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Design Configuration of Water Quality Monitoring System in Surabaya

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Abstract: Water have been important needs for human life in many sectors such as in industry, agriculture, and household that its quality must be conserved so is in Surabaya city. The quality of water could influence the quality of human life directly, thus it is important to have an integrated water quality monitoring system. Information regarding water quality monitoring such as pH, dissolved oxygen, turbidity, and conductivity were collected to produce a periodic decision for controlling, analyzing, and fixing the condition of the water. This paper proposed a design configuration of water quality monitoring system for tap water in Surabaya. First, a comparison study of water quality monitoring technology in terms of area, parameter, and methodology from the previous researchers is presented. From the study, the design configuration of water quality monitoring system to be implemented in Surabaya is concluded. The data collection method is better to be done by using Internet of Things (IoT) technology where it is possible to do multiple data type and multiple point real-time data collection throughout the water distribution network remotely.

Keywords: Water quality monitoring; area; parameter; methodology; internet of things; data collection; real-time; remote; distribution network; Surabaya.

1. Introduction

The world enters industry 4.0 era where the information exchange became so fast due to the internet interference. The growth of industry development becomes faster which also increased the production rate. Although, high production rate was good for the industry, the increment of waste from the production need to be further considered. The waste might affect the water resource such as decreasing the water quality [1]. Low water quality was not safe to be used as drinking water and potentially harmful for public health. Therefore, the water quality needs to be monitored so it can be evaluated to ensure the public health [2].

In order to conserve the water quality, several researches on water quality monitoring had been done conventionally. For instance, samples were collected from several sites then transported to laboratory for further test and analysis. This method was clearly no efficient, which take times and high cost [3]. Further action was necessary if the water quality was low. However, it would not relevant anymore because the time between sample collection and analysis results was too long. Real time and remote monitoring was demanded so fast action could be taken to overcome the reduction of water quality [4] and this can be achieved by implementing Internet of Things (IoT) in water quality monitoring [5].

The IoT connects many entities for exchanging information between them such as utensils, vehicle, appliances, and any kind of tools or machine with embedded sensors and communication software through the internet. Nowadays, the IoT concept has been implemented in many aspects of daily life such as industry, government, household, weather forecast, traffic monitoring, smart farm, and even the water quality monitoring [4]. The IoT utilize a storage system which is based on cloud which enable multiple access from any authorized user anywhere and anytime they are connected to the internet. Therefore, by implementing the IoT, the water quality monitoring surely can be done in real time, moreover in remote area also.

Although, the real-time and remote water quality monitoring is important, it has not been considered yet in Surabaya especially the tap water. This paper will discuss about water quality monitoring in terms of monitoring area in section 2, parameter in section 3, and methodology in section 4. The discussions are based on articles found in the Web of Science by using key word "Water Quality Monitoring IoT" and "Water Quality Monitoring Online". Then, the findings were concluded in section 5 to decide suitable design configuration of water quality monitoring in Surabaya especially for tap water (PDAM) in section 6.

2. Water Quality Monitoring Area

Water covers more than 60% of the earth area. However, not all the water on the earth is used for daily living. It was not necessary to do water monitoring in all water area on earth, except in the area where the water is used for daily living. From the previous research, the water has been monitored in strategic area such as in medical environment [6], industrial environment [7], agriculture [8], aquaculture [9], disaster prone area [10], pipe network [11] and sewage [2], catchment area [1], household [12] and drinking water supply [13] as shown in Figure 1. In this section, each of the water monitoring area is further discussed.

Figure 1. Water quality monitoring area.

The water monitoring in medical environment and industrial environment has not been done for the tap water, but rather chemical solution. It is not that the medical and industrial does not use tap water in their daily routine. However, the main concern of liquid in that area was not the tap water, but another liquid such as chemical solution which directly contribute to the area. For instance, in medical environment, the IV content monitoring in a saline bag [6] and chemical content such as calcium threshold in a solution which unnecessary for medicine [14]. On the other hand, the viscosity of an oil is necessary to be monitored in industrial environment because the oil was used regularly for the machinery [7].

Agriculture [15], aquaculture [16], and disaster prone [10] area can be categorized as one area category of water monitoring. In these areas, it was important to monitor the water especially the necessary amount of water which was used for irrigation [17]. Too less water was not good for the plant in a farm, however, too much water was dangerous for the plant life. In some cases, the water content for watering the plant was also monitored to make sure the plant grows well. As for the disaster- prone area, the water was monitored as an indicator for early notification of disaster such as flood [10].

Another area necessary to be monitored was the tap water distribution area such as the catchment area or water resource area [4, 18], the pipe network itself [19, 20], and the sewage [21]. In these three areas, all the water quality must be guaranteed to be good. Clearly, the water quality in the catchment area such as river bank, lake, and fountain must be good before starting distribution [22]. As the water quality in the pipe network in underground [23] must be guaranteed to prevent quality reduced due to the pipe network issue such as rusty pipe and so on [24]. The water quality in sewage was also needed to be monitored because it was usually hazardous for the environment [21]. To determine the water quality, it was necessary to consider multiple sensor [25, 26] which could work independently and remotely [5] in real time application [27]. This is where the IoT took place in the monitoring system.

Last but not least, the water quality has been monitored near to us which were in household [16] and drinking water area [28]. The household water or tap water as well as drinking water were monitored because the tap water is used directly by the end-user, thus the quality assurance is necessary [21]. The household water can be monitored in the water tank and pipe network [29] inside the house which could be imagined as small version of water distribution network [30]. As for the drinking water, the monitoring could be done in water dispenser before the water reach the glass [5].

3. Water Quality Monitoring Parameter

Several parameters have been considered in water monitoring, such as Fluid Level [6], Viscosity [7], Water Needs [15, 17], Leakage [23, 24], Volatile Organic Compounds (VOC) [4, 28], Environment Parameter (temperature, humidity, pollution) [25, 16], and Water Quality Parameter (pH, oxygen, turbidity, conductivity, mineral content) [5, 21] as shown in Figure 2. Not all the mentioned parameter directly related to water quality monitoring. Also, depends on the monitoring purposes, the monitoring could only consider one parameter or multiple parameter.

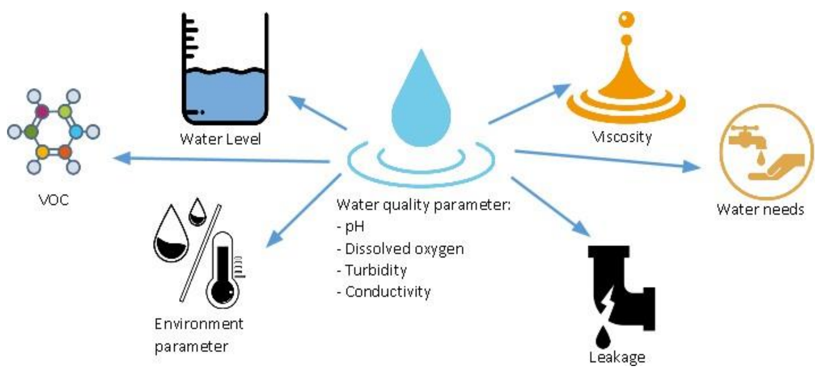

Figure 2. Water quality monitoring parameter

Fluid level and viscosity were the considered parameter in medical and industrial environment. Both these parameters did not relate to water quality monitoring, but rather a solution quality monitoring. For instance, the content of IV saline bag was necessary to be monitored for early notification when the IV was running out [6]. The mineral content in a solution was monitored because there might be some toxic mineral or unwanted mineral included. The solution which was contaminated with unnecessary mineral might not suitable for patient's consumption [14]. On the other hand, the viscosity of an oil was monitored to ensure the industrial machine could work optimally by using the monitored oil as a grease [7].

The plant water needs to be fulfilled, however the needs are not necessary to be fulfilled every time. Therefore, the water needs for plant are considered parameter to be monitored in agriculture area [8, 15] which was determined by using external information such as the temperature surrounding the plant and internal information such as the leaf temperature [8]. The water needs speak about the water volume which has similarity to water usage. However, the term of water usage was usually used for household area [30]. The water usages were monitored for bill efficiency and usually combined with electricity monitoring [12]. Although, both these parameters are not directly related to the water quality parameter, it can still be considered to support the water quality monitoring system.

Leakage was a common problem found in water distribution network which usually use pipe as the distribution medium. The investigation of leakage was conducted by using vibration signal (acoustic, radio, spectrogram) which could be modeled as leakage type, pipe pressure, and current season as presented in [11, 23]. Flow meter also can be used to detect the leakage in house pipe network, however without the ability to pinpoint the leakage location [20]. To enable the location detection, several points of measurement need to be considered in the pipe network. Similar to water usage and water needs, the leakage is not a water quality parameter, but can be considered as supporting parameter in water quality monitoring system.

Through all various water conditions and anthropogenic pressure, the quality of water can be affected by other chemical substances. The water may contain chemical compound such as Volatile Organic Carbon (VOC). It could be measured using spectrometer to see the UV absorbance of the water [13]. In another researches, impedance analyzer was used to collect information of vary impedance of a water due to VOC. It would be dangerous if by any change the VOC or even microbial inside the water was the one that affect health aspect of living creature [27]. The VOC amount in the water is necessary to be monitored in real time and remotely to ensure the water quality. Thus, early notification of microbial re-growth can be obtained as early as possible.

In some researches, the environment parameters such as temperature, humidity, and pollution are included together with VOC in water monitoring system for assessing the water quality [1, 2, 25]. Previous researches have addressed pH, dissolved oxygen, turbidity, and conductivity specifically for water quality parameter [9, 18, 27]. The reported water quality parameter is suitable with the parameter mentioned in standard IS 10500:1991. Another additional information that could be considered in water quality monitoring was the nutrient content as reported in [5]. Combining all the parameter to be considered in water quality monitoring, the water quality can be guaranteed and moreover the abnormality can be quick assessed due to vast amount of data available.

4. Water Quality Monitoring methodology

In doing the water quality monitoring, several methodologies have been conducted by previous researcher. In this paper, the methodologies were categorized based on measurement type and monitoring type. Based on measurement type, the methodologies are divided into direct measurement [1] and indirect measurement [4]. Then, based on monitoring type, the methodologies are divided into offline monitoring [24], online monitoring [8, 13], and remote-online monitoring [9, 29]. Illustration of water quality monitoring methodology is shown in Figure 3.

Figure 3. Water quality monitoring methodology

The direct measurement means the parameter to measure the water quality were measured using the respective sensor. For instance, the temperature was measured using temperature sensor [31] and water pH was measured using pH sensor [9]. On the other hand, indirect measurement was conducted using sensor which was different with the measured parameter, thus a model was needed to obtain the measurement result. For instance, the leaking was measured using acoustic sensor. To locate the leakage, propagation model of the acoustic signal was derived to pinpoint the location of the leakage [11, 19, 20, 23].

Depends on the monitoring type, the water monitoring methodologies are divided into offline, online, and remote-online monitoring methods. The offline monitoring methods were the conventional way to monitor the water quality which was not suggested anymore [15, 24]. Online monitoring was a promising method to monitor the water quality. Any detected abnormality for instance, leakage in the network could be known right away, thus further action could be taken to fix the abnormality [4, 29, 30]. In addition, the online monitoring that can be done remotely was the most suggested method, thus called as remote-online monitoring. These methodologies enabled an online monitoring in a remote area notably the catchment area [5, 18, 25] and buried pipe network [23, 24] which can be done easily by IoT [22]. Some of the previous works also consider multiple point measurement instead of single point measurement to enable abnormality prediction and analysis using model [20, 24] or even artificial intelligence [23]. For instance, water contaminant detection in several point in a house pipe network to analyze the contaminant distribution [28]. In some research, the monitoring was done in several point with different way such as local point measurement, airborne measurement, and satellite [27]. In another research, multiple point measurement was used to obtained different information to produce satisfying hot water in terms of energy usage and water temperature [31].

5. Discussion

In this paper, several aspects regarding water quality monitoring had been discussed in terms of area, parameter, and methodology. Table 1 shows the summary of water quality monitoring. Most of the previous works pay attention to do water quality monitoring in catchment area [4, 25], household area [16, 29] and drinking water [5, 28]. This is because the main function of the water itself which is to be consumed by living creatures.

The leakage monitoring in pipe network also has high attention because it affects the water resource and distribution [23, 24]. Other than that, the water monitoring can be seen in agriculture for the plant water [8, 15] and in aquaculture for the environment condition [9, 16]. The parameter which was being measured to assess the water quality were pH, dissolve oxygen, turbidity, conductivity (EC), and mineral content. This is suitable with parameter mentioned in drinking water standard IS 10500:1991. In some cases, the environment parameter suchas temperature and humidity were considered for luxury application such as home water heater [31]. The volatile organic compounds (VOC) were also necessary to be measured because it affected the long-term health although it was not acutely toxic [2, 28]. Water usages and leaking monitoring was necessary to be monitored for ensuring the high- quality water was well distributed [23, 24]. As for fluid level and viscosity, it was not considered for water quality monitoring as its application was for chemical solution in medical andindustrial application [6, 7, 14].

There were lots of parameter to be considered in doing the water quality monitoring. Therefore, the IoT methodology was the most prominent method to be implemented [26]. That was because it could realize an integrated water quality monitoring by combining many kinds of respective sensor, thus build a sensor network to collect data for assessing the water quality in real time [14]. The IoT also provided a remote-online monitoring, therefore the monitoring could take place in a remote area such as in a catchment area [27]. Moreover, multiple point measurement could also be implemented using this IoT method. Various type of data could be collected, thus opened the possibility of machine learning to develop a decision-making process for pin pointing the abnormality location and determining anecessary action due to abnormality [5, 28].

6. Proposed Design Configuration

The previous researches pay close attention to real-time and remote water quality data collection using sensor network through internet (IoT) real- time and remote data collection. The data is then can be used for analysis such as water quality classification, abnormality location, and further action due to the abnormality accordingly using machine learning method. This section explains the proposed design configuration for water quality monitoring in Surabaya as shown in Figure 4.

The proposed system has multiple point of data collection such as module A, module B, and module C. At least, there are three data collection points such as at the source, along the distribution network, and at the sink. It is expected from multiple data collection point that more information can be obtained, thus better water quality classification and abnormality location analysis can be conducted. In each module, there are sensors such as pH, oxygen, turbidity, conductivity sensors, and flow meter sensors. Data from the sensors are sent to the cloud server. This information is then can be accessed by authorized personal on their smartphone or personal computer anywhere and anytime they were connected to the internet.

Table 1. Summary of water quality monitoring research

References	Monitoring		
	Area	Parameter	Methodology
6	Medical environment	Fluid level	Indirect measurement, remote-online using IoT.
14		Mineral content	
7	Industrial environment	Viscosity	Indirect measurement, online
15	Agriculture	Water needs/ water usages	Indirect measurement, offline
8			Indirect measurement, online
17			Indirect measurement, remote-online using IoT
9, 16	Aquaculture	pH, oxygen, turbidity, conductivity, temperature, VOC	Direct measurement, remote-online using IoT
14	Disaster prone area	Water level	Direct measurement, remote-online using IoT.
11, 20, 24	Pipe network	Leakage	Indirect measurement, offline
23			Indirect measurement, remote-online using IoT
19			Direct measurement, offline
21, 26			Direct measurement, remote-online using IoT
2	Sewage	VOC	Direct measurement, online monitoring
21		pH, oxygen, turbidity, conductivity	Direct measurement, remote-online using IoT
4	Catchment area	VOC	Indirect measurement, remote-online using IoT
1, 25		Temperature, humidity, pollution	Direct measurement, remote-online using IoT
27		pH, oxygen, turbidity, conductivity.	Direct measurement, online
18, 5, 22			Direct measurement, remote-online using IoT

29	Household	Leakage	Indirect measurement,
			remote-online using IoT
12, 30		Water needs/water usages	Direct measurement, remote-online using IoT
16, 31		Temperature, humidity, pollution	
13	Drinking water	VOC	Indirect measurement, online
28			Direct measurement, online
21		Leakage	Direct measurement, remote-online using IoT
5		pH, oxygen, turbidity, conductivity	

Figure 5 shows the proposed module of water quality system monitoring. There are two chambers inside the module box namely lower and upper chamber. On the lower chamber, there is a pipe that goes outside the module box which can be installed directly to the water distribution network and sink pipe. It can also be put float on a water tank at the source point with the help of

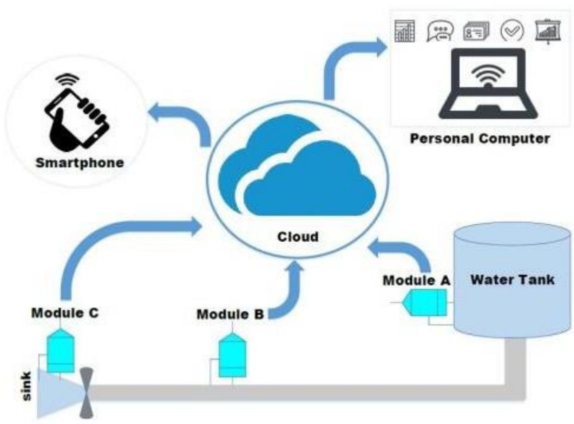

Figure 4. Proposed design configuration of water quality monitoring in Surabaya.

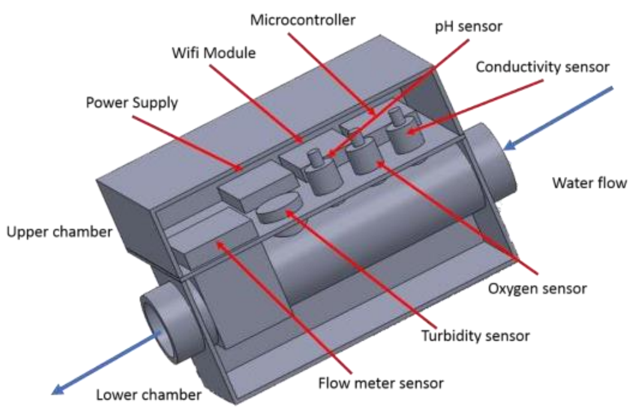

Figure 5. Proposed water quality monitoring module. The module architecture (a); module installed on a water tank (b); module installed on a pipe network (c).

weight and buoy. The sensors are installed to pierce the pipe structure thus it can collect the water quality data. On the upper chamber, there are power supply, microcontroller, and circuit for reading and sending the data from sensors. Lastly, there was also a wifi module for data communication between the module and the cloud.

7. Conclusion

In this paper, preliminary study to decide design configuration for water quality monitoring in Surabaya is presented. Comparison study on water quality monitoring has been conducted in terms of monitoring area, monitoring parameter, and monitoring methodology. Based on the previous researches and future trends suggestion in previous sections, the combination of water quality parameter (pH, oxygen, turbidity, conductivity, VOC), leakage, water usage, are necessary to monitor the tap water quality in Surabaya. Thus, in the proposed monitoring module, there are pH sensor, conductivity sensor, turbidity sensor, and flow meter sensor to obtain that information. Monitoring module are proposed to be installed in multiple point of measurement namely source, network distribution, and sink. By doing this, it is expected that many information can be obtained to conduct water quality and abnormality, and location analysis. The modules are connected using IoT technology, so it can communicate with the cloud server for data storage and authorized personal for a decision. The next step is to develop the module and capture the water quality data of tap water in Surabaya.

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