



## Participatory Water Quality Monitoring System for the Gajahwong River, Yogyakarta City, Indonesia

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**Abstract:** This paper presents the development of Suka Peta (an integrated web-based system of participatory water quality monitoring), which has been developed by the researcher team of the State Islamic University Sunan Kalijaga, Yogyakarta, Indonesia. The system is designed to collect various types of data to generate a report on the water quality status of a river. The study followed a method for research and development that includes the design, development, implementation, and evaluation stages. The final product of this research is a web-based application that could be accessed publicly through [www.status-sungai.com](http://www.status-sungai.com). During the evaluation stage, we conducted an FGD with stakeholders in the Gajahwong River community. The result confirmed that the application has a high potential for engaging the community in water quality monitoring. In addition, the participants have been able to use the application and participate in water quality monitoring efforts.

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### Introduction

Developing a system for water quality management is a challenging effort in terms of finance, human resource capacity, logistics, and organization <sup>1</sup>. Commonly, water quality monitoring is an exclusive task of the authority. Government organizations, such as Environmental Protection Agency (EPA) in America <sup>2</sup>, the Department of Water in

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<sup>1</sup> Thanda Thatoe Nwe Win, Thom Bogaard, and Nick van de Giesen, "A Low-Cost Water Quality Monitoring System for the Ayeyarwady River in Myanmar Using a Participatory Approach," *Water* 11, no. 10 (September 23, 2019): 1984, <https://doi.org/10.3390/w11101984>.

<sup>2</sup> Nathaniel L. Booth et al., "A Web-Based Decision Support System for Assessing Regional Water-Quality Conditions and Management Actions: A Web-Based Decision Support System for Assessing Regional Water-Quality Conditions and Management Actions," *JAWRA Journal of the American Water Resources Association* 47, no. 5 (October 2011): 1136–50, <https://doi.org/10.1111/j.1752-1688.2011.00573.x>.

Western Australia <sup>3</sup>, and other agencies, are usually responsible for collecting and generating reports on water quality status in their respective territories. Similarly, in Indonesia, the task of water quality monitoring in each region is given to the Environmental Agency (BLH) under the supervision of the Ministry of Forestry and Environment (KLHK). In Yogyakarta, water quality monitoring is conducted by the Environmental Agency (BLH). The agency also creates periodical report of water quality status of three rivers in Yogyakarta, namely, Gajahwong, Code, and Winongo.

Although the data on water quality has been made public by the authority in Yogyakarta, it is often difficult for the general public to directly understand and easily use the data. A similar problem could be observed in America, where, although a technical report is widely available, complicated modeling hampers the ability of decision-makers to evaluate scenarios of interventions to improve water quality <sup>4</sup>. Similarly, the public often finds it difficult to access the data and use the technical report because some of the data might not be freely accessible or unpublished <sup>5</sup>. Lastly, the data were exclusively generated by the authority; hence, the public's sense of ownership of the data is missing.

To overcome the challenges in water quality monitoring and increase the public's engagement in the process, we designed a system to monitor water quality monitoring that allows public participation in collecting and inputting the data into our system. The newly developed system is based on a web application that generates an instant report of the water quality data of a river at a certain site. The web-based application uses a combination of citizen science, computation science, and programming. Citizen science is an approach that promotes the active participation of the public in the scientific process in order to achieve engagement and educational goals <sup>6</sup>. The approach has been very popular in the fields of conservation and ecology <sup>7</sup>, biology <sup>8</sup>, and environment <sup>9</sup>. In the

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<sup>3</sup> Department of Water, "Strategic Water Information and Monitoring Plan, Western Australia Prepared by the Department of Water June, 2010," *Department of Water Western Australia*, 2010.

<sup>4</sup> Booth et al., "A Web-Based Decision Support System for Assessing Regional Water-Quality Conditions and Management Actions1."

<sup>5</sup> Yonik Meilawati Yustiani et al., "Formulation of the Integrated Information System of River Water Quality in the Cikapundung River, Bandung, Indonesia," *International Journal of Engineering and Technology* 9, no. 1 (2017): 137-42.

<sup>6</sup> Ashlee Jollymore et al., "Citizen Science for Water Quality Monitoring: Data Implications of Citizen Perspectives," *Journal of Environmental Management* 200 (September 2017): 456-67, <https://doi.org/10.1016/j.jenvman.2017.05.083>.

<sup>7</sup> Vincent Devictor, Robert J. Whittaker, and Coralie Beltrame, "Beyond Scarcity: Citizen Science Programmes as Useful Tools for Conservation Biogeography: Citizen Science and Conservation Biogeography," *Diversity and Distributions* 16, no. 3 (April 13, 2010): 354-62, <https://doi.org/10.1111/j.1472-4642.2009.00615.x>; Margaret D. Lowman and Palatty Alleesh Sinu, "Can the Spiritual Values of Forests Inspire Effective Conservation?," *BioScience* 67, no. 8 (August 2017): 688-90, <https://doi.org/10.1093/biosci/bix057>.

<sup>8</sup> Myriah L. Cornwell and Lisa M. Campbell, "Co-Producing Conservation and Knowledge: Citizen-Based Sea Turtle Monitoring in North Carolina, USA," *Social Studies of Science* 42, no. 1 (February 2012): 101-20, <https://doi.org/10.1177/0306312711430440>.

<sup>9</sup> Cathy C Conrad and Krista G Hilchey, "A Review of Citizen Science and Community-Based Environmental Monitoring: Issues and Opportunities," *Environmental Monitoring and Assessment* 176 (2011): 273-91.

field of water science and management, there have been several efforts to monitor water quality<sup>10</sup>.

To apply the concept of participatory monitoring, we closely work with communities that inhabit the Gajahwong riverbank. The Gajahwong River is presented in this study because of its importance as a water source for people living in the area. It is also a target of the Clean River Program (*Program Kali Bersih*)<sup>11</sup>. Unfortunately, the river has been polluted by domestic and chemical waste due to poor waste disposal practices<sup>12</sup>. Meanwhile, there have been many communities along the riverbank that are involved in the conservation efforts of the Gajahwong River, such as Sekolah Gajahwong and Mrican Youth Organization<sup>13</sup>.

Taking these considerations into account, this research aims at developing a participatory water quality monitoring system to increase the public's engagement and promote citizen science in the community. The paper will explore: 1) the development process of the system; and 2) the evaluation result of the system.

## Method

### *Location and Duration of the Study*

The Gajahwong River is the main river of the Gajahwong Watershed, which extends across Sleman Regency, Bantul Regency, and Yogyakarta City. Its total area is approximately 46.082 km<sup>2</sup><sup>14</sup>. In Yogyakarta City, the Gajah Wong River stretches over three districts, namely Umbulharjo, Kotagede, and Gondokusuman. The upstream of the Gajahwong River gets its water from the Merapi Mountain, whereas in the downstream, the river connects with the Opak River and flows directly to the Hindian Ocean in the south of Java Island. The total population that inhabits the Gajahwong River bank of Yogyakarta City is around 273,362 people. The most dominant land use in the Gajahwong watershed of Kota Yogyakarta is settlements, followed by industrial sites, agriculture, and services.

The study was started in August 2021 and finished its implementation and evaluation stage in January 2023.

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<sup>10</sup> Abby Kinchy, "Citizen Science and Democracy: Participatory Water Monitoring in the Marcellus Shale Fracking Boom," *Science as Culture* 26, no. 1 (2017): 88–110; Raed Fehri, Slaheddine Khelifi, and Marnik Vanclooster, "Testing a Citizen Science Water Monitoring Approach in Tunisia," *Environmental Science & Policy* 104 (2020): 67–72; Simon Yat-Fan Ho, Steven Jingliang Xu, and Fred Wang-Fat Lee, "Citizen Science: An Alternative Way for Water Monitoring in Hong Kong," *PLoS One* 15, no. 9 (2020): e0238349.

<sup>11</sup> Risyanto Risyanto and M Widyastuti, "Pengaruh Perilaku Penduduk Dalam Membuang Limbah Terhadap Kualitas Air Sungai Gajahwong," *Journal Manusia Dan Lingkungan* 11, no. 2 (2004): 73–85.

<sup>12</sup> Risyanto and Widyastuti; Rahmi Ahdiaty and Dewi Fitriana, "Pengambilan Sampel Air Sungai Gajah Wong Di Wilayah Kota Yogyakarta," *Indonesian Journal of Chemical Analysis (IJCA)* 3, no. 2 (September 9, 2020): 65–73, <https://doi.org/10.20885/ijca.vol3.iss2.art4>.

<sup>13</sup> Tsaqifa Taqiyya Ulfah, Izzatin Kamala, and Shinta Noor Latifah, "Environmental Preservation: Mrican Youth Innovation on Slummed Irrigation Channels (Bendung Lepen Gajah Wong)," *Journal of Community Service and Empowerment* 1, no. 3 (2020): 134–41.

<sup>14</sup> Ahdiaty and Fitriana, "Pengambilan Sampel Air Sungai Gajah Wong Di Wilayah Kota Yogyakarta."

### ***The Development of the System***

The study is categorized as research and development (RnD). It aims to develop a product and evaluate its performance <sup>15</sup>. This research applies several stages of research and development projects, including analysis (A), design (D), development (D), implementation (I), and evaluation (E). Therefore, the approach is also known as the ADDIE model <sup>16</sup>.

During the development stage, we develop the web-based application, which is later named Suka Peta. In the process, we involved staffs and students of the Information Technology Study Program of the Faculty of Science and Technology, State Islamic University Sunan Kalijaga, Yogyakarta. We worked back and forth between the Laboratory of Information Engineering and the Laboratory of Ecology and Botany.

### ***The Implementation Stage***

To implement the system, we work closely with the Mrican Youth Organization. First, the research team trained 15 members of the youth organization to collect the water quality data as part of the citizen science approach. The parameters of the water quality data taken are temperature, EC/DHL, TDS, pH, DO, and BOD. We also used macroinvertebrate data as a biological indicator of river pollution, following the guidelines of Biotilik <sup>17 18 19</sup>.

### ***The Evaluation Stage***

During the evaluation stage, we arranged a FGD with stakeholders, including youth organizations, river communities of the Gajahwong River and Winongo River, the Planning Agency of Yogyakarta City, and the Environmental Agency of Yogyakarta City. After conducting the FGD, a SWOT analysis was performed to understand the viability of the project. It is also performed to increase awareness of factors that influence the project (Figure 1.)

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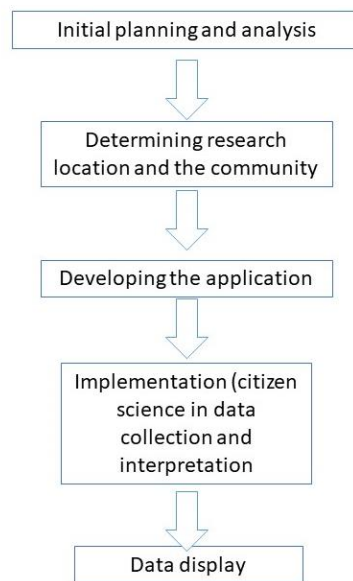
<sup>15</sup> Sugiyono, *Metode Penelitian Tindakan Pendekatan Kualitatif, Kuantitatif Dan RND* (Bandung: Alfabeta, 2014).

<sup>16</sup> E Mulyatiningsih, *Metode Penelitian Terapan Bidang Pendidikan* (Bandung: Alfabeta, 2014).

<sup>17</sup> D Rini, *Ayo Cintai Sungai: Panduan Penilaian Kesehatan Sungai Melalui Pemeriksaan Habitat Sungai Dan Biotilik. Ecoton. Gresik* (Gresik, Jawa Timur: Ecoton, 2011); Sukmawati, Maarifah Dahlan, and Rat Dela, "Biotilik as a Method for Analyzing River Water Pollution Levels," *Teuku Umar University the 2nd International Conference on Public Health 2020*, 2020; Safira Anastasia, Ida Munfarida, and Dedy Suprayogi, "Penilaian Kualitas Air Menggunakan Indeks Makroinvertebrata FBI Dan Biotilik Di Sungai Buntung, Sidoarjo," *Jurnal Serambi Engineering* 7, no. 3 (2022).

<sup>18</sup> Sukmawati, Dahlan, and Dela, "Biotilik as a Method for Analyzing River Water Pollution Levels."

<sup>19</sup> Anastasia, Munfarida, and Suprayogi, "Penilaian Kualitas Air Menggunakan Indeks Makroinvertebrata FBI Dan Biotilik Di Sungai Buntung, Sidoarjo."



*Figure 1. Methods of community participation program*

## Result

### *The Development Stage of Suka Peta*

First, the team conducted a focus group discussion with the members of the laboratory, student helpers, and a study group (Waterforum Kalijogo) about the concepts and technical aspects of the application. The result of this stage is the planning of the project.

Later, the application is named Suka Peta as an abbreviation of *Sunan Kalijaga Pemantauan Kualitas Air*. The work itself has been registered as an intellectual property right (HKI) of the team No. EC00202302505, January 9, 2023.

There are several execution tools for the application that apply to different parties that use it. Generally, there are three parties that could make use of the system. First, ordinary users and the general public could search any water quality data and use the data for their personal advantage. Second, the volunteers who are recruited from the river bank communities are the main actors in this citizen science project. They are involved in the data collection and input and could log in or log out of the system to create, read, update, and delete the sampling locations. Volunteers could access the system via the volunteers' interface, which also provides a private account for each person. Meanwhile, administrators play an active role in verifying the data inputted by the volunteers. They could also create, read, update, and delete the sampling data. And finally, administrators can create, read, and update the volunteer's data. In this context, administrators are hired from the staff of the Laboratory of Ecology and Botany, State Islamic University Sunan Kalijaga Yogyakarta. The administrators are professional staff who are familiar with water quality data and assessment. Figure 2 summarizes all the tools that could be accessed for each parties.

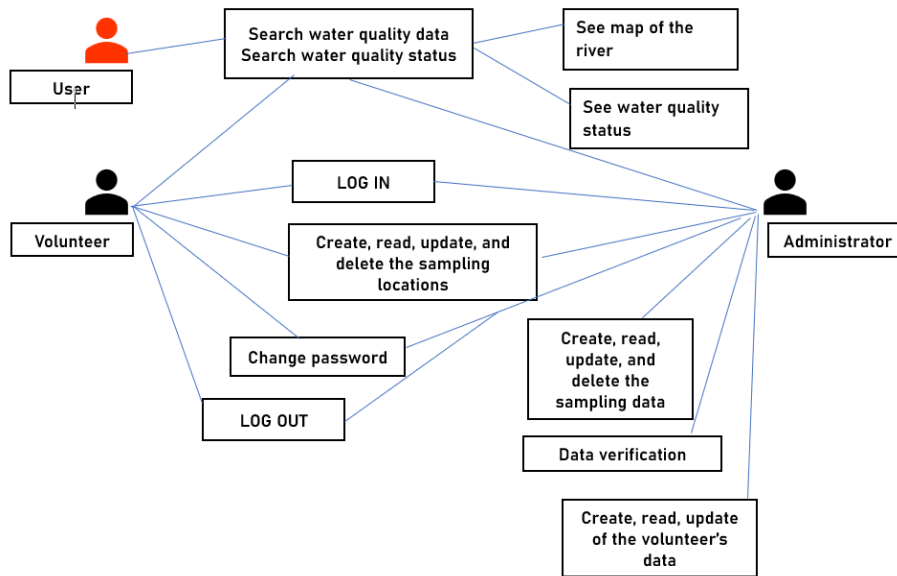


Figure 2. Use case diagram of Suka Peta Web-based application for water quality monitoring

The next figures display the appearance of the website, especially the front page and the display of water quality status (Figure 3.).

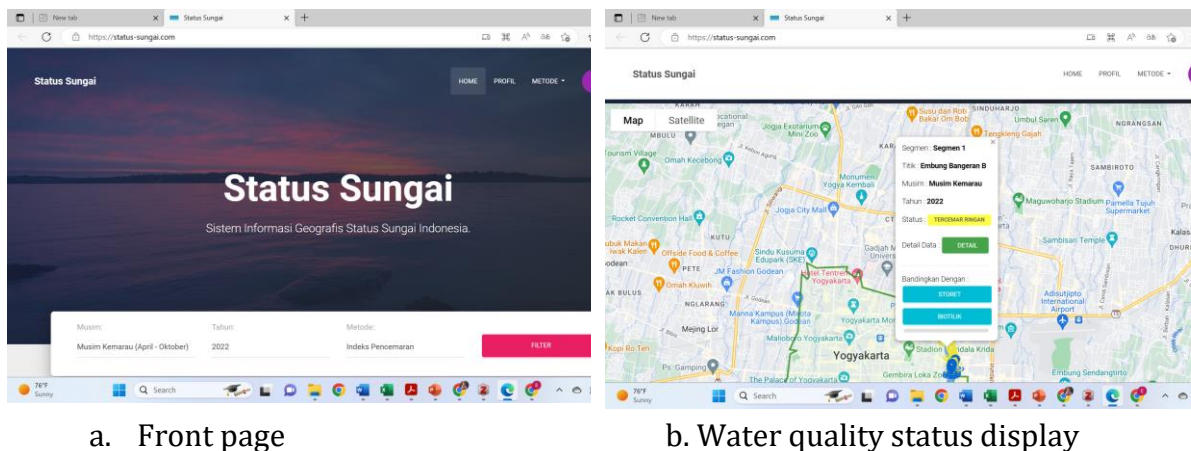
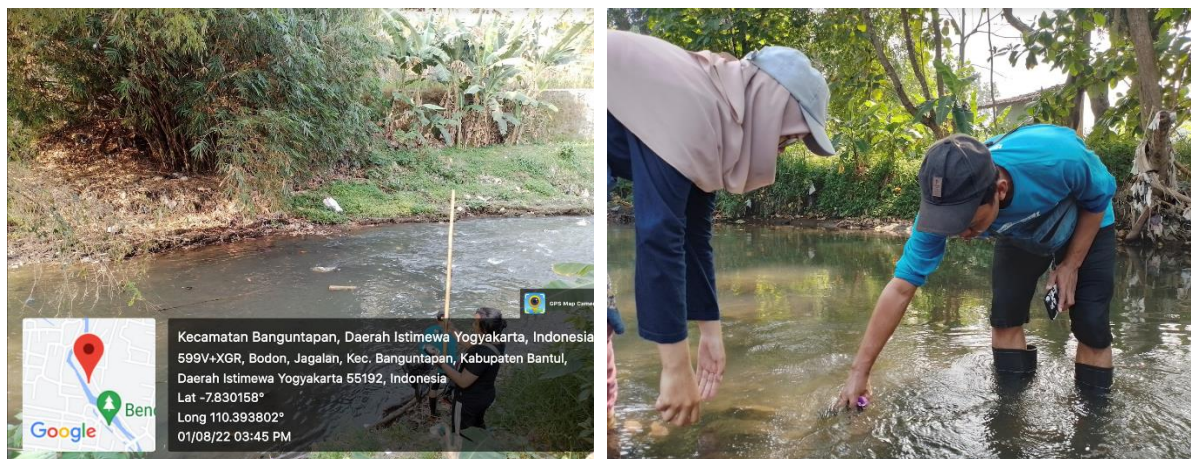


Figure 3. The display of www.status-sungai.com. (a) the front-page appearance, (b) water quality status display

### The Implementation Stage

Before participating in the citizen science part of the data collection process, all volunteers were given training on how to use the application and how to collect water quality data. First, training was conducted to introduce the application. After all volunteers are ready, they are each given a password-protected account. The account could be used to create, read, and input the sampling location, a visual description of the sampling location, and update any necessary data. Next, the training about water quality

measurement was conducted to give a basic knowledge of water quality parameters and tools for measuring them. The research team introduced water strips and meters, such as pH meters, DO meters, EC meters, and DHL meters. In addition, a special training session was conducted to introduce the *Biotilik* method for water quality assessment. Prior to the training, the research team organized a workbook for water quality monitoring guidelines. The participants, then, collected the data by using the workbook and were accompanied by the research team during the first field meeting. On the second field data collection, the community independently collected the data, whereas the team was on standby to provide consultation. After two trials, the participants inputted the water quality data measured using meters and strips into the application. Finally, the application made an automated calculation based on the inputted data. Then the final status of river water quality is displayed in the system (Figure 4.).



a. Research location

b. Data collection

Figure 4. The citizen science process, (a) determining the location, (b) water quality data collection

As a part of the project, the community was then encouraged to participate in the reflection phase. During the phase, the researchers showed the water quality status to the participants and explained the meaning of the numbers and index ( Figure 5.).

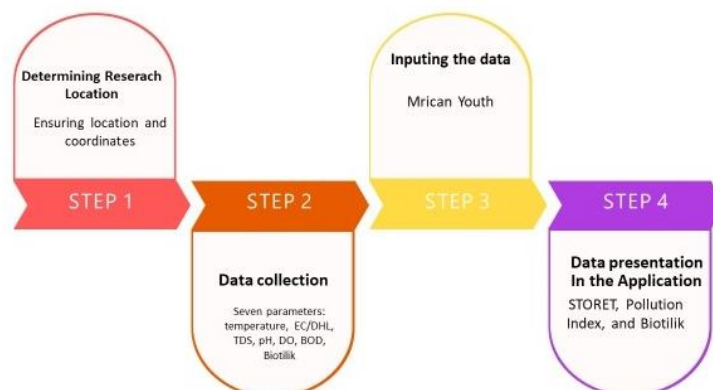
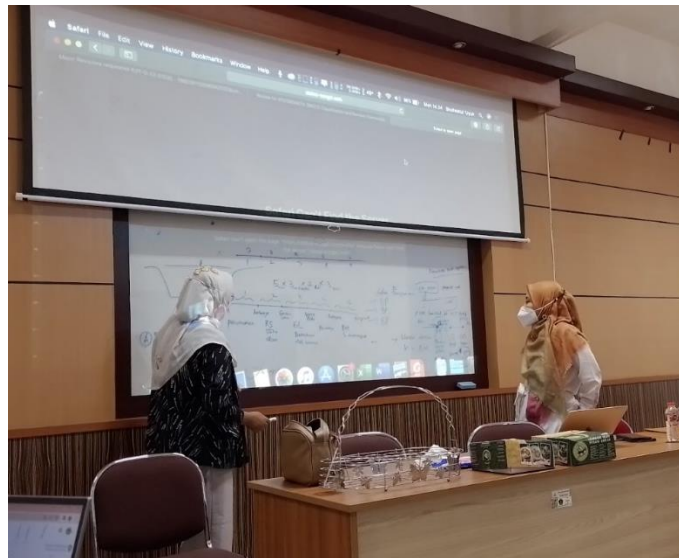


Figure 5. Citizen science process of Suka Peta – A web-based application for water

monitoring

### **Evaluation**

During the evaluation stage, we invited several stakeholders from the Environmental Agency, the Planning Agency, the Public Health Office, river bank communities (Forum Komunikasi Winongo Asri (FKWA)), and the Mrican Youth Organization. The FGD was conducted to understand the internal and external factors affecting the viability of the system (Figure 6.).



*Figure 6. FGD with stakeholders*

The FGD session resulted in a qualitative evaluation for improving the application. The table summarizes the qualitative evaluation of the system based on stakeholders' points of view. (Table 1).

*Table 1. Stakeholders' points of view of Suka-Peta*

Stakeholders	Points of view
Environmental Agency	<ol style="list-style-type: none"><li>1. River water is usually an unacceptable source of drinking water because of pollution from point and non-point sources. Therefore, it is also important to monitor the quality of drinking water, for example, groundwater.</li><li>2. It needs more parameters for monitoring; the researchers may not only depend on water meters and strips but also need laboratory data.</li><li>3. It needs to provide intensive training so the community has sufficient skills to be involved in the citizen science process.</li><li>4. It needs synergy with the authority, the university, and the communities.</li></ol>

Stakeholders	Points of view
Public Health Office	<ol style="list-style-type: none"> <li>1. The system could be expanded to other rivers in Yogyakarta City, not just the Gajahwong River.</li> <li>2. It needs a monitoring system that runs on a regular basis. The office recommends that monitoring be conducted monthly.</li> </ol>
The river bank communities	<ol style="list-style-type: none"> <li>1. Currently, there are several active members of the communities who are involved in independent monitoring of water sources. Perhaps the system could collaborate with the members.</li> <li>2. The communities are ready to help with routine water monitoring work, at least bimonthly.</li> </ol>
The Planning Agency	<ol style="list-style-type: none"> <li>1. The system could be synergized with the work of the authority.</li> <li>2. It needs to involve more communities in the process of citizen science.</li> <li>3. The communities could help with a simple parameter, while the authority is focused on scientific parameters as required by regulations.</li> </ol>

After the FGD, we were then conducted a SWOT analysis to understand the strengths, weaknesses, opportunities, and threats regarding the system. The result of the SWOT analysis is as follow (Table 2).

*Table 2.* SWOT scoring of the system components

Components	Score	Points	Total
<b>STRENGTHS</b>			
The system used automated computation to display water quality data	5	0.05	0.25
Collaboration of multidisciplinary experts	5	0.043	0.215
Motivation of the communities to involve in the citizen science process	5	0.045	0.225
The support of the university in providing laboratories and infrastructures to develop the system	5	0.4	2
The first application that is developed in the area	5	0.35	1.75
			4.44
<b>WEAKNESSES</b>			
Limited equipment to collect water quality data	5	0.03	0.15

Components	Score	Points	Total
The community could only work with a small number of water quality parameters	5	0.1	0.5
An urgent need to develop a more accessible system. It might be improved as a mobile-friendly android-based application.	5	0.03	0.15
An urgent need to develop a more accessible system. It might be improved as a mobile-friendly android-based application.	5	0.23	1.15
An urgent need to collaborate with authorities, hence the application could reach a wider audience.	5	0.043	0.215
			2.165
<b>OPPORTUNITIES</b>			
The system could be integrated the information dashboard provided by Yogyakarta City (Jogja Smart City Application)	5	0.05	0.25
Positive trend of community participation in river management projects	5	0.3	1.5
Potential collaboration with authorities	5	0.12	0.6
Receiving more attention from the communities	5	0.04	0.2
Increasing awareness of the community	5	0.03	0.15
			2.7
<b>THREATS</b>			
The sustainability of the system due to the availability of the funding	5	0.25	1.25
High cost of equipment and water meters	5	0.03	0.15
The availability of intensive trainings for the community before participating in the citizen science process	5	0.14	0.7
The citizen science project is not standardized, therefore could not meet the requirement of regulations	5	0.12	0.6
It needs a strong support from the institutions and authorities	5	0.14	0.7
			3.4

The above result could be presented as the following radar diagram (Figure 7.). The diagram illustrates that the strength of the system outweighs its weakness. However, the threat is higher than the opportunity provided by the system. It shows that the research team should pay more attention to the sustainability of the project in the future.

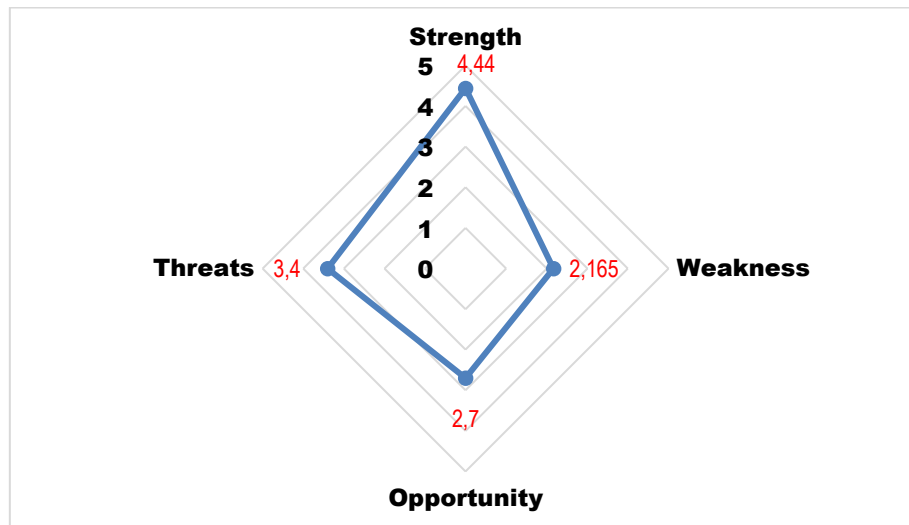


Figure 7. Radar diagram of the strength, weakness, opportunity, and threats of the system

The SWOT analysis provides an understanding of factors that influence the viability and sustainability of the project. The analysis shows that it has a significant strength (4.45); however, it has potential threats (3.4), which hamper the development of the system. In order to improve the system, the researcher may focus on overcoming weaknesses and maximizing opportunities. For example, in terms of public participation, the system has received a positive perception from the riverbank communities. Therefore, in the future, the researchers must develop stronger collaboration with communities and other stakeholders. Similarly, the application could be sustained if it could be integrated with the official application belonging to Yogyakarta City (Jogja Smart Service).

Although water quality monitoring is an important achievement on the international agenda, as stated in the Sustainable Development Goals (SDGs) indicator 6.3.2, the work of participatory water quality monitoring faces many challenges. Data deficiencies are considered a major threat to water quality monitoring because of cost-related issues in providing substantial tools for water quality data collection<sup>2021</sup> In the context of this research, the team finds it difficult to arrange simple meters that can be used by the community without any academic or professional background in water quality data collection. Hence, we could only introduce the community to simple parameters such as temperature, pH, DO, DHL, EC, TDS, and BOD. As an exception, BOD was measured in the Laboratory of Ecology and Botany, State Islamic University Sunan Kalijaga. Thus, the community was only given a simple skill on how to take a water sample before it was processed to measure the BOD level.

<sup>20</sup> World Health Organization and WHO., *Guidelines for Drinking-Water Quality*, vol. 1 (World Health Organization, 2004).

<sup>21</sup> Unicef, "Progress on Drinking Water, Sanitation and Hygiene," 2017.

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Next, the research was also challenged by the capacity of the human resources involved in the project. Some parameters, such as DO, pH, and EC, could be collected by unskilled community members using cheap meters<sup>22</sup>. But, in the long run, water quality managers may need more complex parameters to design strategies and interventions for water quality improvement. The use of smartphone and application<sup>23</sup>, such as applied in this project, has generally provided *education for action* that becomes an important step in citizen science and participatory approach.

## Discussion

### *Community Participation*

By using community based participatory research, the study has developed the application for water quality monitoring. In this regard, community participation occurred in several stages.

#### *Community entry*

The community entry was conducted in 2020, when the research team developed the idea of SukaPeta as a platform for community engagement. During the period, several river communities were approached, including Gajahwong Yogyakarta, Brantas, and Sumba Timur<sup>24</sup>. However, the study faced a geographical obstacle; therefore, it was decided to focus on the Gajahwong community in Yogyakarta. The initial perception of the community toward the application was promising. The score for willingness to participate in the study was 73.32. The score corresponds to several qualities of the application, including ease of access to data input, practical data display, and simple reporting. In other words, the program could be continued due to positive perceptions and a willingness to participate in the study (Figure 8).

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<sup>22</sup> Sabrina Kirschke et al., "Capacity Challenges in Water Quality Monitoring: Understanding the Role of Human Development," *Environmental Monitoring and Assessment* 192, no. 5 (May 2020): 298, <https://doi.org/10.1007/s10661-020-8224-3>.

<sup>23</sup> Jeneen Hadj-Hammou et al., "Getting the Full Picture: Assessing the Complementarity of Citizen Science and Agency Monitoring Data," *PLoS One* 12, no. 12 (2017): e0188507.

<sup>24</sup> Eka Sulistiyowati and Shofwatul Uyun, "The Evaluation of a Website for Participatory Water Quality Monitoring of Rivers in Indonesia." (International Conference on Science and Engineering (ICSE-UIN-SUKA 2021), Yogyakarta, Indonesia, 2022), <https://doi.org/10.2991/aer.k.211222.018>.

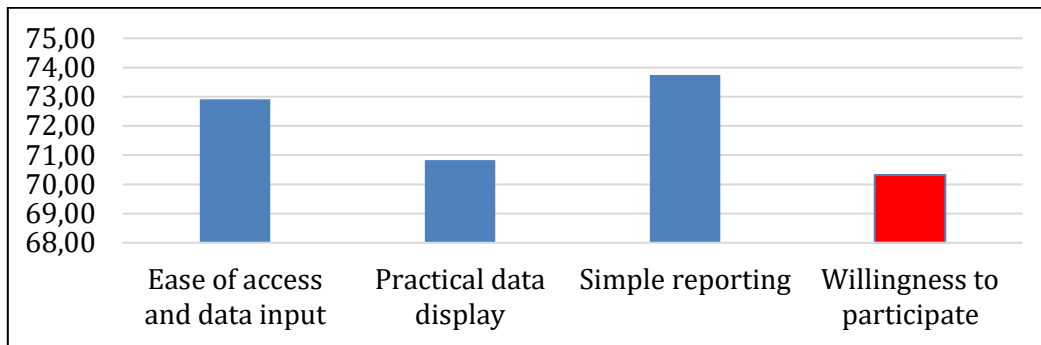


Figure 8. The community's perception on the application and willingness to participate

To enter the community, the researchers collaborate with a gatekeeper <sup>25</sup>. The gate keeper of this study was a key person from the Mrican Youth. He performed the initial community engagement and contact and ensured that community participation was guaranteed.

#### *Participant Recruitments*

The participants were recruited through a volunteer recruitment program conducted by the researchers under the supervision of the gatekeeper. It was granted that all participants were volunteers and members of Mrican Youth. In total, this organization has more than 35 active members.

#### *Knowledge Dissemination*

The study conducted knowledge dissemination in the community by arranging several on-field community meetings. The meetings were also designed as a forum for introducing water parameters and the application. At this stage, the researchers have developed a guidebook for the water monitoring method in the form of leaflets and mini-posters.

#### *Collection of Water Monitoring Data*

The collection of water monitoring data was a big part of the implementation stage in this study. Participants performed all processes of determining the sampling locations, collecting water quality data, collecting biological data, and inputting the data into the application. The researchers and team were on the site to provide consultations of the process.

#### *Monitoring and Evaluation*

As discussed previously, the participants were actively involved in the monitoring and evaluation process, which was conducted during FGDs with other stakeholders of Gajahwong River. A follow up plan was created by active consultation with the authority (Bappeda Kota Yogyakarta). It was recommended that the application is developed further to accommodate other rivers in Yogyakarta City.

<sup>25</sup> Shenuka Singh and Douglas Wassenaar, "Contextualizing the Role of the Gatekeeper in Social Science," *South Africa Journal of Bioethics and Law* 9, no. 1 (2016): 42-46.

## Conclusion

By using the ADDIE approach, this research develops a web-based application for river water quality monitoring. The system involved the riverbank communities as part of a citizen science approach and participatory water quality monitoring. A community based participatory research was performed throughout the process, including community entry, participants recruitment, knowledge dissemination, data collection, and monitoring and evaluation. The development phase involved researchers in informatics engineering and environmental science. The resulted application could be accessed at [www.status-sungai.com](http://www.status-sungai.com). The study developed use-case scenarios for various users of the website. Next, the system was evaluated by stakeholders through an FGD. The result showed that the system has significant strengths and potential opportunities, including the involvement of the authority to integrate the system into the already existing official application (Jogja Smart Service).

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