ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2523-5664 (Print)
ISSN: 2523-5672 (Online)
CODEN: WCMABD

Water Conservation & Management (WCM)

DOI: http://doi.org/10.26480/wcm.01.2024.31.36

CrossMark

RESEARCH ARTICLE

POTENTIAL USES OF SUBMERGED AQUATIC PLANTS AND BACTERIA IN THE DEVELOPMENT OF WATER TREATMENT EQUIPMENT

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ARTICLE DETAILS

Article History:

Received 23 August 2023
Revised 26 September 2023
Accepted 16 October 2023
Available online 19 October 2023

ABSTRACT

Water as one of the basic needs of living things, must be maintained well. Various methods and techniques were developed for water conservation or treating wastewater into reusable water. This research developed a wastewater treatment technique using plants and aquatic bacteria. The plants used were submerged (in water), namely Microsorum Pteropus, Water Fern (Trichomanes L), Bucephalandra, and Hydrocotyle tripartite. While the water bacteria used were active Bacillus and Lactobacillus. After the experimental equipment was designed and made, measurements were made of water parameters in the form of temperature, acidity (pH), Total Dissolved Solid (TDS), dissolved oxygen (DO), turbidity, ammonia levels, and chlorine levels. According to the findings of this study, water product from the aquatic plant treatment showed a good result, meaning that the aquatic plants can neutralize water pH, reduce dissolved solids (TDS), increase oxygen levels (DO), purify water, and eliminate ammonia and chlorine levels. On the other hand, products from bacterial water treatment can neutralize pH, reduce TDS, reduce oxygen (DO), purify water, and eliminate ammonia, however, they cannot remove chlorine. So, water treatment with this method is very safe for the environment, easy, low-cost, and does not produce harmful by-products.

KEYWORDS

Water Treatment, Submerged, Water Parameters, Bacteria, Eco-Friendly

1. INTRODUCTION

Environmental issues are one of the most important and interesting areas to study. Environmental damage in various countries is a major problem that requires a large budget to resolve. Rapid development in various fields such as manufacturing, agriculture, animal husbandry, and trade further aggravates this environmental condition. Here are some examples of cases published by the mass media, namely: the case of pollution of the Elo River in Magelang, which constantly changes the color of the river. This is assumed to be caused by the large number of textile factories in the riverbank area (Gatra, 2020). Furthermore, there is also the incident of the Bengawan Solo River water turning red due to polluted activities of the textile industry (batik, a local ethnic textile) and the liquor industry (iNews, 2019). The results of an investigation by Walhi, environment observer organization in Indonesia reported that the Batanghari River became a very polluted and can't be used anymore.

Waste in this river comes from the rubber industry, palm oil industry, gold mining, coal mining, and deforestation (Republika, 2023). According to Kompas, the daily newspaper, on August 10, 2021, Badan Pusat Statistik (Statistics Indonesia) published a report on the commemoration of River Day on July 27, 2021, which stated that 46% of rivers in Indonesia are in a state of heavily polluted; and according to the report by National Geographic in March 2020, 57% of waste end in rivers, and as much as 8.2% come from textile waste (Kompas, 2021). This shows that the condition of rivers in Indonesia is at an alarming level. This damage will cause many side effects for living things that depend on rivers, especially human health problems, reduced food security due to many dead aquatic animals and plants, and the loss of the main function of rivers as a useful medium for supporting human life.

Some of the parameters of water quality is pH, turbidity, iron content, and other solidities. The metal content that pollutes the water is also an indicator of industrial waste being released into the river. If the public consumes the dissolved metal content in water, it can be very harmful to their health. There are several waste particles in water that can be carcinogens and cause cancer, namely lead, chromium, cadmium, molybdenum, zinc, copper, barium, and nickel (Mohammadi et al., 2019). To solve environmental problems, especially river water pollution, appropriate, cheap, and efficient technology is needed. Currently, there are many methods used to reduce the problem of industrial waste in river, for example, research has shown that that aquatic plants can be utilized to degrade organic matter and phosphate pollution to improve water quality. Wastewater treatment involves utilizing aquatic plants as phytoremediation agents or organic matter traps and cleaning heavy metal pollution, oil materials, and pesticide materials. The aquatic plant used is Azolla sp., Spirodela sp. (Duckweed), Lemna sp., Salvinia sp., Pistia sp., and Eicchornia crassipes (water hyacinth).

The success of the phytoremediation method depends on the selection of plants to be used (Ansari et al., 2020; Farraji et al., 2020; Yang et al., 2020) and this technique can degrade contaminants that affect water quality (Mohebi and Nazari, 2021). The results of another research on five types of plants such as Centella asiatica, Ipomoea aquatica, Salvinia molesta,

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Cite The Article: Rahmi Putri Wirman, Indang Dewata, Heldi, Vandri Ahmad Isnaini (2024). Potential Uses of Submerged Aquatic Plants and Bacteria in The Development of Water Treatment Equipment. *Water Conservation & Management, 8(1): 31-36.*

Eichhornia crassipes, and Pistia stratiotes show that they are able to absorb three pollutants, namely TSS, NH3-N, and Phosphate (Nizam et al., 2020). The plants used are floating plants that reside on the surface of the water. These plants are quite easy to maintain because the structure of the leaves is above the water, so they can easily get sunlight for photosynthesis. Water hyacinth plants are used for textile (*batik*) waste management (Safauldeen et al., 2019), and this plant can reduce COD, TDS, TN, turbidity levels optimally (Alawadhi and Hayder, 2021). Pistia sp. have good nitrate and phosphate absorption abilities and are recommended to be used for water treatment (Dewi et al., 2020). In addition, Pampas grass has also been tested in water treatment (Mirzaee et al., 2021). Ceratophyllum demersum was also used to measure the efficiency in removing Cadmium pollutants (Abdulwahid, 2023). The results of a study also showed that the percentage of degradation of Pistia sp. can reduce BOT by 55.52% and P-PO4 by 60.62%, and water hyacinth can reduce BOT by 23.38% and P-PO4 by 92.68%. These two plants are the best at degrading organic matter and phosphate in water (Astuti et al., 2018).

Another study used the bacterium Pseudomonas aeruginosa to degrade heavy metal waste in water. Pseudomonas aeruginosa bacteria was used to specifically break down aluminium particles in wastewater. The results found that these bacteria can separate and remove 46% of the aluminium particles from the wastewater (Purwanti et al., 2019). Additionally, Fuji Electric Japan made the latest wastewater treatment system using Bacillus bacteria. These bacteria are used as an alternative medium for aeration and the clumping of solid particles. Therefore, waste treatment process that uses this method can save operational costs. The results showed that this method can reduce operational costs by 20% and solid material degradation process costs by 25% (Taguchi et al., 2017). Water treatment can also use non-living materials, such as wastewater treatment using the photocatalyst method made from TiO_2, or titanium dioxide (Dutta, 2020).

Water quality can be determined qualitatively and quantitatively. There are three determining parameters of water quality that are widely used by the community: physical parameters, chemical parameters, and biological parameters. The physical parameters of water include turbidity, temperature, colour, taste, smell, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and electrical conductivity. The chemical parameters of water are pH, Chloride, Chlorine, Sulphate, Nitrogen, Hardness, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), toxic levels, and radioactive levels. While the biological parameters of water are the levels of bacteria, algae, viruses, and protozoa (Hassan Omer, 2020a). Physical parameters can be measured quantitatively using measuring instruments, so that the standard value can be a precise reference for water quality. But qualitatively, physical parameters can also be determined using human senses, such as the level of turbidity, color, smell, and taste. These parameters indicate the presence or absence of other particles dissolved in the water. External factors, such as wind-induced turbidity in shallow water and the influence of strong water currents, can also have an impact on the quality of water (Gómez et al., 2017).

The filtration method (mechanical system) is a straightforward technology that the community frequently uses. This method is quite effective for reducing solid particles, and the system is also supplemented with activated carbon that allows it to remove toxic substances (Cescon and Jiang, 2020). Plant utilization is also a good way to improve water quality. This method is one part of phytoremediation techniques, which use plants to treat and control waste in water, air, and soil (Futughe et al., 2020). The potential of plants used in water treatment can be seen in Table 1. Then research on five aquatic plants; Centella asiatica, Ipomoea aquatica, Salvinia molesta, Eichhornia crassipes, and Pistia stratiotes found that they can reduce harmful substances (TSS, NH3-N, and phosphate) drastically on day 14 (Nizam et al., 2020).

The next method that is also effective in the water treatment process is using bacteria as waste or impurities degraders. Microbes can degrade dissolved solids, heavy metals, and other organic waste. The use of bacteria (flocculating microorganisms) has been proven in wastewater treatment, including coal mining waste, food waste, urban waste, leachate water, heavy metal waste, papermaking waste, textile waste, printing waste, and dyeing waste (Li et al., 2020).

Table 1: The identified plant taxonomic diversity can be used as a water treatment (Moa Megersa, 2014).

Family	Number of derivatives	Percentage	Number of species	Percentage of species
Fabaceae	10	26.3	10	25
Fagaceae	2	5.2	4	10
Malvaceae	3	7.8	3	7.5
Cactaceae	2	5.2	2	5
Cucurbitaceae	2	5.2	2	5
Euphorbiaceae	2	5.2	2	5
Poaceae	2	5.2	2	5
15 Other families	15	39.4	15	37.5
Total	38	100	40	100

From various aspects of this background study, this study develops water treatment tools by utilizing aquatic plants and bacteria and analyzes the effectiveness of these tools by measuring the results of treated water parameters. These tools are expected to be a reference and participate in solving environmental problems using technology that is efficient, measurable, low-cost, and can be applied on a home scale. The use of aquatic plants and bacteria is a natural way of treating so that it will not cause health side effects or waste products.

2. Method

The research method was an experimental process of designing, making, and testing the performance. The initial stage was the collection of supporting data derived from references in the field of environmental science. Supporting information was obtained through observation methods and interviews with the community, peers, and experts in their fields. The design of the water treatment equipment was compact and works efficiently (prototype) in a small size. The design of water treatment equipment using plants and aquatic bacteria can be seen in Figure 1.

The design and manufacture of this tool must provide good work efficiency and improve water quality quickly. The level of working efficiency of the tool is measured based on changes in the parameter values of the treated water. The measured water parameters are temperature, acidity (pH), Total Dissolved Solid (TDS), dissolved oxygen (DO), turbidity, ammonia, and chlorine. The water sample used as a trial was river water, with water parameter testing carried out in the laboratory every day for nine days of the treatment process.

The plants used were freshwater aquatic plants found in Indonesia. Submerged plants, which means drowned plants, live below the surface of water. They include Microsorum pteropus, Water Fern (Trichomanes L), Bucephalandra, and Hydrocotyle tripartita. This plant-growing medium uses a substrate tied to the roots of the plants. To enable photosynthesis in plants, Light Emitting Diode (LED) was used instead of the sun. Artificial sunlight is used in anticipation of irregular changes in sunlight intensity. To increase the level of effectiveness of the tool, in addition to using aquatic plants, aquatic bacteria were also used. The bacteria used in this study were active Bacillus and Lactobacillus. Water bacteria are grown in a solid bacterial house that has high porosity. The higher the porosity of the bacterial house is, the more surface area available, so that more bacteria can live. Pumice stone can also be used as a bacterial house; this media can be easily searched for, and the price is low. For the beginning of device circulation, bacteria must first be grown by dissolving the bacterial starter in the bacterial house container.

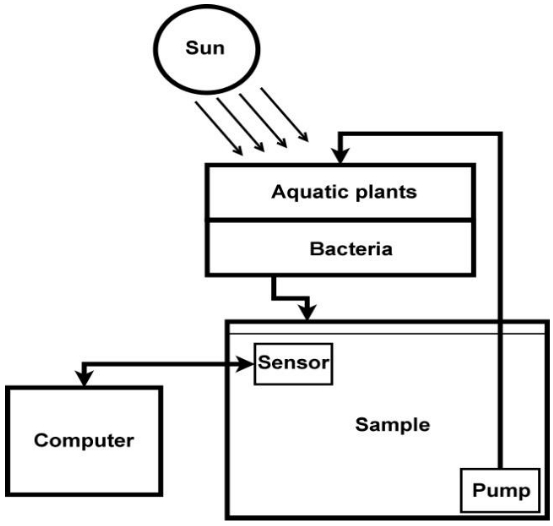

Figure 1: The design of water treatment equipment uses aquatic plants and bacteria.

3. Results and Discussion

3.1 Characteristics of Water Treatment Equipment Using Aquatic Plants and Bacteria

Water treatment equipment consists of a water chamber to be treated, an aquatic plant chamber, a water bacteria chamber (bacterial house), a circulation pump, LED lights as artificial sun, a bacterial house, a CO_2 source to stabilize plants, an oxygen aerator for bacterial growth, and a water temperature sensor. Aquatic plant growing medium uses a substrate tied to plant roots; this medium is also used as ballast so that plants are submerged in water. For bacterial growth, the bacterial source used is as much as 2 mL per 10 L of water. To accelerate the growth of bacteria, the container is given oxygen with an aerator system. Temperature sensor is used as a monitor of temperature parameters to ensure the ideal temperature for the development of plants and aquatic bacteria. Good growth of aquatic plants occurs in the temperature range of 20–30°C. For photosynthesis, plants use artificial light so that the rays they receive are stable and they can receive full sunlight within a day. The irradiation time lasts for 10 hours a day. This study used several types of LED lights, namely white LEDs, white and blue LEDs, white, blue, red, and RGB (polychromatic) LEDs. The characteristics and effects of lights on aquatic plants can be seen in Table 2 below.

Table 2: Characteristics and effects of lamps on aquatic plants

LED Type	Length x Width (cm)	Light Intensity (LUX)	Plant conditions
White LED	15 x 3	4937	The condition of aquatic plants every day decays, the leaves turn yellow and thaw, on the 9th day the plants begin to die
2-color LEDs (white and blue)	15 x 7	12600	The condition of aquatic plants every day is subject to decay, the leaves turn yellow and melt
3-color LEDs (White, red, blue)	45 x 7	27110	The plant develops well for 7 days, but after that it changes color to yellow
LED RGB (*Polychromatic*)	30 x 10	33510	At the beginning the plant is slightly adapted where there are some yellowed leaves but then the plant develops well and the color remains green until the 9th day

Bacterial medium, or bacterial houses, are very important so that bacteria do not dissolve in circulating water. The bacterial house in this study was provided in the form of a porous solid. The more pores the bacterial house has, the more surface area the medium will have, and the more bacteria will grow in the area. From the results of microscope analysis, the bacterial house has pores of varying sizes, with diameters ranging from 0.16 to 0.79 mm with an average of 0.34 mm.

3.2 Parameters of Water Product from Aquatic Plant Treatment

The water temperature during the treatment process ranged from 28.3 to 30.80°C. The pH measurement results from the water product showed a decrease in pH value from 7.73 to 6.19 (Figure 2). Aquatic plants have the ability to reduce alkali levels in water. From observations, there are several factors that cause plants to experience initial adaptation to artificial sunlight (LED lights) at the beginning of the process, so that some leaves experience yellowness and soften (dissolve into water). The dissolution of plant parts reduces the pH value of water. Similarly, water on peatlands are acidic because many plant remains are submerged. Once stabilized, the pH value rises again and persists between values of 6 and 7. Plants will experience severe changes if contaminated with waste, such as water hyacinth plants contaminated with batik waste, so that the measured pH level is 6.55 to 7.9 (Safauldeen et al., 2019). Changes in pH are also influenced by the process of photosynthesis (Kumar and Deswal, 2020)

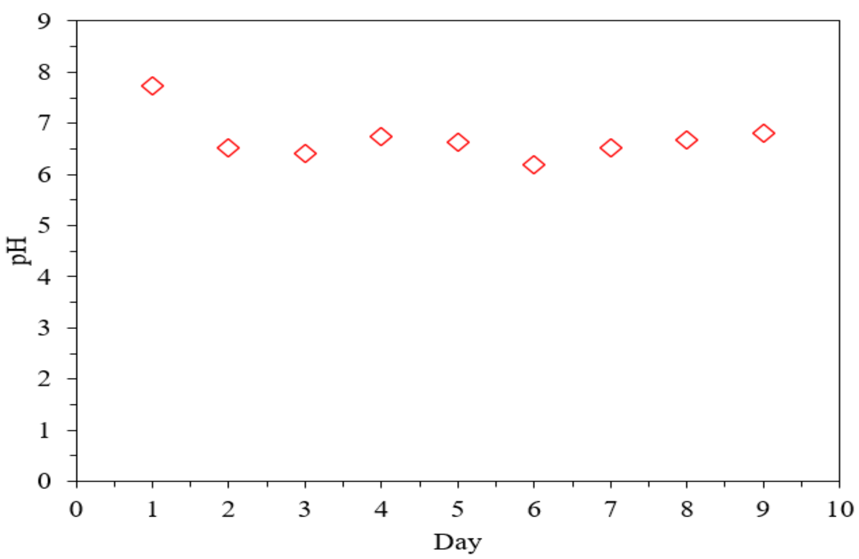

Figure 2: pH measurements result from water samples processed by aquatic plants.

The water-dissolved solids (TDS) parameter in the sample showed a decrease from 333 to 277.6 ppm (Figure 3). From observations, substances or minerals dissolved in water will be consumed by plants for photosynthesis. Day five onward showed a significant decrease in TDS values, indicating that aquatic plants would have adapted first to LED lights at the beginning of the study. Concentrations of wastewater contaminants also affect TDS values. Tests conducted on Salvinia molesta plants can eliminate TDS with an efficiency value of 11% on the first day and an efficiency value of 77% on the 8th day (Alawadhi and Hayder, 2021; Chandanshive et al., 2016).

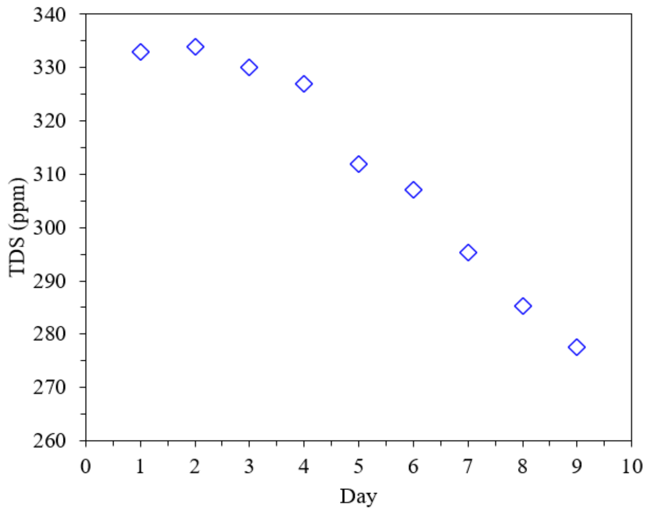

Figure 3: TDS measurements result from water samples processed by aquatic plants.

Then the parameter DO, or dissolved oxygen levels, showed an increase from 51.7% to 165.8% (Figure 4). The increase in DO value is an effect of the process of photosynthesis that produces oxygen in aquatic plants. Moreover, the turbidity level shows a decreasing value, or the water is getting clearer in line with the processing time. The turbidity value in the sample decreased from 89.7 NTU to 7.03 NTU on the ninth day (Figure 5). This proves that plants have absorbed the elements or minerals responsible for water turbidity through photosynthesis.

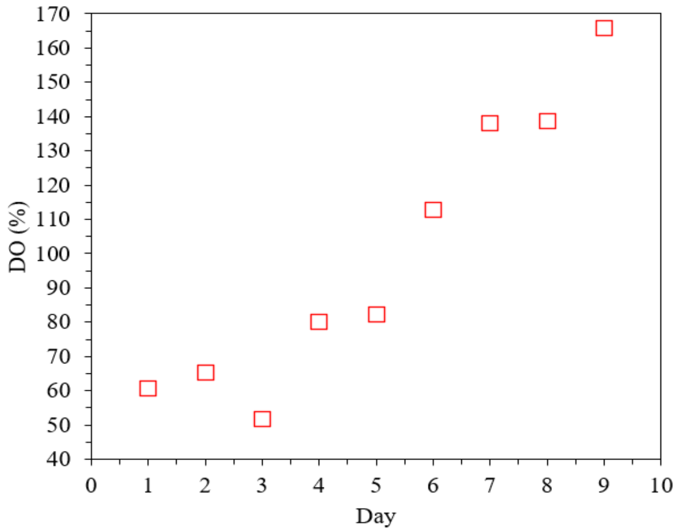

Figure 4: DO measurements result from water samples processed by aquatic plants.

The measurement of ammonia and chlorine levels also decreased. Ammonia in the sample decreased from a value of 0.5 mg/l to completely disappeared on the third day of the processing process and chlorine levels in the sample decreased from a value of 0.1 mg/l to completely disappeared on the second day of the processing process. This shows that ammonia is absorbed by plants and has an important role in the photosynthesis process, but chlorine needs further study to determine whether it is beneficial or has a negative effect (damaging) on aquatic plants (Mustafa and Hayder, 2021). However, chlorine can react with organic substances in water to form toxic compounds and carcinogens called THM trihalomethanes (Hassan Omer, 2020b).

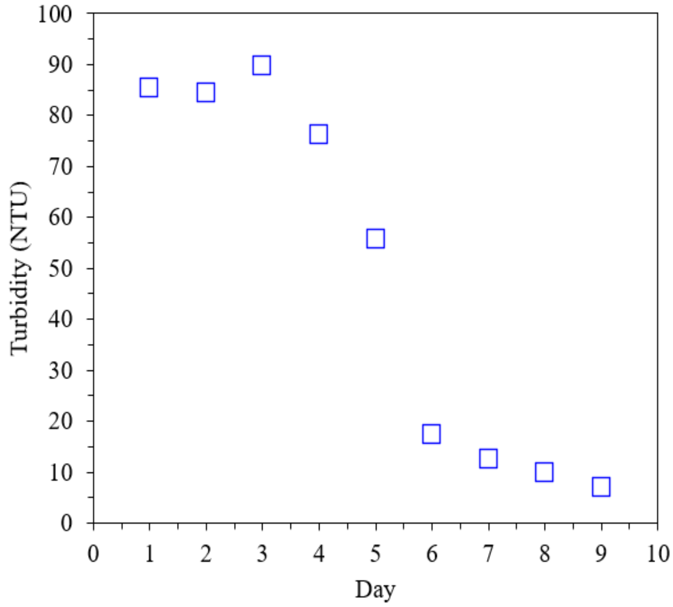

Figure 5: Turbidity measurements result from water samples processed by aquatic plants

Experimental results have shown that the use of submerged plants can improve water quality. Comparison of efficiency values in removing erythromycin also proves that for phytoremediation methods in submersible plants was more efficient (Rocha et al., 2022).

3.3 Parameters of Water Product from Aquatic Bacteria Treatment.

The water temperature during the treatment process ranged from 28°C to 29,70°C. Measurement of pH parameters from the water product showed an increase from 6.57 to 7.09 (Figure 6); this phenomenon is the opposite of processed aquatic plants. Some external factors can also influence the bacteria, such as the basic ingredients of the bacterial house. This increase in pH value slows down on the seventh day, but it takes additional time to prove whether the process of flattening this value will take place continuously the next day, which would mean that water bacteria can neutralize the pH of the water.

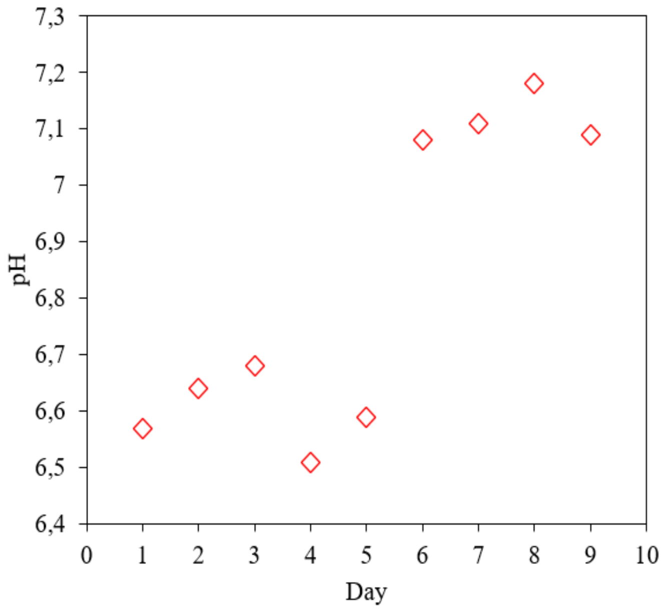

Figure 6: pH measurements result from water samples processed by bacteria.

Furthermore, the TDS parameter, or dissolved solid content, showed a decrease, from 328 to 326 ppm (Figure 7). The results of this TDS measurement have an anomalous pattern that changes, so it cannot be accurately concluded whether water bacteria can increase or decrease TDS significantly. Research observations show this can be influenced by aquatic bacterial culprits and bacterial house substances that dissolve or are released into the water.

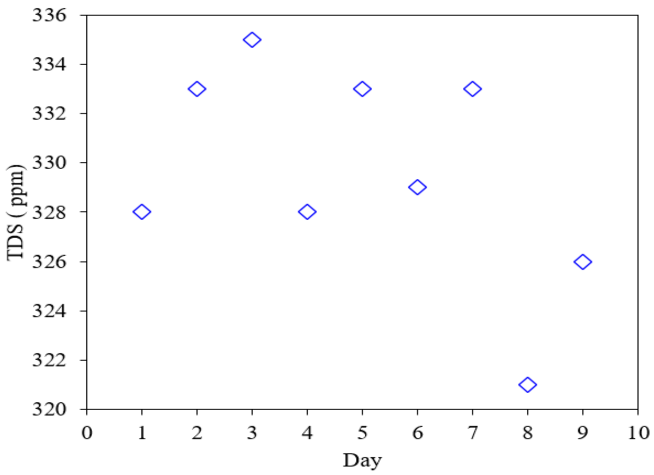

Figure 7: TDS measurement results from water samples processed by water bacteria.

The dissolved oxygen (DO) parameter in this treated water sample showed a decrease from 95.1% to 59.2% (Figure 8). Decreased oxygen levels due to oxygen needed by water bacteria for the degradation process of impurities in water. Furthermore, for water turbidity parameters, this sample decreased from 91.35 NTU to 90 NTU within 9 days (Figure 9). This value is in line with the degradation process of impurities by aquatic bacteria, so the more time goes by, the clearer the water will be.

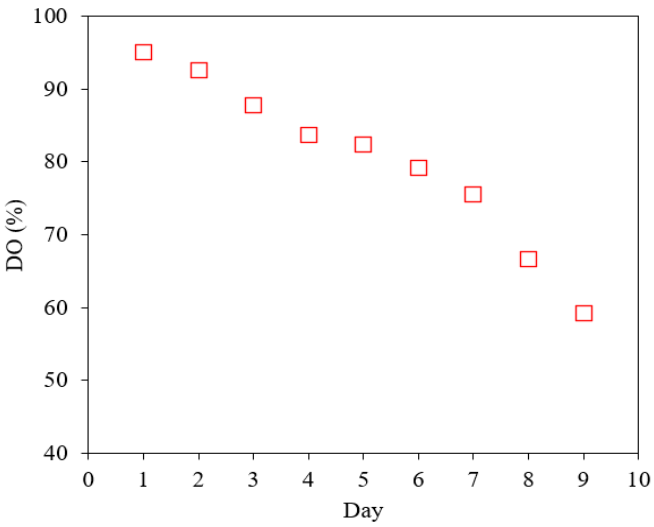

Figure 8: DO measurement results from water samples processed by water bacteria

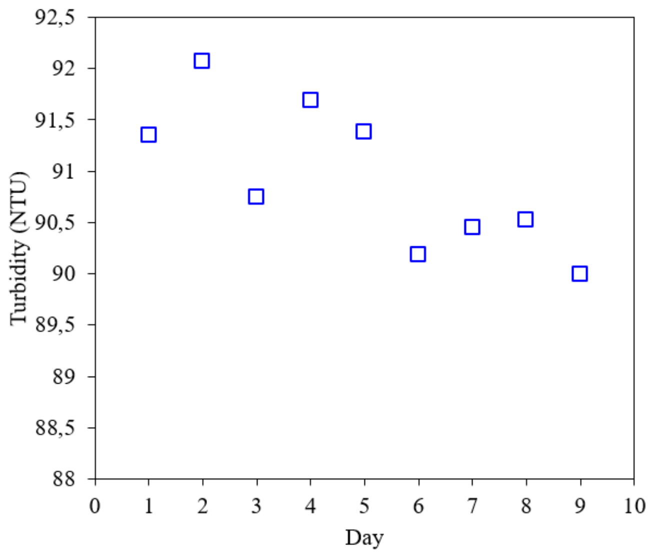

Figure 9: Turbidity measurement results from water samples processed by water bacteria

Ammonia levels in the samples also showed a decrease from 0.5 mg/l and were exhausted on the third day of processing. In studies using Sphingomonas sp. also showed a decrease in ammonia nitrogen from 8 mg/l to 0.3 mg/l within 48 hours (Yun et al., 2019). As for chlorine levels in water, there is no change in value because chlorine not only interferes with the performance of bacteria but can also kill bacteria in water. The higher the concentration of chlorine in the water, the fewer live bacteria there are (Cheswick et al., 2020).

4. Conclusion

The use of aquatic plants and bacteria is a good method for water treatment. Making water treatment equipment with this method was easy, and using simple methods. Findings from the study the water treatment using aquatic plants showed a good performance, which can neutralize water pH, reduce dissolved solids (TDS) levels, increase oxygen levels (DO), purify water, eliminate ammonia and chlorine levels. While water treatment using bacteria can neutralize pH, reduce TDS, reduce oxygen (DO), purify water, and remove ammonia, but it cannot remove chlorine. So, water treatment with this method is very safe for the environment (natural method), the process is easy, low-cost, and it does not produce by-products that are harmful to humans or the environment.

Acknowledgements

The authors would like to acknowledge UIN Sulthan Thaha Saifuddin Jambi and Universitas Negeri Padang for its support.

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