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Online water quality monitoring: a case study in the umbulan drinking water supply system, East Java, Indonesia

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ABSTRACT

Conventional systems that monitor the supply system periodically are considered to be very inadequate. This can cause the water supply distributed to the community to be of poor quality. Therefore, this study aims to evaluate water quality periodically by measuring water parameters such as pH, chlorine and turbidity for 30 days using an online system and portable unit. Portable tools used to measure pH, turbidity and residual chlorine are as follows, namely pH meters (Hanna, HI98017), Turbidity Meters (Hanna, HI 98703), Residual Chlorine meters and measurements with an online system using "Supervisory Control and Data Acquisition". The average parameter value of the results of online daily monitoring for a month for the pH parameter was a minimum 6.92, a maximum of 7.46, a minimum turbidity of 0.08 nephelometric turbidity unit (NTU) and a maximum of 0.94 NTU. While the residual chlorine minimum of 0.29 mg/L and a maximum of 0.58 mg/L. To determine the accuracy of the offline measurements, measurements were also performed with a portable device four times a month. The comparison of the measurement results is very small, which is the difference in pH parameters is between 0.37-0.50, turbidity is between 0.05-0.21 NTU, and residual chlorine is 0.002-0.006 mg/L. Offline measurements using the portable device are consistent with the online daily monitoring. Future research should focus on optimizing sensor technology for enhanced accuracy and reliability, and developing automated data analysis algorithms to streamline evaluation processes.

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1. INTRODUCTION

Water is currently regarded as one of our planet's most scarce natural commodities [1]. The existence of plants, animals, and people depends on the water [2]. Therefore, it is necessary to maintain the quality of drinking water. Untreated pollution in drinking water sources and poor hygiene practices are major problems affecting the entire world [3], [4]. Around 2 billion people consume feces-contaminated water worldwide, and 5 to 10 million people every year pass away from diseases connected to water [5]. Inadequate water supply is primarily caused by anthropogenic and natural factors, including climate, terrain, and floods [6]. The purity of drinking water must satisfy the requirements of being free of pathogens, physical pollutants, and chemicals that could endanger human health [7], [8]. The long-term sustainability of drinking water sources also depends on consumer views on water quality [9], [10]. Taste, fragrance, and aesthetic value of water in terms of appearance and taste [11]–[13]. Numerous complaints from customers who drink water are caused by variations in pH, minerals, and organic content in drinking water [14].

Water consumption is vital for living things. The daily water requirements vary depending on physical exercise, age, health issues, and environmental factors [15]. Currently, more than 5% of people worldwide consume three liters of water daily, with most people consuming at least one liter. It may be necessary for people laboring in hot climates to drink up to 16 liters of water per day [16], [17]. Only 89% of the world's population has access to potable sources of drinking water [18], [19]. Only 40-80% of the population in some areas, such as in Sub-Saharan Africa, there is access to clean water [20]. Additionally, it is believed that 2 billion people drink water from sources containing *E. coli* bacteria [21].

According to the World Health Organization, everyone has the right to access clean potable water, but 12 billion people worldwide do not have access to clean drinking water [22]. Drinking water is an essential resource and a requirement for human existence. Water is essential for daily living and is crucial for community growth [23]. Therefore, people must be constantly conscious of pollution and the safety of drinking water sources [24]. Plans and solutions for the management of water resources can be created through the evaluation of drinking water safety and health risks [25]. There have been varying degrees of drinking water damage owing to rapid industrial and economic growth, water pollution, water shortages, and river and lake pollution [26]. Therefore, it is crucial to safeguard drinking water.

Numerous researchers are working to address the issue of rising water pollution by monitoring and preserving water quality [27]. Public awareness of the need to protect drinking water has steadily increased owing to the increasingly severe pollution of drinking water resources [28]. However, conventional water quality detection systems have numerous shortcomings, including high cost, large volume, inability to achieve long-distance parameter transmission, and a single measurement parameter. An online assessment system can automatically determine whether the local water quality satisfies the requirements and meets the threshold when a value is submitted [29]. However, earlier in water laboratory facilities, the detection of water contaminants was frequently performed manually [30]. According to Demetillo *et al.* [31] remote rivers, lakes, coasts, and other water bodies can benefit from low-cost, real-time water quality tracking systems.

This study aimed to constantly and routinely monitor water quality by measuring water parameters such as pH, chlorine, and turbidity at regular intervals for 30 days. According to this theory, pH, chlorine, temperature, flow, and turbidity are water quality indicators that need to be checked frequently [32]. This method allows for remote dynamic control of water quality, which significantly reduces the time, money, and materials needed to maintain water resources. The system is also capable of conducting live evaluations of water quality.

2. METHOD

Research using a descriptive quantitative design aims to collect data that can be measured numerically and explain the characteristics or phenomena observed. This design provides a clear picture of the variables under study and allows researchers to make generalizations about a broader population. The research was conducted for 30 days, from September 1 to September 30, 2022. Monitoring was performed daily for 24 h. The location for testing and monitoring is in the working area of PT Meta Adhya Tirta Umbulan. The sampling point chosen for quality monitoring was the outlet of the production/processing unit in East Java Province. The research variables were the pH, turbidity, and residual chlorine. The portable test equipment and online system are described in the Table 1. No ethical clearence needed in making the manuscript.

The three portable measuring devices mentioned above must be kept in a good working order to obtain precise readings. This includes taking care of calibration, batteries, and storage strategies when not in use. Therefore, the acquired data can be used for many purposes and will be extremely beneficial, including comparison tools with other measurement results. A number of measurement-related factors were considered in order to use the tool correctly, including accuracy, precision, and sensitivity. Errors frequently arise in portable device measurements and affect the difference between the two measurement results (online and portable).

The errors that arise during these measurements are frequently referred to as uncertainties. Therefore, factors that contribute to systematic errors, including incorrect instrument calibration, environmental effects on the tool, and proper maintenance of the tool, as well as the officer taking the measurement's training or experience, must be kept well. However, because the system is well integrated with computers and devices such as cellphones, errors in online parameter measurements are uncommon. The following describes the online raw water quality monitoring system (supervisory control and data acquisition) mechanism in Figure 1.

Sensor values (pressure, flow, pH, chlorine, and turbidity) at the Offtake Station were collected by the data logger before being sent to Using a virtual private network (VPN), the server. Users can join a local network and connect to a public network using the VPN communication technology. The sensor data sent goes to Server 1 or Server 2, which is currently active, and then the data are processed and displayed to the Scada Human Machine Interface (HMI) is a software used by operators to interact with the control system for operator monitoring. The use of two servers is not without reason, and the use of two servers for redundant functions if one server is down can still be backed-up. Server 3 functions as a web server, which is ability to receive requests (requests) from customers in the form of web pages, which then gives back (response) the outcomes of the request. This enabled the display of the HMI Scada at the Surabaya Office, PT AB office, and mobile phones.

Tabel 1. pH, turbidity, and residual chlorine meter specifications

Description	Remark
pH meter spesification	
Merk	Hanna
Type/Product code	HI 98017
Range	0.0–14
Resolution pH	0.1 pH
Accuracy	±0.1 pH
Calibration value	2
Battery	700 hours
Battery type	4x1.5V
Environment	0-50.0 °C (32.0-122.0 °F)
Dimension tools	175 mmx41 mmx23 mm
Weight tools	95 grams
Turbidity meter spesification	
Merk	Hanna
Type	HI 98703
Range	Automatically
Resolution	0.01 to 9.90 NTU, 1NTU from 100-1000 NTU
Tools accuracy	±2% (0.02 NTU)
Tools repeatability	±1% (0.02 NTU)
Stray light	<0.02NTU
Event mean concentrations (EMC) deviation	0.05 NTU in %
Tool light source	filament lamp
Tool lamp life	More 100.000
Environment	0-50.0 °C (32.0-122.0 °F)
Display	60 mmx90mm liquid crystal display (LCD)
Standard	15, 100, 750 NTU
Calibration	1.2
Tools logging memory	200 times recording
Tools serial interface	RS 232 USB
Tools power supply	1.5V (4) battery AA or AC adaptor
Tools auto shut off	15 minutes not use
Tools dimensions	224 mmx87 mmx77mm
Tools weight	512 grams
Residual chlorine meter spesfication	
Merk	Housing Authority of the City of Houston (HACH)
Type	DR 300
Absorbance range	0-2.5 anti lock bracking system (ABS)
Tools light source	Light emitting diode (LED)
Tools detector	Single pole (SP)
Tools dimension	34 mmx69 mmx57 mm
Tools display	LCD
Enclosure	Waterproof IP 67 at 1 m (3.3 ft) for 30 minutes
Tools storage temperature	-20-55°C
Operating environment	0-50°C
Tools sample cell	25 nmand 1 cm
Tools power requirements	4 AAA batteries
Data storage	Last 50 measurements
Wave length	Fixed wavelength±2nm, different for each model
Dimension	160 mmx40 mmx17 mm
Filter bandwidth	15nm
Weight	0.25 kg (0.55 lbs)

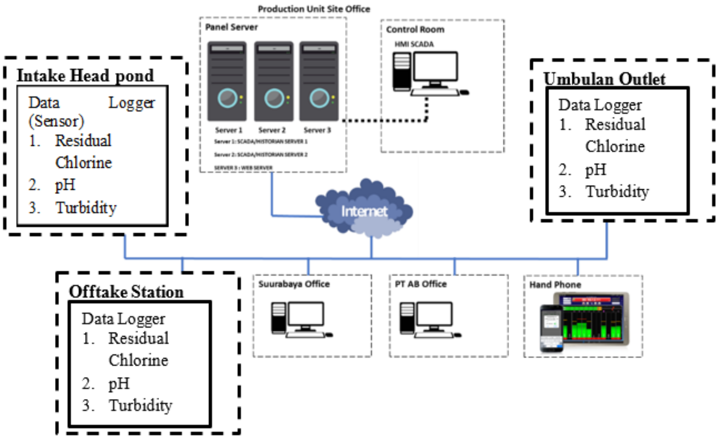

Figure 1. Online raw water quality monitoring system (supervisory control and data acquisition)

3. RESULTS AND DISCUSSION

3.1. Quality of treated water at umbulan outlets

Monitoring of raw water quality at the metering shelter as an outlet from the production unit for 24 h for a period of one month (30 days) in September 2022 for three parameters, namely pH, Turbidity and Residual Chlorine, was also carried out before being distributed to each customer. By monitoring for 24 h continuously for 30 days, the daily average quality monitoring results were obtained for pH parameters and turbidity from residual chlorine from the outlet of the production unit/treated water, as shown in the Figure 2.

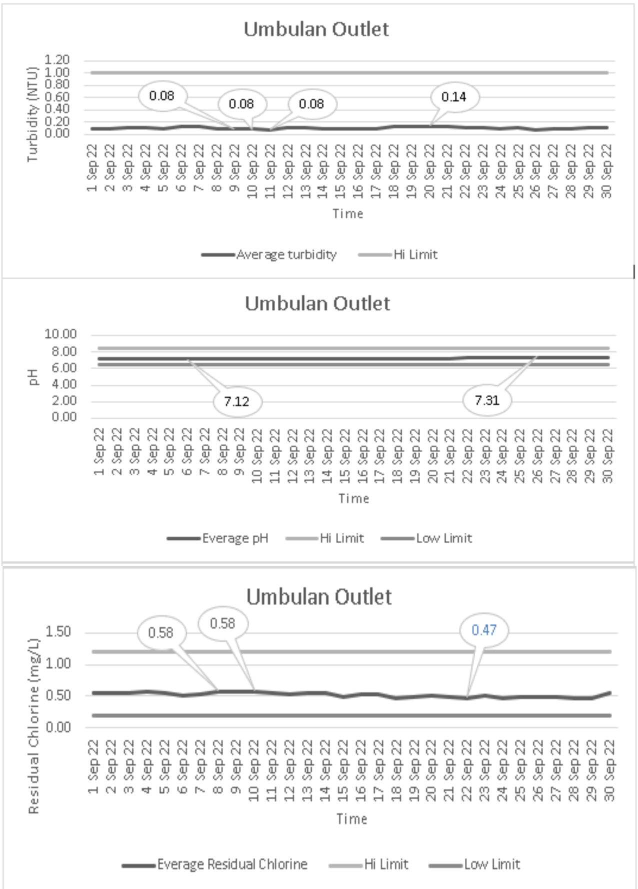

Figure 2. Monitoring of the quality of pH, turbidity, and residual chlorine of drinking water for 30 days

During 24 h of monitoring, a minimum pH value of 7.12 was seen on September 6, 2022, and the highest was 7.31 on September 26, 2022, which was still within the threshold value range of 6.5-8.5. Then for monitoring the turbidity value for 30 days, it is known that the minimum pH value occurred on September 9-11, 2022, namely 0.08 NTU and the highest was 0.14 NTU on September 20 2022 and is still within the threshold value range, namely a maximum of 1 NTU. For the residual chlorine value for 30 days, the highest value occurred on September 20, 2022, namely 0.58 mg/L and the minimum on September 8 and 10, 2022, which was 0.47 mg/L and is still within the threshold value range of 0.2-1.2 mg/L.

3.2. Comparison of measurement results with portable tools and online

In addition to measurements with sensors and carried out online, water quality measurements were carried out directly in the field using a portable device once a week or four times a month. The aim was to compare the measurement results of the portable and online measurements. Table 2 will compare the measurement findings from online measurements supplied in tabular form with those using portable tools.

Table 2. Comparison of measurement results for several parameters using portable and online instruments

Measurement method	Time							
	5 September		12 September		19 September		26 September	
	Head pond	Outlet umbulan	Head pond	Outlet umbulan	Head pond	Outlet umbulan	Head pond	Outlet umbulan
Portable pH	7.5	7.7	7.6	7.7	7.6	7.5	7.6	7.6
Online pH	7.22	7.14	7.12	7.14	7.19	7.13	7.18	7.31
Portable Turbidity (NTU)	0.2	0.16	0.29	0.39	0.22	0.14	0.23	0.2
Online Turbidity (NTU)	0.36	0.1	0.33	0.12	0.35	0.12	0.34	0.08
Portable Res Chlor (mg/L)	-	0.53	-	0.48	-	0.49	-	0.53
Online Res. Chlor (mg/L)	-	0.56		0.53	-	0.5	-	0.5

The findings showed that measurements in the first week showed an average pH value measured using a portable tool of 7.63 and 7.13 online and with a difference of approximately 0.50. For the turbidity value of the portable equipment, the average is 0.48 NTU and online is 0.35 NTU and the difference is 0.12 NTU. While the residual chlorine from portable devices is 0.395 mg/L and online is 0.392 mg/L, the deviation is 0.002 mg/L. Meanwhile, in the second week, the average portable pH was 7.60 and the online pH was 7.12, and the difference was approximately 0.47. For turbidity from portable devices, the average is 0.53 NTU and online is 0.32 NTU and the difference is 0.12 NTU. While the residual chlorine from portable devices is 0.396 mg/L and online is 0.398 mg/L, the difference is 0.002 mg/L. For the third week, the average portable pH was 7.61 and the online pH was 7.13, and the difference was approximately 0.47. For turbidity from portable devices, the average is 0.38 NTU and online is 0.33 NTU and the difference is 0.05 NTU. While the residual chlorine from portable devices is 0.385 mg/L and online is 0.387 mg/L, the deviation is 0.002 mg/L. Meanwhile, in the fourth week, the average portable pH was 7.52 and the online pH was 7.15, and the difference was around 0.37. For turbidity from portable devices, the average is 0.37 NTU and online is 0.29 NTU and the difference is 0.08. While the residual chlorine from portable devices is 0.385 mg/L and online is 0.387 mg/L, the difference is 0.002 mg/L. By comparing the results of measurements carried out directly using portable equipment and online monitoring or measurements for 24 h, the results are not significantly different, in order for the bulk drinking water produced by the drinking water treatment plant to be regarded as having controlled quality.

Raw water for the Umbulan drinking water supply system comes from three sources: the head pond as the main spring, turbine pump runoff, and water from within the project site (the Janti, Gedang, and Buntung springs). Water quality can also be affected by the flow of water entering the head owing to the incomplete Head Pond drainage system. The solution for maintaining the water quality of the Head Pond is to guard the fence around it with a guard on duty for 24 h, so that the spring is completely sterile from community activities. Drainage improvements are also carried out in stages, and only when it rains with high intensity, water flows into the head pond and then affects the quality (turbidity) of the raw water in the intake head pond. Another solution is technology, namely, the installation of monitoring cameras and the installation of pH and turbidity sensors that are carried out online and in real time. In terms of Water Treatment Plant operations, online monitoring will make it easier for operators to consistently observe and maintain the results of bulk drinking water production. Monitoring the water quality is very important because it determines the next process, and if the quality does not meet the requirements, process adjustments will be made or discarded/untreated. If a production failure or unusual sensor readings are observed, the operator can easily make adjustments in the production unit or order the field supervisor to check the condition of the sensor during the offtake. Monitoring of this quality is very important for offtakers/consumers because they'll have access to water that always satisfies drinking water requirements in volume. In addition, the use of water sources with quality that is not maintained will place consumers who use water unconsciously under threat from waterborne diseases.

The Umbulan drinking water supply system is the first project to use the public-private partnership scheme and is included in Indonesia's National Strategic Projects and Priority Projects. The Build Operate Transfer model is being used for the Umbulan drinking water delivery system project, with a 25-year concession period starting from the day of commercial operation. Raw water for the 4,000 L/s Umbulan drinking water supply system comes from the Umbulan spring in Umbulan Village, Winongan District, Pasuruan Regency, and is then distributed to 18 supply points from Pasuruan to Gresik via the Main Transmission Pipeline, which is about 100 km long. A visual representation of the intake and production units can be found in Figure 3.

Figure 3. Lay out intake and production units

The operating system of the Umbulan drinking water supply system includes management and monitoring of raw water sources, production facilities in umbulan and supply points, bulk drinking water transmission facilities, and measurement of drinking water quality standard parameters. Several studies that tested online systems for monitoring water sources have also been described by other studies such as those described by Jiang *et al.* [33] who examined equipment that has an alarm that notifies the responsible staff when water contamination is found. Using a commercially available sensor, the system measures four parameters: pH level, conductivity, temperature, and dissolved oxygen content. The recorded data is transmitted to the station through general packet radio service (GPRS). Measuring how alkaline or acidic the water is in a given location can be done by measuring the pH [34] and as a result, pH is among the most crucial markers of water quality.

A signal conditioning circuit connects the water quality sensor to the Arduino board. An online monitoring system is also employed by Kotamäki *et al.* [35] employing weather and river-based wireless sensor network (WSN)s for agriculture and water monitoring, and the data acquired is relayed to the server over a wireless network via the Zigbee module. They transmit data using global system for mobile communication (GSM) and general packet radio service (GPRS) technologies. A microcontroller-based WSN was also suggested by Chung *et al.* [36] to measure the pH, temperature, and chlorine content of pool water. Data is sent through GSM in this system. Data is gathered from the sleeper nodes and sent via the subbase nodes to the GSM network at the monitoring station using WSN, which is also utilized by Nasirudin *et al.* [37] to measure the quality of fresh water. The value of utilizing wireless technologies to keep an eye on water levels in different sources such tanks, boreholes, and groundwater [38]. Additionally, the device has the ability to remotely transmit information and detect flooding. To assess flow, pH, conductivity, Oxidation Reduction Potential, and turbidity, a low-cost real-time in-pipe sensor node with a sensor array has been proposed by Skadsen *et al.* [39]. This sensor node employs an algorithm to make a determination and to sound an alarm when any contaminants are found [40]. Measured surface water bodies using WSN in accordance with ISO/IEC/IEEE 21451 standards to gather pollution signals. According to the studies mentioned above, the majority of water quality monitoring systems are sensing-based devices that use wireless communication to process data.

4. CONCLUSION

The study demonstrates the use of pH, turbidity, and residual chlorine sensors to control the quality of bulk drinking water before consumption. The sensor readings can be compared with portable devices or laboratory results. The average parameters for pH, turbidity, and residual chlorine were stable for a month at Umbulan Outlets or Production Units. The study presents a low-cost system for monitoring water quality, providing real-time information on parameters, and sending alerts via SMS and email. future research possibilities include expanding the study to different locations and water sources, investigating the correlation between sensor readings and health outcomes, and exploring the feasibility of integrating the monitoring system with existing water treatment infrastructure. Additionally, future research could focus on optimizing the sensor technology to improve accuracy and reliability, as well as developing automated data analysis algorithms to streamline the evaluation process.

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