Nutrien flux in the Bompon Watershed, Magelang, Central Java, Indonesia

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Abstract. In several places, agriculture area is the main contributor of Nitrogen and Phosphate existence in water. This research conducted in Bompon Watershed which has agriculture area 90% of the total area. This study aims to measure the amount of Nitrogen and Phosphate losses during May 2018 – May 2019. The calculation of Nitrogen loss is conducted through field sampling, and load calculation. In the period without measurement, daily load were estimated by interpolation between L and Q relation. The result of this research shows that the most dominant amount of nutrient pollution in Bompon watershed are Nitrate and Phosphate with the number reach 6.5 kh NO$_3$-N/day or 1,084 kg NO$_3$-N/month and 103 kg P/day or 883 kg P/month.

1. Introduction

Human activity in fulfilling needs such as industry, agriculture, and domestic as well produce waste which can affect the water quality. Globally, 80% of industry liquid waste are discarded in water body untreated, and 70% agriculture activity become the main cause of water pollution in the world [1]. The fertilizer applications in agricultural activity to maintain the soil fertility is regarded as a main contributor to Nitrogen (N) and Phosphate (P) existence in surface and groundwater [2].

N and P nutrient in the river will affect not only to the river's ecology but also affect reservoir or wetland supplied by the river, as well as estuary and the sea [3]. The problem resulted by excessive N and P in water body are quality degradation and eutrophication. Eutrophication will affect the aquatic habitat condition, where the blooming algae and water plants cause oxygen deficiency and decease aquatic animal. Moreover, the quality degradation will have an impact on human's health if it exceeds the maximum threshold as much as 10 mg/l for N [4].

According to Zhang et al [5] Surface runoff and soil erosion are main carrier factors in the loss of Nitrogen in agriculture land. The Bompon watershed has 90% agriculture area of the total region which consist of arable land, plantation and rice field (Figure 1). Previous research shows, erosion rate in Bompon riverbed reach 73,13 Ton/Ha/year [6]. Rainfall in Bompon watershed is quite high around 100-200 mm/month also become determining factor of surface runoff which able to carry N and P to water body.

Due to those reasons, calculation of nutrient flux in Bompon watershed is needed and become the purpose of this research. Salvia-Castellvi et al., [3] mentioned that characteristics and hydrology system of a watershed can be measured by qualitative and quantitative counting of nutrient (i.e. concentration and flux). The right spatial and temporal scale are needed to determine the main pollutant source and main process of carrying mineral substances.
2. Study Area and Methods

2.1. Study Area

This study is conducted in Bompon watershed which becomes part in Bogowonto hydrological system and boils down to Indian Ocean. Bompon watershed located in the mountainside of Sumbing Muda and Sumbing Tua volcano. Bompon watershed divided into two districts in Magelang Regency, Kajoran and Salaman with an area of 294.71. Physiographically, the study area located in transition zone of quarter and tersier geologic time. According to Yogyakarta geology map, scale 1:100,000, Bompon watershed formation classified into Kebobutak formation. The constituents’ formation consist of andesite breccia’s, agglomerate tuff, and andesitic.

Agricultural land is dominant landuse in study area. Agriculture in study area categorized into rice fields, plantation, and arable land. The land use of plantation has the largest area of watershed which reach 67% (Table 1). Plantation consists of mahogany, coffee, coconut, cassava, corn and albizia. These plantations are given fertilizer periodically to help its variety growth.
Table 1. Landuse in the study area

| Landuse    | Area (Ha) | Percentage |
|------------|-----------|------------|
| Plantation | 197.72    | 67%        |
| Arable Land| 29.34     | 10%        |
| Settlements| 30.53     | 10%        |
| Rice Field | 37.12     | 13%        |
| Total      | 294.71    | 100%       |

2.2. Sampling and Analysis

The data used in this study are field measurement data for nutrient and water level data. The water level data measured based on logger recording with 15 minutes duration during May 2018 to May 2019. This logger recording will be used as discharge calculation input based on rating curve of previous research conducted by Widasmara and Hadi [7].

Nutrient are sampled for Nitrate, Nitrite, Ammonia and Phosphate. The samples are taken in 4 months, January – April 2019 using 1L bottle sampler. The total amount of the samples are 24. The sampling method is based on the difference of debit which will happen in the rainy time. It is done in order to obtain the samples of normal to extreme condition. The samples are analyzed in the laboratory of Balai Besar Teknik Kesehatan Lingkungan dan Pengendalian Penyakit (BBTKLPP), the Health Ministry by method that is explained in Table 2.

Table 2. Methods for analysis nutrient samples

| No. | Nutrient  | Unit  | Method                                      |
|-----|-----------|-------|---------------------------------------------|
| 1.  | Nitrate   | mg/liter | APHA 2012, Section 4500 – NO₃⁻            |
| 2.  | Nitrite   | mg/liter | SNI 06-6989. 9-2004                        |
| 3.  | Ammonia   | mg/liter | SNI 06-6989. 30-2005                       |
| 4.  | Phosphate | mg/liter | APHA 2012, Section 4500 P-D                |

2.3. Nutrient Flux

In this study, daily nutrient flux is perceived as the product of nutrient concentration and daily discharged water as shown in the equation 1 [3].

\[ L_d = C_d \times Q_d \]  

Where, \( L_d \) is daily flux, \( C_d \) is concentration for day \( d \) and \( Q_d \) is discharge. Interpolation of an empirical relationship between Flux and Discharge is done in a certain period in which there is no measurement of concentration. As stated by Moartar and Meybeck [8], interpolation assumes that the value of Flux (L) and discharge (Q) which are obtained by way of sample taking can represent a longer period of time. This statement is confirm by Salvia-Castellvi et al. [3], a multistage procedure with L-Q interpolation can be done as long as there are enough observation data.

3. Results and Discussions

3.1. Rainfall and Discharge

Daily rainfall during the study is recorded in the rain station of Kalisari which the value ranged among 0mm - 200mm. The highest rainfall (200.3mm) happens in January 2019. The extreme rainfall is the key factor which causes soil erosion and nutrient loss, they mainly happen in short duration rainstorm [9]. The monthly rainfall on March is also categorized as the highest which reaches 1053 mm. According to Wu et al. [10], the higher the rainfall intensity, the amount of loss load of nitrogen will also be getting higher compared to the same slope. The intensity of the rainfall has a linear influence with discharge. Figure 2 present hydrograph of rainfall and discharge during the study from January 2018 to May 2019.
3.2. Nutrient Concentrations and Flux

The nutrient concentrations of the 24 samples taken are shown in Table 3. In general, the concentration values of nutrient have no constant pattern with discharge (Figure 3). A difference appears after flux is calculated. Basically, the value of nutrient flux is following the value of discharge. The higher discharge value, the transfer flux will also be getting higher.

Table 3. Concentration and Discharge Value

| Discharge (m$^3$/s) | NO$_3$ | NO$_2$ | NH$_3$ | Fosfat | NO$_3$ | NO$_2$ | NH$_3$ | Fosfat |
|---------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0.03                | 1.41   | 0.02   | 0.01   | 0.53   | 1.26   | 1.54   | 0.001  | 0.01   | 2.20   |
| 0.05                | 1.36   | 0.05   | 0.03   | 0.42   | 1.49   | 1.18   | 0.001  | 0.03   | 1.55   |
| 0.06                | 0.02   | 0.03   | 0.10   | 0.34   | 1.75   | 1.08   | 0.001  | 0.01   | 1.35   |
| 0.12                | 1.51   | 0.02   | 0.08   | 0.39   | 2.36   | 0.97   | 0.001  | 0.01   | 1.14   |
| 0.15                | 0.70   | 0.05   | 0.07   | 0.32   | 3.50   | 0.96   | 0.001  | 0.01   | 1.47   |
| 0.33                | 1.32   | 0.02   | 0.97   | 4.43   | 0.78   | 0.002  | 0.09   | 0.92   |
| 0.44                | 0.74   | 0.02   | 1.44   | 4.43   | 3.30   | 0.001  | 0.04   | 0.91   |
| 0.56                | 1.12   | 0.02   | 1.64   | 5.50   | 0.86   | 0.002  | 0.01   | 0.97   |
| 0.70                | 0.95   | 0.01   | 0.13   | 7.41   | 0.82   | 0.001  | 0.02   | 1.08   |
| 0.70                | 1.33   | 0.001  | 0.03   | 1.26   | 8.89   | 0.85   | 0.001  | 0.01   | 1.01   |

Figure 4 shows that the rating curve relationship of L-Q is close to 1 on nitrate, phosphate, and ammonia while the value of nitrite is relatively small. The values of $R^2$ for nitrate, phosphate, ammonia and nitrite are 0.97, 0.94, 0.71 and 0.39. If the value is close to 1, it means that the equation result is representative [11]. In this study, it refers to the value of nitrate and phosphate.
In accordance with the rating curve of L-Q, the value of daily nitrate flux is among 20 kg/day – 96.5 kg/day. The highest value is 96.5 kg/day which happens at the same time as the highest debit in January 2019. Meanwhile, the highest value of monthly nitrate flux is on March 2019, 1,084 kg/month. This difference is prompted by the monthly discharge value on March 2019 that is higher than on January 2019 (Figure 5). It strengthens the statement of Moatar and Meybeck [8] who believe that fluxes are highly dependent on discharge.

Figure 3. Concentration and Discharge Value.

Figure 4. Rating Curve Relationship L-Q for Bompon Watershed.
The same pattern also applies on the value of phosphate and ammonia. The highest daily flux value on phosphate is 103 kg/day which happens on January 2019 while the highest monthly loss value is 833 kg/day which is on March 2019. On ammonia, the highest daily value is 2.4 kg/day while its monthly flux value is 20.7 kg/day. It is completely different with nitrite which has a relatively same value in each month. It’s because the general relationship between L and Q data of nitrite that is very poor ($R^2=0.39$).

The value of nitrate and ammonia in the study area are categorized as lower than nitrate and phosphate. The concentration value of both are even still included in the standard of drinking water based on Regulation of Yogyakarta Special Region Governor No. 20, 2008 [12]. According to Vadde et al. [13], the value of ammonia and nitrite in the body of water are mostly generated from anthropogenic which is in form of municipal effluent untreatment human sewage and. In the study area, the effect of anthropogenic is rarely found. This is why the highest nutrient pollutant in the study area refers to nitrate and phosphate which are commonly from agricultural area.

![Figure 5. Monthly Flux and discharge of Bompon Watershed during study period](image)

Period of plant growth also influence on the amount of nutrient flux each month. Generally, nitrate and phosphate flux in November to March continue to increase. Based on time period of agriculture,
November to March is the active growth period for all types of plants in Bompon Watershed, which at that time the farmers do intensive fertilization (Table 4). Active growth period also occurs in June to October especially for paddies, but rainfall and water discharge in that period is very low and impact the nutrient flow. Therefore, the higher discharge transport more soil nutrient.

| Table 4. Fertilizer Applications, Planting, and Harvesting Schedule of Bompon Watershed |
|---------------------------------|-------------------------------|
| Type of Plant  | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
| Rice albizia and Mahogany Coffee | H | F | F | T | F | F | F | T, F | F | F |
| Cassava and Corn Spices Coconut | H | F | T | F | F | F | F | H | T | F |

T : Planting  F : Fertilization  H : Harvesting

References
[1] UNEP. 2016. A Snapshot of The World’s Water Quality: Towards A Global Assessment. Nairobi: United Nations Environment Programme (UNEP)
[2] Mandal, U. M., Sharma, K. L., Prasad, J. V. N. S., Reddy, B. S., Narsimlu, B., Saikia, U. S., Adake, R. V., Yadaiah, P.,Masane, R. N., Venkanna, K.,Venkatrammamma, K.,Satyam, B., Ranju, B., Srivastava., N. N. 2012. Nutrient Losses by Runoff and Sediment from an Agricultural Field in Semi-Arid Tropical India. Indian Journal of Dryland Agricultural Research and Development, Volume 27(1):01-09
[3] Salvia-Castellvi, M., Iffly, J. F., Borght, P. V., Hoffman, L. 2005. Dissolve and particulate nutrient export from rural catchment: A case study for Luxembourg. Science of the Total Environment, Volume 344:51-65
[4] Xu, Z., Hu, B. X., Davis, H., Cao, J. 2015. Simulating long-term nitrate-N contamination Processes in the Woodville Karst Plain using CFPv2 with UMT3D. Journal of Hydrology, Volume 524:72-88
[5] Zhang, Z-Y., Kong, L-L., Zhu, L., Mwiya, R. M. 2013. Effect of Loss by Runoff from an Agricultural Watershed. Pedosphere, 23(2):256-264
[6] Rokhmaningtyas, R.P dan Setiawan, M. A. 2017. Estimasi Kehilangan Tanah Aktual Terkait Pengaruh Vegetasi di DAS Bompon Kabupaten Magelang. Jurnal Bumi Indonesia, Volume 6(2) (in Indonesian)
[7] Widasmara, M dan Hadi, P. 2016. Pemodelan Debit Aliran DAS Bompon Menggunakan Metode rasionol Modifikasi. Jurnal Bumi Indonesia, Volume 5(3) (in Indonesian)
[8] Moatar, F., Meybeck, M. 2005. Compared performances of Different Algorithms for Estimating Annual Nutrient Loads Discharge by The Eutrophic River Loire. Hydrological Processes, Volume 19:429-444
[9] Zhang, G-H., Liu, G-B., Wang, G-L., Wang, Y-X. 2011. Effects of Vegetation Cover and Rainfall Intensity on Sediment-Bound Nutrient Loss, Size Composition and Volume Fractal Dimension of Sediment Particles. Pedosphere, Volume 21(5):676-684
[10] Wu, X. Y., Zhang, L. P., Zhang, M. X., Ni, H. B., Wang, H. 2007. Research on characteristics of nitrogen loss in sloping land under different rainfall intensities. Acta Ecology, Volume 27: 4576-4582
[11] Asdak, C. 2014. Hidrologi dan Pengelolaan Daerah Aliran Sungai. Yogyakarta : Gadjah Mada University Press (in Indonesian)
[12] Pemerintah DI. Yogyakarta. (2008). Peraturan Daerah, Daerah Istimewa. Yogyakarta (in Indonesian)

[13] Vadde, K. K., Wang, J., Cao, L., Yuan, T., McCarthy, A. J., Sekar, J. 2018. Assessment of Water Quality and Identification of Pollution Risk Location in Tiaoxi River (Taihu Watershed), China. Water, Volume 10(2): 183