolved oxygen in water [26]. Then after entering the river body, a biological chemical process occurs that reduces the DO value. This happens because the suspended solids absorb heat from the sun and increase the temperature of the water, thereby reducing levels of dissolved oxygen. The research result showed that the entry of batik waste from Small, Medium Enterprises affected water quality on the COD parameter and the colour temporarily and quickly changed along the river. The river that contains batik waste has characteristic as dark colour water with high suspended material. The presence of batik waste flows accelerates the river sinking process.

![Figure 6. Qual2kw results for TSS parameters](image1)

![Figure 7. Qual2kw results for COD parameters](image2)

Characteristics of COD values also vary where measured from 140 mgl to 400 mgl. In Figure 7 it is known that an increase in the COD graph. Where it is inversely proportional to the DO chart, which shows a downward trend. Increased COD and BOD charts occur starting from Km 5.9. Where in the Km occurred to enter the batik industry waste from C Batik SMEs with an input flow of 0.128 m³/s. Premulung River receives batik wastewater from around 80 Small Medium Enterprises batik industries. It is causing the colour of the river water downstream to become coloured. The existing condition of the Brojo River is very concerning. Before entering Surakarta, the Brojo River water was black in addition to a large amount of rubbish on the surface of the water worsening the condition of
The Brojo River. The Brojo River flows into the Premulung River. Based on an inventory of sources of pollution, the Brojo River receives the burden of waste from household activities, hospitality, and the batik industry.

4. Conclusions

Urban activities have a very close correlation with the amount of pollution that enters the river. The Qual2KW model can simulate migration and transport of pollutants from NPS batik waste well. The model shows that there is a correlation between the value of pollution load in each Sagmen to be compared. The results of the Thornwhaite debit calculation method in the form of a mainstay monthly discharge flow rate, it was concluded that the average peak of the rainy season occurred in February and November of 10.14 m$^3$/second. While the peak of the dry season occurs in July-August, of 0.78 m$^3$/sec for a 50% confidence level. While the Premulung river receives a debit of batik wastewater from around 80 MSMEs in the batik industry. Causing the colour of river water to be coloured.

The results of the COD value show values that vary from 140 mgl to 400 mgl. The Premulung River has a colour condition that tends to be blackish brown due to the disposal of batik industry waste both by large companies, MSMEs and domestic NPS waste due to human activities. Based on the obtained water quality, the water quality of Premulung River is included in the class IV, which has been determined as an agricultural flow. Besides having a pretty good morphological condition, the flow of the river, but some locations are still not arranged and covered by plants so that the sun's penetration is not too good. Then a review of space allocation can be a way to reduce the burden of pollution flowing in rivers.

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