Jurnal E-KOMTEK (Elektro-Komputer-Teknik)
Vol. 5, No. 1 (2021) pp. 65-74
https://jurnal.politeknik-kebumen.ac.id/index.php/E-KOMTEK
p-ISSN : 2580-3719 e-ISSN : 2622-3066

Web-Based Automated Rainwater Storage and Water Quality Monitoring Design Using K-Nearest Neighbor Method

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https://doi.org/10.37339/e-komtek.v5i1.551

Published by Politeknik Dharma Patria Kebumen

Artikel Info
Submitted:
16-04-2021
Revised:
05-06-2021
Accepted:
07-06-2021
Online first :
30-06-2021

Abstract

Clean water is a basic human need that is used for daily activities. However, as the population increases, the need for water also increases. One method of conserving water resources is Rainwater Storage. Conventional rainwater storage cannot be appropriately monitored, maintain water quality, and only works like a container, which, if left to continue, can result in the collected rainwater becoming a source of disease and dangerous for users. This research aims to create an automatic rainwater collection system and water quality monitoring that can control the flow of water that will enter the reservoir to keep the water entering the reservoir of good quality. In the manufacture of this system, three sensors are used, including a pH sensor, a water turbidity sensor, and a TDS (Total Dissolved Solids) sensor. In determining water quality, the k-Nearest Neighbor (k-NN) method is used to classify whether the water is feasible, less feasible, or not suitable for consumption. Data transmission uses the ESP8266 WiFi module, and monitoring data can be viewed on the website. Testing the system using an experimental method, and in testing, it is found that this system can classify water quality with an accuracy rate of 70%.

Keywords: *Rainwater storage, Water quality monitoring, pH, Turbidity, TDS*

Abstrak

Air bersih merupakan kebutuhan pokok manusia yang digunakan untuk aktivitas sehari-hari. Namun seiring dengan bertambahnya jumlah penduduk maka kebutuhan akan air juga semakin meningkat. Salah satu metode konservasi sumber daya air adalah Rainwater Storage. Penampungan air hujan konvensional tidak dapat terpantau dengan baik, menjaga kualitas air, dan hanya berfungsi seperti wadah, yang jika dibiarkan terus menerus dapat mengakibatkan air hujan yang terkumpul menjadi sumber penyakit dan berbahaya bagi penggunanya. Penelitian ini bertujuan untuk membuat sistem penampung air hujan otomatis dan monitoring kualitas air yang dapat mengontrol aliran air yang akan masuk ke waduk agar air yang masuk ke waduk tetap berkualitas baik. Dalam pembuatan sistem ini digunakan tiga buah sensor, antara lain sensor pH, sensor kekeruhan air, dan sensor TDS (Total Dissolved Solids). Dalam menentukan kualitas air digunakan metode k-Nearest Neighbor (k-NN) untuk mengklasifikasikan apakah air tersebut layak, kurang layak, atau tidak layak untuk dikonsumsi. Transmisi data menggunakan modul WiFi ESP8266, dan data pemantauan dapat dilihat di situs web. Pengujian sistem menggunakan metode eksperimen, dan dalam pengujian didapatkan bahwa sistem ini dapat mengklasifikasikan kualitas air dengan tingkat akurasi 70%.

Kata-kata kunci: *Penyimpanan air hujan, Pemantauan kualitas air, pH, Kekeruhan, TDS*

1. Introduction

Clean water is an essential part of basic human needs, which is vital for human life. However, the high population growth, especially in urban areas, means that not all levels of society can enjoy clean water. For example, the middle to lower-class people in Central Java Province, with a total of 4.733 million people (14.56%), tend to experience difficulties accessing clean water [1]. One of the conservations of water resources that can be done is rainwater storage (RS), and it is hoped that it can provide an alternative to meet the needs of clean water for the community [2]. Rain is the process of condensing water vapour in the atmosphere into water droplets heavy enough to fall and usually arrive on land. Rainwater can be used as a source of clean water in cities. In several countries, rainwater is considered a solution to the urgent need for clean water [3].

In 2016, research was carried out on the 'IoT Based Water Quality Monitoring System' [4]. Meanwhile, in 2018 and 2019, there were three studies on 'Water Quality Monitoring System Using IOT [5] [6] [7] and continued in 2020 [8]. A survey about water quality using the k-Nearest Neighbor (k-NN) classification method was done in 2018 [9] and in 2020 [10]. Those studies above discuss the Internet of Things (IoT) application in monitoring water quality and prove that automation in water quality measurement is needed in society. However, those studies did not discuss applying the k-Nearest Neighbor (k-NN) classification method to determine rainwater quality in the Rainwater Storage (RS).

2. Method

We divide the design of this study into several stages, namely starting from the ongoing system analysis, proposed system analysis, user analysis, and system design. Based on the research that has been done, Figure 1 is an overview of the proposed system made.

Figure 1. Proposed System Analysis

This system requirements analysis includes software and hardware requirements, with **Table 1.**

Table 1. Software and Hardware Requirements

Software Requirements	Hardware Requirements	
OS Windows 10 64 bit	Arduino UNO R3	Water Turbidity Sensor
Arduino IDE	Solenoid Valve	pH Sensor
Sublime Text	Relay	TDS (Total Dissolved Solids) Sensor
XAMPP	WiFi Modul ESP8266	Asus A455LF 64-bit Laptop
Firefox Browser	Rain Sensor YL-83	10 GB RAM
	Water Level Sensor	Intel i3 Processor
	Jumper Cable	Powerbank

A block diagram depicts a system that shows the interactions between components. This diagram consists of several boxes that are connected by direct lines or back and forth. The block diagram helps show an outline of the control flow of the entire system. The block diagram for the Automatic Rainwater Storage Equipment System (*Alat Tampung Air Hujan Otomatis*/ATAO) is illustrated in **Figure 2.**

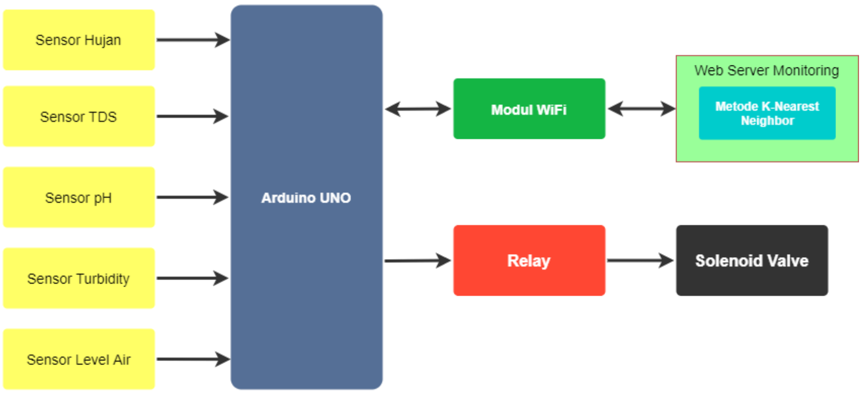

Figure 2. Block Diagram System

From the picture above, this Automatic Rainwater Storage Equipment System (*Alat Tampung Air Hujan Otomatis*/ATAO) uses the Arduino UNO microcontroller as a sensor computing centre that receives sensor measurement data from the rain sensor. In addition to the rain sensor, the Arduino UNO also receives measurement data from a water level sensor, a TDS sensor (Total Dissolved Solids), a pH sensor, and a turbidity sensor. Rain sensor data is used to determine the reading of TDS sensor data, pH, and turbidity sensors.

Figure 3 is the schematic/hardware design of the Automatic Rainwater Storage Equipment System (*Alat Tampung Air Hujan Otomatis*/ATAO) system proposed.

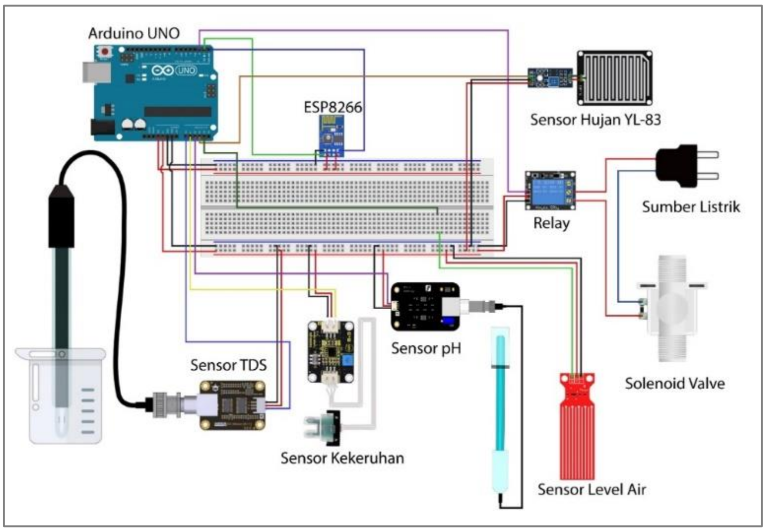

Figure 3. Hardware Design

The following is an explanation of each component of the hardware circuit of the system proposed:

1. The ESP8266 WiFi module communicates with the webserver, both sending data and receiving responses.
2. Rain Sensor YL-83 is used to detect rainfall, whether it is raining or not.

3. The TDS sensor is used to measure the amount of dissolved solids/TDS (Total Dissolved Solids) from rainwater flowing in the gutter.
4. The pH sensor is used to measure the pH level data of rainwater flowing in the gutter.
5. A turbidity sensor is used to measure the turbidity level of flowing rainwater. The scale used by this sensor is the Nephelometric Turbidity Unit (NTU).
6. The water level sensor is used to measure the water level in the reservoir, and this water level data can be used to determine whether the reservoir lid is opened or not.
7. A solenoid valve is used to control the flow of rainwater flowing into the tank by opening and closing the water channel. Because this solenoid valve uses a voltage source of 220V, a relay is used to control the solenoid valve, with the input from pin 2 of the Arduino UNO.

The k-NN algorithm uses the neighbour classification as the predictive value of the new test sample. Near or far neighbours are calculated based on the Euclidian distance. The flow of the k-Nearest Neighbor method is as **Figure 4.**

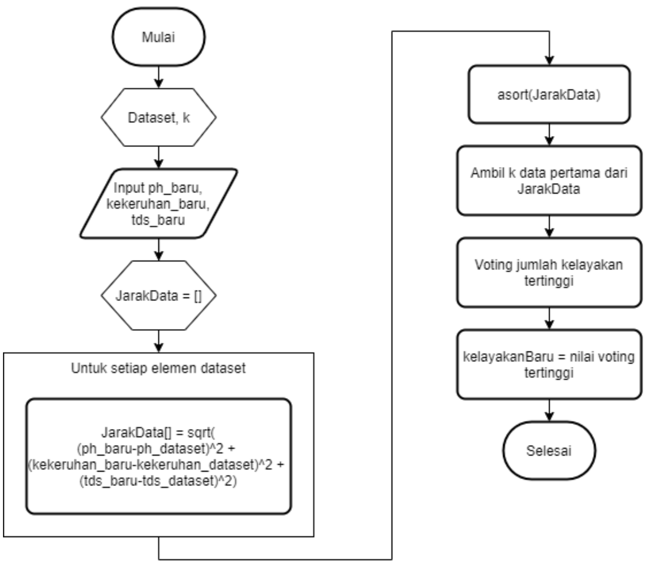

Figure 4. k-Nearest Neighbor Method Flow

Data normalization is used to reduce bias in the dataset because several parameters have very significant distance values. The results of dataset normalization can be seen in **Table 2.**

Table 2. Dataset Method

No	pH	Turbidity	TDS	Normal pH	Normal Turbidity	Normal TDS	Feasibility
1	7.93	0.33	86	0.49391	0.00000	0.00000	Feasible
2	5.72	1.58	416	0.10957	0.23148	0.26442	Less Feasible
3	7.61	4.53	983	0.43826	0.77778	0.71875	Feasible
4	8.86	5.73	392	0.65565	1.00000	0.24519	Less Feasible
5	9.50	2.94	1334	0.76696	0.48333	1.00000	Not Feasible
6	10.13	3.60	442	0.87652	0.60556	0.28526	Not Feasible
7	5.93	4.14	844	0.14609	0.70556	0.60737	Less Feasible
8	6.38	5.19	1155	0.22435	0.90000	0.85657	Not Feasible
9	9.81	2.30	215	0.82087	0.36481	0.10337	Not Feasible
10	10.81	3.31	270	0.99478	0.55185	0.14744	Not Feasible
11	9.54	4.84	911	0.77391	0.83519	0.66106	Not Feasible
12	10.84	5.53	860	1.00000	0.96296	0.62019	Not Feasible
13	5.09	2.37	334	0.00000	0.37778	0.19872	Less Feasible
14	6.11	3.89	948	0.17739	0.65926	0.69071	Less Feasible
15	7.63	4.44	597	0.44174	0.76111	0.40946	Feasible
16	8.52	5.38	1197	0.59652	0.93519	0.89022	Less Feasible
17	9.54	2.51	350	0.77391	0.40370	0.21154	Less Feasible
18	10.02	3.45	211	0.85739	0.57778	0.10016	Not Feasible
19	5.91	4.71	376	0.14261	0.81111	0.23237	Feasible
20	6.38	5.38	760	0.22435	0.93519	0.54006	Feasible

Before the new data is tested, the data is normalized together with the dataset, resulting in **Table 3.**

Tabel 3. Test Data

pH	Turbidity	TDS	Normal pH	Normal Turbidity	Normal TDS
10	1	100	0.85391	0.12407	0.01122

After all, the data has been normalized. The next step is to calculate the distance from each standard dataset element with new standard data using Euclidean Distance, and the results can be seen in **Table 4.**

Table 4. Data Distance Calculation

No	Data Distance	Feasibility
1	0.38095	Feasible
2	0.79354	Less Feasible
3	1.04914	Feasible
4	0.92806	Less Feasible
5	1.05561	Not Feasible
6	0.55447	Not Feasible
7	1.09295	Less Feasible
8	1.30883	Not Feasible
9	0.25988	Not Feasible
10	0.47052	Not Feasible
11	0.96663	Not Feasible
12	1.04686	Not Feasible
13	0.91032	Less Feasible
14	1.09809	Less Feasible
15	0.85691	Feasible
16	1.22344	Less Feasible
17	0.35316	Less Feasible
18	0.46235	Not Feasible
19	1.01335	Feasible
20	1.15496	Feasible

After that, all data are sorted from small to large (ascending) then the first k data are taken (for example, k=5). After that, from the data, it is calculated how many are suitable for consumption, less ideal for consumption, and how many are not ideal for consumption.

3. Results and Discussion

Figure 5 displays the entire series of automatic rainwater collection systems and water quality monitoring. The dimensions of this tool are 40 cm x 50 cm x 35 cm.

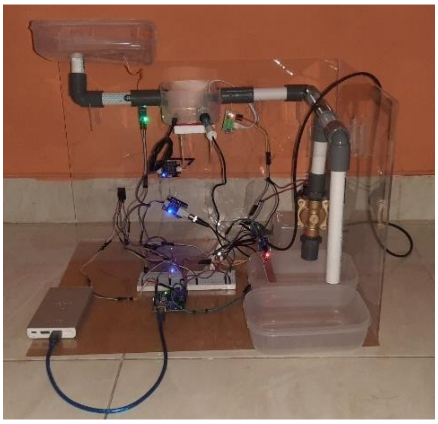

Figure 5. Hardware Display

Meanwhile, **Figure 6** is a view of home display monitoring of rainwater quality, presented in table order based on data entry date (data entered will appear in the top row).

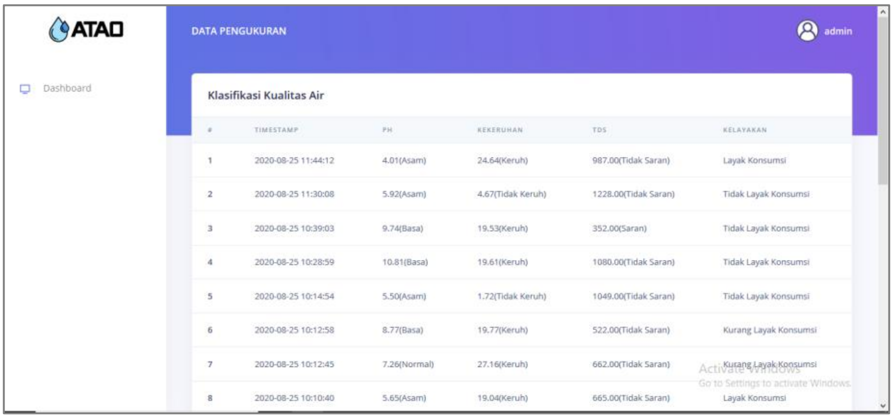

Figure 6. Software Display

Next is testing the method's accuracy using the proposed equipment that produces the data shown in **Table 5.**

Table 5. Measuring Result based on the equipment

No.	pH	Turbidity	TDS	Result
1	8.41	7.5	102	Less Feasible
2	6.89	10.11	645	Feasible
3	7.88	7.73	896	Feasible
4	4.75	2.6	151	Feasible
5	9.77	8.73	51	Not Feasible
6	9.44	1.98	690	Feasible
7	7.18	4.64	742	Feasible
8	5.04	2.64	518	Feasible
9	10.58	9.49	944	Not Feasible
10	4.28	8.52	794	Less Feasible
11	7.26	7.55	328	Feasible
12	6.42	6.53	1077	Not Feasible
13	5.65	19.04	665	Feasible
14	7.26	27.16	662	Less Feasible
15	8.77	19.77	522	Less Feasible
16	5.5	1.72	1049	Not Feasible
17	10.81	19.61	1080	Not Feasible
18	9.74	19.53	352	Not Feasible
19	5.92	4.67	1228	Not Feasible
20	4.01	24.64	987	Feasible

From the data in the table above, there are six inconsistent data from the 20 data tested. Moreover, from the data above, the accuracy can be calculated as follows:

$$Accuracy(\%) = \frac{test\ data - unknown\ test\ data}{set\ data} \times 100\% = \frac{20-6}{20} \times 100\% = \ 70\%$$

Design of Automated Rainwater Collecting Equipment and Web-Based Water Quality Monitoring provide alternative solutions to existing problems. Through research and system testing, problem-solving is obtained as follows:

1. In hardware design, the components used for automatic rainwater collection are the rain sensor, water level sensor, and solenoid valve. The features used for monitoring water quality parameters are pH sensors, turbidity sensors, TDS sensors (Total Dissolved Solids), where the measurement results of each sensor are sent via the ESP8266 WiFi module. All of these components are integrated into the Arduino UNO.
2. Software design uses the back-end programming language PHP, MySQL database, and Apache web server, which monitors water quality and feasibility.
3. From testing the results of water quality measurements using water samples, the test results can be good. In trying the k-Nearest Neighbor (kNN) method works, an accuracy value of 70% is obtained from the total 20 water samples used.

4. Conclusion

From the research conducted, starting from the initial stage to the process of testing automatic rainwater collection equipment (*Alat Tampung Air Hujan Otomatis*/ATAO), it can be concluded that:

a. An Internet of Things (IoT) based system can automatically control the quality of incoming rainwater, open storage streams if the flowing rainwater is feasible, and close the storage stream if the flowing rainwater is not possible.

b. The k-Nearest Neighbor (k-NN) method can be used to determine the feasibility of water-based training data. The parameters used are pH levels, turbidity levels, and TDS, with all data normalized first. The story of the accuracy of the system in determining the feasibility of water using the k-Nearest Neighbor (k-NN) method is 70% of those 20-test data.

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