Seasonal and Temporal Assessment of Surface Water Quality in Saguling Reservoir Indonesia Using Water Quality Index

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Research

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Abstract

Developments in agriculture, industry, and urban activities have caused deterioration of water resources such as rivers and reservoirs in terms of quality and also quantity. This includes the Saguling Reservoir, which is located in Citarum basin, Indonesia. A review of previous studies reveals that Water Quality Index (WQI) is efficient for the identification of pollution sources as well as for the understanding of temporal and spatial variations in reservoir water quality. The NSFWQI (The National Sanitation Foundation Water Quality Index) is one of the calculation methods of WQI. NSFWQI is commonly used as an indicator of surface water quality is based on Nitrate, Phosphate, Turbidity, Temperature, Fecal coliform, pH, DO, TSS, and BOD parameters. The average index of NSFWQI was determined to be 48.42 during the dry season, 43.97 during the normal season, and 45.82 during the wet season. A calculation of the WQI classified the water quality in the Saguling Reservoir as “bad” in condition. This study reveals that the strongest and most significant correlation between the concentration parameters and the WQI score is the turbidity concentration fecal coli, which is used to determine the required parameters for the calculation of WQI with reduced parameters if needed. This research also conducted nitrate concentration distribution analysis around Saguling Reservoir using the Inverse Distance Weighted method.

Introduction

The deterioration in surface water quality has become a major problem due to several key issues such as increased pollution activities, climate change, also weak law enforcement [1,2,3]. Increasing access to drinking water supply in terms of quality, quantity, and continuity has always been a challenge for countries in Southeast Asia including Indonesia. One of the reasons for the lack of access to drinking water is due to the poor quality of water sources due to pollution. [4,5]. Based on the results of monitoring of rivers and lakes in Indonesia that have been conducted by the Indonesian Ministry of Environment in 2012 known that more than 50% of water quality parameters have exceeded the quality standards for surface water quality Class I (surface water which is used for drinking water purposes) based on Government Regulations Number 82 of 2001 such as BOD (biochemical oxygen demand), COD (chemical oxygen demand), Fecal coli, and Total coliform.

Monitoring conducted on forty-four major rivers in Indonesia shows that only four rivers meet Class II (surface water which is used for irrigation purposes). Besides, monitoring has also been carried out on fifteen major lakes in Indonesia and all lakes are indicated to have entered hypertrophic status. Water quality monitoring is an important action to determine a baseline status for surface water such as reservoirs and rivers. Indonesia itself has implemented water pollution control and monitoring activities regularly, as in other countries, to obtain a representative spatial and temporal representation of water quality information.

Water quality assessment is generally performed by calculating the water quality index (WQI). WQI is a unique and valuable measure to describe the status of water quality as a single index that will be very useful in determining policies and strategies and the selection of technologies that will be used to improve surface water quality [6,7,8]. Besides, the water quality index can be used as a form of communication on how water quality conditions and the effectiveness of pollution control are carried out both to the community and policymakers. Kennel et al. showed the water quality index from the different perspectives, which included WQI (min) which are calculated by considering only five parameters that include TSS, DO, pH, temperature, and EC [9]. Besides, there is also the term WQI (DO) which is used to see water pollution conditions only based on DO (Dissolved Oxygen) parameters. WQI (min) and WQI (DO) are a form of simplification of The National Sanitation Foundation Water Quality Index (NSFWQI) which makes effective use of cost and time which will be very useful if implemented in developing countries.

However, NSFWQI water quality criteria for the classification of water quality indicators are based on the turbidity, temperature, phosphate, nitrate, fecal coliform, pH, DO, TS, and BOD_5 parameters. After measuring these parameters, each parameter is assigned a numerical weight or value of the index from the curves, and the mathematical equations are used to calculate the final index. The NSFWQI index with a decreasing scale indicates an increase in water pollution to make the indicator decreases eventually. The water quality conditions are valued as excellent, good, fair, poor, or very poor [9,10,11].

In Indonesia, the calculation of the water quality index has to conducted using the Storets Method and The Pollution Index Method which is regulated by the Decree of The Ministry of Environmental and Forestry Number 115 of 2003 concerning Guidelines for Determining Water Quality Status.

This study was conducted in the Saguling Reservoir because the Saguling Reservoir is a series of three reservoirs located on the Citarum River. The Citarum River itself has important for the survival of Indonesian people, especially in West Javanese because it contributes to the availability of clean water, irrigation water, and electricity. The surface water samples are analyzed under two conditions (wet and dry seasons), with a total of forty-four water quality parameters. This study provides a seasonal and temporal assessment of the Saguling Reservoir as an important aspect of surface water conditions. It also provides a better understanding of water pollution that results from anthropogenic sources.

Materials And Methods

2.1 Sampling points and study location

Water quality monitoring locations in the Saguling Reservoir consist of eleven monitoring locations. Details of these locations are in Table 1 and Figure 1 below. These eleven locations are representative because they show each segment of the Saguling Reservoir, from the discharge input of the reservoir inlet, the middle of the reservoir, to the reservoir outlet.

2.2 Water quality analysis

The data used in this research is primary data and secondary data. The secondary data includes the discharge data of Saguling Reservoir from 2003 to 2015. The primary data was the results sampling of water quality from Saguling Reservoir. Parameter of temperature, DO, pH, and EC was measured by in situ by YSI instrument. Total phosphate was also calculated by using the ascorbic acid method (APHA and AWWA, 1999). BOD was determined by a five-day incubation process, and COD was determined by using the close reflux method. Besides that, Total coliform and Fecal coliform was determined by using a membrane filter and incubate at 41.5°C for 7 hours. Assessment of all water quality parameter was done by following the Standard Methods for the Examination of Water and Wastewater (APHA and AWWA, 1999).

2.3 Water quality index

NSFWQI is one of the calculation methods for determining surface water quality indices such as rivers and lakes [12]. This method uses 9 parameters in determining the index, which is: nitrate, phosphate, turbidity, temperature, fecal coliform, pH, DO, TSS, and BOD. Not only NSFWQI, other Water Quality Index calculation methods are Weight Arithmetic Water Quality Index (WAWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), also Oregon Water Quality Index (OWQI) [13]. The calculation method has been formulated by several national and international organizations.

In this study, the calculation method used was NSFWQI. Each measured concentration of the nine parameters is then transformed into unit-less sub-index values. Sub-index values can be done by transforming each parameter into 0 to 100 scales by using the sub-index curves. The curves sub-index is a linear form. This index is generally determined by the Delphi method, which is based on the weight (Wi) and sub-indices of those nine main parameters.

The weighting factor indicates the importance of each test as an the overall measure of water quality. The weighting factors of each parameter for determining WQI are shown in Table 2.

After several steps, the NSFWQI value can be determined using the equation:

See equations 1 and 2 in the supplementary files.

The ratings of the water quality index were determined using the following Table 3.

After NSFWQI values were obtained, these values were compared to Table 3 to determine water quality status for each sampling location.

2.4 The correlation matrix

The correlation matrix was used to determine the relationship between water quality parameters and the water quality index that have been obtained. The correlation matrix was done by SPSS during dry, normal, and wet years.

Results And Discussion

3.1 Water Quality Data of the Saguling Reservoir during Dry, Normal, and Wet Years

Table 4 shows the average water quality data for the Saguling Reservoir at several monitoring locations during normal years. At 11 monitoring locations, water temperatures were generally in normal conditions, which was around 26^{o}C to 27^{o}C. The concentration of dissolved residue or TDS at 11 monitoring locations remained below the quality standards for surface water quality Class I (surface water which is used for drinking water purposes) based on Government Regulations Number 82 of 2001.

The highest TDS concentration was found at the Cihaur location and was 308.2 mg L^{-1}, while the lowest TDS concentration was measured at the Muara Ciminyak location. For turbidity parameters, the highest concentration was a water sample from the Nanjung location, which was 196.3 NTU, while in 10 other locations, the turbidity concentration was below 100 NTU. The lowest turbidity concentration was measured at the Tailrace location. pH condition at the monitoring location was generally normal, in the range of 7-8. However, at the monitoring location of Muara Cijambu and Tailrace, the water conditions were alkaline, having a pH of more than 10. Alkaline conditions in water can be affected by various factors and can be an indicator of polluted waters. Other information in Table 4 includes water samples from 11 monitored locations, nitrate parameters in all locations remain under the clean water quality standards (Class I in Government Regulation Number 82 of 2011). For phosphate parameters, water samples at the Cimerang location have exceeded the Class III of water quality standards based on Government Regulation Number 82 of 2001 which is a maximum of 1 mg L^{-1}. For DO parameters, overall from 11 monitoring locations it was shown that the concentration of DO in water samples was very small, which was in the range of 0 - 1.5. Besides, for the Fecal coli parameter, monitoring of 11 locations shows that the water quality of these locations is still under the Class III of water quality standards. By reviewing 9 test parameters, the water quality from the Najung site was found to have a worse quality compared to other locations for turbidity, nitrate, DO, BOD, and fecal coli.

Table 5 shows the average water quality data of the Saguling Reservoir at several monitoring locations during a dry year. At 11 monitoring locations, water temperatures were generally at normal conditions, which are around 26^{0}C to 27^{0}C, and slightly lower at the Cimerang location, which was 25^{o}C. The concentration of dissolved residue or TDS at 11 monitoring locations was still under the quality standards for surface water quality Class I (surface water which is used for drinking water purposes) based on Government Regulations Number 82 of 2001.

The highest TDS concentration was found at the Cihaur location (330.5 mg L^{-1}), while the lowest TDS concentration was at the Muara Ciminyak location. When compared with TDS data during normal years, TDS concentrations during dry years tend to be greater. For the turbidity parameter, the highest concentration was found in water samples from the Nanjung location, which was 220.9 NTU, while in the other 10 locations, the turbidity concentration was below 60 NTU. The lowest turbidity concentration was measured at the Tailrace location. Water pH at the monitoring location was generally normal, in the range of 7-8. But at the monitoring location, intake water was determined to be alkaline with a pH of more than 11. Other information that can be gathered from Table 5 is that nitrate measurements from all 11 locations are still under clean water quality standards (Class I in Government Regulation Number 82 of 2001). For the phosphate parameter, water samples from 11 locations are also still under the Class III of water quality standards based on Government Regulation Number 82 of 2011, which is a maximum of 1 mg L^{-1}. The concentration of DO in water samples from all 11 locations was determined to be very small, in the range of 0 - 1.2 mg L^{-1}. Fecal coli measurements from 11 locations did no deviate from Class III of water quality standards. Bolstad and Swank [14] concluded that transportation of coliforms in water can occur mainly through land or direct input by warm-blooded animals (e.g. livestock). By reviewing 9 test parameters, water quality from the Najung site was found to have worse quality compared to other locations with regards to turbidity, nitrate, phosphate, DO, BOD, and Fecal coli. Overall data regarding water quality during dry years shows that concentrations are higher than water concentrations for various parameters during normal years.

Table 6 shows the average water quality data of the Saguling Reservoir at several monitoring locations during the wet year. At 11 locations, water temperature was generally in normal, and around 25^{o}C to 27^{o}C, slightly lower than the water temperature during normal and dry years. The highest TDS concentration was found at the Cihaur location (299.1 mg L^{-1}), while the lowest TDS concentration was found at the Muara Ciminyak location.

When compared to TDS data during normal and dry years, TDS concentrations during wet years tend to be smaller than water quality data from dry years and are not much different than measurements during normal years. The highest concentration of turbidity was in the water sample from the Nanjung location of 193.6 NTU, while in the other 10 locations the turbidity concentration was below 65 NTU. The lowest turbidity concentration was at the Muara Cihaur location. Water pH was generally normal, and in the range of 6-8. Other information that can be gathered from Table 6 is that nitrate measurements from all locations were determined to be in accordance with clean water quality standards. Phosphate measurements from all 11 locations were also still under the Class III of water quality standards based on Government Regulation Number 82 of of 2001, which is a maximum of 1 mg L^{-1}. The concentration of DO in water samples from all locations was very small, in the range of 1-3 ppm, slightly better than the quality of DO during normal and dry years. The Fecal coli measurements were still under the Class III of water quality standards based on Government Regulation Number 82 of of 2001. By reviewing 9 test parameters, water quality from the Nanjung site was found to have worse quality compared to the other locations for turbidity, nitrate, phosphate, BOD, and Fecal coli parameters. Overall water quality data during the wet year reveals lower concentrations of water for various parameters during the dry year and not much of a difference in the water concentrations during the normal year.

3.2 NSFWQI Values of Saguling Reservoir during Dry, Normal, and Wet Years

In this part, the NSFWQI value will be discussed spatially for each monitoring location, and temporally, which is based on the conditions during the dry year and the wet year.

Figure 2(b) shows the results of the NSFWQI water quality in the Saguling Reservoir during the dry year period where the distribution of monitoring points is shown in Figure 2(a). The NSFWQI values obtained were then compared to Table 2 on the NSFWQI water quality ratings. The Saguling Reservoir during dry years shows that at the Nanjung monitoring point the water quality at fair water quality category with an index score of 45. This is also seen at the monitoring points of Batujajar and Cihaur with index scores of 49 and 46, respectively. While in Cimerang, Cihaur Estuary, Cipatik Estuary, Ciminyak Estuary, Cijere Estuary, Cijambu Estuary, Intake, and Tailrace, the water quality ratings are medium or average. Index scores are as follows: Cimerang- 51, Cihaur Estuary- 53, Cipatik Estuary- 56, Ciminyak Estuary- 55, Cijere Estuary- 54, Cijambu Estuary- 57, Intake- 59, and Tailrace- 61. The highest index score at 11 monitored locations during the dry season was at the Tailrace location. The lowest index score was at the Nanjung location.

Figure 3(b) shows the results of NSFWQI water quality in the Saguling Reservoir during the normal season period where the distribution of monitoring points is shown Figure 3(a). The NSFWQI values obtained were then compared to Table 2 regarding NSFWQI water quality ratings. The value of NSFWQI Saguling Reservoir during dry years shows that all monitoring points have a medium or average water quality. Index scores obtained at each monitoring point are as follows: Nanjung - 43, Batujajar, Cimerang and Intake have scores of 60, Cihaur - 58, Cihaur and Ciminyak Estuaries have scores of 57, Cipatik Estuary, Cijambu Estuary, and Tailrace have scores of 59, and Cijere Estuary- 56. The highest index score at 11 monitored locations during the normal season was found at the Batujajar and Cimerang locations, while the lowest index score was measured at the Nanjung location.

3.3 Correlation Matrix of Water Quality and NSFWQI Values of the Saguling Reservoir during Dry, Normal, and Wet Years

From Table 7, 8 and 9, it can be seen that the strongest and most significant correlation between parameter concentration and WQI score is the turbidity concentration and Fecal coli. This indicates that these parameters make a major contribution to the WQI value or water quality data at the Saguling Reservoir location, whether it is a dry, normal, or wet year. Using these two parameters (obtained from the correlation matrix), the calculation of NSFWQI can be cost-effective and save time and energy, which are fundamental aspects of an effective monitoring program in water quality determination [15].

3.4 Nitrate Concentration Distribution using IDW (Inverse Distance Weighted)

With regard to the NSFWQI values above, the highest NSFWQI value for dry, normal, and wet conditions is measured in the Nanjung post, which is a post located in the most upstream area before entering the Saguling Reservoir. This may be caused by the upstream river basin conditions of the Saguling Reservoir, which are dominated by pollution sources that include agricultural, domestic, and industrial activities. In order to prove that the pollution is concentrated in the Saguling Reservoir inlet, the nitrate concentration distribution was analyzed using the Inverse Distance Weighten Method.

IDW (Inverse Distance Weighted) method is a simple deterministic method performed by considering the points in the vicinity. The assumption of this method is that the interpolation value will be more similar to near sample data than to more distant data. Weights will change linearly according to the distance to the sample data. This weight will not be affected by the location of the sample data. IDW assumes each point size has a local effect that decreases with distance. The points that are closer to the estimated location are given greater weight than those located further away, so they are called inverse distance weighted. The general equation of Inverse Distance Weighted is shown below:

See equation 3 in the supplementary files.

Below is the use of IDW to determine nitrate concentrations in the Saguling reservoir: **See figure 5.**

Figure 5 shows the distribution of nitrates during the wet year in the Saguling Reservoir. In the figure, it can be seen the different nitrate concentrations at 11 monitoring locations. At the monitoring point in Nanjung, the concentration of nitrate is shown in red and ranges between 3.24-3.75 mg L^{-1}. Meanwhile, at the monitoring point in Batujajar, (shown in light green) has nitrate concentration values between 1.15-1.66 mg L^{-1}. Whereas at other monitoring points that include Cihaur, Cimerang, Cihaur Estuary, Cipatik Estuary, Ciminyak Estuary, Cijere Estuary, Cijambu Estuary, Intake, and Tailrace (shown in dark green), nitrate concentration values range between 0.623-1.14 mg L^{-1}. The highest value of nitrate concentration during the wet season is in the Nanjung locations, while the lowest value of nitrate concentration is found at Cihaur, Cimerang, Cihaur Estuary, Cipatik Estuary, Ciminyak Estuary, Cijere Estuary, Cijambu Estuary, Intake, and Tailrace. However, nitrate parameter water samples in 11 locations are still under the Class III of water quality standards based on Government Regulation Number 82 of 2001, which is a maximum of 20 mg L^{-1}.

Nitrate concentrations of more than 0.2 mg L^{-1} can lead to eutrophication (enrichment) of waters and subsequently stimulate the growth of algae and aquatic plants rapidly (blooming). This is detrimental because it can affect the health and biodiversity of the local aquatic ecosystem. Naturally, the concentration of nitrate in natural waters is only a few mg L^{-1} and is one of the compounds that functions to stimulate the growth of marine biomass so that it directly controls the development of primary production. This function is closely related to the fertility of waters. James et al. [16] concluded that high nitrate concentration is affected by agricultural activities, aquaculture, industry and household waste or population waste.

Figure 6 shows the distribution of nitrates during a normal year in the Saguling Reservoir. In the figure, the different nitrate concentrations at each monitoring location can be seen. At the monitoring point in Nanjung, the concentration of nitrate is shown in red and the range value is 3.24-3.75 mg L^{-1}. Meanwhile, at the monitoring point in Batujajar, nitrate concentration values between 2.74-3.02 mg L^{-1} are indicated in orange. Furthermore, at other monitoring points, namely Cihaur, Cimerang, Cihaur Estuary, (shown in neon) have nitrate concentration values between 2.17-2.45 mg L^{-1}. At the monitoring point of Cipatik, Ciminyak and Cijere Estuaries, (shown in dark green) have nitrate concentration values between 1.59-1.88 mg L^{-1}. Meanwhile Cijambu Estuary, Intake, and Tailrace (shown as light green) have nitrate concentrations in the range of 1.89 -2.16 mg L^{-1}. The highest value of nitrate concentration during normal season is in Nanjung, while the lowest value of nitrate concentration is found at Cijambu, Intake, and Tailrace. However, nitrate parameter water samples in 11 locations are still under the Class III of water quality standards based on Government Regulation Number 82 of 2001, which is a maximum of 20 mg L^{-1}.

Figure 7 shows the distribution of nitrates during the dry year in the Saguling Reservoir. In the figure, it can be seen that there are different nitrate concentrations at each monitoring location. At the monitoring point in Nanjung, the concentration of nitrate is shown as a red color and the range value is 3.24-3.75 mg L^{-1}, while the monitoring point in Batujajar is shown as an orange color with nitrate concentration values between 2.74-3.02 mg L^{-1}. Other monitoring points, namely Cihaur, Cimerang, Cihaur Estuary, are shown as a neon color with a nitrate concentration value of 2.17-2.45 mg L^{-1}. The monitoring points of Cipatik, Ciminyak and Cijere Estuaries, are shown as a dark green color with nitrate concentration values between 1.59-1.88 mg L^{-1}. Furthermore, Cijambu Estuary, Intake, and Tailrace are shown as a light green color with nitrate concentration values in the range 1.89 -2.16 mg L^{-1}. The highest value of nitrate concentration during the dry season is in Nanjung, while the lowest value of nitrate concentration is shown at Cijambu, Intake, and Tailrace. However, nitrate measurements for all 11 locations are still under the Class III of water quality standards based on Government Regulation Number 82 of 2001, which is a maximum of 20 mg L^{-1}.

Conclusions

Water quality assessment is usually conducted by calculating the index of water quality. Water quality index (WQI) is a valuable and unique rating used to describe overall water quality status in a single term that is helpful for the selection of appropriate treatment techniques to resolve issues of concern. The NSFWQI, which is the commonly used indicators for surface water quality are based on these parameters: turbidity, temperature, phosphate, nitrate, fecal coliform, pH, DO, TS, BOD. The NSFWQI values of the Saguling Reservoir during a dry year (for the study period) has a clear increasing trend from Nanjung to the Tailrace station (upstream to downstream). NSFWQI fluctuations occur in several locations, such as at the Cihaur and Muara Cipatik stations. Water quality at the Nanjung Station is classified into class IV fair water quality with a WQI value between 26 and 50. This value reveals the poorest conditions of the Saguling Reservoir compared to normal and wet conditions. This study also shows that the strongest and most significant correlation between parameter concentration and the WQI score is the turbidity concentration and fecal coli, which are usable for determining the required parameters if the calculation of the WQI (with reduced parameters) is needed.

Declarations

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interest

The authors declare that they have no competing interests

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Authors' contribution

MM contributes to the preparation of literature studies, compilation of research frameworks, also collecting and analyzing data as well. AS contributes to the preparation of hypotheses and research objectives. NF contributes to analyzing data with Inverse Distance Weighted method.

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Tables

Table 1 Water quality monitoring locations in the Saguling Reservoir

Monitoring Station	Location	GPS (decimal unit)	
		LS	BT
1a	Citarum River	107°32'10,7"	06°56'29,8"
1b	Citarum River Trash Boom Batujajar	107°28'35,0"	06°54'58,9"
2	Cihaur Cipeundeuy Village	107°28'32,3"	06°53'13,5"
3	Cimerang	107°27'09,0"	06°53'13,4"
4	Muara Cihaur Kampung Maroko	107°25'54,4"	06°54'13,0"
5	Muara Cipatik	107°27'25,5"	06°56'07,6"
6	Muara Ciminyak – floating nets fishing location	107°26'03,8"	06°57'14,6"
7	Muara Cijere	107°24'50,8"	06°56'14,9"
8	Muara Cijambu	107°22'22,4"	06°56'00,4"
9	Near Intake Structure	107°22'26,3"	06°54'54,4"
10a	Tailrace	107°20'57,0"	06°51'49,8"

Table 2 NSFWQI

No	Parameter	Code	Unit	Weighting factor
1	Temperature	T	^0C	0.1
2	Dissolved solid	TDS	mg L^{-1}	0.07
3	Turbidity	TUR	NTU	0.08
4	pH	pH		0.11
5	Nitrates	NO3-N	mg L^{-1}	0.1
6	Total Phosphate (TP)	PO4	mg L^{-1}	0.1
7	Dissolved oxygen	DO	mg L^{-1}	0.17
8	Biochemical Oxygen Demand	BOD	mg L^{-1}	0.11
9	Fecal Coli	FC	Colony/100mL	0.16

Table 3 NSFWQI

No	Score	Description
1	91–100	Excellent water quality
2	71 –90	Good water quality
3	51-70	Medium or average water quality
4	26-50	Fair water quality
5	0-25	Poor water quality

Table 4 Water Quality Data of the Saguling Reservoir during a Normal Year

No	Parameter Location	Temperature °C	Total Dissolved Solids mg L^{-1}	Turbidity NTU	pH -	Nitrate mg L^{-1}	Phospate mg L^{-1}	Dissolved Oxygen mg L^{-1}	Biochemical Oxygen mg L^{-1}	Fecal Coli Colony/100 mL
1	Nanjung	26,3 ± 1,0	241,8 ± 108,4	196,3 ± 135,8	7,5 ± 0,4	2,6 ± 1,5	0,5 ± 0,2	0,8 ± 1,4	40,4 ± 11,7	1100,0 ± 0,0
2	Batujajar	26,8 ± 0,5	228,7 ± 93,3	87,7 ± 71,0	7,4 ± 0,3	1,8 ± 0,9	0,3 ± 0,1	1,0 ± 1,3	19,5 ± 3,6	1100,0 ± 0,0
3	Cihaur	27,4 ± 0,4	308,2 ± 104,4	71,6 ± 59,4	7,9 ± 0,4	1,9 ± 0,8	0,3 ± 0,1	1,0 ± 1,4	19,5 ± 4,6	1100,0 ± 0,0
4	Cimerang	27,3 ± 0,2	252,8 ± 66,7	43,6 ± 40,7	8,1 ± 1,9	2,5 ± 2,0	1,3 ± 2,2	1,1 ± 1,5	16,0 ± 3,2	1100,0 ± 0,0
5	Muara Cihaur	27,3 ± 0,2	203,8 ± 55,8	33,6 ± 38,0	7,6 ± 0,3	1,2 ± 0,4	0,4 ± 0,2	1,2 ± 1,5	15,6 ± 2,4	210,0 ± 0,0
6	Muara Cipatik	27,2 ± 0,2	123,1 ± 32,4	41,9 ± 38,5	7,6 ± 0,3	1,2 ± 0,2	0,4 ± 0,1	1,1 ± 1,6	12,8 ± 4,3	150,0 ± 0,0
7	Muara Ciminyak	27,9 ± 1,3	111,1 ± 25,5	35,8 ± 31,2	7,5 ± 0,2	1,4 ± 0,4	0,3 ± 0,1	1,1 ± 1,4	12,0 ± 3,1	1100,0 ± 0,0
8	Muara Cijere	27,2 ± 0,3	143,7 ± 37,5	34,3 ± 34,4	7,7 ± 0,2	1,6 ± 0,6	0,3 ± 0,2	1,3 ± 1,9	12,5 ± 2,8	1100,0 ± 0,0
9	Muara Cijambu	27,7 ± 1,1	155,1 ± 42,8	57,2 ± 60,2	10,7 ± 6,7	1,2 ± 0,6	0,3 ± 0,1	1,1 ± 1,5	11,6 ± 3,8	210,0 ± 0,0
10	Intake	27,0 ± 0,6	161,4 ± 41,3	37,4 ± 42,5	7,8 ± 0,3	1,4 ± 0,6	0,3 ± 0,1	1,4 ± 1,9	13,0 ± 4,3	64,0 ± 0,0
11	Tailrace	26,7 ± 0,1	181,8 ± 0,0	32,9 ± 0,0	12,0 ± 0,0	1,7 ± 0,0	0,2 ± 0,0	1,0 ± 0,0	12,3 ± 0,0	23,0 ± 0,0

Table 5 Water Quality Data of the Saguling Reservoir during a Dry Year

No	Parameter Location	Temperature °C	Total Dissolved Solids mg L^{-1}	Turbidity mg L^{-1}	pH -	Nitrate mg L^{-1}	Phospate mg L^{-1}	Dissolved Oxygen mg L^{-1}	Biochemical Oxygen mg L^{-1}	Fecal Coli Colony/100mLs
1	Nanjung	25,9 ± 0,7	320,4 ± 117,0	220,9 ± 187,9	7,4 ± 0,1	3,3 ± 1,1	0,4 ± 0,2	0,6 ± 1,0	50,3 ± 5,3	1100,0 ± 0,0
2	Batujajar	27,5 ± 0,6	296,9 ± 52,0	50,2 ± 49,2	7,6 ± 0,1	2,6 ± 0,6	0,3 ± 0,1	0,9 ± 1,2	26,0 ± 4,1	1100,0 ± 0,0
3	Cihaur	27,7 ± 0,5	330,5 ± 52,7	62,5 ± 45,4	8,2 ± 0,3	2,4 ± 1,0	0,3 ± 0,1	0,8 ± 1,1	21,3 ± 3,7	1100,0 ± 0,0
4	Cimerang	25,0 ± 5,8	266,7 ± 31,6	45,6 ± 55,8	8,0 ± 0,3	2,1 ± 0,7	0,2 ± 0,1	0,9 ± 1,3	14,4 ± 3,7	1100,0 ± 0,0
5	Muara Cihaur	27,4 ± 0,5	250,3 ± 34,8	44,0 ± 50,4	7,7 ± 0,1	2,0 ± 0,5	0,3 ± 0,1	1,0 ± 1,4	15,2 ± 3,3	210,0 ± 0,0
6	Muara Cipatik	26,1 ± 3,0	139,5 ± 15,9	41,9 ± 53,1	7,7 ± 0,4	1,6 ± 0,4	0,3 ± 0,1	1,0 ± 1,4	10,3 ± 2,6	150,0 ± 0,0
7	Muara Ciminyak	27,3 ± 0,4	136,9 ± 19,9	40,7 ± 52,0	7,5 ± 0,1	1,6 ± 0,4	0,3 ± 0,1	0,9 ± 1,3	9,3 ± 2,6	1100,0 ± 0,0
8	Muara Cijere	26,2 ± 3,0	162,1 ± 27,0	27,8 ± 25,8	7,6 ± 0,3	1,7 ± 0,4	0,3 ± 0,1	1,1 ± 1,5	9,3 ± 2,5	1100,0 ± 0,0
9	Muara Cijambu	27,3 ± 0,3	162,2 ± 5,3	39,5 ± 53,9	7,6 ± 0,2	1,4 ± 0,4	0,2 ± 0,1	1,0 ± 1,4	8,5 ± 1,5	210,0 ± 0,0
10	Intake	26,9 ± 0,2	182,5 ± 26,0	39,6 ± 39,5	11,6 ± 9,1	1,6 ± 0,4	0,3 ± 0,1	1,2 ± 1,7	10,6 ± 3,0	64,0 ± 0,0
11	Tailrace	26,8 ± 0,2	209,6 ± 0,0	27,6 ± 0,0	7,2 ± 0,0	1,6 ± 0,0	0,2 ± 0,0	1,0 ± 0,0	9,7 ± 0,0	23,0 ± 0,0

Table 6 Water Quality Data of the Saguling Reservoir during a Wet Year

No	Parameter Location	Temperatur °C	Total Dissolved Solids mg L^{-1}	Turbidity NTU	pH -	Nitrate mg L^{-1}	Phospate mg L^{-1}	Dissolved Oxygen mg L^{-1}	Biochemical Oxygen mg L^{-1}	Fecal Coli Colony/100 mL
1	Nanjung	25,8 ± 0,4	245,5 ± 83,4	193,6 ± 101,6	7,4 ± 0,2	2,5 ± 1,5	0,3 ± 0,1	1,5 ± 1,4	29,2 ± 19,7	1100,0 ± 0,0
2	Batujajar	26,9 ± 0,7	213,8 ± 49,6	62,9 ± 50,4	7,4 ± 0,2	1,7 ± 0,8	0,3 ± 0,1	2,9 ± 3,4	15,7 ± 4,5	1100,0 ± 0,0
3	Cihaur	26,1 ± 3,3	299,1 ± 77,1	56,0 ± 53,0	7,4 ± 1,4	2,1 ± 1,3	0,3 ± 0,2	2,2 ± 2,7	20,2 ± 9,2	1100,0 ± 0,0
4	Cimerang	25,8 ± 3,2	240,7 ± 58,8	40,1 ± 35,3	7,4 ± 0,9	1,7 ± 1,0	0,2 ± 0,1	2,5 ± 3,2	13,6 ± 4,4	1100,0 ± 0,0
5	Muara Cihaur	25,8 ± 3,3	200,4 ± 52,4	38,7 ± 31,0	7,1 ± 0,8	2,0 ± 0,8	0,2 ± 0,1	1,7 ± 1,5	12,1 ± 2,8	210,0 ± 0,0
6	Muara Cipatik	25,9 ± 3,2	123,5 ± 22,0	45,3 ± 35,2	7,0 ± 0,9	1,3 ± 0,7	0,3 ± 0,1	1,8 ± 1,7	9,3 ± 3,4	150,0 ± 0,0
7	Muara Ciminyak	25,9 ± 3,2	114,8 ± 23,2	40,0 ± 35,2	6,9 ± 0,8	1,2 ± 0,6	0,3 ± 0,1	1,7 ± 1,6	7,6 ± 2,9	1100,0 ± 0,0
8	Muara Cijere	25,9 ± 3,3	146,1 ± 26,5	39,6 ± 34,8	7,0 ± 0,9	1,5 ± 1,0	0,2 ± 0,1	1,7 ± 1,5	11,2 ± 3,8	1100,0 ± 0,0
9	Muara Cijambu	25,9 ± 3,5	154,6 ± 33,9	43,9 ± 40,8	7,1 ± 0,8	1,4 ± 0,9	0,2 ± 0,1	1,6 ± 1,5	9,0 ± 1,7	210,0 ± 0,0
10	Intake	25,6 ± 3,4	165,1 ± 39,4	39,4 ± 38,8	6,8 ± 0,9	1,5 ± 1,0	0,2 ± 0,1	1,9 ± 1,8	11,0 ± 3,6	64,0 ± 0,0
11	Tailrace	25,2 ± 3,2	181,5 ± 0,0	49,3 ± 0,0	6,8 ± 0,0	1,4 ± 0,0	0,2 ± 0,0	1,0 ± 0,0	10,0 ± 0,0	23,0 ± 0,0

Table 7 Correlation Matrix of the Saguling Reservoir Water Quality during a Normal Year

	Temperature	TDS	Turbidity	Ph	Nitrate	Phosphate	DO	BOD	Fecal Coli	WQI
Temperature	1									
TDS	-0.363	1								
Turbidity	-0.620	0.454	1							
pH	-0.031	-0.124	-0.230	1						
Nitrate	-0.545	0.670	0.633	-0.115	1					
Phosphate	0.039	0.364	0.033	-0.169	0.647	1				
DO	0.420	-0.413	-0.674	-0.142	-0.442	-0.024	1			
BOD	-0.662	0.542	0.969	-0.315	0.701	0.133	-0.660	1		
Fecal Coli	0.006	0.420	0.412	-0.529	0.617	0.375	-0.224	0.436	1	
WQI	0.272	-0.645	-0.762	-0.273	-0.570	-0.529	0.635	-0.479	-0.643	1

Table 8 Correlation Matrix of the Saguling Reservoir Water Quality during the Dry Year

	Temperature	TDS	Turbidity	pH	Nitrate	Phosphate	DO	BOD	Fecal Coli	WQI
Temperature	1									
TDS	0.043	1								
Turbidity	-0.260	0.542	1							
pH	0.044	-0.117	-0.141	1						
Nitrate	-0.111	0.874	0.818	-0.188	1					
Phosphate	-0.062	0.529	0.828	0.071	0.742	1				
DO	0.047	-0.724	-0.779	0.516	-0.863	-0.625	1			
BOD	-0.133	0.749	0.938	-0.176	0.958	0.822	-0.850	1		
Fecal Coli	-0.172	0.454	0.343	-0.319	0.596	0.358	-0.593	0.459	1	
WQI	0.023	-0.747	-0.821	-0.320	-0.639	-0.745	0.579	-0.566	-0.759	1

Table 9 Correlation Matrix of the Saguling Reservoir Water Quality during the Wet Year

	Temperature	TDS	Turbidity	pH	Nitrate	Phosphate	DO	BOD	Fecal Coli	WQI
Temperature	1									
TDS	0.215	1								
Turbidity	0.041	0.403	1							
pH	0.652	0.765	0.389	1						
Nitrate	0.210	0.846	0.797	0.717	1					
Phosphate	0.414	0.488	0.451	0.624	0.628	1				
DO	0.833	0.391	-0.132	0.705	0.232	0.388	1			
BOD	0.218	0.764	0.875	0.665	0.986	0.628	0.171	1		
Fecal Coli	0.529	0.410	0.326	0.639	0.487	0.703	0.509	0.492	1	
WQI	-0.305	-0.735	-0.914	-0.708	-0.720	-0.680	-0.220	-0.700	-0.920	1

Figures

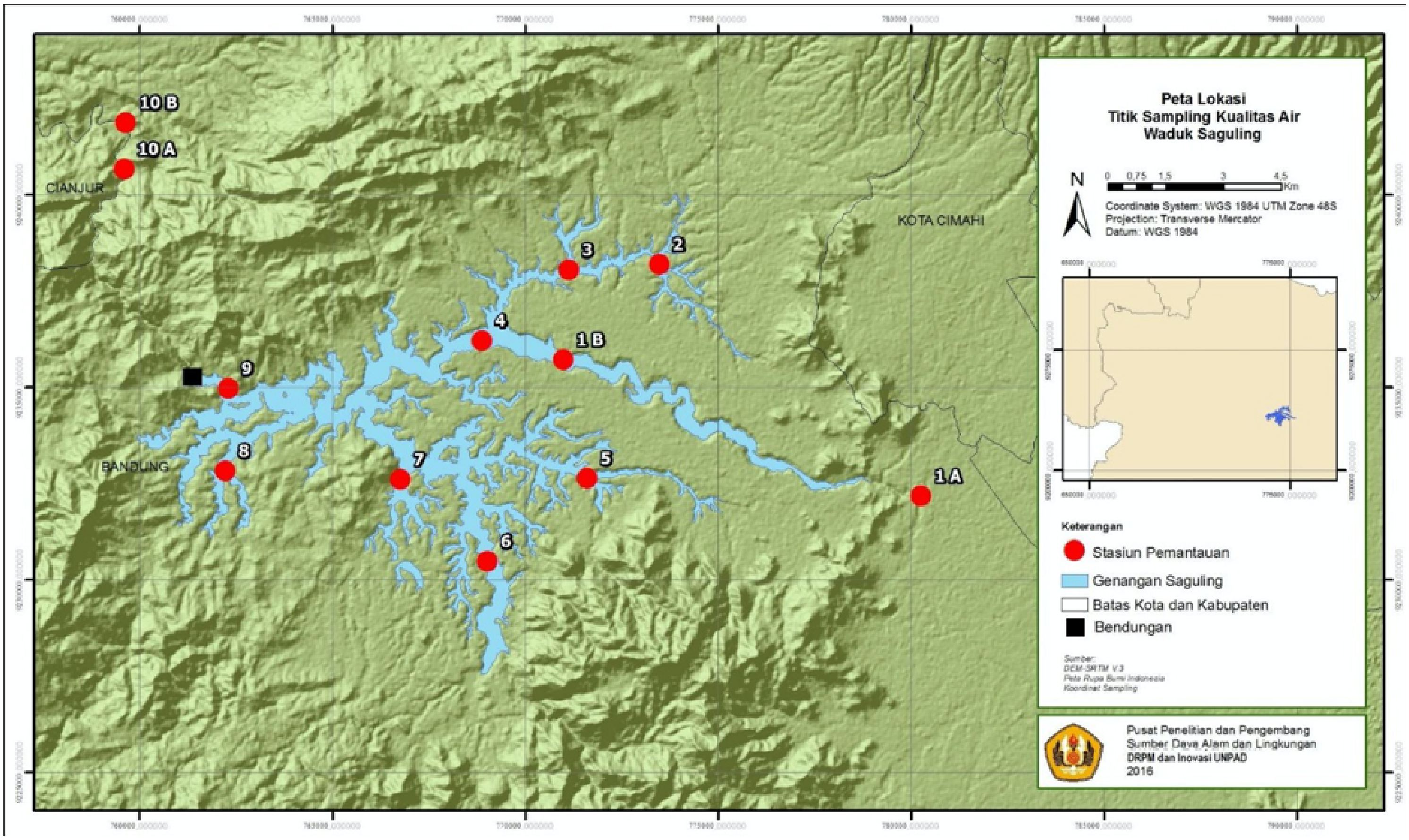

Figure 1

Water quality monitoring locations in the Saguling Reservoir

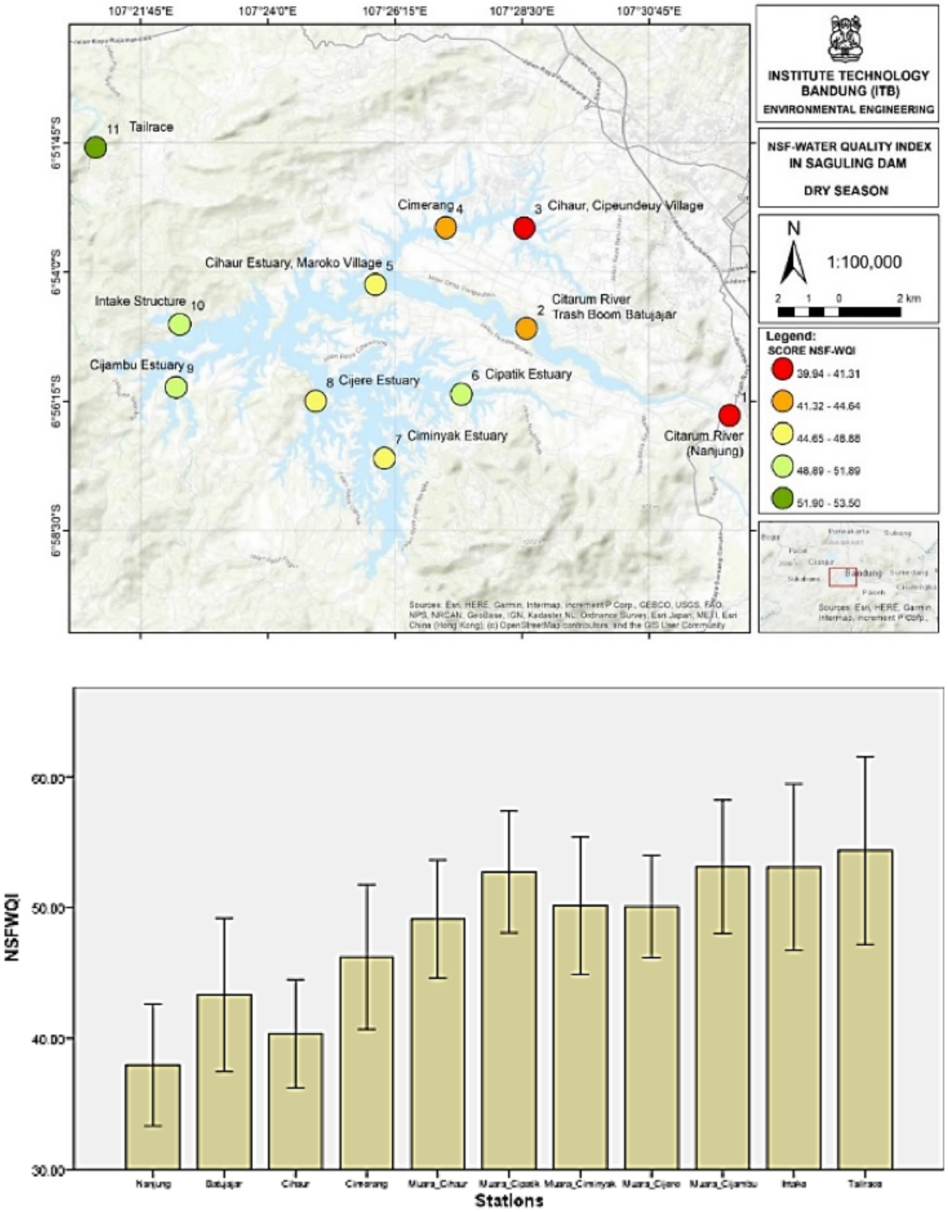

Figure 2

(a). NSFWQI during the Dry Season. (b). NSFWQI value during value the Dry Season for each monitoring location

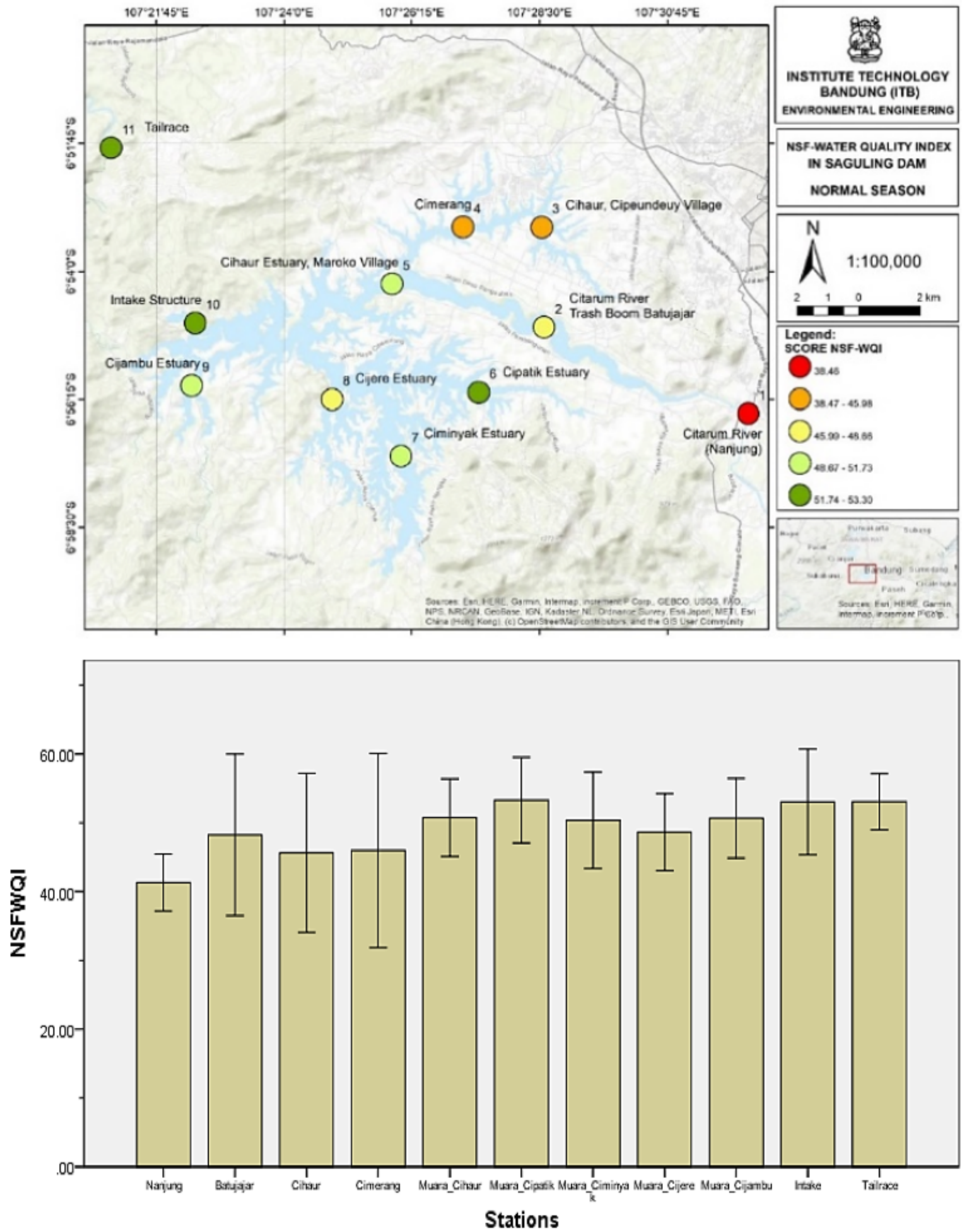

Figure 3

(a). NSFWQI value in the Normal Season. (b). NSFWQI value during the Normal Season for each monitoring location

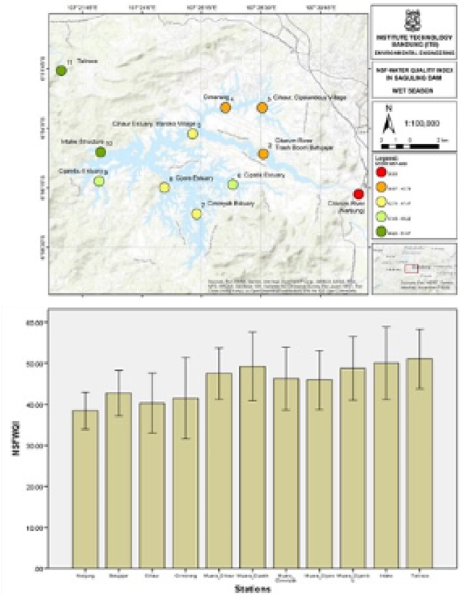

Figure 4

(a). NSFWQI value during the Wet Season. (b). NSFWQI value during the Wet Season for each monitoring location

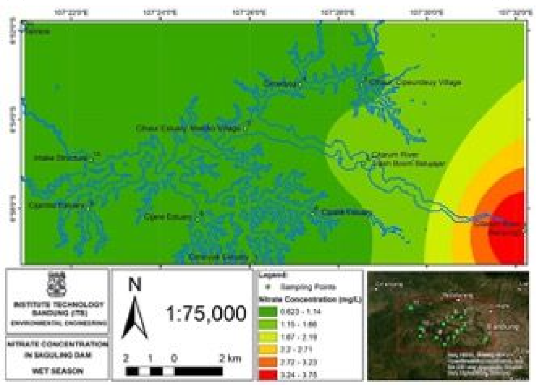

Figure 5

Nitrate distribution during Wet Year

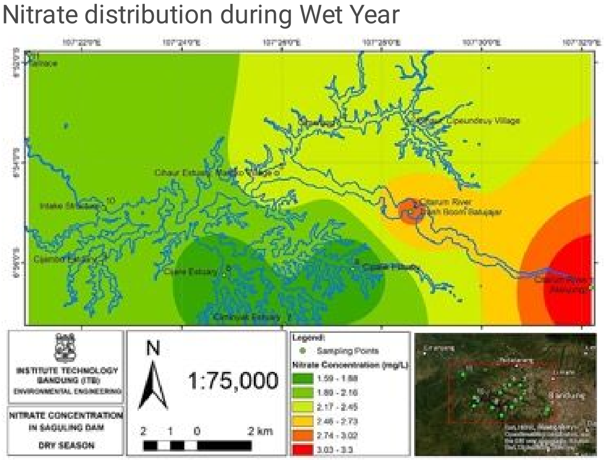

Figure 6

Nitrate distribution at Normal Year

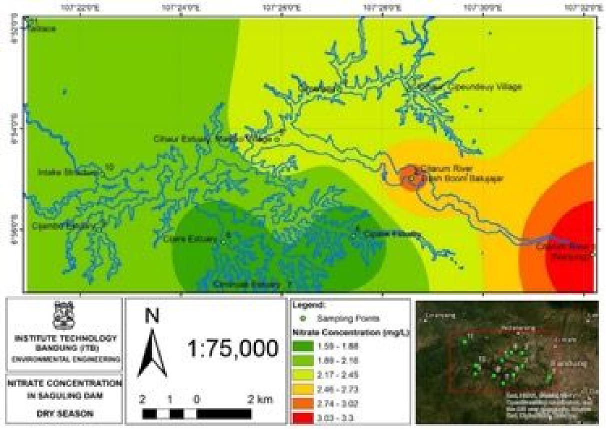

Figure 7

Nitrate distribussion at Dry Year