Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control
Journal homepage: http://kinetik.umm.ac.id
ISSN: 2503-2267
Vol. 5, No. 3, August 2020, Pp. 219-226

Geographic information system for a community-based water quality mapping of rivers in Indonesia

Shofwatul Uyun
Universitas Islam Negeri Sunan Kalijaga Yogyakarta

Article Info

Keywords:
GIS, Water, Quality, Mapping, Community

Article history:
Received 22 January 2020
Revised 23 February 2020
Accepted 25 July 2020
Published 31 August 2020

Cite:
Uyun, S. (2020). Geographic Information System for a Community-Based Water Quality Mapping of Rivers in Indonesia. Kinetik: Game Technology, Information System, Computer Network, Computing, Electronics, and Control, 5(3).
doi:https://doi.org/10.22219/kinetik.v5i3.1042

*Corresponding author.
Shofwatul Uyun
E-mail address: shofwatul.uyun@uin-suka.ac.id

Abstract

River Water with good quality status is the primary needs for the Indonesian people who live along the river. Indonesia has more or less 303 rivers with varied status of water quality. On the other side, the government is obliged to conduct the current situation mapping and to spread the status of river water quality to the surrounding society. It is certainly not an easy job considering the amount and width of the monitoring area. Therefore, this research has proposed a new concept to map the status of river water quality using the STORET method by involving the active participation of the local river community. The locations of research are: Kambaniru river, Brantas river, dan Gajah Wong river. There are seven parameters used to determine the status of river water quality those are: temperature, EC/DHL, TDS, PH, DO, BOD and Caliform. The river community can report the data of analysis result into a system in accordance with the sampling location by enclosing the spatial data. The system will present the status of water quality starting from each point of location to the status of water quality of certain river. The testing result functionally indicates that the system is able to give perfect accuration value. While from its usability, the respondents' responses are as follows: very agree 60.40%, agree 37.95%, and disagree 1.65%.

1. Introduction

Water is an important resource that cannot be separated from human's life. It is an abiotic component that influences others. One of meaningful source of freshwater is river. The importance of water in the river as main water source has been discussed elsewhere. In Indonesia, however, freshwater pollution remains a huge issue, in which the increasing number of cases of waterborne disease becomes inevitable. It has been reported by [1], saying that the consistent use of upstream rivers for bathing and other sanitary activities link to 7.5% of all diarrhea-related deaths annually. This finding indicates that water quality remains a big problem, even in this modern day. River water quality monitoring in its action is not an easy task, in which it involves a significant amount of parameters and is challenged by the vastness of the studied area. These two challenges imply a huge investment to laboratory analysis and to laborious work in data collection. Public participation, therefore, becomes an increasingly trend in water quality monitoring world-wide, as it has been stressed by [2], whereas [3] used geographic information system for groundwater mapping. Beside using IoT application for water management [4] and automation monitoring [5]. UNEP recognizes that participatory public participation for any ecological monitoring actions is an important aspect of sustainable development. Yet, in the budget-cut countries, such as Indonesia, there are large gaps in water monitoring activities. Coupled with the vastness of areas to be monitored, a limited capacity of human resource, and limited equipment, water quality monitoring is a difficult problem at its peak. Another challenge for Indonesia is that the policy instrument for measuring water quality has just been released in 2003, long after the concept of Water Quality Index (WQI)-as the early document in water quality monitoring- has been released in 1990s. This shows that the Ministry of Environment is relatively late in issuing water quality instruments, although the document of Decree No. 81/ year 2003 completely adopts the readily available Water Pollution Index (WPI) and Storet Index.

In Indonesia, private research in water quality monitoring has been widely conducted, for example a research about water quality index [6][7][8][9][10], water pollution index [11][12], storet index [11] and comparison between pollution and storet indexes [13]. Besides, there are also researches that use the combination of the three indexes. One of the important researches is the use of water quality index [6] in measuring water quality of West Java's rivers (Cisadane, Ciliwung, Cileungsi, Citarum, Cimanuk, and Citanduy). Other similar researches have been conducted in the urban Jakarta, exploring the quality of drinking water in Jakarta [9][7]. The parameters for measuring water quality are extensive, hence some researches focus on several parameters [14][15][16] and optically complex waters [17]. With this regard, those researches develop fuzzy tsukamoto [18] and ANFIS for predicting Biological Oxygen Demand (BOD) in the Surma River and designing a model for stream water and water sea [19].

In Indonesia water quality is assessed using an official instrument called Water Quality Document that is based on The Decree No. 82 Year 2001 [20]. Based on this document, water quality status is divided into four classes. Class I refers to water supplied for potable uses, class II relates to water for infrastructure and irrigation demands, Class III refers to water that can be used for fisheries and animal husbandry, and last, Class IV categorizes water for watering plants. Although the work for water quality monitoring has been conducted widely by some authorities, most of the result do not readily available, and publicly assessable. ICEL, for example, is an independent organization that commits to the actions for preventing pollution as well as monitoring the status of water quality in Indonesia. The website of ICEL provides data for water quality only for four years (2012-2015). This indicates that ICEL faces obstacles in updating the data and the data maintenance. Another limitation of ICEL is that it only generates an overall conclusion for each river, yet it is quite possible that water pollution occurs in segmented area. This cannot be portrayed by ICEL.

This research, therefore, explores the possibility of information about water quality status to be readily available to the public. By taking geographical account, the website will also involve the beneficiary community in the process of inputting data. In this regard, the community will be trained in collecting simple water quality data. This will be the strength for this research that it develops a system for community-based water quality monitoring in real time and uses a GIS in its development.

2. Methods

2.1 Materials and Tools

This research uses data in the form of seven water quality parameters, including temperature, Electrical Conductivity/EC, Total Dissolved Solid/TDS), pH, Dissolved Oxygen/DO, Biochemical Oxygen Demand/BOD, fecal coliform. The parameters were measured on site, except for fecal coliform, using water measuring tools such a TDS and EC meter, DO-kit, pH meter, thermometer. For measuring fecal coliform, we took water samples to be analyzed by the Laboratory of Environmental Health in Yogyakarta.

2.2 System Design and Algorithm

The major concept in this research is the involvement of community in collecting and inputting the data. Three communities from three rivers, Kambaniru River in Nusa Tenggara Timur, Brantas River in East Java, and Gajah Wong River in Yogyakarta are chosen to actively participate in monitoring water quality. The concept was, then, developed into an application, and the community was participated in data collection and input. Next, the application was calculated and a conclusion about water quality status of the locations was drawn. At this phase, the research team actively accompanied the community in the data gathering process as well as in providing education about water quality status. In this research, we worked with the community of Brantas River (Brantas Berdaya) and Gajah Wong (Forsidas Gajahwong). But, for Kambaniru River, since there was no such an established community, so we worked with the community of Paluanda Lama Hamu –a community that was established as an organization to conserve *tenun ikat* (a kind of traditionally woven fabric). Generally, we applied the following concept Figure 1. Whereas, the research's workflow is depicted in Figure 2.

2.3 Appointing Administrator and Volunteer of Each River

So far, the monitoring for water quality has been conducted by the government's authorities, specifically the government's officers who are appointed to conduct the tasks. The job requires a specific skills and a lot of time to complete the process. Community Based Water Monitoring has been a promising concept to fulfil the mandate of water quality monitoring [1]. The program may benefit from the existing communities such as Pamerti Code, Boyong River Community, River Environment Caring and Preserving Community, Winongo Asri Community Forum, Banyu Bening, Sleman River Community Forum, Gajah Wong Caring Community, Tambak Bayan River Community and Yogyakarta River Community Association. By having those communities, an administrator is appointed in each river, at the same time the volunteers arrive from within the community itself.

2.4 Water Quality Monitoring Data Input by the Volunteers

The conclusion for water quality status is drawn from water quality measurement from a number of sampling locations. The data is then inputted to the database by the volunteers. In this regard, each volunteer has an account as a user. The user has an access to the system and the user can also input the coordinate of the sampling location. Users measure the water quality up to 3-5 times. The algorithm for data collection is shown in algorithm 1.

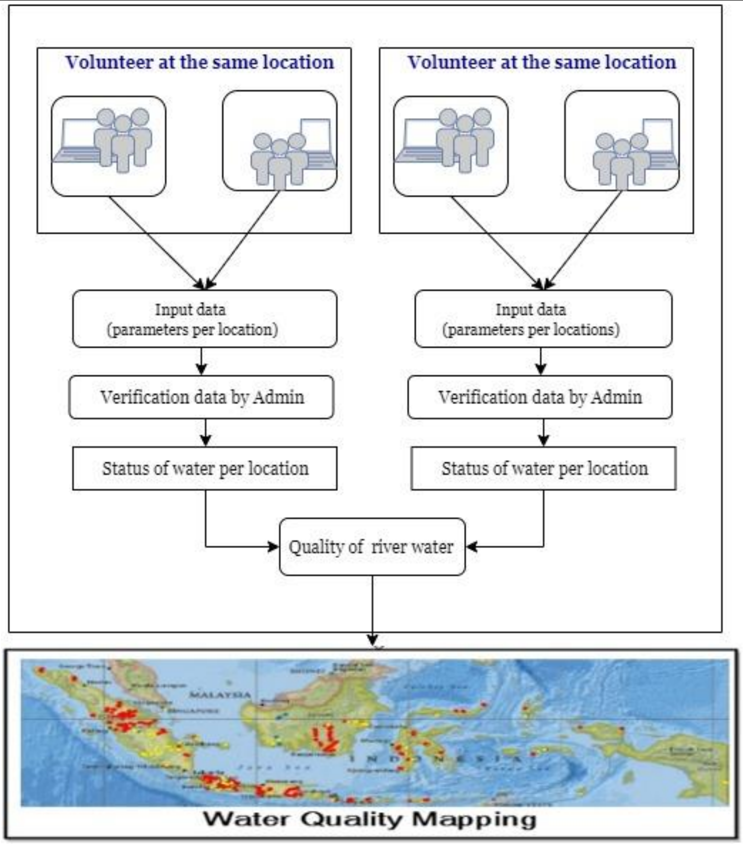

Figure 1. General Concept of Proposal for Mapping Status of River Water Quality by Utilizing Spatial Data

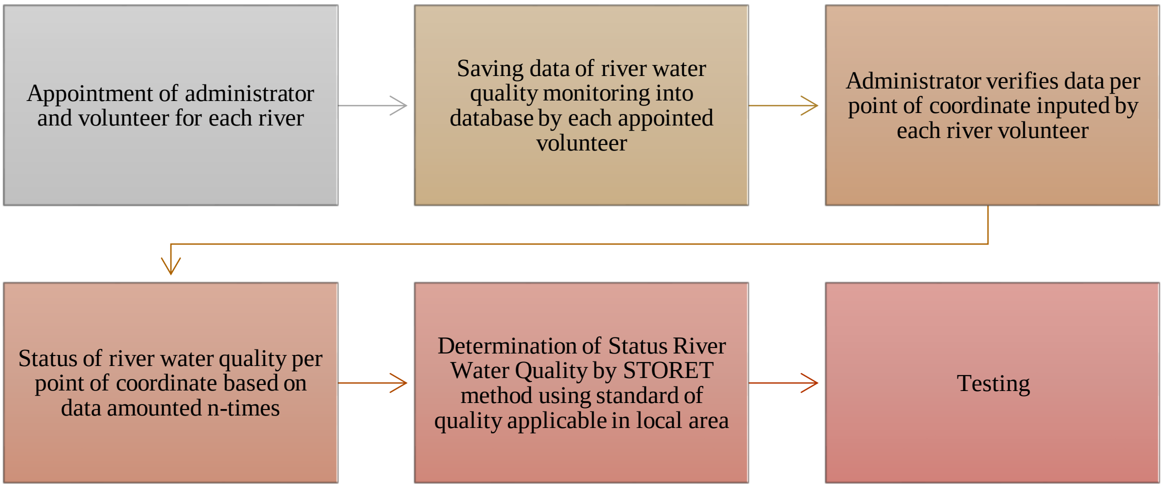

Figure 2. Research Flow

ALGORITHM 1. The Algorithm for Data Collection

1. Each volunteer inputs the data
2. The location signer uses GPS or inputs the latitude and longitude coordinate points
3. Input the number of repeat to take the river water sample
4. **REPEAT**
5. Measure the water sample for biological, chemical, and physics parameter
6. Input the value for the biological parameter(dissolved oxygen, BOD and fecec caliform)
7. Input the value for the physics parameter (temperature, conductivity to electricity and dissolved particle)/////il
8. Input the value for chemical parameter (degrees of acidity/PH)
9. **UNTIL** the number of repeat determined
10. The data form is delivered to the system to be verified by the administrator of each river

2.5 Verification for the validity of the data by the administrator

The rough data inputted by the volunteers does not readily available on line. The data is verified and validated by the administrator. If this validation process completes, then the water quality status for each location will appear on screen, corresponding to the location's coordinate. For example, temperature data derived from latitude -7.600861111 and longitude 112.1094167, with 3 replications, are as follow: 29 °C; 28.4 °C and 28.4 °C. Meanwhile, the data for EC from 3 locations are 314 mhos/cm, 292 mhos/cm and 310 mhos/cm, then these data are inputted in the system. The system will draw a conclusion regarding water quality status in that particular coordinate and is matched with the Storet Index criteria.

Table 1 describes some of the data collected by the participants. Morever, Storet is flexible with the numbers of parameters that can be used to determine the water quality status. We can even work with only 7 parameters, as it occurs in this research. In principle, Storet uses a comparison of water quality standards based on the minimum and maximum value and the class of the water. The following table illustrates our measurement to water quality and shows how we calculate the storet index based on the water quality standard as set by the Decree No 115 Year 2003, as shown in Table 2.

Table 1. Example Water Quality Data of Gajah Wong River Yogyakarta at the Latitude -7.600861111 and Longitude 112.1094167

No	Parameter	Unit	R1	R2	R3
1	Temperature	°C	29	28,4	28,4
2	EC / DHL	mhos/cm	314	292	310
3	TDS	mg/L	157	156	156
4	pH		7,7	7,5	7,4
5	DO	mg/L	6,1	4,75	6
6	BOD	mg/L	6,22	7,9	13,83
7	Coliform	MPN/100 ml	93	150	460

Table 2. Determination of Value System to Determine Status of Water Quality

Value	Parameter		
	Phisycs	Chemicals	Biology
Maximum	-1	-2	-3
Minimum	-1	-2	-3
Average	-3	-6	-9

The final score is found from the result of score addition of each parameter from the comparative addition of the value of measurement result with its quality standard. If the value of measurement result is higher than the quality standard, it will find the values as shown in Table 3. The algorithm for total score of parameters is shown in algorithm 2. The total score is found for each sampling location to determine the status of water quality in the coordinate point. The classification of water quality status is determined by referring to the system of value of US-EPA which data is shown in Table 3 and Table 4.

Table 3. Standard Value of Quality of Seven Parameters for Kambaniru, Brantas and Gajah Wong Rivers

No	Parameter	Unit	Kambaniru	Brantas	Gajahwong
1	Temperature	°C	± 3	± 3	± 3
2	EC / DHL	mhos/cm			
3	TDS	mg/l	1000	1000	1000
4	Ph		6 - 8.5	6 – 9	6 – 9
5	DO	mg/l	3	3	>= 3
6	BOD	mg/l		6	6
7	Coliform	MPN/100 ml	10000	10000	10000

Table 4. Classification of Water Quality Using System of Value of "US-EPA"

Class	Description	Score		Information
		Min	Max	
A	Excellent	0	-	meet the quality standard
B	Good	-10	-1	lightly polluted
C	Average	-30	-11	averagely polluted
D	Bad	-	-31	heavily polluted

ALGORITHM 2. The Algorithm for total score of parameters

```
1.  Determine the parameter used (chemicals, physics or biology)
2.  Determine the number of repeat used for each sampling location
3.  Determine the value of quality standard for each parameter
4.  Make matrix U_ij (i=the number of repeat, j=the number of parameter)
5.  Find the maximum, minimum and average of matrix U_ij per parameter
6.  IF maximum_value(parameter) >= quality_standard(parameter) THEN
7.     max_score(parameter) ← value(parameter)
8.  ELSE
9.     max_score(parameter) ← 0
10.    IF min_value(parameter) >= quality_standar(parameter) THEN
11.       min_score(parameter) ← value(parameter)
12.    ELSE
13.       min_score(parameter) ← 0
14.       IF average_value*parameter >= quality_standard*parameter THEN
15.          average_value(parameter) ← value(parameter)
16.       ELSE
17.          average_score(parameter) ← 0
18. Score (parameter) ← max_score (parameter)+min(score(parameter)+average_score(parameter)
19. Total_score←score(parameter1)+score(parameter2)+..+score(parameter n)
```

2.6 Determination of Status of River Water Quality with STORET method using quality standard in accordance with prevailing rule in local area

The status of river water quality is performed based on the accumulation of calculation of the data form as the measurement result of seven parameters by all coordinate points inputed by the Volunteer with the same river object. For example, for Kambaniru river, the volunteer takes the sample of river water and the measurement for seven parameters as many as 10 coordinate points, and each coordinate is taken as a sample as many as three to five times of repeat, then the status of water quality per coordinate point is determined from the measurement result of STORET method with the data as much as n times of repeat conducted. While to determine the status of river water quality, it is found based on the measurement result of accumulation of 10 coordinate points with three to five times of repeat each. The algorithm to find the data accumulation to determine the status of water quality is as shown in algorithm 3.

ALGORITHM 3. The algorithm to find the data accumulation to determine the status of water quality

```
1.  Determine the maximum value of measurement result in certain parameter from the whole spatial data in the selected river
2.  Determine the minimum value of measurement result in certain parameter from the whole spatial data in the selected river
3.  Determine the average value of measurement result in certain parameter from the whole spatial data in the selected river
4.  Compare the value of monitoring result (maximum, minimum and average) with quality standard in each parameter
5.  The score is found by adding the result of data comparation of the monitoring results with the quality standard in accordance with the
    characteristic of parameter used (physics, chemicals and biology)
6.  IF the score >= 0 THEN
7.     The status of river is "Meeting the Quality Standard"
8.  ELSE
9.     IF the score >= -10 and the score <= -1 THEN
10.       The status of river is "Lightly polluted"
11.    ELSE
12.       IF the score >= -30 and the score <=-11 THEN
13.          The status of river is "Averagely polluted"
14.       Else
15.          The status of river is "Heavily polluted"
16.       END IF
17.    END IF
18. END IF
```

2.7 Testing

The testing is conducted to find out the accuration level of system developed based on the concept of monitoring the status of river water quality by actively involving the local river community. Besides the accuration level, the testing is also conducted to find out the level of system usability by the respondents.

3. Results and Discussion

The algorithm suggested has been implemented in the application of system monitoring of river water quality by actively involving the river community. For example, Brantas river is located in East Java area, then an admin account will be made for Brantas river. The Brantas admin can make some user accounts for the volunteers of Brantas river community. The monitoring of the status of river water all this time has been conducted by several parties, one of which is Perum Jasa Tirta1. The procedure conducted to determine the status of river water quality is long enough and the result cannot be directly accessed widely by the society. The process of taking the sample is conducted twice a week or once a month by the determination of sampling location.

There are ten points of sampling location to take the data sample, among others are: Pendem bridge, Bumiayu bridge, Sengguruh reservoir, Lodoyo reservoir, Ngujang bridge, Mrican reservoir, Ploso bridge, Lengkong baru reservoir, Porong and Gunungsari reservoir. After the data sample of river water is collected, then the analysis is conducted in several closest environmental laboratories. For example, for Porong bridge location, the water sample is analyzed at Mojokerto environmental laboratory. The officer inputs the entry data for each sampling location at the work format to conduct the analysis related to the status of river water by the appointed officer. At one location the sample collecting should be conducted as many as three to five times of repeat. The data then will be processed by the system to determine the status of river water quality at Pendem bridge location and will be directly performed visually with four different colours showing the status of Brantas river. The example of data of analysis result is shown in Table 5.

Table 5. Data of Analysis Result Taken in Pendem Bridge Location

	Temperature	PH	DHL	DO	BOD	TDS	Caliform
Pendem bridge 1	23	7	388	6.93	6.22	211.2	93
Pendem bridge 2	23.9	7.3	307	5.6	7.9	281.2	150
Pendem bridge 3	23	7.3	322	3.2	13.83	243.5	460
Pendem bridge 4	25	6.2	257	3.3	15.25	326.6	460

The next process is determining the status of Brantas river water quality accumulatively by involving the data of analysis result of ten sampling locations. Each location used in this process is the data average result of each sampling location with several times of repeat. The researchers have conducted socialization and mentoring to the river volunteers (Kambaniru, Brantas dan Gajahwong). The application testing is conducted in two steps: *first,* the accuration level of the determination result of status of river water quality by referring to the mapping result conducted by the river water expert amounted 100%. *Second,* for the usability, the respondents' responses are as follows: very agree 60,40%, agree 37,95% and disagree 1,65%. Besides, based on the mapping result of the system related to river water quality based on the sample data used in this research, it is stated that the status of water quality for Brantas river is good, while the status for the other two rivers those are Gajah Wong and Kambaniru are lightly polluted. For the future the concept we have proposed can be developed and implemented by involving the whole river communities so that the status of river water quality per coordinate can be accessed widely by the society. In the socialization and testing, the research has actively involved some communitites located in three rivers (Kambaniru, Brantas and Gajah Wong). There are some suggestions given by the river communities for the future purpose as follows: hopefully the more interesting performance can be developed and the mobile application form can also be developed. Besides, the status of river quality can be widely spread to the whole regions in Indonesia. Then it can also perform the quality status in addition to river, such as well, reservoir, and lake. A suggestion for the developer that will adopt our concept is by adding the performance of testing result with information of complete location name, not only in the form of coordinate point, so it will be easier to understand where the testing location is. Besides, the registration form for the system user can be added and also the data input can be grouped based on the time.

The process of monitoring rivers with very wide watersheds is very difficult to do if you still use conventional methods as is currently done. So far, the local office has routinely taken water data samples at each observation point. Furthermore, the water sample is analyzed to determine the status of river water quality using the STORET method. In fact, to find out the status of water quality in a particular river requires coordination between local government officials which requires a lot of time and money. This is certainly very different if the monitoring process is carried out by actively involving local river communities who can input observation data on water samples for each observation point. In general, the system is capable of processing automatically using the STORET method based on the input of observation sample data. The output of this process produces a level of river water quality status both at each observation point and as a whole. n addition, the system is able to display detailed spatial data for each point of the observation area. Therefore, the proposed use of a new concept for mapping the status of river water quality by involving the active role of the local river community is proposed to have an advantage over the management that has been done manually.

4. Conclusions

Based on the result of research conducted related to the concept proposal in the Mapping of Status of River Water Quality by utilizing the information technology and involving the river community and being able to present the spatial data, it can concluded as follows. This research has succeeded in improving a new concept to assist the government or the society in mapping the status of river water quality in Indonesia in an integrated manner in one system. The integrated monitoring system of river water quality is by elaborating the role of environmentalist community in participatory way using the information technology. The system testing result is able to perform the information of status of river water quality in Indonesia that is easy to access by the general society. The functional testing result has reached 100%, while for the usability, the respondents' responses are as follows: very agree 60,40%, agree 37,95% and disagree 1,65%.

Acknowledgements

This research is supported by Lembaga Penelitian dan Pengabdian Masyarakat, Universitas Islam Negeri Sunan Kalijaga, Yogyakarta, Indonesia.

References

[1] T. Carlson and A. Cohen, "Linking community-based monitoring to water policy: Perceptions of citizen scientists," *J. Environ. Manage.*, Vol. 219, Pp. 168–177, 2018. https://doi.org/10.1016/j.jenvman.2018.04.077

[2] C. Team *et al.*, *Fresh Water for the future*, June. United Nations Environment Programme, 2012.

[3] S. F. Elbeih, "An overview of integrated remote sensing and GIS for groundwater mapping in Egypt," *Ain Shams Eng. J.*, Vol. 6, No. 1, Pp. 1–15, 2015. https://doi.org/10.1016/j.asej.2014.08.008

[4] S. Noorjannah Ibrahim, A. L. Asnawi, N. Abdul Malik, N. F. Mohd Azmin, A. Z. Jusoh, and F. N. Mohd Isa, "Web based water turbidity monitoring and automated filtration system: IoT application in water management," *Int. J. Electr. Comput. Eng.*, Vol. 8, No. 4, Pp. 2503–2511, 2018. https://doi.org/10.11591/ijece.v8i4.pp2503-2511

[5] E. A. R. Hussein and M. O. Waheed, "Fuel station monitoring and automation based on WSN," *Int. J. Electr. Comput. Eng.*, Vol. 8, No. 5, Pp. 3647–3656, 2018. https://doi.org/10.11591/ijece.v8i5.pp3647-3656

[6] A. D. Sutadian, N. Muttil, A. G. Yilmaz, and B. J. C. Perera, "Development of a water quality index for rivers in West Java Province, Indonesia," *Ecol. Indic.*, Vol. 85, No. November 2017, Pp. 966–982, 2018. https://doi.org/10.1016/j.ecolind.2017.11.049

[7] D. Sutjiningsih, "Water Quality Index for Determining the Development Threshold of Urbanized Catchment Area in Indonesia," *Int. J. Technol.*, Vol. 8, No. 1, Pp. 143, 2017. https://doi.org/10.14716/ijtech.v8i1.3971

[8] Z. Wu, D. Zhang, Y. Cai, X. Wang, L. Zhang, and Y. Chen, "Water quality assessment based on the water quality index method in Lake Poyang: The largest freshwater lake in China," *Sci. Rep.*, Vol. 7, No. 1, Pp. 1–10, 2017. https://doi.org/10.1038/s41598-017-18285-y

[9] N. V. Sidabutar, D. M. Hartono, T. Edhi, B. Soesilo, and R. C. Hutapea, "The quality of raw water for drinking water unit in Jakarta-Indonesia," *AIP Conf. Proc.*, Vol. 10, No. 1, 2017. https://doi.org/10.1063/1.4978140

[10] K. A. Shah and G. S. Joshi, "Evaluation of water quality index for River Sabarmati, Gujarat, India," *Appl. Water Sci.*, Vol. 7, No. 3, Pp. 1349–1358, 2017. https://doi.org/10.1007/s13201-015-0318-7

[11] D. Jubaedah, S. Hariyadi, I. Muchsin, and M. M. Kamal, "Water Quality Index of Floodplain River Lubuk Lampam South Sumatera Indonesia," *Int. J. Environ. Sci. Dev.*, Vol. 6, No. 4, Pp. 252–258, 2015. https://doi.org/10.7763/IJESD.2015.V6.600

[12] A. Rahim and T. R. Soeprobowati, "Water pollution index of Batujai reservoir, Central Lombok Regency-Indonesia," *J. Ecol. Eng.*, Vol. 20, No. 3, Pp. 219–225, 2019. https://doi.org/10.12911/22998993/99822

[13] G. R. Barokah, F. Ariyani, and T. H. Siregar, "Comparison of Storet and Pollution Index Method to Assess the Environmental Pollution Status: A Case Study from Lampung Bay, Indonesia," *Squalen Bull. Mar. Fish. Postharvest Biotechnol.*, Vol. 12, No. 2, Pp. 67, 2017. https://doi.org/10.15578/squalen.v12i2.287

[14] A. A. M. Ahmed and S. M. A. Shah, "Application of adaptive neuro-fuzzy inference system (ANFIS) to estimate the biochemical oxygen demand (BOD) of Surma River," *J. King Saud Univ. - Eng. Sci.*, Vol. 29, No. 3, Pp. 237–243, 2017. https://doi.org/10.1016/j.jksues.2015.02.001

[15] M. H. Gholizadeh, A. M. Melesse, and L. Reddi, "A comprehensive review on water quality parameters estimation using remote sensing techniques," *Sensors (Switzerland)*, Vol. 16, No. 8, 2016. https://doi.org/10.3390/s16081298

[16] N. Ullah and P. Choudhury, "Flood Flow Modeling in a River System Using Adaptive Neuro-Fuzzy Inference System," *Environ. Manag. Sustain. Dev.*, Vol. 2, No. 2, Pp. 54, 2013. https://doi.org/10.5296/emsd.v2i2.3738

[17] T. Kutser *et al.*, "Remote sensing of black lakes and using 810 nm reflectance peak for retrieving water quality parameters of optically complex waters," *Remote Sens.*, Vol. 8, No. 6, 2016. https://doi.org/10.3390/rs8060497

[18] Q. Kotimah, W. Firdaus Mahmudy, and V. Nur Wijayaningrum, "Optimization of fuzzy Tsukamoto membership function using genetic algorithm to determine the river water," *Int. J. Electr. Comput. Eng.*, Vol. 7, No. 5, Pp. 2838–2846, 2017. https://doi.org/10.11591/ijece.v7i5.pp2838-2846

[19] K. Toming, T. Kutser, R. Uiboupin, A. Arikas, K. Vahter, and B. Paavel, "Mapping water quality parameters with Sentinel-3 Ocean and Land Colour Instrument imagery in the Baltic Sea," *Remote Sens.*, Vol. 9, No. 10, 2017. https://doi.org/10.3390/rs9101070

[20] Keputusan Menteri Negara Lingkungan Hidup, "Keputusan Menteri Negara Lingkungan Hidup Nomor 115 Tentang Pedoman Penentuan Status Mutu Air," *Jakarta Menteri Negara Lingkung. Hidup*, Pp. 1–15, 2003.