Estimating water quality status using pollution index method in Jatigede Reservoir, Sumedang-West Java

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Abstract. Jatigede Reservoir is one of the public water bodies in Sumedang. As public water, the water quality in the reservoir is easily changed due to the input of water from rivers and water pollution in the vicinity. It means that natural and anthropogenic activities in the waters that produce excess domestic and agricultural waste around the reservoir can cause a decrease in water quality in the reservoir. In sustainably supporting its designation, the quality of water in the reservoir must be maintained and monitored so that the reservoir has good water quality and is in accordance with the water quality standard for its intended purpose. The research was carried out from September 2020 to February 2021 with a survey method. The determination of the research location was carried out using the purposive sampling method. The results of the status of water quality in the waters of the Jatigede Reservoir are included in the category of Fulfill Quality Standards to Lightly Polluted, and the average Pollution Index value ranges from 1.75 to 3.01 in class II water quality standards and 0.86-1.94 in class III water quality standards. The high value of the pollution index in this research is due to the high value of biochemical oxygen demand (BOD). The highest BOD value was obtained around the Fish Cage Culture at station 3, which makes station 3 becomes the station with the highest pollution index value.
Key Words: fisheries, Jatigede Reservoir, pollution index, water quality.

Introduction. The primary purpose of making the Jatigede Reservoir is as a hydroelectric power plant and other derivative functions such as providing drinking water, irrigation, tourism, and capture fisheries (Nurhayati et al 2020). Cimanuk River is the largest water supply river in Jatigede Reservoir. The Cimanuk watershed serves as the primary drainage system for agriculture, fisheries, and clean water supply for the Cirebon and Indramayu regions (Nurrohman et al 2019). The development of agricultural land and household waste can cause pollution problems in the waters, such as chemical fertilizers from agriculture and domestic waste that accumulates in the Cimanuk River (Yustiani et al 2018). Lakes and surface water reservoirs are the planet's most important freshwater resources and provide numerous benefits (Bhutekar et al 2014).

Determining water quality and water fertility status is essential for lake or reservoir management (Muhtadi et al 2018). Currently, the overall fertility condition in the waters of the Jatigede Reservoir is mesotrophic-eutrophic. So that the Jatigede Reservoir is still classified as suitable and feasible for the survival of the organisms in it (Faishal et al 2019). Meanwhile, there is no data on determining the status of water quality in the waters of the Jatigede Reservoir. Knowledge of the current status of water conditions and determination of its mechanism are prerequisites to devising a sound solution to the problem (Le et al 2010).

Water quality management is an effort to maintain water to have the required quality according to its designation, to ensure that water quality remains in its natural condition and can be used sustainably because the physical and chemical parameters of waters affect species diversity and ecosystem stability (Forio & Goethals 2020). In water management, several physicochemical factors can influence and play a role in the quality of the waters, such as the intensity of sunlight, water transparency, temperature, acidity, dissolved oxygen, biochemical oxygen demand, nitrogen, and phosphorus (Malathi et al 1999). One of the efforts in managing water resources is to evaluate water pollution to determine water quality. The pollution index (PI) evaluation is one of the water quality analysis methods stipulated in the Decree of the Minister of the Environment No. 115 of 2003 and has been applied in Indonesia to evaluate the level of pollution in waters. This method calculates the observations of the applicable quality standards with Government Regulation Number 82 of 2001.

Management of water quality based on the PI can be an alternative in assessing the quality of water bodies for specific purposes as input and data for consideration for decision-makers in water management. So they can execute on water quality improvements due to pollution according to the quality standard for its designation. PI is a calculation method of several parameters taken according to the designation of a waters (Minister of Environment Decree No. 115 of 2003). The purpose of this study is to provide information about the condition of water quality and water quality status in the Jatigede Reservoir as a reference for quality status data for further management efforts.

Material and Method

Description of the study site. The study was carried out from September 2020 to February 2021, both in situ and ex-situ. Measurements for acidity, temperature, and dissolved oxygen (DO) were conducted in situ. Ex-situ analysis of nitrate and phosphate was carried out at the Aquatic Resources Management Laboratory, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, and analysis of total suspended solids (TSS) and total dissolved solids (TDS) was carried out in the environmental laboratory of the Faculty of Civil and Environmental Engineering of Bandung Institute of Technology.

The study was carried out at six stations. The determination of the research stations was based on the characteristics and position of the water body towards activities that can cause pollution inputs in the waters of the Jatigede Reservoir. Stations 1 and 2 are river zones that have the potential to bring pollution from anthropogenic and agricultural activities. Stations 3 and 4 are stations with several fish cage cultures. These station are also a transition zone. While stations 5 and 6 represent the lacustrine zone. The geographic coordinates for the six stations are as follows:

- station 1 (60°55'52.6” S, 108°5'46.9” E): the main inlet sourced from the Cimanuk River, Cialing River, and Cibuntu River;
- station 2 (60°55'19.6” S, 108°5'45.7” E): this station is the confluence of two rivers, namely the Cimuja and Cijajaway rivers;
- station 3 (60°55'11.8” S, 108°5'42.1” E): this station is a transition zone, and the water at this station comes from the Cihonje River. At station 3, there are also several nets for capture fisheries and aquaculture activities with the cage culture method;
- station 4 (60°55'16.1” S, 108°6'50.7” E): it is the estuary of the Cacaban River. Just like station 3, this station is also a place for capture fisheries and aquaculture activities with the cage culture method;
- station 5 (60°53'31.1” S, 108°6'13.5” E): this station is the estimation of the zone with the lowest biochemical oxygen demand (BOD) due to the minor activity in this area;
- station 6 (60°51'46.0” S, 108°6'10.9” E): this station is an outlet at Jatigede Reservoir.

Map of research stations can be seen in Figure 1.

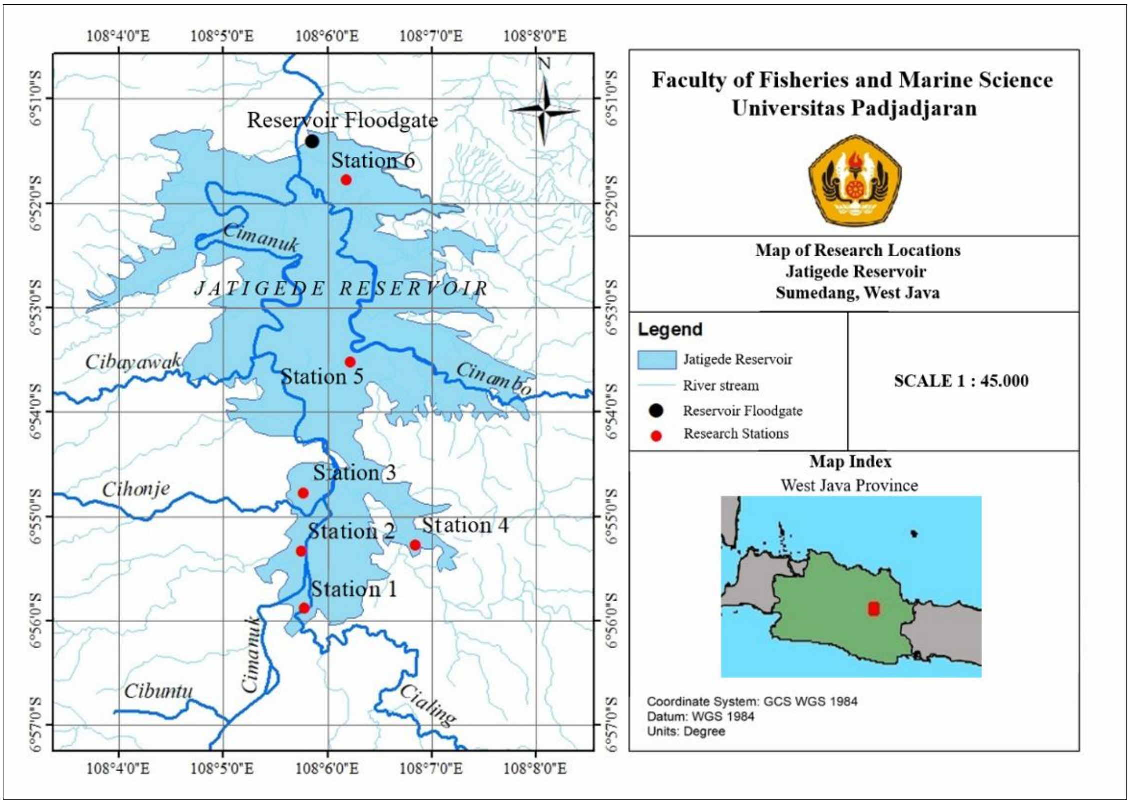

Figure 1. Map of research stations.

Sampling and measurement. Sampling was carried out six times with an interval of once a month. Sampling was carried out on the surface layer of the water. Analysis of water physicochemical parameters was carried out on ten parameters: transparency of water, temperature, TSS, TDS, acidity, biochemical oxygen demand (BOD), dissolved oxygen (DO), ammonia, nitrate, and phosphate concentrations. The calculation of the PI uses the Decree of the State Minister of the Environment Number 115 of 2003. The calculated water quality sample will show an PI value with category qualifications with a value of 0-1 being a category that Fulfils Quality Standards, 1-5 is a Lightly Polluted category, 5-10 is a Moderately Polluted category, and > 10 is a Heavily Polluted category. The formula for the pollution index can be seen below:

$$PIj = \sqrt{\frac{(\frac{Ci}{Lij})^2\mathrm{m} + (\frac{Ci}{Lij})^2\mathrm{R}}{2}}$$

where: PIj = concentration of water quality parameters stated in the water quality standard;
Lij = concentration of water quality parameters listed in the water designation standard;
Ci = concentration of water quality parameters obtained from the survey results;
(Ci/Lij)M = value of Ci/Lij (maximum index);
(Ci/Lij)R = value of Ci/Lij (average index).

Data and analysis. The method used in this study is a survey method, and the method used in data collection is purposive sampling. Purposive sampling is a method that determines the sampling point or observation data collection point based on the researcher's consideration. The analysis method was carried out in a comparative descriptive analysis that refers to Government Regulation Number 82 of 2001 concerning Water Quality Management and Water Pollution Control.

The government classifies water into four classes of quality: class I for potable water, which could be used as drinking water; class II for water that could be used for water recreation facilities and aquaculture; class III for water that could be used for aquaculture; and class IV for water that could be used to irrigate crops.

Results and Discussion

Physicochemical parameters. In general, the water quality of the Jatigede Reservoir in almost all the parameters is following their designation, specifically for class II and III water quality standards; only BOD parameter is not in accordance with class II or III water quality standards. According to Tatangindatu et al (2013) the high concentration of BOD is caused by the high amount of oxygen needed by microbes to oxidize organic matter in the waters. Moreover, the high concentration of BOD is thought to be due to the high demand for oxygen consumption in the waters of the Jatigede Reservoir due to the weathering process of trees below and fishery cage culture activities at stations 3 and 4.

The results of physical parameter evaluation showed that the transparency in the waters of the Jatigede Reservoir ranged from 38 to 150 cm. According to Kordi & Tancung (2005), ideal transparency for aquatic organisms ranges from 30 to 40 cm, whereas if the transparency value is less than 25 cm, it will be harmful to plankton and can cause a decrease in DO values in the waters.

The results showed that the water temperature of the Jatigede Reservoir ranged from 27.2 to 29.7^{o}C. These values indicate that the temperature conditions are relatively stable because the highest average temperature to the lowest temperature is not more than a count of 1 deviation. According to Beveridge (2004), an increase in temperature in water bodies will cause the amount of DO in the water to decrease, the speed of chemical reactions increases, and the life of fish and other aquatic animals is disrupted.

TDS concentrations in the Jatigede Reservoir ranged from 110 to 142 mg L^{-1}. A high TDS can affect the transparency value of water, and the transparency value has a relationship with the productivity of water, meaning that a high TDS value can determine high productivity in waters. A higher concentration of TDS indicates the presence of higher amount of dissolved salts as well as plants nutrients in water (Dhunggana 2019).

The TSS value in this research ranged from 4 to 17 mg L^{-1}. According to Widodo et al (2019) TSS is affected by land use activities in the upstream area. The analysis results show that the TDS and TSS values in the waters of the Jatigede Reservoir are still far below the water quality standard threshold that has been set. According to Government Regulation number 82 of 2001, the maximum concentration of TDS in the waters of the Class II Water Quality Standard is 1000 mg L^{-1}, and the TSS is 50 mg L^{-1}. It means that that the values of TDS and TSS in the waters of the Jatigede Reservoir were following the reservoir designation.

The pH values in the waters of the Jatigede Reservoir tend to be stable, ranging from 6.84 to 7.72, with the highest average pH of 7.18 at station 2. Although the average value at station 2 is higher than any research station, the average pH value at the Jatigede Reservoir has a value that is not much different between the stations. A large amount of house waste can cause the relatively higher pH at station 2 from the previous inundation that is still visible and can also be caused by the depth being shallower than other stations. The total alkalinity of the reservoir is a reflection of its carbonates and bicarbonate profiles (Wetzel 2001). A high pH value is due to runoff agricultutre, washing and bathing activity (Umavathi et al 2007).

Monthly BOD values in Jatigede Reservoir tend to fluctuate, with concentrations ranging from 3.24 to 16.22 mg L^{-1}. The highest average BOD value was at station 3 of 13.24 mg L^{-1}, and the lowest was at station 6 of 5.95 mg L^{-1}. BOD indicates the amount of oxygen that organisms require to decompose organic matter under aerobic conditions (Salmin 2005). The results showed that cage cultivation activities could cause the high value of BOD concentration at station 3. The higher BOD values are attributed to the organic load from discharge of municipal sewage (Nuruzzaman et al 2018). According to local cage cultivators, cage cultivation in Jatigede Reservoir consumes 2 tons of fish feed per day. According to Tamyiz (2015) a high amount of nutrient input (fish feed) in water bodies can reduce the DO value in a wide area, and increase the BOD value, and the ammonia concentration.

The concentration of DO in the Jatigede Reservoir during the sampling time ranged from 4.3 to 5.8 mg L^{-1}. The highest average value was found at station 5, 5.78 mg L^{-1}. The lowest average value of DO was found at station 3, which was 4.90 mg L^{-1}. A reduction of DO concentration can be caused by a higher than average temperature and mineralisation of organic substances (Rajwa-Kuligiewicz et al 2015). According to the Environmental Government Regulation number 82 of 2001, the values of Class II and III Water Quality Standards are 4 and 3 mg L^{-1}, meaning that the DO concentration in the waters of the Jatigede Reservoir is excellent because it meets the water quality standard classes II and III. The high concentration of DO is because the Jatigede Reservoir has not yet flowered and has not been covered by macrophytes. According to Effendi (2003), 35% of DO sources come from oxygen diffusion in the atmosphere.

The analysis of nutrient parameters in the waters of the Jatigede Reservoir showed that the concentration of ammonia ranged from 0.001 to 0.0044 mg L^{-1}. The highest average ammonia concentration at station 2 was 0.0031 mg L^{-1}, and the lowest average concentration at station 1 was 0.0019 mg L^{-1}. At stations 3 and 4 there were low ammonia concentrations because water samples were only taken from the water's surface. Ammonia concentrations will be higher if water samples are taken at depth certain water. In fishery activities, waste and food residue that decompose will settle to the bottom of the waters, waste originating from food residue in the waters usually contains protein, which can be degraded to NH_3 (Warlina 2004).

The nitrate concentration in the Jatigede Reservoir ranged from 0.008 to 0.044 mg L^{-1}. The highest average nitrate concentration was at station 2, 0.028 mg L^{-1}. The high average nitrate concentration at station 2 compared to other stations is thought to be due to ammonia biodegradation which is also highest at station 2, and according to Seitzinger (1988), ammonia oxidation will produce nitrate. Based on the zoning aspect, station 2 is close to settlements, and the station's depth is lower than other stations. The lowest average nitrate concentration at station 6 is 0.018 mg L^{-1}. Following Ramadhan & Yusanti (2020), domestic and agricultural waste are the primary sources of enrichment of nitrate nutrients, seeing the location of station 6, far from residential and agricultural waste.

Phosphate values at the time of sampling ranged from 0.054 to 0.122 mg L^{-1}, and the highest average phosphate concentration was at station 2 of 0.095 mg L^{-1}; according to Wantsaen (2015), oligotrophic waters have phosphate levels of 0.003-0.001 mg L^{-1}, mesotrophic waters have phosphate levels between 0.011 and 0.03 mg L^{-1}, and eutrophic waters have phosphate levels between 0.03 and 0.1 or more. When referring to Wantsaen (2015), the waters of the Jatigede Reservoir are categorized as eutrophic waters. The cause of such high phosphate concentration is represented by pollutants of agricultural and municipal origin (Wojtkowska & Bojanowski 2018).

Water quality status. The water quality standard is a reference value as a benchmark for the quality of a water parameter and then divided into four classes. The water quality standard in freshwater is regulated in Government Regulation number 82 of 2001. Water quality standards are usually measured and assessed based on each test parameter. One method that can be used to determine water quality status is the PI method. Based on the research results regarding the status of water quality in the waters of the Jatigede Reservoir, the evaluation of the parameters such as acidity, DO, BOD, ammonia, nitrate, phosphate, TDS, and TSS shows that Jatigede has a PI value ranging from 0.86 to 3.34, falling into water quality standards class II, while the PI value using water quality standards class III has a value range of 0.6-2.54, meaning that there are research stations categorized as fulfilling quality standards and slightly polluted, both for calculations with water quality standards class II and III. Although the Jatigede Reservoir is newly operational, the unclear management of the Jatigede Reservoir makes this reservoir lack policy firmness. According to Hamzah et al (2016), poor water quality can disrupt reservoirs' primary function, threaten the sustainability of water resource management, and cause environmental damage.

A sampling of the research was carried out for six months, and start from the middle of the dry season to see changes in the pollution that occurred during the dry and rainy seasons. Based on the results of PI calculations in the waters of the Jatigede Reservoir (Figure 2), it can be seen that the trend of PI values at the research locations tends to fluctuate and differ at each station. This can happen because the distribution of station points is divided based on the type of pollution input and the zoning of water input in the reservoir. The monthly quality status of Jatigede Reservoir waters can be seen in Table 1.

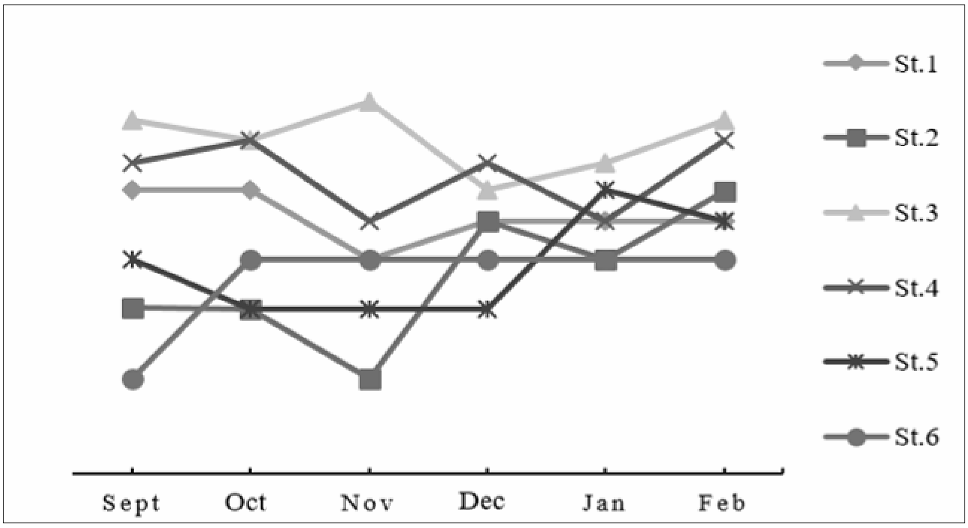

Figure 2. Grafic of pullution index.

Table 1

Data series for water quality status during the research

Station	*September 2020*		*October 2020*		*November 2020*	
	Class II	*Class III*	*Class II*	*Class III*	*Class II*	*Class III*
1	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Fulfill Quality Standards
2	Lightly Polluted	Fulfill Quality Standards	Lightly Polluted	Fulfill Quality Standards	Fulfill Quality Standards	Fulfill Quality Standards
3	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted
4	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted
5	Lightly Polluted	Fulfill Quality Standards	Lightly Polluted	Fulfill Quality Standards	Lightly Polluted	Fulfill Quality Standards
6	Fulfill Quality Standards	Fulfill Quality Standards	Lightly Polluted	Fulfill Quality Standards	Lightly Polluted	Fulfill Quality Standards
Station	*December 2020*		*January 2021*		*February 2021*	
	Class II	*Class III*	*Class II*	*Class III*	*Class II*	*Class III*
1	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted
2	Lightly Polluted	Lightly Polluted	Lightly Polluted	Fulfill Quality Standards	Lightly Polluted	Lightly Polluted
3	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted
4	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted
5	Lightly Polluted	Fulfill Quality Standards	Lightly Polluted	Lightly Polluted	Lightly Polluted	Lightly Polluted
6	Lightly Polluted	Fulfill Quality Standards	Lightly Polluted	Fulfill Quality Standards	Lightly Polluted	Fulfill Quality Standards

The water quality status mainly decreased in September-November (dry season). MI (Maximum Index) in PI calculation is BOD parameter, which contributes to the decline in water quality status in this research. Station 3 in November has the highest BOD concentration that is 16.22 mg L^{-1}, and at station 6, there is an increase in BOD concentration in October, this causes the PI value at stations 3 and 6 to increase in the dry season where other stations decrease in the value of the PI.

Entering the rainy season (December-February), the PI value at each station tends to vary. Stations 1 and 6 tend to have a constant PI value. Stations 2 and 4 decreased the PI value in January and increased in February, while for station 5 it increases in January and decreases in February. At station 3 every month in the rainy season, the graph shows an increase from the beginning of the rainy season to the end of this research sampling, meaning that the influence of the season is evident on the quality status of waters. This phenomenon is also following Ling et al (2017). A rainfall event can greatly affect the physicochemical characteristics of a water body by changing its hydrological conditions, bringing substantial amounts of pollutants via rainfall runoff.

Based on the results of the categorization of the PI values in Table 1, it can be seen that by using the class II water quality standard as a reference parameter, the category with status Fulfill Quality Standard is only found at station 6 in September, and at station 2 in November, while the results of others stations are categorized as Lightly Polluted. However, if using the class III water quality standard as a reference parameter, more samples are classified as Fulfill Quality Standard. At station 6, the results of the PI calculation show the status Fulfill Quality Standard is present on every month, which follows Rezagama & Tamlikha (2016) that the level of water pollution compared inversely with the distance between the location of the water with aquaculture and anthropogenic activities.

The average value of water quality status is calculated based on the sum of the PI values for each station and then divided by the number of samples taken. Based on the results of PI calculations using Class II water quality standards, almost all stations are categorized as Lightly Polluted. However, supposing the PI calculation uses Class III water quality standards as a reference for water quality standards, in that case, the calculation results show that Jatigede Reservoir has an average PI value ranging from 1.76 to 3.05 for using class II water quality standard as reference parameters value, and 0.86-1.94 for using class III water quality standard as reference parameters value. The results can be seen in Figure 3.

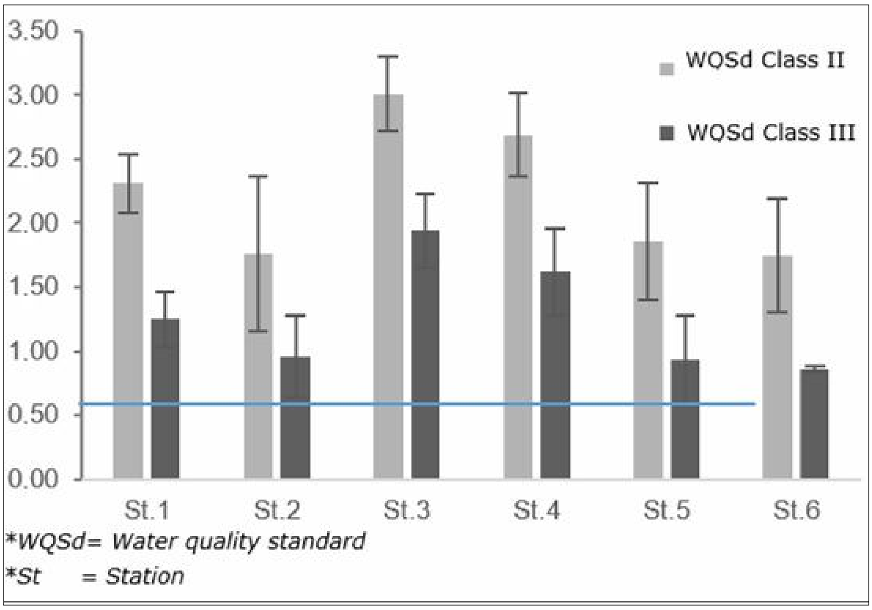

Figure 3. The average value of the pollution index.

The calculation of PI value follows the estimation of the determination of the sampling point according to the contamination load. Stations 5 and 6 are stations with the lowest pollution load indications because they are far from anthropogenic activities and cultivation or agricultural activities. Following Rezagama & Tamlikha's (2016) research, anthropogenic and aquaculture activities can contribute to water pollution.

Based on the pollution load parameter, the highest pollution load is located at station 3. The highest average PI value is located at station 3 because the maximum index value states that the parameter contributing to the highest pollution value of PI calculation is the BOD parameter. The PI calculations followed Yudo (2010) that BOD is a benchmark index number of pollutants from waste in the water. The greater the concentration of BOD in water, the higher the concentration of organic matter in waters.

The results of the average PI calculation in this research were also processed using Arcgis software with data interpolation methods to obtain infographic data. The results can display information in graphs about the condition of the distribution of PI values in the waters of the Jatigede Reservoir (Figure 4). The distribution pattern of Class II and III water quality standards is relatively the same. Stations 3 and 4 become stations with a higher pollution load than other stations, although other stations are still categorized as lightly polluted when using class II water quality standards as reference quality of the parameters (Lij). The class II water quality standard is used as a reference parameter in this study because of the designation of the Jatigede Reservoir, which includes water tourism (Nurhayati et al 2020).

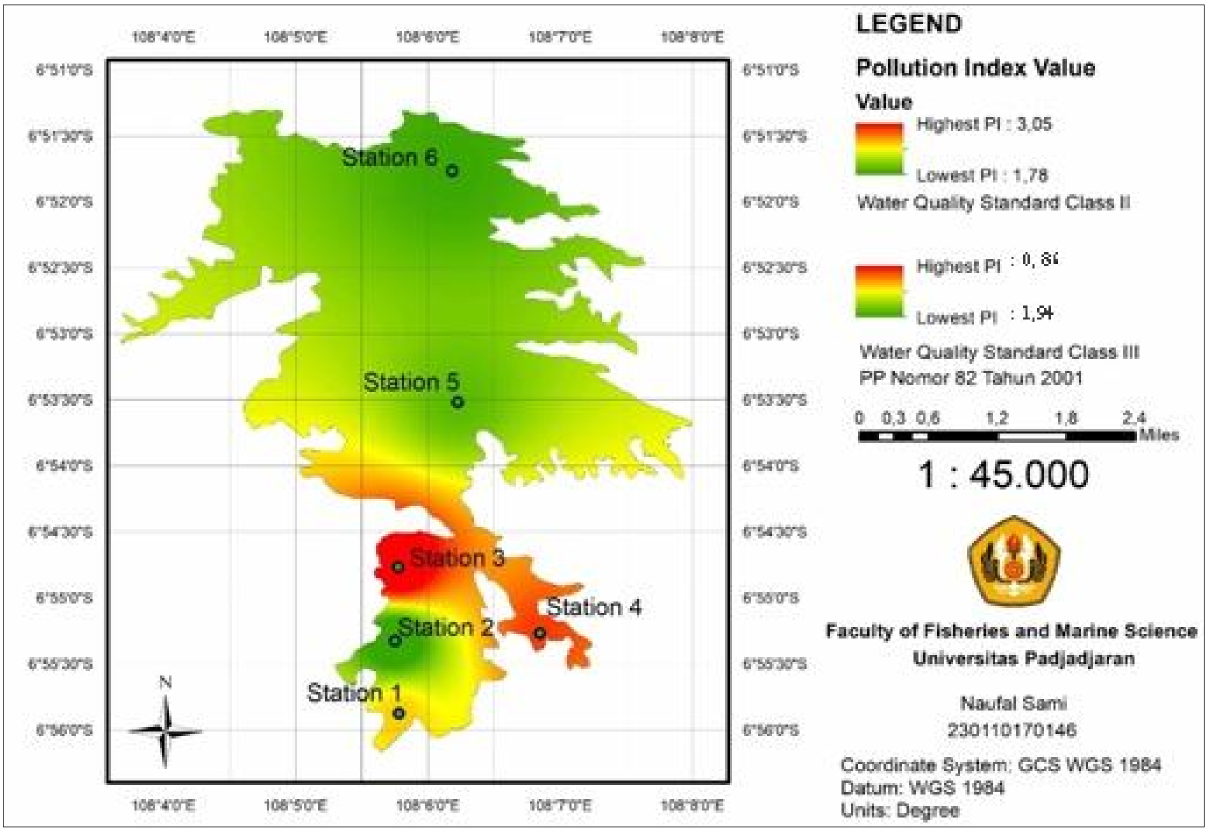

Figure 4. Distribution of pollution index values in Jatigede Reservoir.

The research results on determining the status of water quality using the PI method can project the designation of the Jatigede Reservoir for further management. Based on the research results, the waters of the Jatigede Reservoir did not Fulfill Quality Standard when using class II water quality standards. Due to the high value of oxygen demand for degrading organic matter in waters, this is because of the large amount of weathering activity and degradation of organisms in the waters. However, based on the observation parameters, the Jatigede Reservoir still has the status of waters that Fulfill Quality Standard when referring to the class III of water quality standard as reference quality of the parameters (Lij).

The research results showed that the status of water quality in the waters of the Jatigede Reservoir by using the PI in the Class III water quality standard was mainly in the status of Fulfill Quality Standard. It means that the characteristics and quality of the waters at the Jatigede Reservoir designation were determined in class III water quality standards and could become a water source for the fishery, animal husbandry, and crop irrigation activities. However, based on the Sumedang Regency Regional Regulation number 4 of 2018 concerning the Sumedang Regency Spatial Plan, the Jatigede Reservoir is prohibited from fisheries cage cultivation activities, even though many fish cages have been made. It also causes the water quality status at the station where the cages are cultivated to be classified as Lightly Polluted status.

Looking at the results of this research, Jatigede Reservoir has more significant potential in the fisheries sector than water tourism. The results of the quality status distribution map can be used as infographics to educate cage culture cultivators about the impact of the high value of pollution produced in these aquaculture activities, and the results of research on water quality status can also be an useful information for managers regarding water quality and fishery potential in Jatigede Reservoir as an effort to manage and empower the community.

For sure, fish cage cultivation activities can be an effort to empower the surrounding community who lost their jobs due to inundation of reservoirs because the fish cage cultivation method aims to increase production to get maximum profit (Gandhi et al 2017). However, it needs to be improved and supported by policies and management of appropriate monitoring and maintaining the water quality conditions and water quality status to realize sustainable fisheries in the waters of the Jatigede Reservoir. So that there is no excessive pollution due to overexploitation in terms of fish cage cultivation as happened in Cirata, Saguling, and Jatiluhur Reservoir, which can reduce water quality, with less maintenance and monitoring, it could happen in Jatigede Reservoir if the number of the fish cage keeps growing. This could reduce the primary function of the reservoir and pollute the environment (Hamzah et al 2016). The results of the water quality status in Jatigede Reservoir can also be an effort for the local government to optimize the capture fisheries sector in Jatigede Reservoir, seeing the risk of pollution caused by the legalization of floating net cage cultivation.

Conclusions. Based on the water quality standards in Government Regulation Number 82 of 2001, almost all test parameters in the waters of the Jatigede Reservoir were still included in the Class II and III of water quality standards, which means that the waters of the Jatigede Reservoir can be used as water tourism, water sources for the fishery, animal husbandry, and crop irrigation activities. The water quality status in the Jatigede Reservoir waters is being categorized as Fulfill Quality Standards - Lightly Polluted, with an average pollution index value ranging from 1.75 to 3.01 in Class II and 0.86-1.94 in Class III water quality standards. The highest average pollution index value was at station 3, located near the floating net cages. The contributor to the high value of the pollution index in this research is the high value of the BOD parameter. The highest BOD parameter value is obtained at station 3 near the fish cage cultivation activities.

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Conflict of interest. The authors declare that there is no conflict of interest.

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