Phytoremediation of tofu wastewater using Eichhornia crassipes

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Abstract. The tofu industry in Indonesia is generally dominated by small industries so that the wastewater produced is not properly managed. The tofu industries generally produce wastewater from the washing, pressing, and molding process. Phytoremediation can be used as an alternative solution for tofu wastewater remediation process because of its advantages as a cost-effective, efficient, and eco-friendly technology. This research used parallel reactor with circulation flow. Eichhornia crassipes with 1500 gram/compartment was used as the growing medium. The variables used in this study is the phytoremediation treatment and phytoremediation time. Phytoremediation treatment variations used anaeration and aeration methods for 10 days. The results of this study showed that the effectiveness of the average decrease in the two treatments; (1) anaeration treatment could reduce BOD 59.84%, COD 58.95%, TSS 86.79% and ammonia 25.43%, (2) aeration treatment could reduce BOD 80.67%, COD amounting to 78.28%, TSS 65.79% and ammonia 49.79%. Percentage of absorption of pollutant levels (BOD, COD, TSS, ammonia) in tofu wastewater increases with increasing phytoremediation time and number of compartments. According to the effectiveness value, aeration treatment was the most effective treatment in reducing the levels of tofu wastewater pollutants.

1. Introduction
Tofu industry is one of the fast-growing industries among the small-scale industries in Indonesia. Waste generated by tofu industries can be divided into 2 types the solid waste and the liquid waste. The wastewater was generated from the washing, pressing, and molding process. Therefore, wastewater from the industries is quite high. The wastewater from the tofu making contains very high organic substances, pH 3.5-5 [3,4]. Wastewater by tofu industry are generally discharge into the river and will surely disrupt the biotic lives of the river, decline the water quality caused by the high content of organic substances, and can cause a bad odour and pollution of the surface and ground water [1]. Several technologies for wastewater have been investigated previously, i.e., aerobic anaerobic, aerobic-bio filter, and phytoremediation. This study used phytoremediation technology, where can be used as an alternative solution for remediation process because of its advantages as a cost-effective, efficient, eco-friendly technology based on the use of plants. The experiments were conducted by
utilizing Eichhornia crassipes as a medium in parallel reactors. It was expected that after phytoremediation could increase the effectiveness of processing and reduce pollutant concentration, so that the resulting liquid waste can be discharged into the waters.

2. Materials and Methods

The research conducted was an experimental study followed by analysis of samples in the laboratory to analyze the effectiveness of phytoremediation using Eichhornia crassipes in the absorption of levels of BOD, COD, TSS and ammonia in tofu wastewater with parallel reactor systems. This research was conducted in October - November 2016 on the rooftop of the Faculty of Engineering, Hasanuddin University. The location for extracting tofu wastewater is located on Jalan Baji Nyawa precisely at Tri Sanjaya's tofu factory while water hyacinth plants are taken in the swamp area around the Mawang Lake, Gowa Regency. For sample testing carried out at the Center for Environmental Health Engineering and Disease Control Class I Makassar.

2.1. Preparation of Parallel Reactors

The research reactor was arranged in parallel and connected with a ½ ” diameter PVC pipe and in each valve mounted valve. This reactor consists of 7 compartments / tubs filled with ± 70 liters of tofu wastewater per compartment. The first compartment is a reservoir and compartment 2-7 for phytoremediation. In this reactor the pump is attached so that the waste water flow will return to the first compartment (circular flow). Before being filled with wastewater, the reactor must be calibrated first. Debit calibration is carried out so that the volume of uniform wastewater in each compartment during the phytoremediation process takes place.

2.2. Preparation of Planting Media

Retrieval of Eichhornia crassipes plants was obtained around the Mawang lake in Gowa district. Before being used for phytoremediation, Eichhornia crassipes must first go through the acclimatization process to determine the length of time water hyacinth can survive and live in wastewater. Acclimatization of Eichhornia crassipes, preceded by washing the plants clean from mud and soil. After that, acclimatization was carried out for 7 days with clean water [2]. After acclimatization for 7 days the selection of water hyacinth plant samples was used to be used as phytoremediator. Selected plant samples with fresh green leaves and relatively the same size. Water hyacinth plants used have specifications with criteria: the number of leaves is 4-7 strands, leaves are still fresh and not yellow, plant height is 20-30 cm.
2.3. Preparation of Tofu Wastewater
The waste water used in this study was tofu wastewater taken from the Tri Sanjaya factory which is on Jalan Baji Nyawa. In the implementation of sampling based on SNI wastewater - Section 59: Methods for sampling wastewater (SNI 6989.59: 2008).
Tofu wastewater has a very low pH so that lime was added to increase the pH of tofu wastewater. The initial pH used in this study was 6, that the optimum growth requirement for water hyacinth is at pH 6-7.5 [5]. After the calcification process, quality tests for pH and temperature parameters are carried out directly in the field while BOD, COD, TSS and Ammonia are taken to the laboratory.

2.4. Analytical Methods
Samples were put into a reactor containing 70 liters of tofu wastewater for each compartment. The phytoremediation process uses two types of treatment, namely aeration treatment and aeration treatment for 10 days [7].

3. Result and Discussion
Based on the results of observations made, it was known that the tofu wastewater produced by Tri Sanjaya's tofu factory was immediately disposed to a water body near the tofu production site without any processing.

| Parameter   | Unit | Result Without Aeration | Result Aeration |
|-------------|------|--------------------------|-----------------|
| BOD         | mg/L | 1.940                    | 2.164           |
| COD         | mg/L | 3.300                    | 3.108           |
| TSS         | mg/L | 509                      | 502             |
| Ammonia     | mg/L | 0.26                     | 0.3             |
| pH          | mg/L | 3.4                      | 3.9             |
| Temperature | mg/L | 32                       | 35              |

Table 1 showed the characteristics of wastewater used in the study. In this study, tofu wastewater was treated by phytoremediation to reduce the concentration of pollutants contained in the wastewater.

a. BOD (Biological Oxygen Demand)
Based on the results of laboratory testing data obtained BOD concentration data in samples of tofu wastewater after phytoremediation by anaerobic treatment. The BOD concentration in each compartment after going through the phytoremediation process with anaerobic treatment, from the table it can be seen that all compartments every day experienced a decrease in BOD concentration. The most optimal decline occurred on the 5th day, with BOD concentrations in each compartment, namely 733.46 mg / l, 709.503mg / l, 696.285 mg / l, and 677.18 mg / l. But on the 10th day BOD levels in wastewater have increased this because most plants have died and decay resulting in increased organic matter in wastewater so that BOD levels also increase.

In the anaerobic treatment there was a decrease in BOD concentration from the first day to the fifth day but still did not meet the quality standards set out in South Sulawesi Governor Regulation
No.69 of 2010 concerning Waste Water Quality Standards for Businesses and / or Soybean Processing Activities which were 150 mg/l [8].

The effectiveness of elimination of tofu wastewater BOD levels for anaeration treatment on the first day of phytoremediation levels of pollutant reduction is still relatively low, this is evident from the low percentage effectiveness. This condition occurs because water hyacinth plants are still adjusting to tofu wastewater so it is not too effective in absorbing waste. Then on the second day phytoremediation of the effectiveness of absorption began to increase but not too significantly from the first day of phytoremediation. On the third day of phytoremediation, the effectiveness of absorption began to be high with an absorption percentage of 66.667%. This can occur because of cooperation between aerobic microorganisms and water hyacinth plants. Where from the process of metabolism of microorganisms produced CO2 which is then used by plants to carry out photosynthesis, from the photosynthesis process produced glucose / carbohydrates which will become nutrients for water hyacinth in addition to oxygen produced which will be reused by aerobic microorganisms to decompose the organic content in tofu wastewater.

As for the fourth and fifth day of the phytoremediation process, the level of effectiveness of absorption of BOD levels is not much different from the third day. In this condition the absorption of BOD levels is due to the change of organic matter by microorganisms because of the advanced process of rhizofiltration, which is the phytocaccumulation process where water hyacinth plants attract substances that accumulate around the roots and transmit them to other parts such as stems and leaves. this is made clear by the condition of plants that begin to wilt [6].

On the last day of phytoremediation, the effectiveness of BOD absorption has decreased. Tofu waste water is waste water with a high content of organic matter, although the BOD concentration decreases from day 1 to day 5 but the BOD concentration in wastewater is still high. The high concentration of organic load causes aerobic microbes to die because of lack of oxygen for their metabolic processes besides the absorption of high organic loads on water hyacinth plants causes plants to become saturated so that the absorption process stops and the plants will experience wilt. This can be seen in the condition of plants on the 10th day where most plants have withered and died.

For the anaeration treatment, the most effective absorption of BOD levels occurred on the 5th day, namely in the R4 compartment with an absorption percentage of 71.994%.

b. COD (Chemical Oxygen Demand)

The decrease in COD in the anaeration treatment has the same pattern as the decrease in BOD concentration, where the most effective absorption occurs on day 5 of rice with COD concentrations in each compartment namely 1425 mg/l, 1.394 mg/l, 1.289 mg/l and 1.155 mg/l. The increase in COD concentration was caused by water hyacinth plants had passed the saturation point, so that the ability of plants to absorb organic matter decreased even the concentration of organic matter in wastewater increased because plants were thought to release organic matter that had been absorbed again.

In general, the anaeration treatment was able to reduce COD concentration significantly, although it did not meet the quality standard of 300 mg/l based on South Sulawesi Governor Regulation No.69 of 2010 concerning Waste Water Quality Standards for Businesses and /or Soybean Processing Activities.

Absorption of COD levels in the most effective anaeration treatment occurred on the 5th day in the R4 compartment with a absorption percentage of 75.141%.

c. TSS (Total Suspended Solid)

The data obtained from the test results show that the TSS content in the initial wastewater before being processed exceeds the environmental quality standard. After going through the phytoremediation process, TSS concentrations experienced a significant decrease.

The decrease in TSS concentration in the aeration treatment is directly proportional to the residence time and number of reactors where the longer the residence time and the more the number of compartments, the lower TSS concentration, so that the lowest TSS concentration occurred on the 10th day for all compartments namely 66.12 mg / l, 64.73 mg / l, 58.25 mg / l and 52.3 mg / l. Decreasing
TSS content after processing using water hyacinth plants is caused due to the process of absorption by plants, decomposition of dissolved organic matter and settling the results of decomposition of organic materials.

The quality standard required for TSS parameters based on the Governor of South Sulawesi Regulation No.69 of 2010 concerning Waste Water Quality Standards for Businesses and / or Soybean Processing Activities is 200 mg / l. In the anaeration treatment the TSS concentration has met the required quality standards from the first day of processing.

From the results of the analysis, it was found that on the first day of phytoremediation, a very drastic decrease in organic levels reached 77.374% to 82.346% of the initial concentration.

This significant decrease in TSS concentration is due to the calm water conditions causing particles or colloids to easily settle at the bottom of the compartment. In addition, colloids that float in waste water attach to the roots of water hyacinth and the rest are degraded by microorganisms. The level of effectiveness of TSS reduction is quite constant from the first day to the last day of processing.

d. Ammonia

Ammonia concentrations obtained during the phytoremediation process fluctuate, this can be caused by the unstable nature of ammonia in water (Parwaningtiyas, 2012).

Ammonia concentration after phytoremediation without addition of aeration. Based on these data the concentration of ammonia fluctuated where on the first and second days of processing, the concentration of ammonia was higher than the concentration before processing, this was due to microorganisms present in wastewater excreting the catabolic results. Then there was a decline on the 3rd day until the 5th day and then increased again on the 10th day.

The decrease in ammonia concentration in this treatment occurs because of the absorption of ammonia compounds by the water hyacinth root and with the help of microorganisms that grow around the roots, the ammonia compound will undergo nitrification into nitrite and nitrate compounds. These nitrite and nitrate compounds are then absorbed by the roots to be used as nutrients.

The quality standard for ammonia parameters is not regulated in the Governor of South Sulawesi Regulation No.69 of 2010 concerning Waste Water Quality Standards for Businesses and / or Soybean Processing Activities. But according to Effendi (2003), ammonia levels in the waters should be no more than 0.2 mg/l because if more than 0.2 mg/l, the waters will be toxic to several types of aquatic organisms.

e. Changes of pH

Based on the test results obtained the pH value in tofu wastewater before processed was acidic, so that in this study before tofu wastewater was processed first lime was added until the pH value reached pH 6. Liming was carried out so that the water hyacinth plants can grow properly so that the process phytoremediation runs optimally.

According to research conducted by Ratnani (2011), at a pH of about 6-7.5 hyacinths have better growth while a pH below 4.2 can poison the growth of water hyacinth, so water hyacinth dies. Table 6 shows the pH value obtained after tofu wastewater through the phytoremediation process by anaerating treatment.

The results showed, in the anaeration treatment it was found that the pH value increased from pH 6 to pH 7.3. The increase in pH that occurs can be caused by photosynthesis, denitrification and breakdown of organic nitrogen. In addition, the respiration of microorganisms to produce carbon dioxide (CO₂). The dissolved carbon dioxide undergoes an equilibrium reaction so that it produces OH⁻ ions which cause an increase in pH value.

The pH standard based on the Governor of South Sulawesi Regulation No.69 of 2010 concerning Waste Water Quality Standards for Businesses and / or Soybean Processing Activities must be in the range 6 - 9, and this aeration treatment has fulfilled these requirements.

f. Temperature
Temperature is one of the physical parameters that directly or indirectly affects the growth and development of aquatic biota. The temperature of tofu wastewater before processing is very high because soybean boiling is carried out during the production process.

4. Conclusions
The most optimal remediation rate of tofu wastewater in the anaeration treatment was able to reduce: BOD up to 677.18 mg/l (71.99%), COD of 1154.624 mg/l (75.14%), TSS up to 52.3 mg/l (91.45%) and Ammonia of 0.150 mg/l (48.09%) while in the aeration treatment it was able to remediate BOD up to 54.41 mg/l (97.70%), COD of 91.109 mg/l (97.74%), TSS up to 10.327 mg/l (98.13%) and ammonia at 0.062 mg/l (80.19%). For the anaeration treatment, the concentrations of BOD and COD still exceed the specified quality standards while for the treatment of aeration all parameters have met the quality standards based on the Governor of South Sulawesi Regulation No. 69 of 2010.

References
[1] Angraini. 2014. Wastewater Management Know Anaerobic Using a Batch System. Reka Lingkungan Journal, Volume 2(1).
[2] Metcalf and Eddy, Inc. 2003. Wastewater Engineering: Treatment, Disposal and Reuse. McGraw-Hill, Inc: USA.
[3] Natalina dan Hardoyo. 2013. Use of Water Hyacinth and Water Spinach in the Improvement of Tofu Industry Wastewater Quality. University of Lampung.
[4] Nindra, Dharma Yoga, and Eko Hartini. 2015. Effectiveness of Lotus and Hyacinth Plants in Reducing BOD Levels in Tofu Industry Wastewater. Visikes Journal, Volume 14(2).
[5] Nurmitha, A. Aulia. 2013. Fitoremediation of Household Waste Treatment by Utilizing Hyacinth Plants. Environmental Engineering Department. Universitas of Hasanuddin. Makassar.
[6] Ratnani. 2011. Utilization of Hyacinth Hyacinth to Reduce COD, pH, Odor and Color Content in Tofu Wastewater. Momentum Journal, Volume 7(1).
[7] Ratnani. 2012. Combination ability of Hyacinth and Active Mud to Reduce Pollution in Tofu Industry Wastewater. Momentum, Volume 8(1).
[8] Wirawan. 2012. Domestic Wastewater Processing Using Apu Wood Plants with DFT Hydroponic Planting Technique. Natural Resources and Environment Journal. University of Brawijaya.