Water quality index for river water assessment of Serang River Basin and Kulon Progo Regency, Yogyakarta

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Abstract. Yogyakarta Province development in the past decade has been attracting many investors, especially in tourism and education sectors. This growth is resulted in large scale infrastructure constructions and increase of population. It causes higher waste production and may polluted the river water. Kulon Progo Regency is one of the regencies in Yogyakarta Province with vast infrastructure development for the last 4 years. Therefore, the research was carried out in Serang river basin and Kulon Progo Regency with the aim to assess the water quality. The method used was utilizing Water Quality Index (WQI) and Inverse Distance Weighted (IDW) interpolation using GIS software. TSS, temperature, DO, COD, TC and FC value had been utilized to assess the river water parameters. The result shows that from 2011-2018, rivers in Kulon Progo Regency is classified into three types: river water quality standard IV, standard III and Standard II. Further study should be performed to model the river water quality with different land use, pollution sources, and hydrological condition scenarios.

Keywords: water quality index, river water assessment, river water quality standard

1. Introduction
Kulon Progo Regency is a vastly developing area and some large scale infrastructures are built in this place. Some of these developments are Yogyakarta International Airport (YIA), railway tracks to YIA, metropolis city, south route highway (Jalan Jalur Lintas Selatan), toll road connecting Cilacap Regency (West Java Province) to Yogyakarta Province, Bedah Manoreh road, and another toll road. The government target is to increase the economic condition in Kulon Progo Regency. These developments are potentially influence the river ecosystem condition. It can increase number of solid wastes at the river bank and in the river channels, industrial and domestic waste water, agricultural waste water (pesticides and chemical substances), and poultry waste water (biological contaminants) that are polluted river water. Therefore, a water quality monitoring and accurate assessment of river water quality are important to formulate an effective pollution control program. Water Quality Index (WQI) has been widely used to evaluate river water pollution [1,2,3,4]. Spatial and temporal water quality monitoring data was utilized. This study aims to understand the characteristics of pollutant in the river and to evaluate the river water quality standard.
2. Methodology

2.1. Study Area

Kulon Progo Regency is one of five regencies in Yogyakarta Province, Indonesia. It is an area of 58,627.512 hectares, 110°1’37“ - 110°16’26“ E and 7°38’42“ - 7°59’03“ S, with a topography 0 – 1.000 meter located within three river basins, they are: Bogowonto, Progo and Serang River Basin. Serang River Basin covers the biggest catchment area of 24152.86 hectares, as much as 41.2% of total Kulon Progo area. Bogowonto river basin only covers 5.6% of the total Kulon Progo area, and its water resources are also serve other regency [5]. Therefore, in the research, we are focusing on rivers within Serang River Basin area. Serang River has a discharge, length, width and depth of 1.500 m³/sec, 23.16 km, 60 meter and 8 m, respectively. (see Table 1 and Figure 1) Environmental Agency of Kulon Progo Regency has been consistently monitoring river water quality in Serang River and Papah River [6]. Serang River prones to contamination because it flows through urban area of Wates City, capital of Kulon Progo Regency. The flow pattern of Serang river is dendritic type.

Table 1. Sampling Sites Locations and Coordinates [6]

| River | Code | Location        | coordinat S    | coordinat E    |
|-------|------|-----------------|----------------|----------------|
| S1    | pelimpahan | 07°49’38“    | 110°07’604“    |
| S2    | serang     | 07°50’120“    | 110°10’251“    |
| S3    | sideman    | 07°52’019“    | 110°09’337“    |
| S4    | pekik jamal | 07°54’505“   | 110°08’311“    |
| S5    | karangwuni | 07°54’509“    | 110°05’040“    |

| P1    | Jangkang Kidul | 07°49’58.7“ | 110°12’55.6“ |
| P2    | banguncipto    | 07°49’11.9“ | 110°12’52.1“ |
| P3    | sukoreno      | 07°51’35.3“ | 110°12’43.6“ |
| P4    | tugu pensil    | 07°52’32.6“ | 110°12’24.4“ |
| P5    | margosari     | 07°51’47.5“ | 110°10’28.6“ |

Figure 1. Sampling Site of Serang and Papah River, Kulon Progo Regency
2.2. Water quality index calculation

Water quality index is important for resolving multi-parameter water analysis into single digit scores [7]. One of the methods to determine the water quality index is river water pollution indices method (Pij) according to Law of Ministry of Environmental No. 115 year 2003.

Water pollution index is utilized to evaluate water body quality and compare it with the river quality standard [8]. Water quality can be decreasing caused by contaminant substances in the water body. In order to monitor the amount of contaminant substances, water pollution index can be applied. Water pollution index is calculated using this equation [9]:

\[
P_{ij} = \sqrt{\left(\frac{C_{ij}}{L_{ij}}\right)_M^2 + \left(\frac{C_{ij}}{L_{ij}}\right)_R^2}
\]

Where:
- \(P_{ij}\): pollution index
- \(L_{ij}\): Concentration of water quality standard j, for parameter i
- \(C_{ij}\): Concentration of parameter i

Water usage classification utilized in equation (1) is class I classification based on Government Law No. 82 year 2001. The \(P_{ij} > 1\) means that river water quality does not meet class I water standard stated in the Government Law.

Procedures to calculate water quality index are as follows:
1. Calculate pollution index (Pij) for parameters: Total Suspended Solid (TSS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Fecal Coli and Total Coliform;
2. Determination of Water Quality Index based on Pij, categorized in Table 2.

| Pollution Index (Pij) | Water Quality Index | Notes |
|----------------------|---------------------|-------|
| \(P_{ij} \leq 1\)    | 100                 | Class I water quality standard |
| \(P_{ij} \geq 1\) and \(P_{ij} \leq 4.67\) | 80                 | 4.67 is Pij for class II water quality standard |
| \(P_{ij} \geq 4.67\) and \(P_{ij} \leq 6.32\) | 60                 | 6.32 is Pij for class III water quality standard |
| \(P_{ij} \geq 6.32\) and \(P_{ij} \leq 6.88\) | 40                 | 6.88 is Pij for class IV water quality standard |
| \(P_{ij} \geq 6.88\) | 20                  |       |

WQI is influenced by several variables such as: decrease of pollutant load and restoration act on some water resources, water discharge availability and fluctuation which influenced by land use change and local-regional-global climate, water use, magnitude of erosion and sedimentation.

2.3. GIS and water quality

In sample collection, standard methods are applied, such as preservation and analysis of different water quality parameter TSS, DO, BOD, and COD are measured. Microbial contaminants are detected by measuring Total Coliform (TC) and Feacal Coliform (FC) which is calculated by the standard Most Probable Number (MPN) method. ArcGIS 10 version software is utilized for data analysis using Inverse Distance Weighted (IDW) technique of spatial analysis [10,11,12,13]. The parameters and its sampling points, locations, coordinate points are done. The analysis is conducted in the laboratory of Environmental Agency in Kulon Progo Regency.
3. Result and discussion

3.1. Physiochemical properties of river water and IDW interpolation using GIS

The quality of river water varies from location to location influenced by the surface characteristics. The variation of water quality are shown in Figure 2. The TSS of river water samples in wet and dry varies from 3.6 to 19.2 mg/L and 3 to 54 mg/L respectively. The TSS is within the permissible limit has given by raw water standard of 50 mg/liter, that can be used for irrigation water. Compare to 2017 data, there is an increase of coliform concentration from 22000 count/100ml to 350000 count/100ml in 2018. It shows heavy contamination from coliform bacteria. This contamination might due to waste water from poultry industries that located near the river.

![TSS](image1)
![DO](image2)
![BOD](image3)
![COD](image4)
![Fecal Coliform](image5)
![Total Coliform](image6)

Figure 2. Water Quality Parameters Used for Calculating Water Quality Index: TSS (a), DO (b), BOD (c), COD (d), Fecal Coliform (e) and Total Coliform (f) In Wet and Dry Season
Figure 3 shows the spatial distribution of the water quality (pH) value in the river, where the green area represents the river location of a pH = 6, that may show chloride or salt concentration in the river water. The yellow and red area are represent the pH of 7 and 8.7, respectively. A pH 8.7 is an evidence of alkaline water where pollutant can be from algal bloom (high nitrogen in river from agricultural excess), industrial waste (rich in bases) or domestic waste. From the IDW interpolation result, we can get the information on spatial distribution of water concentration (pH) in Serang and Papah river, and get the land use information to evaluate the source of contamination.

![Figure 3. IDW Interpolation of water Quality (pH) of Serang and Papah River](image)

### 3.2. Water Quality Index value

The calculation result of WQI values are ranging from 35.8 - 81, thus can be classified into three types, those are river water quality standard IV (poor water quality), standard III (moderate quality), and Standard II (good water quality), shown in Table 2. Based on Figure 4, it can be concluded that “good” water quality category are found in most sampling points. The poor water utilized for irrigation purpose is 40%, as the good and moderate water are about 28% and 32%, respectively, of river area. The ArcGIS software is powerful tool to develop spatial distribution maps of physiochemical parameters.
4. Conclusions
River water contamination occurs in the upstream area. Also, it takes place at the middle area of Serang river. It is because this river flows through Wates City where industrial and residential area are located. The excess from agriculture activities and waste water from industry or household can become the source of pollutant transported by rainwater into the river. The research result shows that water quality variation between dry and wet season. The rain may cause increasing in discharge and decreasing of pollutant concentration through dilution. The research shows that the WQI value has been decreasing for the last 4 years, as the development in Kulon Progo Regency is increasing. It shows that WQI value that incorporating TSS, BOD, DO, COD, TC and FC parameters may become strong tool to assess the dynamics of environmental quality. Rivers within the Kulon Progo Regency, from year 2011 to 2018, is ranging in classify into three types: river water quality of standard IV (poor), standard III (moderate) and Standard II (good). Further study should be performed using river water quality modelling software to assess different land use, pollution sources, and hydrological condition scenarios.

References
[1] Kachroud M, Trolard F, Kefi M, Jebari S, Bourrie G. 2019. Water Quality Indices: Challenges and Application Limits in the Literature. Water, 11, 361; doi:10.3390/w11020361
[2] Saraswati S P, Ardion M V, Widodo Y H, Hadisusanto S. 2019. Water Quality Index Performance for River Pollution Control Based on Better Ecological Point of View (A Case Study in Code, Winongo, Gadjah Wong Sreams). Journal of The Civil Engineering Forum. Vol 5 No.1. 47-55
[3] J Yisa T, Jimoh. 2020. Analytical Studies on Water Quality Index of River Landzu. American Journal of Applied Sciences 7 (4). 453-458
[4] Japan International Cooperation Agency (JICA). 2008. Study on Regional Water Supply Development Plan for Greater Yogyakarta in the Republic of Indonesia JICA.
[5] Asian Development Bank. 2016. Indonesia Country Water Assessment the Asian Development Bank, Metro Manila, Philippines.
[6] Badan Pusat Statistik. 2018. Statistics of Kulon Progo Regency in Figures
[7] Abbasi S A, Sarkar C. 2006. Qualidex-A New Software for Generating Water Quality Indice. Environmental Monitoring and Assessment, Volume 119, pp. 201-231.
[8] Environmental Agency of Kulon Progo Regency. 2018. Document of Performance Information Regional Environmental Management (in Bahasa Indonesia)
[9] Ministry of Environmental and Forestry. 2017. Indonesia Environmental Quality Index.
[10] Mahagamage M.G.Y.L, Manage.P.M. 2015. Mapping Spatial Distribution of Water Quality Parameters using GIS in Groundwater of The Kelana River Basin. Sri Lanka. Proceedings of Academics World 12th International Conference, Singapore, 20th December 2015, ISBN: 978-93-85832-75-8

[11] Wijayanti Y, Yuniasih B, Verma N, Krisdiarto A W, Safitri L. 2018. Water Quality Mapping using GIS in Groundwater of Yogyakarta City, Sleman, Kulonprogo and Bantul Regency Area, Yogyakarta Province. *IOP Conference Series: Earth and Environmental Science*. 195 012012

[12] Verma N, Anda M, Wijayanti Y. 2019. Artificial Recharge for Sustainable Groundwater Management Plan in Yogyakarta *Indonesian Journal of Urban and Environmental Technology* 2(2) 120-133 DOI : http://dx.doi.org/10.25105/urbanenvirotech.v2i2.4364

[13] Wijayanti Y, Nakamura T, Nishida K, Haramoto E, Sakamoto Y. 2013. Seasonal Differences and Source Estimation of Groundwater Nitrate Contamination. *International Journal of Water and Environment Technology* 11 (3), 163-174.