Monitoring the pH Levels of Well Water in the Home Industri Sarung Goyor Village, Pemalang, Using IoT Technology and Inverse Distance Weight Method

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ABSTRACT

The Sarung Goyor Home Industry business, located in Wanarejan Utara Village, Pemalang, has been running for several years. However, the use of residual textile dyes in the process of making goyor sarongs now poses a threat to the quality of well water in the area where residents live. This condition is a serious concern because some residents rely on water from the well for drinking, cooking, bathing, and washing. One of the impacts of this textile waste is abnormal water pH. The solution requires real-time monitoring of the pH of well water by utilizing Internet of Things (IoT) technology and pH sensors. In this solution, direct sampling using sensors is carried out at 3 monitoring points around the industrial area and processed to estimate the pH level of residents' well water. This monitoring system succeeded in showing that the average pH of well water was in a safe condition, namely 7.18, not much different from tests carried out with reference sensors, namely a pH range between 6.96 to 7.20. The findings show that in testing the assembled sensor, the IDW method has a measurable error rate with an RMSE of about 0.2629 and a MAPE of about 4.669%. When compared with the test results using a reference sensor, the RMSE value reaches around 0.4666 and the MAPE is around 6.553%.

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1. INTRODUCTION

Water is a very important resource for life and the natural environment. This is the reason why water sources should continue to be monitored to detect the presence of pollutants that can harm water quality [1]. Contaminated water is closely linked to the transmission of diseases such as cholera, diarrhea, hepatitis type-A, typhoid fever, dysentery, and polio. Diarrhea causes around 500,000 deaths every year [2], [3]. One of the activities that causes material waste is industry. Liquid waste or liquid waste is one type of waste that is often produced in this activity [4]. Waste from synthetic textile dyes can significantly change the physical properties of water, such as the pH conditions of the water [5]. pH is an important factor in the body to maintain balance and coordinate metabolic processes. Water with a high pH can cause weight gain and slowing of immune reactions, while water with an alkaline pH can cause an inability to synchronize key nutrients in the body [6].

Sarung Goyor Home Industry Village in Wanarejan Utara Village, Pemalang, has been a source of livelihood for residents for many years. This home industry activity is evenly distributed in all places in this village. However, the use of textile dye waste in the production of goyor sarongs creates the potential for polluting well water in the area. Residents usually use well water for drinking, cooking, bathing, and washing, so this problem is very serious and requires a fast and appropriate solution. If polluted water is used for daily needs, it will cause serious problems, especially for health [7]. Predicting changes in water quality is an indicator of water pollution, in predicting this it is necessary to have controls to monitor water quality and be able to identify strategies that can be implemented so that water resource management can be better [8]. Measurement of groundwater levels in situ is generally carried out using two approaches, namely deploying sensors in wells and using water level measuring devices [9]. Data access to control water inreal timee can be done using remote monitoring technology based on IoT (Internet of Things) [10].

The development of IoT technology is an opportunity to develop systems that can monitor water quality [11], [12]. In general, there are various sensors used as a medium for monitoring water quality, including pH sensors, turbidity sensors, temperature sensors, and humidity sensors [13]. One of the efforts to overcome the problem of well water pollution is the use of Internet of Things (IoT) technology and water pH sensors as a proposed solution. In this way, real-time monitoring of well water conditions is carried out, so that it can identify the level of water pollution accurately and efficiently [13]. By monitoring in real-time, changes in well water quality can be detected as soon as they occur. This allows quick action to identify and address potential problems before they become more serious. Well-designed and executed IoT instruments can play an important role in improving the quality and reliability of collected data and reducing overall monitoring costs [14]. With advances in sensor technology in recent years, several studies have been carried out to develop low-cost monitoring systems [15]-[19].

IoT technology can monitor water pH as in research on the application of Internet of Things (IoT) technology in agriculture and aquaculture in coastal areas of Vietnam [20]. Other research related to water monitoring, such as developing a system for measuring water quality based on IoT, this system was created to create a tool that has a relatively low cost and can measure water quality based on IoT technology. The sensors used include pH, conductivity, and turbidity sensors. The three sensors use LMC 6001. The output from LMC 6001 is a voltage which is a parameter of each sensor. Remote measurements are carried out via the IoT platform, namely ThingSpeak, using the SN8200 Wi-Fi module connected to the STM32F411RE microcontroller, while the UART protocol is used as a communication medium between the controller and the Wi-Fi module [21]. In the field of aquaculture, pH sensors are used to read the pH value contained in it, then the data can be viewed remotely via a cellphone connected to the internet [22]. In more limited measurement environments, prototype water pH sensors are used to monitor the pH of the water in the aquarium. The aim is to find out whether the current conditions in the aquarium are suitable for the living environment of endemic fish or not [23].

One method that can be used to estimate the pH level of water in various places is the Inverse Distance Weight (IDW) method. The IDW method is used to interpolate data spatially [24]. The IDW method can be used to estimate the pH level of well water in each house using only samples from several wells so that it can speed up handling of pollution problems [25]. Utilizing the IDW method can reduce the use of IoT equipment, so costs will be more economical [15], [16], [19]. The IDW (Inverse Distance Weight) method is a spatial interpolation method used to estimate values at certain locations based on known values at other locations, with inverse distance weights. In research related to wells, the IDW method was compared with the Ordinary Kriging method to identify the distribution of aquifer depth in areas experiencing limited clean water supply in Semarang City [26]. In a broader context, the IDW method was used to map water quality indicators in the Wadi El Bey river basin, Tunisia. Results from the use of IDW helped identify key areas requiring control in the Wadi El Bey River [27]. The IDW method was also used to analyze the level of water pollution reflected in the upper part of the Cañete River watershed. In this study, data collection was carried out at 9 monitoring points [28]. From several references, this means that the IDW method can also be used to analyze the pH levels of water in a home industry village.

The production of Goyor sarongs, which has been running for decades, should not harm the health of residents. By utilizing IoT technology and the Inverse Distance Weight method, it is hoped that this research can contribute to determining the estimated pH level of water in residents' wells in the home industry area, Wanarejan Utara Village, Pemalang at a more cost-effective rate. This is also expected to reduce the negative impact of textile dye waste in making Goyor sarongs on the environment and public health. With continuous monitoring, pollution problems can be handled quickly and precisely, so that the surrounding environment can be maintained, and residents can live healthily and comfortably [29]. Apart from the Goyor sarong home industry, this technology can also be applied in other textile home industries where waste flows into rivers, potentially polluting the environment and affecting the quality of water consumed by the community.

2. METHODS

In this research, integration was carried out between Internet of Things (IoT) technology and the Inverse Distance Weighting (IDW) interpolation method. IoT technology is used to acquire water pH data from wells in real-time, while the IDW method is used to analyze the data that has been collected to obtain estimates of water pH levels in residents' places. The aim is to efficiently monitor and provide accurate information about the pH quality of well water to local communities. The analysis results are visualized through a web display in the form of a scatter graph so that the data is easier to interpret. The IoT-IDW architecture can be seen in Fig. 1.

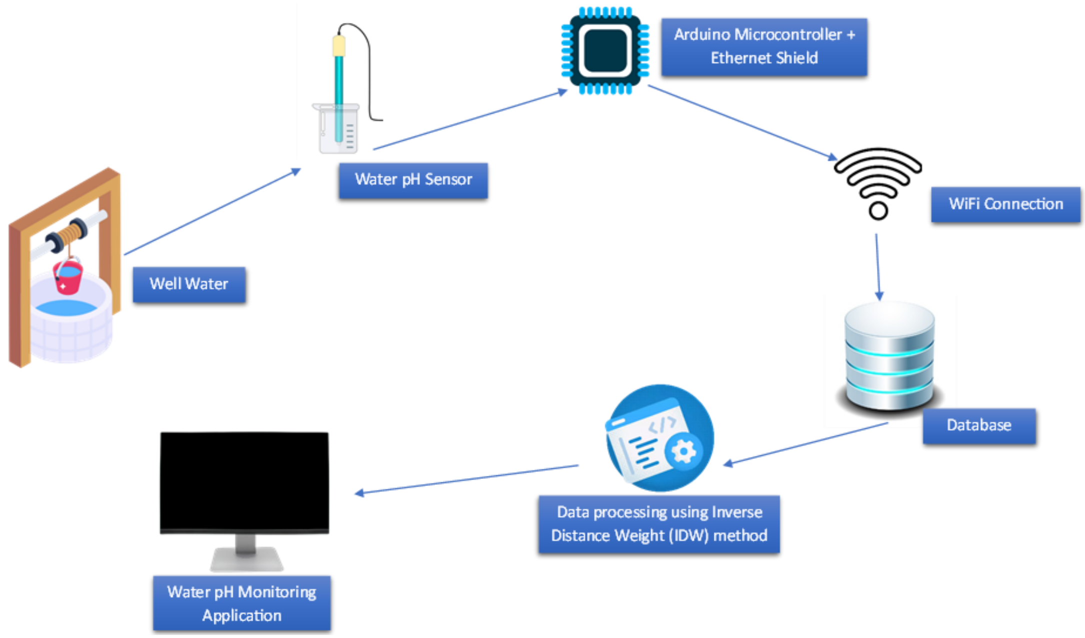

Fig. 1. IoT-IDW Architecture

The sensor used to measure the pH of well water is the PH Electrode Probe Sensor with a BNC connector, while the electronic device used to detect the pH value in liquid is the pH 0-14 Liquid Sensor Module. Both devices are connected to the Arduino Uno microcontroller. To connect this circuit to the internet network, the Ethernet Shield W5100 is used. The data captured via the IoT device is then sent to the MySQL database.

The pH detection sensor used has several prominent specifications and features. This sensor operates with a heating voltage of 5 ± 0.2V (AC DC) and consumes a working current of around 5-10mA. The concentration range that can be detected by this sensor is PH0-14, with a detection temperature range between 0 to 80 degrees Celsius. The response time of this sensor is very fast, only 5 seconds, and the turnaround time is about 60 seconds. This sensor has a component power of 0.5W and can operate in a temperature range of -10 to 50 degrees Celsius (with a nominal temperature of 20 degrees Celsius) and a maximum humidity of 95% RH (with a nominal humidity of 65% RH). This module measures 42mm×32mm×20mm and produces an analog voltage signal output. Additionally, this sensor is equipped with 4 M3 mounting holes for easy installation. This package includes one liquid pH detection sensor module with a value range of PH0-14 and one pH electrode probe with BNC interface.

The pH sensor calibration process begins by preparing standard pH solutions, such as pH 4, pH 7, and pH 10. Soak the pH electrode probe into this solution, adjust the offset until it reads correctly at a pH 7 solution, and adjust the slope by immersing it in the solution Lower and higher pH. Once the calibration is complete, connect the pH sensor to the Arduino Uno microcontroller via the analog pin. Make sure the electrode probe is connected to the pH reader module, and that the module is connected to the analog pin of the Arduino Uno. Next, mount the Ethernet Shield W5100 on top of the Arduino Uno and configure the Ethernet connection using the Arduino code corresponding to the desired IP address and port. In the program loop, read data from the pH sensor and transmit the data over the network connection provided by the Ethernet Shield. With this, Arduino Uno can be used to read and transmit pH data over the network into a MySQL database.

Data stored in the database is analyzed using the IDW method. IDW incorporates the inverse distance of two raised points into a mathematical power of 2 that represents the exponent of the distance between close points [30]. The function of the IDW method can be seen in (1) [31].

$$\phi(z) = \frac{1}{2}\sum_{i}^{n}\left[\frac{1}{d_{0i}^{p1}}\,(z - zi)^2\right] \quad (1)$$

z is the estimated value at an unsampled location x_0; zi is the value of the i-th sample on location xi; n is the number of samples used in interpolation; $d_0 i$ represents the data-to-unknown distance (D-U), that is, a measure of the distance from the i-th sample location (xi) to an unknown point (x_0); and p_1 generally a non-negative coefficient used to adjust for the relative influence of distance $d_0 i$ in the calculation process. The flow diagram for integrating IoT technology and the IDW method in estimating well water pH levels can be seen in Fig. 2.

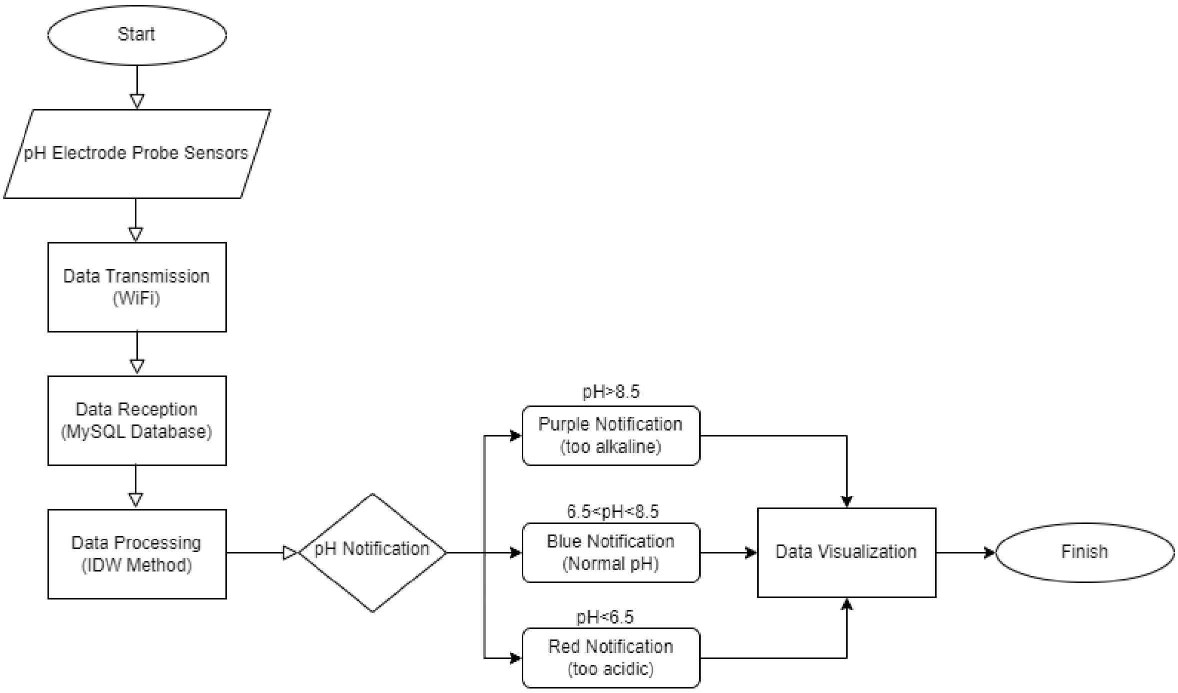

Fig. 2. System Flow Diagram

After analyzing the data using the IDW method, the next step is to visualize it via a web display in the form of a scatterplot graph. The pH condition of water can be recognized by the different colors on the graph, where pH > 8.5 is displayed with a purple coordinate point, which indicates that it is too alkaline. Conversely, pH < 6.5 is marked in red, indicating a tendency to be too acidic, while normal pH (6.5 < pH < 8.5) is indicated by a blue dot. The results of the analysis using the IDW method to display the distribution of well water pH are presented in the form of a web visualization graph and can be seen in Fig. 3.

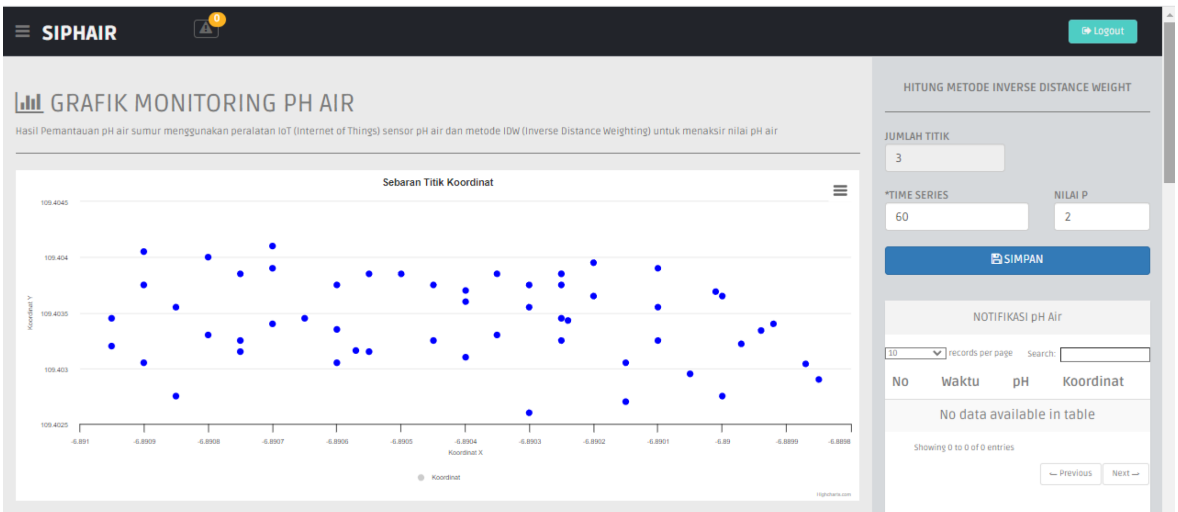

Fig. 3. Well water pH distribution graph

2.1. Dataset

Direct sampling using sensors was carried out at 3 monitoring points, namely point 1 with coordinates -6.889945, 109.403348, point 2 with coordinates -6.89024, 109.40343, and point 3 with coordinates -6.89057, 109.40316. Three data sets at this monitoring point are used to calculate the estimated pH value of well water in the Rt area. 02, Rw. 03, for a total of 50 community wells. The data collection scenario can be seen in Fig. 4.

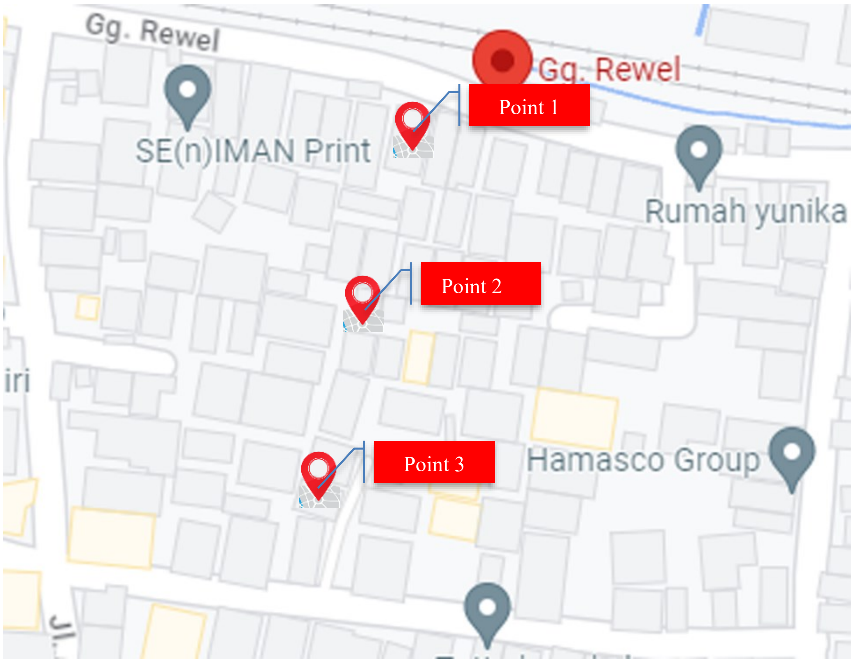

Fig. 4. Data Collection Scenarios

Each monitoring point carries out data acquisition simultaneously. Data is taken every 60 minutes. At each point, a sensor is set to measure the pH value of the well water. The frequency of measurements carried out every hour aims to obtain a representative dataset during the observation period. As a quality control effort, each sensor is calibrated periodically to ensure the accuracy of measurement results. In addition, routine monitoring of equipment conditions and the surrounding environment is carried out to ensure data integrity and reliability. These steps were implemented to minimize the potential for error and ensure the quality of the data produced is consistent and reliable in calculating well water pH estimates throughout the region. The results of data collection from 3 monitoring points can be seen in Table 1.

Table 1. Results of taking well water pH data from 3 monitoring points

Vrl	pH	Points	Created at
2.51	7.34	1	27/08/2023 9:01
2.51	7.33	1	27/08/2023 10:01
2.53	7.21	2	27/08/2023 9:01
2.54	7.17	2	27/08/2023 10:01
2.54	7.17	3	27/08/2023 9:01
2.55	7.13	3	27/08/2023 10:01

Calculation of the distance between the sample point and the point whose pH value will be estimated is carried out using the Haversine method. Haversine is an algorithm that can determine the distance between two objects on a spherical surface. In the context of pH monitoring and estimation, the use of the Haversine method is significant because it allows accurate geographic distance calculations between monitoring points and pH estimation points in water wells. By combining this distance information with pH data acquired via IoT technology, Haversine's method makes a crucial contribution to ensuring accurate and precise pH estimates. By adapting geographic distance calculations to Haversine's level of accuracy, pH estimates can be more precisely positioned and interpreted according to geographic location, assisting in more careful monitoring of water quality. Haversine has now been developed using a simple formula, which, with computer calculations, can provide a very accurate level of precision between two points [32]. The formula for the Haversine method can be seen in (2).

$$d = 2r \,.\, \arcsin\left(\sqrt{\sin^2\left(\frac{lat2-lat1}{2}\right) + \cos(lat1)\,.\cos(lat2)\,.\sin^2\left(\frac{lon2-lon1}{2}\right)}\right) \tag{2}$$

d is the distance between two points in units corresponding to the earth's radius r. $lat1, lon1$ are the latitude and longitude coordinates of the first point, and $lat2, lon\ 2$ are the latitude and longitude coordinates of the second point. The results of calculating the distance between the monitoring point and the point whose pH value will be estimated using the Haversine method can be seen in Table 2.

Table 2. Results of calculating the distance of monitoring points using the Haversine method

Coordinates	Distance point 1	Distance point 2	Distance point 3
-6.88994, 109.40334	1	35	73
-6.88997, 109.40322	14	38	67
-6.88987, 109.40304	35	60	79
-6.88992, 109.4034	6	36	77
-6.89057, 109.40316	73	47	0
-6.89024, 109.40343	34	0	47
-6.88985, 109.4029	51	73	85
-6.89045, 109.40375	72	42	66
-6.89015, 109.40305	40	43	48
-6.8908, 109.404	119	89	96

2.2. Model Evaluasi

Evaluation of the results was carried out using 2 methods, namely the method of testing the prototype sensor that was built and calculating the accuracy from the results of the IDW method calculations. Sensor accuracy testing was carried out using a reference sensor and compared with the sensor prototype that was built [23]. The reference sensor used as a comparison is the pH Meter Auto Calibrate with LED Backlight sensor with an accuracy of +/- 0.01 pH. Meanwhile, testing the accuracy of the IDW method calculation results is carried out by analyzing RMSE and MAPE to identify the error level of the method that has been used [26].

Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) calculations were carried out to assess the error between the values estimated by the prototype sensor and the reference sensor. RMSE measures how well the model approximates the true value, while MAPE measures the average percentage error.

The significance of these metrics lies in their ability to provide a clear picture of how well a prototype sensor can reproduce the results of a reference sensor. RMSE provides information about the absolute error rate, while MAPE indicates the relative error percentage. By combining these two metrics, model evaluation can provide a holistic understanding of the extent to which the prototype sensor is reliable in measuring water pH compared to the reference sensor, as well as how accurate the IDW method is in analyzing the data produced by the sensor. The formula for the RMSE model can be seen in (3) [33].

$$RMSE = \sqrt{\sum_{i=1}^{n}(yi - \widehat{yi})^2/n} \tag{3}$$

RMSE stands for Root Mean Square Error. n represents the number of observations or data points in a sample or data set. yi is the actual value or observation measured at the i-th observation. $\widehat{yi}$ is the value predicted or estimated by the model at the i-th observation. $\sum$ is the sigma sign which indicates the addition operation. $(yi - \widehat{yi})^2$ is the squared difference between the actual value and the predicted value at the i-th observation. $\sqrt{}$ is a square root operation.

MAPE is an evaluation metric that measures the magnitude of prediction error in percentage. It not only measures the deviation between the original measured water quality parameter values and the predicted values, but also considers the ratio between the deviation and the original measured values. The formula for the RMSE model can be seen in (3) [34].

$$MAPE = \frac{1}{D}\sum_{i=1}^{D}\left|\frac{O_i - P_i}{V_i}\right| \tag{3}$$

D represents the number of data points in the data set, O_i and $representP_i$ represents the original measured water quality parameter values and predicted values, respectively. The closer to 0 on these four performance evaluation metrics, the higher the overall accuracy in forecasting and matching the proposed hybrid model.

3. RESULTS AND DISCUSSION

Water pollution is increasing due to human actions and natural disasters, and water monitoring systems are becoming a focal point for society [35]. One of the aims of technology like this is to be able to control water levels automatically and provide warnings as early as possible when water is polluted [36]. It is important to have alternative techniques that can provide information about areas that have not been sampled without incurring much additional cost or effort. Various methods can be used to estimate values at locations that have not been measured in optimal space and time. One method is inverse distance weighting (IDW) [37]. The IDW method assumes that values from unsampled points are more similar to values from closer sampled points [38].

Wanarejan Utara village is a home industry village that has been producing goyor sarongs for decades. It is feared that waste such as textile dyes will pollute the water conditions in residents' homes. Almost all residents use their well water for daily consumption, such as for toilets, cooking, and drinking. Therefore, it is necessary to monitor the quality of the well water that residents have been consuming. In this research, a tool has been designed that can detect the pH quality of residents' well water. The results of taking water pH data at 3 monitoring points for the last 7 hours can be seen in Fig. 5. From this figure, it is shown that the average water condition at each monitoring point produces consistent data. Changes in water pH levels did not show significant changes in the data.

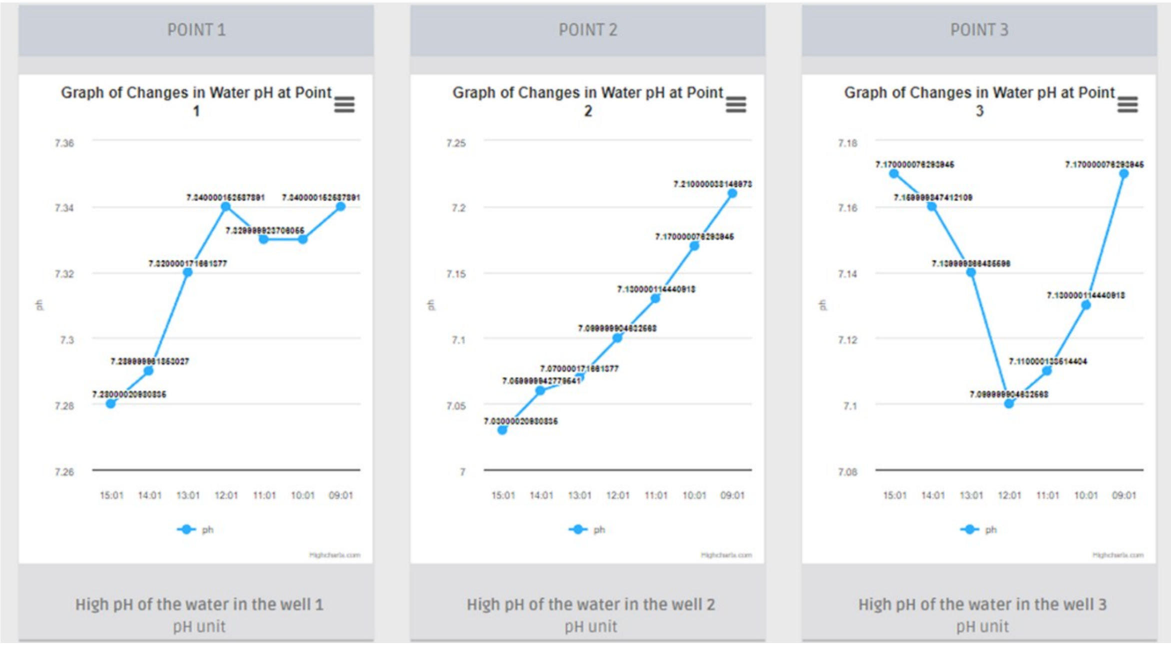

Fig. 5. Graph of changes in water pH at 3 monitoring points

From the data taken at 3 monitoring points, the data was then analyzed using the IDW method. The total estimated using the IDW method is at 50 other residents' well points. The P value is 2, whereas from various literature reviews the P value is mostly 2 [39]. The estimated results of measuring water pH levels using the IDW method can be seen in Table 3.

Table 3. Estimated results of measuring water pH levels using the IDW method

Value_P	Coordinates	Distance point 1	Distance point 2	Distance point 3	pH	Created at
2	-6.88994, 109.40334	1	35	73	7.28	30/08/2023 8:34
2	-6.88997, 109.40322	14	38	67	7.25	30/08/2023 8:34
2	-6.88987, 109.40304	35	60	79	7.21	30/08/2023 8:34
2	-6.88992, 109.4034	6	36	77	7.27	30/08/2023 8:34
2	-6.89057, 109.40316	73	47	0	7.1	30/08/2023 8:34
2	-6.89024, 109.40343	34	0	47	7.24	30/08/2023 8:34
2	-6.88985, 109.4029	51	73	85	7.19	30/08/2023 8:34
2	-6.89045, 109.40375	72	42	66	7.11	30/08/2023 8:34
2	-6.89015, 109.40305	40	43	48	7.17	30/08/2023 8:34
2	-6.8908, 109.404	119	89	96	7.14	30/08/2023 8:34

Table 3 presents the estimated results of measuring water pH levels using the Inverse Distance Weighting (IDW) method. For example, the pH value of water measured at coordinates -6.88994, and 109.40334 is 7.28. This measurement was carried out on August 30, 2023, at 8:34. This IDW method considers points calculated by the distance to the three closest measurement points, with each distance to point 1 being 1 meter, to point 2 being 35 meters, and to point 3 being 73 meters. Thus, the results of estimating the pH of water at that location are obtained by giving greater weight to closer measurement points. This information is useful for understanding the distribution and variations in water pH levels around the measurement point in question.

To make monitoring easier, the estimation results are displayed in a web-based application. The estimation results are displayed in the form of a Scarlett graph. Estimation results that show a water pH level < 6.5 will show a red dot indicator, water pH > 6.5 and < 8.5 will be blue and water pH > 8.5 will be purple. Determination of indicator values is taken based on WHO information where normal water that is suitable for consumption is water pH > 6.5 < 8.5 [40]. The pH value ranges from 1 to 14 with a value of 7 as the neutral point [22]. If the pH value is less than 7, it indicates acidity. On the other hand, if the pH value is more than 7, it indicates alkalinity [41]. The results of calculations using the IDW method that have been carried out can be seen in the graphic distribution in Fig. 6.

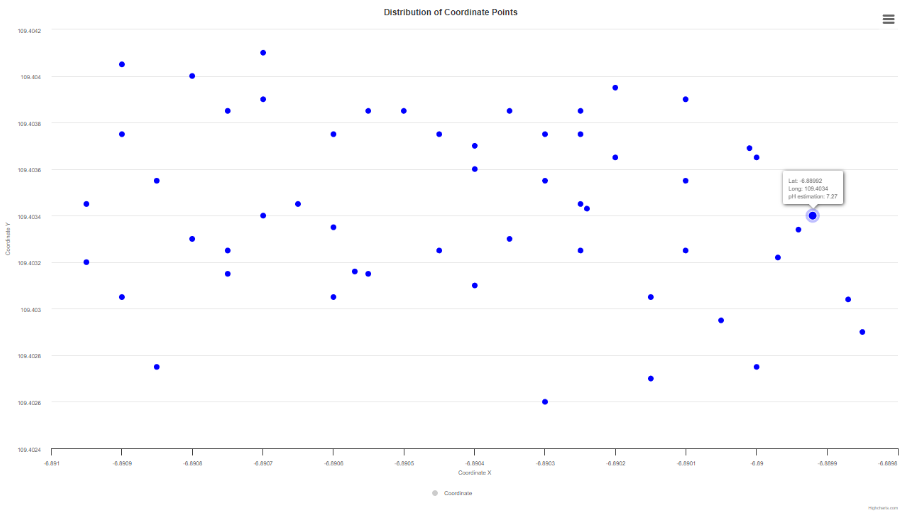

Fig. 6. Results of estimating water pH in 50 residents' wells using the IDW method

Fig. 6 it shows that all indicators are blue, thus giving the conclusion that the condition of the well water in Wanarejan Utara village is normal, and still suitable for consumption. The average pH of well water shows a water pH level of 7.18, the smallest water pH level is 7.09, and the largest water pH level is 7.28.

3.1. Evaluate the results

Testing was carried out using the RMSE and MAPE methods. These two methods are often used to evaluate the results of research using IoT technology [42], [43], [44]. The test scenario is carried out by taking into account the error difference between direct measurement values using assembled sensors, measurement values using assembled sensors processed using the IDW method, and direct measurements using reference sensors.

MAPE measures the average percentage error of predictions relative to actual values. To calculate MAPE, the difference between the actual value and the predicted value is taken, then the absolute value is calculated, and the results are normalized by taking into account the proportion to the actual value. Meanwhile, RMSE measures the magnitude of the overall prediction error by giving greater weight to large errors. In RMSE calculations, the difference between the actual value and the predicted value is taken, squared, the average is calculated, and the square root of the result is taken. Both MAPE and RMSE produce values that indicate how close the prediction is to the actual value, with lower values indicating more accurate predictions. Actual value in this context refers to data obtained through reference sensors, namely sensors that have been tested for suitability on the market. Meanwhile, the prediction value is obtained through an assembled sensor, which was developed in this research by utilizing IoT technology. Apart from using assembled sensors, prediction values are also obtained through the application of assembled sensors using analysis from the IDW method.

This test was carried out at a resident's well with geographic coordinates lat: -6.88992 and long: 109.4034. The distance from the test site to monitoring point 1 is 6 meters, to point 2 is 36 meters, and to point 3 is 77 meters. Table 4 shows the results of measurements of water pH levels that were carried out at the residents' residences.

Table 4. Results of measuring water pH levels at the test location

Assembled Sensor	IDW	Reference Sensor	Data Collection Time
7.12	7.28	7.54	2023-08-27 09:01:49
7.09	7.20	7.49	2023-08-27 10:01:49
6.99	7.31	7.52	2023-08-27 11:01:49
6.96	7.30	7.48	2023-08-27 12:01:49
6.98	7.29	7.47	2023-08-27 13:01:49
6.98	7.29	7.51	2023-08-27 14:01:49
7.21	7.28	7.52	2023-08-27 15:01:49

The first test carried out error measurements between the assembled sensor and measurements using the IDW method. The error test results between the assembled sensor and the IDW method measurements can be seen in Table 5.

Table 5. Testing the assembly sensor error with the calculation results of the IDW method

Assembled Sensor	IDW	Difference (Error)	Squared Error
7.12	7.28	-0.16	0.0256
7.09	7.20	-0.11	0.0121
6.99	7.31	-0.32	0.1024
6.96	7.30	-0.34	0.1156
6.98	7.29	-0.31	0.0961
6.98	7.29	-0.31	0.0961
7.21	7.28	-0.07	0.0049

From the tests in Table 5, the RMSE value is 0.2629 and the MAPE value is 4.669%. The second test carried out error measurements between the assembled sensor and the reference sensor. The error test results between the assembled sensor and the reference sensor can be seen in Table 6.

Table 6. Assembly sensor error testing with reference sensors

Assembled Sensor	Reference Sensor	Difference (Error)	Squared Error
7.12	7.54	-0.42	0.1764
7.09	7.49	-0.40	0.1600
6.99	7.52	-0.53	0.2809
6.96	7.48	-0.52	0.2704
6.98	7.47	-0.49	0.2401
6.98	7.51	-0.53	0.2809
7.21	7.52	-0.31	0.0961

From the tests in Table 6, the RMSE value is 0.4666, and the MAPE value is 6.553%. From these data, the proposed scheme achieves low RMSE and MAPE values, indicating that the proposed scheme is quite good at retrieving water pH data [42]. There is no absolute value that can be considered "minimal" or "adequate" for MAPE or RMSE, as these evaluations are highly dependent on the specific context of the application and the data being tested. However, based on several other references, the RMSE and MAPE values obtained are considered good for measuring water conditions [45], [46], [47].

4. CONCLUSION

A Well Water pH Level Monitoring System has been successfully created in Sarung Goyor Home Industry Village, Pemalang, using IoT Technology and the Inverse Distance Weight (IDW) Method. From the monitoring results, it was revealed that the pH of the well water in the village was in safe condition, with an average pH of 7.18, making it suitable for consumption. Tests using the reference sensor also showed a pH range of 6.96 to 7.21, which is generally considered safe. System performance assessment involves calculating Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) in error testing of assembled sensors. The results reveal that the IDW method has an error rate with an RMSE of 0.2629 and a MAPE of 4.669% in testing the assembled sensor. In comparison with tests using a reference sensor, the RMSE value reached 0.4666 and the MAPE was 6.553%. Even though the estimated water pH level from a series of tests shows safe conditions, it is recommended to continue conducting further research regarding well water quality, such as turbidity, bacteria, chemicals, temperature, dissolved oxygen, and levels of organic and inorganic pollution, to ensure water safety for consumption. . This system can not only be implemented for home industries but can also be used for large-scale industries. In addition, it is necessary to explore other interpolation methods to identify the best approach for estimating water pH levels more accurately in the future.

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