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Utilization of Aquatic Plants as Phytoremediation Agents of Tofu Liquid Waste

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The tofu industry produces a lot of tofu liquid waste and has the potential to cause waters to be toxic and dangerous for the life of the biota aquatic. This research uses a phytoremediation method using floating water plants. The purpose of this research was to obtain water plants that have better absorption ability as phytoremediation agents for tofu liquid waste between Lemna and Kiapu aquatic plants. This research was conducted at the Laboratory of Aquatic Resources, Faculty of Fisheries and Marine Sciences, Padjadjaran University from March to September 2019. The method used in this research was an experimental method with a Completely Randomized Design (CRD) consisting of three treatments and five replications. Tofu liquid waste samples were obtained from the Tofu Factory in the Cibuntu Tofu Industry Center. Physical and chemical parameters observed include temperature, acidity, dissolved oxygen, BOD_5, nitrate, and phosphate. The results showed that the Kiapu had better nitrate and phosphate absorption ability than Lemna and the combination treatments for 15 days of observation. The result showed that the decrease in nitrate concentration was 10.12-62.24% and the decrease in phosphate concentration was 6.67-54.23%. Kiapu can be recommended as phytoremediation agents for tofu liquid waste to remediate high organic matter before being discharged directly into water bodies.

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Keywords: Lemna sp.; phytoremediation; Pistia stratiotes; tofu liquid waste.

1. INTRODUCTION

Tofu is one of the foods that are favored by the people of Indonesia because it has good taste and is easy to get. The tofu industries thrive in Indonesia, one of which is in the city of Bandung is the Cibuntu Tofu Industry Center as a tofu-making area. Cibuntu Tofu Industry is spread over in the Babakan Sub-district of Ciparay which is dominated by home industries located in the Babakan and Sukahaji Villages. Babakan Urban Village was inaugurated as the Cibuntu Tofu Craftsman's Center in 2012 by the Bandung City Government through the Bandung City Industry and Trade SME Cooperative Office. The total of small and micro industries in Babakan Sub-district Ciparay reached 739 units and Babakan Sub-district reached 30.58% [1].

The process of making tofu produces liquid waste and solid waste. The resulting wastewater is quite large and comes from the process of washing, soaking and disposing of liquid from a mixture of solid tofu [2]. Tofu industry liquid waste contains high organic ingredients, especially protein and amino acids derived from soybeans. Protein compounds have the greatest amount, reaching 40%-60%. These organic compounds cause tofu industry liquid waste containing high BOD, COD and TSS. Tofu industry liquid waste in general has the characteristics of temperatures ranging from 37-45ºC; BOD_5 6,000-8,000 mg/L and COD 7,500 - 14,000 mg/L [3]. Tofu liquid waste discharged directly into water bodies can cause water problems because it contains protein (N-total) of 226.06-434.78 mg/L. Therefore, the inclusion of tofu liquid waste into the aquatic environment will increase the total nitrogen in these waters [3] which degrade into inorganic materials such as ammonia under oxidation to nitrite and nitrate [4].

Tofu liquid waste can cause waters to be toxic and dangerous for the life of biota [5], can reduce oxygen levels in the waters and cause the death of fish and another biota aquatic [2]. Tofu waste has the potential to pollute air and soil. Air pollution in the form of odour pollution resulting from anaerobic degradation of organic matter. Soil pollution in the form of pollution from liquid waste that enters the soil can damage groundwater [6]. Tofu wastewater needs to manage to reduce the negative impact on the aquatic environment.

Several processes are already widely used for treating tofu liquid waste so as not to pollute the environment, including the process of using aerobic - anaerobic reactors, aerobic bio-filter, and phytoremediation [7]. Researchers in this study used phytoremediation method to treat tofu liquid waste. Phytoremediation is from the Latin word *Pytho*, which means plant, and the word *Remidium,* which means to restore balance [8]. Phytoremediation promises economically effective biotechnology that uses plants to clean polluted water and soil. Phytoremediation can be used for inorganic and organic contaminants that exist in soil, air, and water [9].

Kiapu (local name) or *Pistia stratiotes* has the potential to removal concentrations of wastewater pollutants that have high organic concentrations. This plant is used as an absorber of toxic elements in industrial wastewater. Kiapu has several advantages, including high germination, rapid growth, absorption rate or absorption of nutrients and water which is large, easily found, and high adaptability to climate [10].

Lemna (local name) or *Lemna* sp. can absorb pollution through the roots which can absorb well from aquatic and sedimentary components [11]. Besides, Lemna has an effective phytoremediation ability in improving the quality of water contaminated [12]. Based on the description, Lemna and Kiapu aquatic plants have the ability as phytoremediation agents. Both of these aquatic plants are used in remediating tofu liquid waste. The purpose of this study is to obtain water plants that have better absorption ability as phytoremediation agents for tofu liquid waste between Lemna and Kiapu aquatic plants.

2. METHODOLOGY

This research was conducted at the Laboratory of Aquatic Resources, Faculty of Fisheries and Marine Sciences, Padjadjaran University in March - September 2019. The method used in this study was an experimental method with Completely Randomized Design (CRD) consisting of three treatments and five replications. Plant weight used is 25 grams [13] and plants were obtained from the Ciparanje Wet Laboratory, Faculty of Fisheries and Marine Sciences, Padjadjaran University. Tofu wastewater is fresh from the Cibuntu Tofu Industry and obtained directly from the industry from the process of removing liquid from a mixture of solid tofu. The treatments given are as follows:

1. Treatment A: 5 L wastewater sample + 25 g of Lemna plant.
2. Treatment B: 5 L wastewater sample + 25 g of Kiapu plant.
3. Treatment C: 5 L wastewater sample + 12.5 g Lemna and 12.5 g Kiapu plant.

2.1 Research Stages

2.1.1 Preliminary stage

A preliminary stage was conducted using a tofu wastewater sample that had been deposited for a week. The treatment used are:

Treatment 1 = 1 L of tofu wastewater without dilution;

Treatment 2, ratio 1: 5 = 200 mL tofu wastewater + 1000 mL distilled water;

Treatment 3, ratio 1: 6 = 200 mL tofu wastewater + 1200 mL distilled water;

Treatment 4, ratio 1: 7 = 200 mL tofu wastewater + 1400 mL distilled water;

Treatment 5, ratio 1: 8 = 200 mL tofu wastewater + 1600 mL distilled water;

Treatment 6, ratio 1: 9 = 200 mL tofu wastewater + 1800 mL distilled water;

Treatment 7, ratio 1: 10 = 200 mL tofu wastewater + 2000 mL distilled water.

Observation of the seven samples was carried out to see the resilience of plants during given tofu wastewater for 12 days of observation.

2.1.2 Main research

The main stages of research carried out are:

1. Tofu liquid waste before use carried out to deposit for a week [14]. Then, dilution is made in the ratio of 1:10, which is 1 liter of tofu wastewater plus 10 liters of distilled water. The wastewater used in the study was 5 liter. The comparison of the dilution was based on the results of the preliminary stage that had been done before.
2. Plants are selected which have green leaves and acclimatized for three days in water.
3. The study was conducted for 15 days by measuring the concentration of Nitrate, Phosphate, and BOD_5 on days 0, 5, 10, and 15. The measurement of nitrate and phosphate concentration uses The Spectrophotometric Method and BOD_5 concentration uses The Winkler Method.
4. Measurement of water quality acidity (pH), dissolved oxygen (DO) and the temperature are done every day using a pH meter, DO meter, and thermometer.

2.1.3 Measurement of physical-chemical parameters

The observed characteristics of tofu wastewater consisted of physical parameters and chemical parameters. The physical-chemical measurement is carried out at the Aquatic Resources Laboratory. The physical-chemical parameters measured and the analysis tools used are presented in Table 1.

2.1.4 Tofu wastewater analysis without dilution

Tofu wastewater before dilution is analyzed to determine the initial characteristics of tofu wastewater. Analysis of tofu wastewater without dilution is presented in Table 2.

2.2 Analysis Data

The analysis in this research is quantitative descriptive analysis. The decrease in nitrate and phosphate concentrations analyze using ANOVA with the F test (p = .0,5). The difference between treatments was analyzed using Duncan's Multiple Range Test (DMRT) (p = .0,5). Analysis of decreasing concentrations of nitrate, phosphate, and BOD_5 was carried out using the formula [15]:

$$P = \frac{Ct - Co}{Ct} \; x \; 100\%$$

Information:

P = Decrease in nitrate/ phosphate/ BOD_5 concentration (mg/L)
Ct = Water concentration after phytoremediation (mg/L)
Co = Water concentration before phytoremediation (mg/L)

Table 1. Water quality parameters

Parameters	Unit	Method	Analysis tools
		Physical parameter	
Temperature	ºC	-	Thermometer
		Chemical parameters	
pH	-	Potentiometric	pH meter
DO	mg/L	Potentiometric	DO meter
BOD_5	mg/L	Winkler	Winkler Bottle
Nitrate	mg/L	Spektrofotometric	Spektofotometer
Phosphate	mg/L	Spektrofotometric	Spektofotometer

Table 2. The result of the analysis

Parameters	Unit	Result
BOD_5 concentrations	mg/L	29,2
Nitrate concentration	mg/L	9,484
Phosphate concentration	mg/L	7,250

3. RESULTS AND DISCUSSION

Based on preliminary tests that have been done, it shows that the 1:10 treatment gives the best results compared to other treatments. Plants can absorb pollutants in tofu liquid waste well which is characterized on the fifth-day wastewater starts to clear, there are microorganisms in the water, roots, and leaves of Kiapu plants are better than other plants and before phytoremediation. Based on the results of the preliminary test, the tofu wastewater treatment was deposited for one week and the concentration used was 1:10 treatment for the main research.

The condition of wastewater tofu after phytoremediation is odourless compared to before phytoremediation. The condition of Lemna and Kiapu is still alive, but some plants began to shrivel at the end of the study.

3.1 Water Quality Parameters

3.1.1 Temperature

The mean temperature results of each treatment in an observation I increased to observation II by ±1ºC, while the temperature values in observation II to observation III did not a large increase (Fig. 1). The increase in the temperature of wastewater in each treatment is due to the process of biodegradation, which is the process of breaking down organic matter by bacterial and fungal microorganisms [4]. Lemna can grow well in the temperature range of 6ºC–33ºC [16], while Kiapu grows well in a temperature range of 20ºC–32ºC [17]. Based on the measurement results, the temperature range of 21.32ºC-22.12ºC during observation still allows Lemna and Kiapu to live and grow.

3.1.2 Acidity

The mean acidity value at observation I is classified into acid, the average acidity value at observation II approaches neutral and the average acidity value at observation III is classified as neutral. Daily acidity values continued to increase until the 15t[h] day (observation III) in each treatment (Fig. 3). The highest acidity measured was 7.10 in observation III and the lowest acidity was 5.12 in an observation I (Fig. 2). The acidity value increases in each treatment until observation III can be caused by the activity of microorganisms in the decomposed of organic nitrogen [18].

Lemna has a life tolerance in the range of acidity 5-9 and will grow better at acidity 6.5-7.5 [16], while Kiapu grows well in the pH range 6.0-7.5 [17]. The acidity value during the study still allows Lemna and Kiapu to live and grow, also supports the life of microorganisms for the decomposition of organic matter. Based on observations, phytoremediation using Lemna, Kiapu, and a combination of both plants was able to increase the acidity of the water media for 15 days of observation.

3.1.3 BOD_5

The BOD_5 concentration decreased until observation II in the Lemna treatment and a combination of both, and the Kiapu treatment could reduce the BOD_5 until the observation III. Lemna plants and the combination of both are effective in reducing BOD_5 until the 10^{th} day and Kiapu plants are effective in reducing BOD_5 until the 15^{th} day (Fig. 4).

The decrease in BOD_5 during the observation in Lemna treatment was 45%, Kiapu treatment was

97%, and combined treatment was 53%. Plants produce oxygen derived from photosynthesis and diffusion from the atmosphere, increasing the amount of dissolved oxygen in the water. Dissolved oxygen in the water will be used by microorganisms to decompose organic matter, and the decomposition of organic matter is absorbed by plants as nutrients for growth, thus reducing the value of BOD_5. The decrease in BOD_5 is caused by the phytodegradation process.

Phytodegradation is the absorption of organic contaminants from wastewater by plant roots and undergoes decomposition through metabolic processes in plants [19]. Organic matter is degraded by microorganisms that grow on the surface of the media and live on plant roots [20].

3.1.4 Dissolved oxygen

Dissolved oxygen measurement fluctuate for 15 days of observation. The value of dissolved oxygen decreased until observation II in the Lemna treatment and the combined treatment, except for the Kiapu treatment is constant. Then, dissolved oxygen values increased at observation III in all treatments (Fig. 5).

Based on Fig. 6, there is a decrease in dissolved oxygen in the Lemna and combined treatment in the first three days, due to aquatic plants undergoing a process of respiration that can cause oxygen loss in water. Besides, Lemna plants have leaves that float on the surface of the water and almost cover the entire surface of the water. As a result, some oxygen produced from

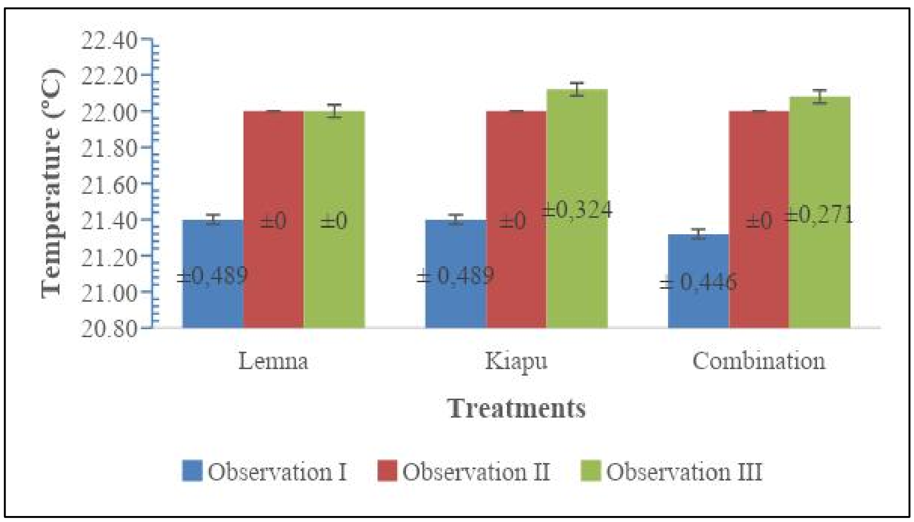

Fig. 1. The temperature values during the observation

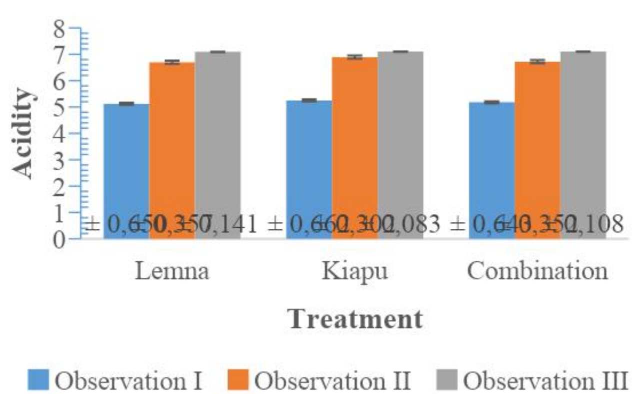

Fig. 2. The average pH value during the observation

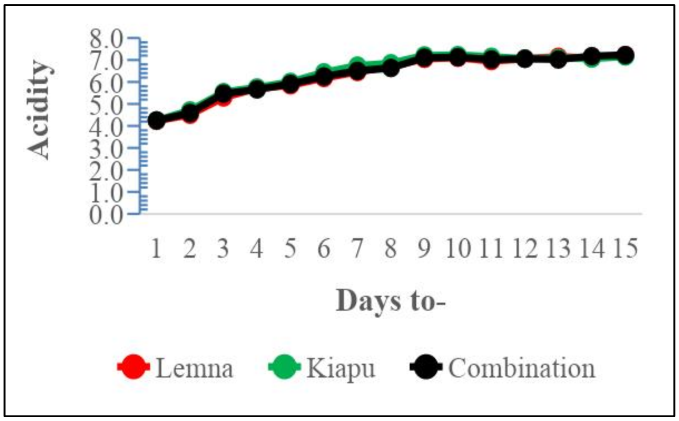

Fig. 3.The Daily pH value

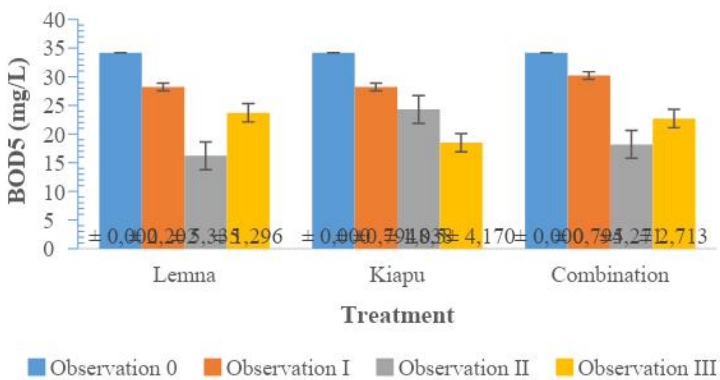

Fig. 4. The BOD_5 values during the observation

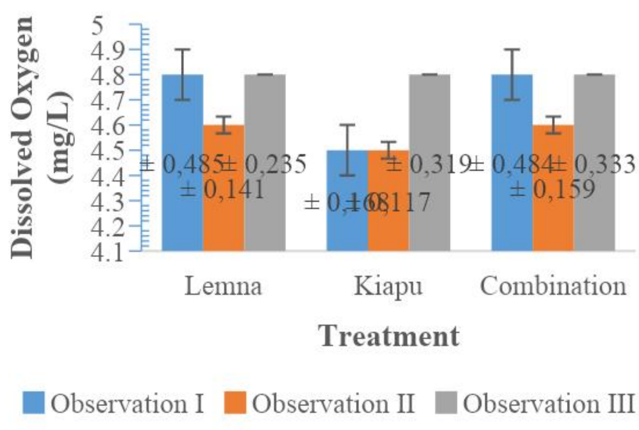

Fig. 5. The average dissolved oxygen

the photosynthesis process will be released into the air and only a small portion is released into the water [21]. Plants need the dissolved oxygen for respiration and metabolic processes which then produce energy for growth [4].

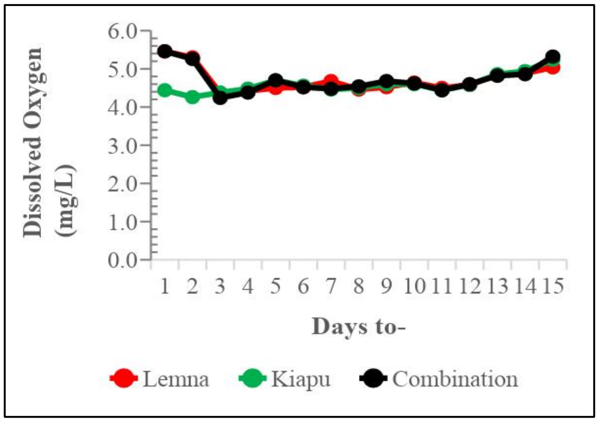

Fig. 6. The daily dissolved oxygen values

3.2 Removal of Nitrate Concentrations

Nitrate concentration decreased until observation III in all treatments. The highest decrease in nitrate concentration occurred on an observation I, which ranged from 53.16%-62.24% and the decrease in nitrate concentration in observations II and III was not very high (Fig. 7). The concentration of organic matter decomposes into nitrate as the result of the nitrification process that is absorbed a lot by aquatic plants at the beginning of the research [22], so that plants absorb nitrate concentrations higher on an observation I.

The decrease in nitrate concentrations in observations II and III did not differ greatly because plants began to die characterized by the roots of the Lemna and Kiapu began to break free. Damaged plant roots will make plants less effective in absorbing nitrates in the water and also reduce plant weight. Kiapu plants can reduce nitrate concentrations up to 62.24% and the highest compared to other plants. This shows that the Kiapu plant has a good ability to reduce the concentration of nitrates in wastewater. Kiapu can reduce the concentration of wastewater pollution through its long and thick roots [23]. Based on the DMRT test (p = .0,5), Kiapu can be recommended to decrease nitrate concentration compared to other treatments for 15 days of observation.

3.3 Removal of Phosphate Concentration

Phosphate concentrations fluctuated in the Lemna and Kiapu treatments until observation III, except for the combined treatment which continued to decline. The Lemna and Kiapu plants effectively reduced the phosphate concentration up to Observation II as seen from the percentage decrease in phosphate concentration in observation II greater than observation I. The combined treatment was only effective in reducing phosphate concentration up to Observation I, as seen from the decrease in phosphate concentration in observation I was greater than observation II and III (Fig. 8).

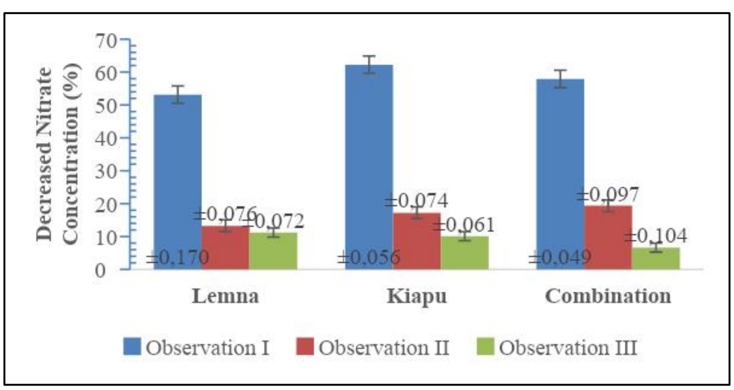

Fig. 7. The decreased nitrate concentration

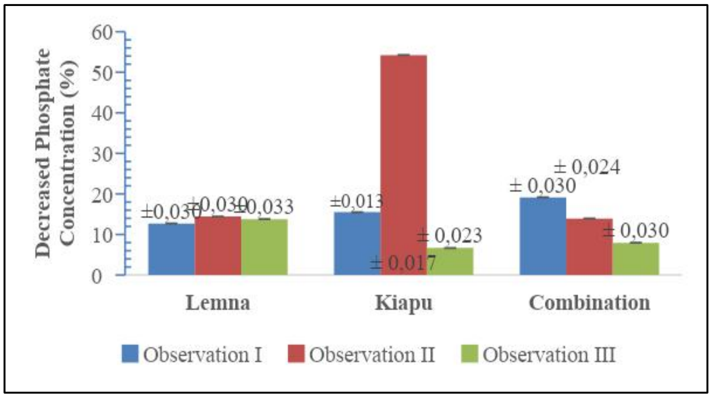

Fig. 8. The decreased phosphate concentration

Kiapu plant has a good ability to reduce the concentration of phosphate in tofu wastewater media. Kiapu plants can absorb high amounts of nutrients [24]. Based on the DMRT test (p = .0,5), showed that the Kiapu plants were better at lowering and absorbing phosphate than Lemna plants and the combination of both for 15 days of observation.

4. CONCLUSION

Based on the research that has been done, it can be concluded that:

1. Kiapu can absorb nitrate and phosphate better than Lemna and combined treatments for 15 days of observation with the result of a decrease in nitrate concentration of 10.12-62.24% and a decrease in phosphate concentration of 6,67-54.23%.
2. Kiapu can be recommended as phytoremediation agents for tofu liquid waste to remediate high organic matter before being discharged directly into water bodies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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