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The Study of Water Lettuce *(Pistia stratiotes L.)* Application in Reducing COD Levels of Tofu Wastewater Using Batch System Phytoremediation

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Abstract. Tofu industry wastewater contains high complex organic materials such as BOD, COD, and an acidic pH. High concentration of tofu wastewater can cause damage to aquatic ecosystems, so it requires treatment before finally being discharged. Phytoremediation is one of wastewater treatment methods that can be applied. The objective of this research was to determine the effect of Water Lettuce application and its COD removal efficiency. The research method used was the experimental method with laboratory-scale batch reactor, using Water Lettuce with amount 200 and 400 grams which had already acclimatized for 7 days, sample 5L of tofu wastewater within and without pH controlled, and was done with 3 replications. The results showed there is an effect of Water Lettuce in reducing COD content of tofu wastewater with removal efficiency of 24%, 57%, 82% for experiment 1 (200 gr, pH acid), 2 (400 gr, pH acid), and 3 (200 gr, pH neutral), respectively. The condition of Water Lettuce in every experiment was differ because pH and weight affected it, but at the end of experiment, the Water Lettuce died because it had a saturation point of growth, it showed the roots and the body was separated and became black, the leaves color became yellow to brown.

Keywords: COD, Tofu Wastewater, Water Lettuce

1. Introduction

1.1. Background

Tofu is one of the favorite foods of Indonesian that makes the demand increase year to year [1]. High demand for tofu provides a decent profit for industry players that make people open up their own tofu's home industry [2]. However, most of the tofu home industries are not really aware of the waste produced and finally end up in surface water that causes a lot of problems like unpleasant odor because of the high complex organic materials that are BOD, COD, TSS, and an acidic pH in tofu wastewater [3].

COD (Chemical Oxygen Demand) is the amount of oxygen needed to decompose inorganic pollutants in the water [4]. COD levels in the water must be low, so it will be good for the aquatic ecosystem. The levels of BOD content can be the same as COD content however the levels of BOD cannot be higher than the levels of COD content [5].

According to the results of tofu wastewater testing from one of the tofu home industries in Samosir, data obtained that COD content was 1760.56 mg/L, 14219.7 mg/L, and 15094.8 mg/L. This

COD content exceeds the quality standard of tofu wastewater, Minister of Environment Regulation Number 5 of 2014 stipulates the maximum COD content of 300 mg/L. High organic concentration in tofu wastewater can cause eutrophication where the water body becomes rich in dissolved nutrients, decreased dissolved oxygen content and decreases the carrying capacity of the water body to aquatic biota [6]. Therefore, the necessity of treating tofu wastewater is a must to make it safe to dispose of to the environment and prevent problems like what happened in Jombang East Java that experienced the decreasing of water quality and headaches due to the stench caused by tofu wastewater [7]. One of treatments that can be applied for reducing the levels of COD is phytoremediation process using Water Lettuce *(Pistia stratiotes L.)* [8]. Researchers have observed this Water Lettuce as a phytoremediator for treating tofu wastewater, however there is no detailed information whether the tofu wastewater was diluted or not, but it showed there is a reduction for COD. This research will also use Water Lettuce as a phytoremediator for treating tofu wastewater without doing any dilution to know the effect of Water Lettuce in decreasing COD levels of original tofu wastewater.

1.2. Problem Statements

The problem statements of this research are:

1. Is the phytoremediation process using Water Lettuce able to reduce COD content of tofu wastewater?
2. Is the pH control effect in reducing COD content of tofu wastewater?
3. Is the amount of Water Lettuce effects in reducing COD content of tofu wastewater?

1.3. Objectives

The objectives of this research are:

1. To determine the effect of Water Lettuce in reducing COD content of tofu wastewater
2. To study the effect of pH control in reducing COD content of tofu wastewater
3. To study the effect of Water Lettuce's amount in reducing COD content of tofu wastewater

2. Methodology

2.1. Research Sites

The research was conducted in Samosir, North Sumatra Province of Indonesia. The sample was analyzed in the Laboratory of the Samosir Regency Environmental Service.

2.2. Tools and Materials

The materials used in this research were liquid caustic soda (NaOH) 48% and Water Lettuce only. The liquid caustic soda used for neutralizing the pH of tofu wastewater.

The tools needed were 1 L beaker glass, 30 mL volumetric pipette, glass rod, 1 big reactor with dimension 100 m x 80 m for acclimatization process, and 12 reactor basins for the treatments.

Figure 1. Reactor for Acclimatization Process

Figure 2. Batch Reactor for Experiments

2.3. Experiment Procedure

The research was conducted with a laboratory-scale batch reactor. The treatment used was Water Lettuce as a phytoremediator with weight variation of 200 grams and 400 grams. Then, the treatment using 200 grams of Water Lettuce has 2 treatment experiments that treated original tofu wastewater and neutralized tofu wastewater with NaOH. For the details, it will be shown in **Table 1**.

Table 1. Type of Experiments

No Experiment	Weight of Water Lettuce	Amount of Wastewater	Treatment
Experiment 1	200 gr	5 L	Without neutralization
Experiment 2	400 gr	5 L	Without neutralization
Experiment 3	200 gr	5 L	Neutralized pH

Every experiment has control and treatment basins (three replications). The sample used was 100% of tofu wastewater without any dilution.

The tofu wastewater for experiment 1 and 2 used was original tofu wastewater with initial pH of 3.8. The samples were taken from industry then directly put into each reactor basin, 5L for each reactor basin. Then, for experiment 3, researchers neutralized the tofu wastewater first. The initial pH of tofu wastewater was 3.8, it will be neutralized to pH 7 using liquid caustic soda (NAOH) 48% by dripping it little by little then stirring until it reaches the desired pH which is 7.

2.4. Acclimatization Process

Plant acclimatization aims to make Water Lettuce adapt to the new environment [8]. Plants are acclimatized by placing them into a reactor tank that has been filled with water and the plants are cleaned of impurities that stick to the roots and leaves first [6]. The acclimatization process in this research was carried out for 7 days using PDAM water before being transferred to the phytoremediation process [6]. In the acclimatization process, the plants did not experience significant changes so that it could be continued for the phytoremediation process of tofu wastewater.

2.5. Phytoremediation Process

At the phytoremediation process, the volume of wastewater used was 5 L for each basin. The tofu wastewater was 100% pure without any dilution. This study was a batch system phytoremediation method or wastewater treated in a reactor state or did not flow [9]. There are three types of experiment in this research, Water Lettuce that have been acclimatized are directly placed into 4 basins (1 control, 3 treatments) for each experiment 1 and 2 with a predetermined plant weight. However, for the experiment 3, the sample will be neutralized first until it achieves pH 7 then divided into 4 basins, next filled with Water Lettuce that is already acclimatized with 200 grams of weight.

COD testing of tofu wastewater was carried out on day 0 or when the samples were taken directly from tofu home industry, day 2, 4, 7, 9, 11, and day 14 with a grab sampling method in the morning. COD testing using closed reflux method (SNI-6989.2:2009). The pH testing of tofu wastewater was carried out only on day 0 for neutralizing pH of sample purpose using ATC digital pH meter.

3. Result and Discussion

3.1. Result

3.1.1 The Effect of Water Lettuce in Reducing COD

Three experiments resulted there is an effect of Water Lettuce in reducing COD content in tofu wastewater. The result shown in **Table 2** was taken from the average of 3 replications for the treatments. The COD reduction might be caused by the deposition of solids so that the wastewater discharge material is also reduced. The reduction of COD concentration was also due to Water Lettuce because it has rhizofiltration, phytodegradation, and phytovolatilization process. This is evidenced by the results of COD reduction with treatment higher than without treatment (control parameter). The reduction also occurred due to the absorption of Water Lettuce and the supply of oxygen from Water Lettuce's photosynthesis [5].

Table 2. The Result of COD Reduction

Day	Control Experiment 1 (mg/L)	Treatment Experiment 1 (mg/L)	Control Experiment 2 (mg/L)	Treatment Experiment 2 (mg/L)	Control Experiment 3 (mg/L)	Treatment Experiment 3 (mg/L)
0	1760.56	1760.56 ± 2.2^{-13}	14219.7	14219.7 ± 1.8^{-12}	15094.8	15094.8 ± 1.8^{-12}
2	1660.00	1637.27±9.47	13611.7	12185.97±302.68	15094.8	12809.36±166.5
4	1610.00	1503.63±65.68	12611	10533.47±146.11	15045.3	10346.51±431.9
7	1470.00	1340.62±21.44	1119.7	9099.9±58.03	11040.1	8678.49±282.6
9			9766.8	8248.73±223.62	7828	6840.22±52.4
11			8766.5	6103.17±296.64	5873.3	4477.25±106.9
14					4595.6	2651.59±115.8
%	16%	24%	38.35%	57.08%	70%	82%

3.1.2 The Effect of pH Controlled

To determine whether controlling the pH effect to COD reduction or not, it will be determined by comparing the treatment in experiment 1 which used 200 gr of Water Lettuce and 5 L of tofu wastewater without neutralization (acid, pH 3.8) with experiment 3 which also used 200 gr Water Lettuce and 5 L of tofu wastewater that already neutralized (neutral, pH 7). According to the result in **Table 2**, it showed controlling the pH adding the duration of plant growth from 7 days to 14 days. It happened because Water Lettuce is able to grow with optimum pH 6.5-7 [10]. Even though the pH of experiment 1 acid (3.8), Water Lettuce is still alive which means it can still be tolerated by Water Lettuce but does not perform well to reduce the COD content.

Physical condition of Water Lettuce during the experiment 1 showed some of the leaves immediately looked wilted and wrinkled on day 2, then on day 4 all the leaves withered and yellowed, on day 7 plant showed death because the roots and plant's body separated, the roots emerged to the surface of the wastewater and the leaves drowned in the wastewater.

Physical condition of Water Lettuce during the experiment 3 showed it still fresh until day 4, on day 7 until 9 it showed some of the tips of the leaves start to wrinkle and dry up, some of the leaves start separated from the roots, and on day 14 the plant's body and roots separated and the color of all leaves became yellow to brown.

Controlling the pH of tofu wastewater made Water Lettuce performed well in reducing the COD content of tofu wastewater. The removal efficiency for experiment 3 which controlled the pH achieved 82%, however, experiment 1 showed just 24% removal efficiency.

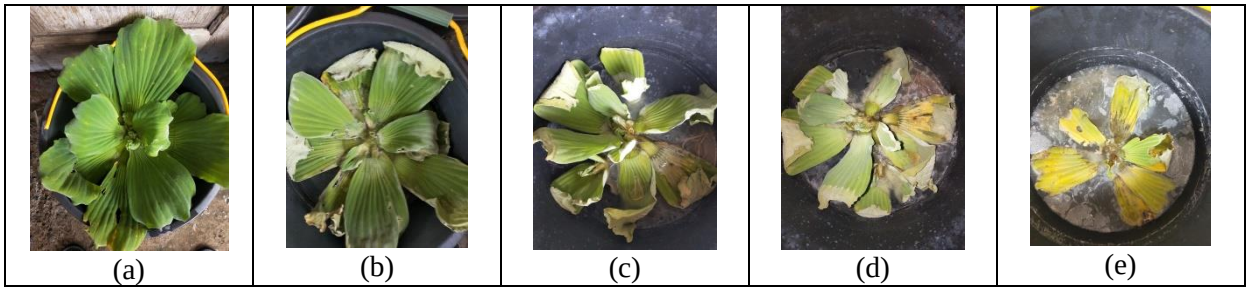

Figure 3. (a) Fresh; (b) Withered; (c) Wrinkled; (d) Start Separated; (e) Death

3.1.3 The Effect of Water Lettuce Amount

Determining the effect of Water Lettuce Amount by comparing experiment 1 which used 200 gr of Water Lettuce and experiment 2 which used 400 gr of Water Lettuce. The amount of Water Lettuce affected the reduction of COD concentration, the more amount of Water Lettuce the more removal efficiency achieved because 400 gr of Water Lettuce has big roots to absorb the water pollutants rather than 200 gr of Water Lettuce.

Water Lettuce in experiment 2 was able to grow until 11 days. The physical condition of Water Lettuce started to wrinkle on day 4, and on day 9 the roots started to emerge to the surface of wastewater and on day 11 the leaves separated from root and made the leaves drown.

3.2. Discussion

The observation of the experiment was done until there is no growth of Water Lettuce or until it died with indicators: the root of the plants separated from the body and the leaves color became yellow to brown.

According to the result in **Table 2**, it showed experiment 1 achieved removal efficiency 24% for treatment and 16% for control, experiment 2 achieved 57.08% for treatment and 38.35% for control, and experiment 3 achieved 82% for treatment and 70% for control, with initial concentration of COD 1760.56, 14219.7, and 15094.8 of experiment 1, 2, and 3, respectively. Based on the result, neutralizing the pH achieved highest removal efficiency rather than without neutralization. Compared to the previous research regarding utilization of Water Lettuce in reducing COD content of tofu wastewater, it achieved 36.23% removal efficiency (from 555.1 mg/L to 353.8 mg/L) within 2 days. However, the research does not mention whether they used 100% of tofu wastewater or the diluted one. Then, the previous research does not mention the weight of the Water Lettuce that was used and why the research was just conducted in 2 days [11]. Therefore, researchers cannot compare the result with previous research, but researchers can conclude that Water Lettuce is able to reduce COD content of tofu wastewater.

Then, let's compare the result in this research with previous phytoremediation research regarding utilization of Water Lettuce in reducing the content of COD in tempeh wastewater. This research used tempeh wastewater which has been diluted using distilled water with a concentration of 15%. So, each reactor is filled with 12.75 L distilled water and 2.25 L tempeh wastewater. The plant used was 0, 10, and 20 plants. The research was conducted within 12 days. The result showed, it achieved removal efficiency 52.05%, 62.03%, 64.02% of 0 plant, 10 plants, 20 plants, respectively, with initial concentration of COD was 201.72 mg/L [12]. According to this result, Water Lettuce with phytoremediation process is able to reduce COD content of tempeh wastewater

Referring to this research and previous research, Water Lettuce can reduce COD content of tofu wastewater. However, the results still did not achieve the quality standard of tofu wastewater based on The Minister of Environment Regulation Number 5 of 2014 that stipulates the maximum COD content of 300 mg/L. Therefore, next research regarding phytoremediation using Water Lettuce is needed. The

next researcher may increase the amount of Water Lettuce to add the removal efficiency of COD reduction.

4. Conclusion

From the result and discussion above, it can be conclude that:

1. In this research, Water Lettuce has an effect to COD reduction both for neutralized and original tofu wastewater
2. Controlling the pH has an effect in reducing the COD concentration. Neutralizing pH made Water Lettuce grow for 14 days and achieved high removal efficiency rather than without neutralized pH. Even though the initial COD of experiment 3 was 10 times of initial concentration COD of experiment 1, but neutralizing the pH helped Water Lettuce performed well
3. The amount of Water Lettuce also affects the performance of Water Lettuce in reducing COD content. The more amount of Water Lettuce, the more it achieved removal efficiency

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