Determination pollution load capacity of Ngrowo River as wastewater receiver from hospital activities

N Lusiana¹, B Rahadi¹ and Y Anggita²

¹ Study Program of Environmental Engineering, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia
² Student of Environmental Engineering Study Program, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia

E-mail: novialusiana@ub.ac.id

Abstract. Industrialization and domestic activities very potentially to contribute water pollution addition especially into a river. One of domestic activities that may produce wastewater is a hospital activity. Public Regional Hospital in Tulungagung is located at Kedungwaru that will developed in order to further support the existing infrastructure. Assessment towards water quality and load pollution capacity of Ngrowo River as wastewater receiver is very important before hospital development began. The method used in this research was mass balance method, pollution index to determine of water pollution status based on the parameters of temperature, pH, total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate and phosphate. The quality parameters obtained in this study were compared with the class II water quality standard. The maximum pollutant load was calculated to determine the pollution load capacity. The result show that water quality of Ngrowo River was categorized in low pollution (around 3.75 – 3.99 for index pollution) based on class of II of water quality standard. Load pollution capacity at downstream have exceeded 28,673.3 kg/day for BOD and 34,339.3 kg/day for COD in existing condition. Based on the findings in this study, it is recommended that hospitals are obliged to have wastewater treatment plant installed. Such approach is critical to maintain the quality of surroundings environments as well as to prevent water pollution to occur.

1. Introduction

The interrelationship between land use and water quality of upland tributaries which drain forests into higher-order streams with a variety of downstream land use has received less attention [1]. In addition, there are three distinguished attributes between the temperate and tropical catchments: a. point source pollution, b. fertilizer usage, and c. crop species cultivations [2]. Also, land use effects may differ between temperate and tropical river basins because of urban land-use systems with different levels of anthropogenic influences, geology and climate, the impact of agricultural land use, soil properties, and nutrient availability [3]. Furthermore, water quality is often degraded by land use. Intensive agriculture increases erosion and sediment load, and leachate of nutrients and other agrochemicals into streams, rivers and groundwater. Indeed, agriculture has become the largest source of excess nitrogen and phosphorus to waterways and coastal zones [4].

The problem of river water pollution in the downstream area is the disposal of wastewater from human activity into water bodies. One of the contributors to river water pollution is hospital activity. One of the regional general hospitals in Tulungagung is planned to be expanded by increasing the
number of beds from 468 to 756 units. The addition of number of beds can certainly increase the amount of wastewater produced by both hospitals and laboratory activities. In addition to wastewater, hospital also generates hazardous wastes such as infectious waste, pathological waste, sharps, pharmaceutical waste, genotoxic waste, chemical waste, and radioactive waste [5].

Negative effects that may arise as a result of unhealthy environmental conditions due to poor management of hospital wastewater, including: the presence of pathogenic bacteria that cause disease. Many studies have been conducted on hospital wastewater in different countries such as France, India, Nigeria, Ethiopia, Iran, Morocco, Pakistan, Indonesia and Korea. These studies showed that BOD values varied from 242 mg/L to 632 mg/L, while COD values varied from 616 mg/L to 1388.75 mg/L. Heavy metals such as Cadmium, Chromium, Copper, Lead, Mercury, Nickel and Zinc were also found in hospital wastewater [6]. The purpose of this study was to determine the effect of hospital development on water quality and load pollution capacity of the Ngrowo River as recipients of wastewater.

2. Materials and Method
2.1. Data and sampling
Data used are water quality data in dry season with the parameter temperature, pH, TSS, DO, BOD, COD, nitrate, phosphate. River water quality was obtained from laboratory testing by environmental province agency laboratory, from the period of 21 to 22 November 2018. Hospital wastewater as well as other wastes were determined by wastewater parameters such as BOD, COD, TTS, pH, microbiology and others [5].

Sampling was taken by instantaneously (grab sampling) method, in which the sample was taken at certain times and the sample can represent the wastewater or the water body as a whole. Sampling was carried out three times by determining three points. This was done to find out the true picture of the river's condition. The procedure for sampling was based on Behmel et al. [7]. Firstly, sample bottles were prepared and rinsed with distilled water. The sampling devices was prepared and rinsed. Then, the samples were taken according to location and placed into sample bottles. The location coordinates were recorded and plotted on the map. Put the label on the sample bottles. Then the sample was preserved prior measurement.

2.2. Collecting data
2.2.1. Determination of water sample location
Some considerations to determine the sampling location for river water was carried out according to method described by Mahfud et al. [8] as follows: 1. Natural water sources, locations that have never or are still slightly contaminated; 2. Polluted water sources, namely locations that have undergone changes or downstream from pollutant sources; and 3. The source of water that is utilized, namely the location of utilization. The sampling location selection in this study was based on 3 (three) location coordinate points, namely at the upstream point (T1) which is the point where the part has not received pollution load with location coordinates 81°59'44,199 "LU and 117°23'58,644" BT is 500 m from T2, T1 point aims to determine the state of river water quality before it is affected by waste water entering the water body. The outlet point of wastewater treatment plant (T2) is the point of the water body that receives direct pollutant load from hospital waste with location coordinates 81°59 '44,270 "LU and 117°24' 29,686" BT and downstream points (T3) are outlets after the wastewater mixes with water body Kedungwaru River with location coordinates 81°59'44,704 "LU and 117°24 '39,352" BT is 500 m from T2. The point of sampling location can be seen in Figure 1.
2.3. Determination of discharge
River discharge is the amount of water flowing in a channel or river per unit of time. The commonly applied method for determining river discharge is the river profile method (cross section). In this method the discharge is the product of multiplication between the vertical cross-sectional area of the river (river profile) and the velocity of the water flow [9].

\[ Q = A \times V \]  

Where, \( Q \) = flow debit (m\(^3\).s\(^{-1}\))  \( A \) = vertical cross-sectional area (m\(^2\))  \( V \) = velocity of river flow (m.s\(^{-1}\))

2.4. Water quality testing method
The biochemical oxygen demand (BOD) was measured using the method described in SNI 6989. 72: 2009 [10], and for pH was meaning using pH device, operation procedure based on SNI 06-6989-11-2004 [11]. Chemical oxygen demand (COD) was analyzed using spectrophotometry (QI/LKA/19), dissolved oxygen (DO) was analyzed using iodometry method described in SNI 06 – 6989. 14 – 2004 [12]. Nitrate was analyzed using spectrophotometry UV-Visible described in SNI 6989. 79: 2011 [13], while for phosphate was analyzed using spectrophotometry by ascorbic acid described by SNI 06 – 6989. 31 – 2005 [14] and total suspended solids (TSS) was measured using spectrophotometry [15].

2.5. Determination of pollution load
River pollution load is the amount of a pollutant contained in river water. River pollution can be caused by industrial, residential and agricultural activities. River pollution load can be calculated using the formula [16]:

\[ \text{BPS} = (C_s)_{j} \times Q_s \times f \]  

\( \text{BPS} \) = river pollution load (kg/day)  \( C_s \) = measured level is actually pollutant-\( j \) element (mg/L)  \( Q_s \) = River water discharge (m\(^3\)/day)  \( f \) = conversion factor = (1 kg) / (1,000. 000 mg) x (1 liter) / (1 m\(^3\)) x 86,400 = 86.4.

2.6. Determination of pollution load capacity (DTBP)
Calculation of pollution load capacity (DTBP) can be determined using equation 3, Calculation of capacity is obtained from the difference in full pollution load and without pollution load [16].

\[ \text{DTBP} = \text{polluted load according to quality standards} - \text{measured pollutant load} \] (3)

2.7. Determination of water quality status
The pollution index (IP) is determined for an allotment. IP is also can be developed for several purposes for all parts of the body of water or part of a river. The equation used in calculating IP is as follow [17]:

\[ PIj = \sqrt{\frac{(C_i)^2}{M_i} + \frac{(C_i)^2}{R}} \] (4)
Where, $P_{Ij} =$ Pollution Index for designation (j) $C_i =$ concentration of water quality parameters measured by, $L_{ij} =$ concentration of water quality parameters included in the water quality standard (j) $(C_{ij} / L_{ij}) M = C_{ij}/L_{ij}$ maximum value $(C_{ij}/L_{ij})$, $R =$ average, $(C_{ij}/L_{ij})$ value.

This method can directly connect the level of contamination by whether or not the river is used for certain usages and with the value of certain parameters. Evaluation of PI values is: $0 \leq P_{Ij} \leq 1.0 =$ fulfilling the quality standard (good condition) $1.0 < P_{Ij} \leq 5.0 =$ mild pollutant $5.0 < P_{Ij} \leq 10 =$ moderate pollutant $P_{Ij} > 10 =$ severe contamination [17].

3. Results and Discussion

3.1. Hospital wastewater quality

Wastewater produced by hospitals has certain characteristics include physical, chemical and biological. Hospital wastewater contains various types of microorganisms, depending on the type of hospital, the level of treatment carried out before disposal and the type of facility available (laboratory, clinic). Indeed, there are some types of microorganisms that are pathogenic. The results of testing the quality of processed Wastewater Treatment Plants (WWTPs) in December 2018 can be seen in Table 1.

Hospital’s wastewater has been sufficiently processed as indicated by the effluent has meet the standard value for effluent discharge. Yet, some fluctuation was remained where at certain time there was some parameters exceeded that of the standard effluent discharge requirement. Hospital wastewater, originated from various sources, such as kitchen, laundry, toilets, laboratories activities, and etc., was collected in an equalization pond. This equalization pool serves to flatten the flow and organic load of the wastewater before entering the next wastewater treatment unit. From the equalization tank, the wastewater which was naturally oxidized, is then moved to the WWTP which is operated anaerobically. The series of WWTP units was using the vegetative anaerobic method starts from the sedimentation tank reactor baffle to anaerobic filter. Then flows to horizontal sand filter and enters the disinfectant pool before the treated wastewater is discharged into the water body.

Table 1. Hospital wastewater quality after treatment

| Parameter | Unit | Testing result | Standard* |
|-----------|------|----------------|-----------|
| BOD       | mg/L | 6.24           | 30        |
| COD       | mg/L | 42.05          | 80        |
| TSS       | mg/L | 14             | 30        |
| Ammonia   | mg/L | <0.005         | 0.1       |
| Phosphate | mg/L | 1.440          | 2         |

Note: *standard value by Decree of the Minister of Environment [18]

3.2. Discharge of Ngrowo River

The discharge from T1 to T3 points has increased due to differences in river dimension. T3 points have a greater dimension than T1 and T2 points. In addition, the T3 point is the point that has received input from Tulungagung Hospital wastewater, thus changing the flow velocity at that point. T2 points has a significant discharge differences because sample was collected from the location with additional pollutants from hospital wastewater (near WWTP outlet pipe). Therefore, the discharge of water river has been declining.

Table 2. Discharge of Ngrowo River

| Location | Discharge (m³/s) |
|----------|-----------------|
| Upstream (T1) | 19.8709 |
| Middle (location get additional pollutant from hospital) (T2) | 0.0014 |
| Downstream (T3) | 19.8723 |
3.3. Water quality of Ngrowo River

TSS is a solid that dissolved and cannot settle directly, and it responsible to cause turbidity of water. TSS consists of particles that are smaller in size and weight than sediments, such as clay, certain organic materials, microorganism cells, etc. TSS is suspended material (diameter >1μm) retained in the milli-pore filter with a pore diameter of 0.45μm [19]. Figure 2a shows that decreasing of TSS concentration at T3 point caused by the discharge value on this point is greater than others, that suspended solids are degraded. Government Regulation No. 82 of 2001, class II quality standards shows the TSS concentration allowed is 50 mg/L. Hence, compared to the standard quality of the Ngrowo River, the TSS concentration at points T1, T2 and T3 was still below the value of the specified quality standard. It also shows that the disposal of wastewater from Tulungagung hospital did not affect TSS parameters in Ngrowo River and it is still in good category.

Government Regulation No.82 of 2001 stipulates class II quality standards that allow BOD levels to be 3 mg/L, and the result shows that BOD concentration at all points has exceeded that of the regulation standard. T2 point has the highest BOD concentration because the location got more pollutants from the hospital wastewater as much as 6 mg/L. The BOD graph (Figure 2b) shows that additional of pollutant from the hospital does not give a significant effect for T3 point (small difference of BOD concentration among T1 point and T3 point). Input of high organic matter can also come from domestic settlement activities around the Ngrowo River. Oxidation of a certain amount of organic matter was occurred in an aerobic state. BOD concentration increases if the level of waste contamination increased. BOD is an important indicator of pollution to determine the strength or level of contamination in wastewater, industrial waste, or contaminated water. BOD is usually calculated in 5 days at 20°C (BOD5).

Based on Figure 2, the COD level from T1 to T2 point increased from 45 mg/L to 53.1 mg/L, while the COD concentration from T2 to T3 point decreased to 49.6 mg/L. However, based on class II quality water standards by the Government, it shows that the standard allowed for COD concentration is 25 mg/L. The COD values for the three points T1, T2 and T3 far exceed the applicable quality standards. T1 point received pollutants that causing COD concentration to become much higher, possibly due to pollutants from domestic wastewater. Based on land use map, T1 area is dominated by urbanization and agricultural activity. The COD value at the T3 point decreased, where it should increase since this point received input of hospital wastewater from T2. This is due to the large volume of water discharge at point T3, which may potentially dilute the wastewater.

T1 point has a high DO concentration, indicating a low occurrence of water pollution. While, the DO concentration at T2 point decreased, possibly due to the organic materials contained in the wastewater input from causing less oxygen was dissolved in the river. The increase in DO concentration in T3 is may be due to the rocky river conditions and turbulence, causing the aeration to occur. The greater the DO value in water indicates that the water has good quality. Conversely, if DO value is low, this indicates that the water is polluted [21]. Increasing the organic material in the water may cause an increase in BOD value and a decrease in DO value. Clean water contains a high DO value, and a low value in BOD and TSS. If the level of DO decreases, the animals living in the water body will die. If the BOD and COD levels increases, the water is becoming polluted [22].

Based Figure 2, it can be seen that the nitrate level at T1 was 0.164 mg/L while at T2 point was 0.147 mg/L and at T3 point was 0.171 mg/L. Nitrate concentration at T3 point has the highest concentration compared to the two points namely T1 and T2. Nitrate levels at points T1, T2 and T3 were far below the specified quality standards, indicating that the water of the Ngrowo River is still in the safe category. Risks to human health associated with high levels of nitrate in drinking water include thyroid gland dysfunction, gastric cancer, and decrease in the capacity of blood to transport oxygen (known as methemoglobinemia) in infants below six months old [23].

Naturally, the levels of phosphates in surface and ground water bodies are not harmful to human health, animals or the environment. However, extremely high levels of phosphates can cause digestive problems. Furthermore, excessive amounts of phosphates in water bodies can lead to eutrophication, a condition of accelerated algal production to extreme quantities until they die off. The bacteria responsible for their decomposition use up and hence deplete the DO concentration in the water bodies to such levels that can kill fish [24].
Figure 2. Water quality of Ngrowo River (a) TSS, (b) BOD, (c) COD, (d) DO, (e) Phosphate, (f) Nitrate

3.4. Determination of pollution load and pollution load capacity

Based on the calculations in Table 3, the pollution in Ngrowo River before polluted by hospital wastewater are no longer proper to accommodate more wastewater. It is because the amount of BOD and COD was higher than the quality standard. But, the TSS and Nitrate levels were still below the quality standards. Moreover, high concentration of phosphate causes T1 to no longer be able to accommodate pollutants with high phosphate content. T2 location also shows the same condition, where it is no longer able to receive additional pollutant load due to BOD and COD pollutant have exceeded the quality standards. Yet, the pollutant load for TSS, phosphate and NO$_3$ were still below the quality standards. T3 shares the same condition as T2, only the BOD and COD pollutant loads that exceed the quality standard. Among the three locations, T3 has a greater pollutant load capacity (TSS, phosphate and NO$_3$) than that of other locations due to the dimensions of the river and the larger water discharge.

Similarly, previous research by Masyruroh et al. [25] based on the results of measurements of the Hospital wastewater quality in May and June 2013. There are parameters exceeding water quality standard for the waste parameter free Ammonia (NH$_3$-N) as many as 0.3 mg/L and 2.74 mg/L (standard quality 0.1 mg/L). While the results of water quality measurements Cibanten in June 2013 can be concluded as follows: there are parameters that exceed the quality standards in accordance with regulation PP 82/2001, i.e., Dissolved Oxygen (DO) and BOD. However, based on the percentage in terms of increase of parameters level of upstream to downstream, the DO shows an increase (101.563%) compared to only BOD that is only 84.211%. The contribution of wastewater from the Serang District General Hospital to Cibanten River water quality is still at a reasonable level.
Table 3. Pollution load and pollution load capacity of Ngrowo River

| Sample Points | Value (mg/L) | Actual pollution load (kg/day) | Maximum pollution load (kg/day) | Pollution load capacity (kg/day) |
|---------------|-------------|-------------------------------|-------------------------------|---------------------------------|
| T1 BOD        | 19.70       | 33821.860                     | 5150.537                      | -28671.300                     |
| T1 TSS        | 26.000      | 44637.990                     | 85842.290                     | 41204.300                      |
| T1 COD        | 45.000      | 77258.060                     | 42921.140                     | -34336.900                     |
| T1 DO         | 10.100      | 17340.140                     | 6867.383                      | 10472.800                      |
| T1 Phosphate  | 0.205       | 351.953                       | 343.369                       | -8.584                          |
| T1 NO₂        | 0.164       | 281.563                       | 17168.460                     | 16886.890                      |
| T2 BOD        | 23.100      | 2.794                         | 0.363                         | -2.431                          |
| T2 TSS        | 28.000      | 3.387                         | 6.604                         | 2.661                           |
| T2 COD        | 53.100      | 6.423                         | 3.024                         | -3.398                          |
| T2 DO         | 9.080       | 1.098                         | 0.484                         | 0.614                           |
| T2 Phosphate  | 0.169       | 0.020                         | 0.024                         | 0.003                           |
| T2 NO₂        | 0.147       | 0.018                         | 1.209                         | 1.192                           |
| T3 BOD        | 19.700      | 33824.240                     | 5150.900                      | -28673.300                     |
| T3 TSS        | 26.000      | 44641.130                     | 85848.340                     | 41207.200                      |
| T3 COD        | 45.000      | 77263.500                     | 42924.170                     | -34339.300                     |
| T3 DO         | 10.100      | 17341.360                     | 6867.867                      | 10473.500                      |
| T3 Phosphate  | 0.200       | 343.393                       | 343.393                       | 0                               |
| T3 NO₂        | 0.160       | 274.715                       | 17169.670                     | 16894.950                      |

Note: (-) = pollution load capacity has been exceeded

3.5. Determination of water quality status
T1 and T3 points have the same water quality status of low pollution. This is because at T1 point, the parameters of BOD, COD and phosphate concentration have exceeded that of the class II water quality standards. While at T3 point, both BOD and COD concentration exceed the quality standards. Water quality in T2 was also categorized as low pollution due to the additional wastewater input from the hospital. T2 point is where the wastewater was received, thus increasing the pollution index produced. The presence of hospital wastewater did not cause a significant change in Ngrowo River water quality status. The biggest pollutant source of the Ngrowo River is from domestic wastewater include gray water and black water.

Table 4. Water quality status of Ngrowo River

| Sample location | Pollution Index | Status     |
|-----------------|-----------------|------------|
| T1              | 3.75            | Low pollution |
| T2              | 3.99            | Low pollution |
| T3              | 3.87            | Low pollution |

4. Conclusions
The condition of Ngrowo River water quality at the three observation locations was low pollution as indicated by a high value of BOD, COD and phosphate concentration. The findings confirmed that T1 point was unable to accommodate pollutant load with high BOD, COD, and phosphate. While T2 and T3 was no longer able to accommodate BOD and COD pollutant load, but still have ability to receive pollutant loads with phosphate and nitrate concentration. The additional input of wastewater from the hospital activity did not significantly affect to water quality of Ngrowo River.
References

[1] Sidle R C, J W Hornbeck 1991 Cumulative effects: a broader approach to water quality research J. Soil Water Conserv. 46 268-271.

[2] Ometo J P H B, Martinelli L A, Ballester M V, Gessner A, Krusche A V, Victoria R L, M Williams 2000 Effects of land-use on water chemistry and macro invertebrates in two streams of the Piracicaba River basin, South-East, Brazil Freshwater Biol. 44 327-337.

[3] Dudgeon D 2008 Tropical Stream Ecology Academic Press.

[4] Foley J A, Defries R, Asner G P, Barford C, Bonan, G and Carpenter S R 2005 Global consequences of land use Sci. 309 5734 570-574.

[5] Muhlich M M, Scherrer F D, Daschner 2003 Comparison of infectious waste management in European hospitals J. Hosp. Infect. 55 260-268.

[6] Emmanuel E Y Perrodin G Keck JM Blanchard P Vermande 2005 Ecotoxicological risk assessment of hospital wastewater: a proposed framework for J. Hazard. Materials. 117 1-11.

[7] Behmel S, Damour M, Ludwiq R, Rodriguez M J 2016 Water quality monitoring strategies—a review and future perspectives Sci. Total Environ. 571 1312–1329.

[8] Mahfud M, Lihawa F, Iyabu H, Sakakibara M 2014 Study of mercury pollution on the environment in North Gorontalo Regency Final Report University of Gorontalo Gorontalo. [In Indonesian]

[9] National Standard Agency Indonesia National Standard Document Number 6989.59:2008 Wastewater Sampling Method [In Indonesian]

[10] National Standard Agency Indonesia National Standard Document Number 06 – 6989. 14 – 2004 DO Testing Method [In Indonesian]

[11] National Standard Agency Indonesia National Standard Document SNI 06-6989. 11 – 2004 pH Testing Method [In Indonesian]

[12] National Standard Agency Indonesia National Standard Document Number 6989. 72: 2009 BOD Testing Method [In Indonesian]

[13] National Standard Agency Indonesia National Standard Document Number 6989. 79: 2011 Nitrate Testing Method [In Indonesian]

[14] National Standard Agency Indonesia National Standard Document Number SNI 06 – 6989. 31 – 2005 Phosphate Testing Method [In Indonesian]

[15] National Standard Agency Indonesia National Standard Document Number SNI 06 – 6989.3-2004 TSS Testing Method [In Indonesian]

[16] Decree of the Minister of Environment No. 110 of 2003 concerning determination of Pollution Load Capacity [In Indonesian]

[17] Decree of the Minister of Environment No. 115 of 2003 concerning determination of water quality index guideline [In Indonesian]

[18] Decree of the Minister of Environment No. 58 of 1995 concerning standard of wastewater from hospital activity [In Indonesian]

[19] Jamie B, Richard B 1996 Water quality monitoring - a practical guide to the design and implementation of freshwater quality studies and monitoring programs Published on behalf of United Nations Environment Program and the World Health Organization

[20] Sasongko, A L 2006 Contribution of domestic wastes around the River Tuk to the water quality of the Kaligarang River and its handling efforts (Case study of Sampangan and Bendor Ngisor Villages, Gajah Mungkur District, Semarang City) Undergraduate Thesis University of Diponegoro Semarang. [In Indonesian]

[21] Zulkifli H 2009 Water quality status of downstream of Musi river based on phytoplankton commodity Undergraduate Thesis University of Sriwijaya Palembang. [In Indonesian]

[22] Sunarsih E 2002 Water quality parameters and index Undergraduate Thesis University of Sriwijaya Palembang. [In Indonesian]

[23] Gulis G, Czompolyova M, Cerhan J R 2002 An ecologic study of nitrate in municipal drinking water and cancer incidence in Trnava District Slovakia Environ. Res. 88 3 182–187.
[24] Fadiran A O, Dlamini S C, Mavuso A 2007 A Comparative study of the phosphate levels in some surface and ground water bodies of Swaziland Bulletin Chem. Soc. Ethiopia 22 2 197-206.

[25] Masyuroh A, Erry K 2013 Analysis of water quality of Cibanten River around public regional hospital in Serang regency J. Fondasi 2 2 99-110. [In Indonesian]