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Improving Wastewater Quality System Using the Internet of Things-Based Phytoremediation Method

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ABSTRACT

Water is an important part of all living things, including humans, animals, and plants, but concern for clean water is decreasing due to numerous human activities, which cause pollution. Water pollution is characterized by changes in physical, chemical and biological contents due to the wastes generated from the actions of living things, such as water irrigation. Therefore, this research aimed to overcome irrigation wastewater pollution using the Internet of Things (IoT)-based phytoremediation method, water hyacinth, apu-apu, and lotus. It was carried out using a tool monitoring system based on IoT technology with parameters for measuring pH, temperature, and water turbidity through the internet network. The results showed that the acidity level increased by 7–8 with a decrease in COD using water hyacinth, apu-apu, and lotus by 41.55%, 32.77%, and 32.91%, respectively. The BOD level using water hyacinth, as well as apu-apu and lotus decreased by 37.82%, and 31.54%, respectively. The decrease in phosphate level using water hyacinth, apu-apu and lotus was by 3.55%. Finally, the decrease in nitrate level using water hyacinth plants, apu-apu and lotus was 13.83%, 9.61% and 19.61%, respectively.

Keywords: phytoremediation; irrigation wastewater; IoT.

INTRODUCTION

Wastewater is generated from human activities during irrigation due to the accumulation and indiscriminate disposal of waste, which has significant negative impact on the environment and living things. Therefore, it is important to treat water waste to reduce the levels of polluting materials contained in water (Hu et al. 1999; Rafik et al. 2023; Serikbayeva et al. 2023; Hamdan et al. 2023).

The research on water pollution using plants, including the phytoremediation and aeration processes, has been conducted (Anamet et al. 2013). Phytoremediation is the use of aquatic green plants, in collaboration with microbiota, enzymes, water consumption, soil amendments, and agronomic techniques to remove, contain or neutralize harmful contaminants, such as heavy metals, pesticides, xenobiotics, organic compounds, toxic aromatic pollutants, and acidic mining drainage from the environment (Suresh and Ravishankar 2004; Yuliasni et al. 2023). Furthermore, aeration is the process of adding dissolved oxygen to the water to increase the percentage of its content (Hussain et al. 2019). It is a process in physics that prioritizes mechanical, rather than biological elements. Increasing the oxygen content in water removes the taste and smell of volatile substances, such as hydrogen sulfide and methane (Komala and Aziz 2019). Wastewater treatment by monitoring water quality, is a method of taking regular water samples to analyze the condition and characteristics of water (Harrou et al. 2018). Treatment can also be conducted using a monitoring system based on Internet of Things (IoT) with parameters measuring acidity (pH), temperature, and turbidity in water through the internet network (Noerhayati et al. 2022; Daigavane and Gaikwad 2017; Hendrawati et al. 2019). IoT is a medium for wireless data transmission over the Internet without any interconnection between humans and computers. This concept is useful in remote monitoring through a web server (Gondchawar and Kawitkar 2016; Nehru 2018). Several aquatic plants were used in the phytoremediation process carried out in this research, including water hyacinth, apu-apu, and lotus. The water hyacinth plant, also known as *Eichornia Crassipes*, is aquatic and often used to absorb pollutants (Ali et al. 2020; Rahmawati 2020). It also absorb nutrients in organic and inorganic compounds found in wastewater (Gumelar et al. 2015). Apu-apu aquatic plant (*Pistia stratiotes*) is a phytoremediator used to treat heavy metals, as well as organic and inorganic substances (Mamonto 2013). Furthermore, lotus is a plant with roots and leaves at the bottom and above the water's surface, respectively. This plant is widely used as a phytoremediator to absorb the pollutants contained in wastewater (Ain Khaer and Nursyafitri 2019). It is important to note that the research on irrigation water monitoring using the IoT-based phytoremediation process is still limited. Therefore, this research was conducted to determine the quality control system of irrigation wastewater using the IoT-based phytoremediation method.

MATERIALS AND METHODS

Plants quality

The sampling location for the wastewater test was the irrigation canal of Sukoanyar Village, Tumpang District, Malang Regency, geographically located at 7°59'13" South Latitude and 112°44'52" East Longitude. This research was conducted from January to February 2021.

Figure 1 is a pictorial representation of the sampling location for irrigation wastewater carried out at 2 sites. Samples 1 and 2 are located inside and near the tertiary canal of the Irrigation Area of Sukoanyar Village, Tumpang District, Malang Regency, Indonesia.

Research framework

Experiments were carried out directly on irrigation waste to meet the need of clean water using hydroponic plants, such as water spinach, lettuce, and pakcoy. Furthermore, the data consisting of

Figure 1. Irrigation wastewater sampling location

BOD, COD, nitrate, and phosphate tests were collected from the laboratory to determine their sensor, pH (acidity), turbidity, and temperature (Khatamian et al. 2019).

The irrigation wastewater used in this research was taken from irrigation canal. The wastewater test was carried out in the laboratory to determine the water content of the irrigation before the phytoremediation process. This was done by inserting the wastewater into a neutralizer system, installed with water hyacinth (*Eichornia Crassipes*), apu-apu (*Pistia Stratiotes*), and lotus (*Nymphaea sp*.) plants as shown in Figure 2. This process lasted 14 days, and the temperature, pH, and turbidity level were checked using IoT. The outcome of the wastewater treatment is re-tested with litmus paper and laboratory tests to determine change in water content and value.

Research variables and parameters

A control variable was used to determine the data from previous research (Menberu et al. 2021). The pH, turbidity, temperature, BOD and COD, nitrate, and phosphate levels are the parameters used in this research.

Tool design

Figure 2 is a container design using Autocad software with the holding tanks used for wastewater treatment (Ghernaout 2019). The holding tank with the highest elevation is the unprocessed type. The second tub is the aeration result tank from the

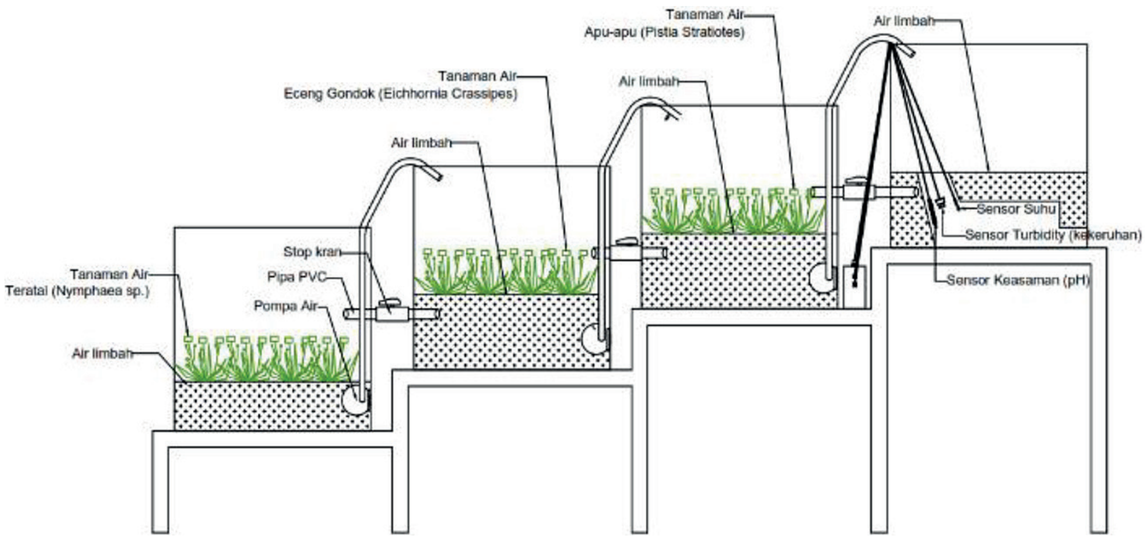

Figure 2. Tool design

first holding tank comprising various water plants, such as water hyacinth, lotus, and apu-apu.

Sensor testing is the calibration or adjustment of tool data designed with existing tools to measure the acidity (pH), turbidity, and temperature of water quality (Sadrishojaei et al. 2021). The pH sensor test, error value of temperature sensor testing (Table 1), and turbidity testing of each observation are 7.25%, 2.77%, and 6.94% (Table 2). This shows that the results of observations using IoT produced good value.

RESULTS

Range finding test

The range finding test (RFT) is the initial stage in a series of irrigation wastewater treatments using the bed system and the phytoremediation method (Thani et al. 2020). The number of plants to be used is calculated by determining the RFT stage of each aquatic mass plant and divided by the wet weight of plants (Damanik and Purwanti 2018). In this RFT, concentration variations are carried out to determine the ability of plants to absorb pollutants (Güsewell 2004). The concentration variations used were 0% (control), 10%, 20%, 40%, 60%, and 80%, which were reduced to 0% (control), 20%, 25%, 30%, 35%, and 40%. This research showed that the three types of plants had no significant death effect (Table 3–5). Therefore, the aquatic plants did not die nor wither for 7 days.

The phytoremediation test analyses the load per plant unit carried out on each plant (Trapp and Karlson 2001). By calculating the volume of

Table 1. Temperature sensor testing

No	Termometer read (°C)	Sensor read (°C)	Difference	Error (%)
1	24	23.5	0.5	2.13
2	23.5	23	0.5	2.17
3	23.5	23	0.5	2.17
4	24	23.5	0.5	2.13
5	24	23.5	0.5	2.13
6	25	24	1	4.17
7	25	24	1	4.17
8	25	24	1	4.17
9	25	24	1	4.17
10	25	24	1	4.17
11	25.5	25	0.5	2
12	25.5	25	0.5	2
13	25.5	25	0.5	2

Table 2. Turbidity testing

No	Sensor results	Convert in volts (V)	Avometer (V)	Difference	Error
1	475	2.32	2.50	0.18	7.76
2	383	1.87	2.00	0.13	6.95
3	437	2.14	2.00	0.14	6.54
4	495	2.42	2.50	0.08	3.31
5	393	1.92	2.10	0.18	9.38
6	453	2.21	2.40	0.19	8.60
7	381	1.86	2.00	0.14	7.53
8	418	2.04	2.10	0.06	2.94
9	473	2.31	2.50	0.19	8.23
10	361	1.76	2.00	0.24	1.64
11	530	2.59	2.50	0.09	3.47
12	450	2.20	2.40	0.20	9.09
13	570	2.79	3.00	0.21	7.53
14	471	2.30	2.50	0.2	8.70
15	428	2.09	2.10	0.01	0.48
Error averrage					6.94

Table 3. Results of the water hyacinth plant range finding test

Irrigation wastewater concentration (%)	Number of water hyacinths	Stay alive	Die	Water hyacinth death effect
0	2	2	0	0
10	2	2	0	0
20	2	2	0	0
40	2	2	0	0
60	2	2	0	0
80	2	2	0	0

Table 4. Results of the apu-apu plant range finding test

Irrigation wastewater concentration (%)	Number of apu-apu	Stay alive	Die	Apu-apu death effect
0	2	2	0	0
10	2	2	0	0
20	2	2	0	0
40	2	2	0	0
60	2	2	0	0
80	2	2	0	0

Table 5. Results of the lotus plant range finding test

Irrigation wastewater concentration (%)	Number of lotuses	Stay alive	Die	Lotus death effect
0	2	2	0	0
10	2	2	0	0
20	2	2	0	0
40	2	2	0	0
60	2	2	0	0
80	2	2	0	0

water multiplied by the initial BOD, the obtained waste load capacity received by each water hyacinth, apu-apu and lotus plant is 2.2 mg, 3.2 mg, and 2.4 mg, respectively.

COD parameter analysis

The COD value of each plant was analyzed (Abdalla and Hammam 2014) using the following formula:

$$\text{COD (mg/L)} = \frac{(A - B)\text{NFas} \times \text{P}}{V\ sample} \times 1000 \quad (1)$$

- The COD value of wastewater before being treated was 61.4 mg/L.
- The COD value of water hyacinth after processing was 25.6 mg/L.
- The COD value of apu-apu after processing was 20.15 mg/L.
- The COD value of apu-apu after processing was 20.23 mg/L.

Figure 3 shows that the COD of the water before and after the aeration and fire mediation processes decreased using the water hyacinth, apu-apu, and lotus (Rahman and Hasegawa 2011).

BOD parameter analysis

The following formula is used to calculate the BOD for each plant (Baklouti et al. 2018):

$$DO_0 = \frac{V\ Thiosulfat \times N\ Thiosulfat \times \times 1000 \times BeO_2 \times P}{V\ Sample} \quad (2)$$

- the BOD value of wastewater before being treated was 23.17 mg/L,
- the BOD value of water hyacinth after processing was 8.64 mg/L,

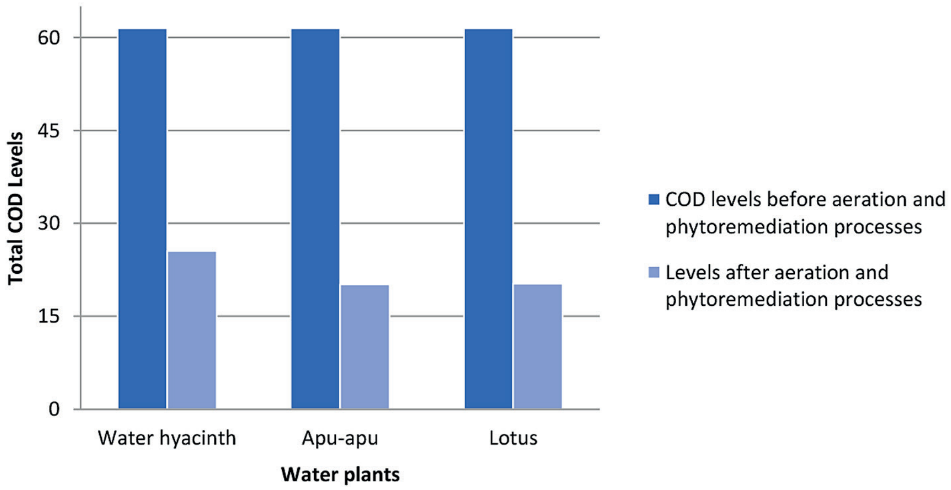

Figure 3. COD parameters graph

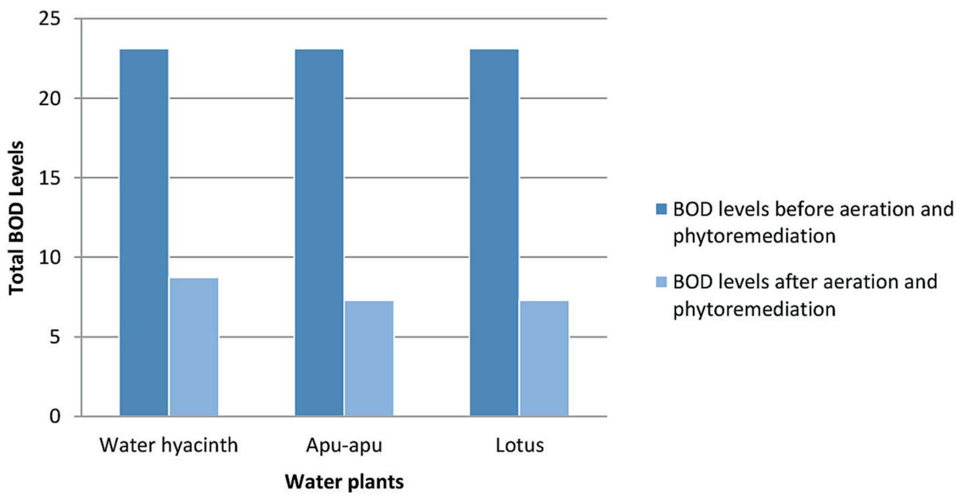

Figure 4. BOD parameters graph

- the BOD value of apu-apu after processing was 7.32 mg/L,
- the BOD value of lotus after processing was 7.29 mg/L.

Figure 4 shows that the BOD of water before and after the aeration and fire mediation processes decreased in value due to the use of water hyacinth, apu-apu, and lotus. This is in accordance with the research by (Rahman and Hasegawa 2011) that water hyacinth has the ability and mechanism to absorb arsenic as well as evaluate its potential in phytoremediation technology.

Phosphate parameter analysis

Phosphate parameter analysis was carried out based on the research by (Oumani et al. 2019), the results of which are shown in Table 6. The phosphate level of irrigation water before the aeration and firemediation processes was 0.7664, indicating that it was quite high. Furthermore, through the neutralization of aeration and phytoremediation, a decrease in the value of the phosphate level <0.0272 was obtained (Ng and Chan 2017).

The test method used to analyze nitrate parameters is according to the Screening Spectrophotometer (Korostynska et al. 2012). Figure 5 and Table 7 shows the value of the nitrate content of the irrigation water before the aeration and phytoremediation process of 10.03. Furthermore, this neutralization process showed a decrease in the nitrate level (Shyamala et al. 2019).

pH and temperature analysis

This research observed the increase and decrease in the degree of acidity or pH of wastewater (Gobi et al. 2011). The analysis showed that the wastewater pH fluctuated in the range of 6.5–9 due to prolonged exposure towards the neutral. This showed that the wastewater treatment process can increase or decrease the pH of the treated water (Deng and Zhao 2015).

At this stage, the wastewater temperature in each reactor, which ranges from 22–26 °C was measured. The decrease and increase in temperature were due to environmental factors (Gupta et al. 2016).

Table 6. Results of irrigation wastewater tests before and after treatment on phosphate parameters

No.	Parameter	Unit	Method	Ahead of processing	After of processing	Quality standards	Description
1	Water hyacinth plant						
	Phosphate	mg/L	SNI 06-6989.31-2005	0.7664	< 0.0272	< 2	Safe
2	Apu-Apu plant						
	Phosphate	mg/L	SNI 06-6989.31-2005	0.7664	< 0.0272	< 2	Safe
3	Lotus plant						
	Phosphate	mg/L	SNI 06-6989.31-2005	0.7664	< 0.0272	< 2	Safe

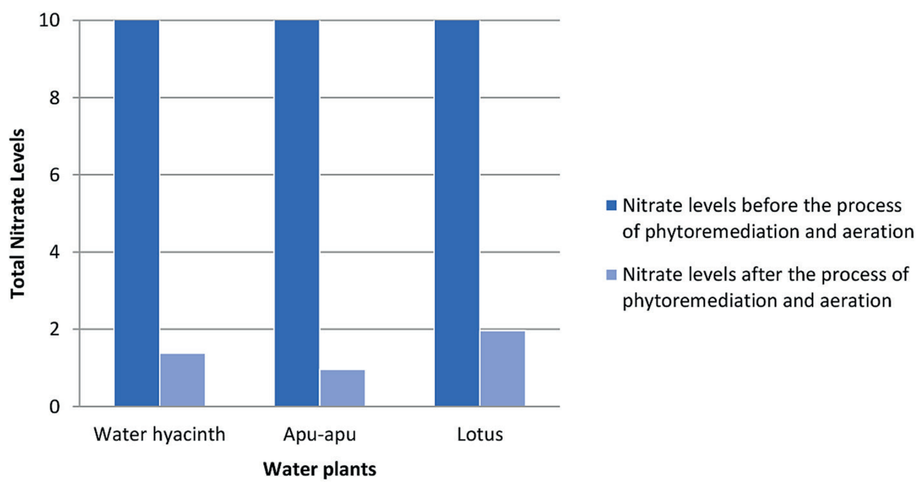

Figure 5. Graph of nitrate parameters

Table 7. Results of tests on nitrate parameters on irrigation wastewater before and after processing

No.	Parameter	Unit	Ahead of processing	After of processing	Quality standards	Description
1	Water hyacinth plant					
	Nitrate	mg/L	10.03	1.387	< 10	Safe
2	Apu-apu plant					
	Nitrate	mg/L	10.03	0.9634	< 10	Safe
3	Lotus plant					
	Nitrate	mg/L	10.03	1.967	< 10	Safe

Testing of acidity and temperature sensors

Testing of pH and temperature sensors was carried out under several conditions in the laboratory (Liang et al. 2007). The first test was conducted when the pH and temperature were below or above the average undesirable condition. Meanwhile, the second test was carried out when the pH and temperature were below or above the desired condition. The results of the pH sensor research showed an increase in value which originally ranged from 6.53 to 7.64 (Table 8).

The turbidity sensor needs to be tested in advance to determine the desired conditions of the water sample (Siregar et al. 2017). This includes providing the digital value on the sensor at 0–1023, at a temperature range of 25–30 °C. Table 9 show the results from testing the turbidity sensor.

The water circulation system was conducted based on the research by (Castiglioni et al. 2014), with pH and temperature of 6.5–8.5 and 25–30 °C, respectively. Various conditions were used to obtain the needed circulation pump to make the desired condition. The following table shows the water circulation test results.

Table 8. pH and temperature sensors testing

No.	Initial pH	Final pH	Initial temperature (°C)	Final temperature (°C)	Pump status
1	4.23	3.4	25.44	26.13	ON
2	4.64	3.8	25.19	26.06	ON
3	4.33	3.8	25.06	26.06	ON
4	4.75	4.33	25.06	26.06	ON
5	3.63	4.68	25.06	26.06	ON
6	6.67	7.55	25.75	26.31	ON
7	6.69	7.38	25.75	26.25	ON
8	6.53	7.65	25.69	26.19	ON
9	6.99	7.89	25.69	26.25	ON
10	7	7.86	25.69	26.25	ON

Table 9. Turbidity sensor testing

No.	Turbidity initial	Final turbidity	Temperature initial (°C)	Final temperature (°C)	Pump status	Pump time (seccond)
1	373	626	25.69	25.89	ON	± 30
2	303	398	25.13	25.44	ON	± 30
3	336	429	24.94	25.38	ON	± 30
4	677	745	24.81	25.38	ON	± 30
5	301	416	24.81	25.38	ON	± 30
6	564	780	26.5	27.75	ON	± 60
7	494	617	26.56	27.69	ON	± 60
8	483	607	26.5	27.75	ON	± 60
9	536	684	26.5	27.69	ON	± 60
10	503	635	26.56	27.69	ON	± 60

CONCLUSIONS

The characteristics of irrigation wastewater before processing had a pH, COD, BOD, phosphate and nitrate contents of 6, 61.44 mg/L, 23.11 mg/L, 0.7664 mg/L, and 10.03 mg/L, respectively. The wastewater was treated with a phytoremediation process using water hyacinth, apu-apu, and lotus, followed by aeration. This research showed a pH increase in a range of 7–8 and a decrease in COD level by using water hyacinth, apu-apu, and lotus by 41.55%, 32.77%, and 32.91%, respectively. The decrease in BOD level using water hyacinth was 37.82%, while apu-apu and lotus was 31.54%. Meanwhile, the decrease in phosphate level using those three plants was 3.55%. The decrease in nitrate level using water hyacinth, apu-apu, and lotus was 13.83%, 9.61%, and 19.61%, respectively.

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