Terraced Wetland Construction of Liquid Waste Pollution Countermeasures from Tofu Industry (Case Study of Tofu Industry in Mojosongo, Surakarta)

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Abstract. Tofu is a food that every level of society liked because of its low price and many nutrient contents. Tofu making uses a lot of water for sorting, immersion, boiling, and filtering to produce enough liquid tofu waste. The problem that most rises related to the tofu industry is the problem of waste processing. If the tofu waste is disposed of directly into the river, it will affect the life of biota and pollute the environment. Therefore facility is needed for wastewater treatment that can be used continuously with a wetland construction system. The A filter composition consists of sand, charcoal, and zeolite. The B composition consists of soil, palm fiber, sand, charcoal, and zeolite with cattail plants (Thypa latifolia). C composition consists of soil, palm fiber, sand, charcoal, and zeolite with cattail plant (Thypa latifolia) and Phragmites australis. The three compositions are then analyzed in filtering the tofu industrial wastewater. The best result of tofu liquid waste processing is using the C wetland composition construction; pH with a value of 6.7, BOD with a value of 146mg/L, COD 338mg/L, TSS 123mg/L.

1. Introduction
The population enhancement impacts the increasing industrial world in Surakarta, especially the tofu industry, marked by the number of factories operating. The other provides benefits and affects environmental pollution in water areas.

Tofu is a traditional food for most Indonesian people. That is liked by most level society. Besides, it consists of a lot of nutrition. The tofu-making process is relatively cheap with a delicious and straightforward taste, and the price is affordable by all levels of society [1]. The tofu industry needs a lot of water to sort, immerse, peel the skin, grill, boil, and filter. Tofu factory in its processing produces solid and liquid waste [2].

Without well-handling, tofu liquid waste discharged into the water can kill biotic in the water, such as microorganisms that have a role as the water’s biological balance management. The tofu liquid waste contains a high organic compound proportion, which causes various side effects such as smells bad, water pollution, multiple sources of disease, increasing mosquito populations, and degrading environmental aesthetics [1].

High levels of BOD, COD, and low pH can cause decreasing in oxygen levels in the water and high TSS levels because the tofu liquid waste causes the water to become cloudier. To anticipate that potential impact, minimize waste using a wastewater processing installation (IPAL) is needed. However, because the IPAL system needs high operational costs and relatively long
development, it requires wastewater processing facilities that are economical and can be used continuously with an artificial wetland system [3].

In the use of artificial wetland systems or wetland construction, there is a filtration method for decomposing tofu liquid waste at the early step. Filtration is one of the essential operations in the water purification process. The water purification mechanism is divided into three methods: filtering mechanism of large solids, precipitation of particle suspended that finer, and removing organic and inorganic impurity that is not adsorbed [4].

An artificial wetland system or wetland construction is a system built to use nature; its process involves wetland vegetation, soil, and associated microbial related to help treat water waste in a more controlled environment. Wetland construction can function as a waste processing system because of the type of water plant factors, the depth, and the type of media used [5].

The cattail plant (Typha latifolia) is a fast-growing plant in a bad environment and has strong environmental adaptability. It also has a role as a habitat provider for various animals in the swamp ecosystem, besides being able to "catch" pollutants and mud to keep the water clear [6]. Phragmites australis is a type of aquatic plant most often used in wetland construction systems because it can form monocultures, significantly changing the structure and function of wetland ecosystems. These plants are essential in the water-carbon exchange between wetland vegetation and the atmosphere [7]. From the characteristics of the two plants above, these plants can positively reduce the parameter values of BOD, COD, Total Nitrogen, Total Phosphorus, and Ammonia [8].

2. Materials and methods

The research was started by measuring the volume of wastewater in one of the tofu factory in Mojosongo Surakarta in a day. A sampling of liquid tofu waste for quality testing is pH, TSS, COD, and BOD in the laboratory.

The equipment used is a jerry can for taking wastewater 65 L, clear plastic 2m, plastic tub with diameter 40 cm to build wetland construction, faucet, \( \frac{1}{2} \) inch PVC pipe, and hose to drain off the liquid waste. Media for filtering liquid waste using wetland construction are soil, palm fiber, charcoal, sand, zeolit, plant cattail (Typha latifolia), and Phragmites australis. The wetland construction making process is made stratified filter. The details for the tofu-waste filter treatment design are as follows:

(i) Filter A. After that, it’s coated with plastic on the container. The bottom layer is zeolite 15 cm deep, the upper layer is charcoal 15 cm deep, and the top layer is sand 15 cm.

(ii) Filter B. Same as the first composition, it only differs in the thickness of the media. At the bottom layer of zeolite as deep as 15 cm, the upper layer of charcoal as deep as 15 cm, the next upper layer is sand 15 cm, the next layer of palm fiber 15 cm, the top layer of soil and planting plants with a distance of 10 cm Cattail plant (Thypa Angustifolia).

(iii) Filter C. It is the same as the second composition. At the bottom layer of zeolite as deep as 15 cm, the next upper layer of charcoal as deep as 15 cm, the next upper layer of sand 15 cm, the next upper layer of palm fiber 15 cm, the top layer of soil 15 cm. It only differs on the media thickness. Planting 10 cm Cattail (Thypa Angustifolia) and Phragmites australis were planted.

(iv) Tofu liquid waste flows into filter A then took the results from filter B to be tested, but filter A is still poured into filtering B with a timely treatment of 24 hours left. The sample has tested and flowed again to filter C with time 24 hours left, then taken to be tested.
3. Results and discussions
The beginning characteristics of tofu waste taken from tofu factory left for one day then analyzed for pH, COD, BOD, TSS. The beginning parameter value level is listed in table 1.

| No. | Parameters | Unit | Analysis Result | Quality Standard |
|-----|------------|------|-----------------|------------------|
| 1   | pH         | -    | 4.2             | 6-9              |
| 2   | COD        | mg/L | 1818            | 275              |
| 3   | BOD5       | mg/L | 920             | 150              |
| 4   | TSS        | mg/L | 2425            | 100              |

Based on table 1 above, it can be seen that tofu-waste from the industry in Mojosongo is not suitable to be disposed of directly into the water. The tofu-waste has content the BOD, COD, TSS, and pH values exceed the quality standards of wastewater from Regional Regulation Number 5 of 2012. These are BOD (150mg/L), COD (275mg/L), TSS (100mg/L), and pH (6-9). Thus the waste needs to be treated before being discharged into the water. To treat the tofu-waste from Mojosongo, it is tested through a fast filter from filter A, consisting of sand, charcoal, and zeloit. The test results are as follows:

| No. | Parameters | Unit | Analysis Result | Quality Standard |
|-----|------------|------|-----------------|------------------|
| 1   | pH         | -    | 4.3             | 6-9              |
| 2   | COD        | mg/L | 1716            | 275              |
| 3   | BOD5       | mg/L | 581             | 150              |
| 4   | TSS        | mg/L | 875             | 100              |

All the parameters testing still exceeds the wastewater quality standard because filter A uses three filter media types without timely treatment. The next step is the effect of adding some media; soil, palm fiber, and cattail plants (Thypa latifolia). As research was conducted (Laili Faridatuzzahro, 2015), the soil is a suitable medium as plants grow, media for microorganism growth, and helped adsorption process from bio-degradation. Plant cattail gave influence in the elimination of pollutant parameters [9]. The result can be seen in Table 3: Based on table 3, the reduction of a parameter value appropriate with the standard quality value of wastewater from Regional Regulation Number 5 of 2012 is BOD. Additionally, Typha latifolia only reduces COD concentration, BOD, because Typha latifolia provide surface area for microorganism and can transfer oxygen from leaf to the root [10]. For other three-parameter can exceed quality standard wastewater, so in the filter C given the addition, it is planted Phragmites australis, which can reduce Chemical Oxygen Demand (COD) concentration in the amount of 82.5%. In contrast, Cattail can reduce COD concentration by 50% to 93% with a variation of time [11]. The result of testing can be seen in Table 4.
Table 3: Data on waste reduction in the filter B

| No. | Parameters | Unit | Analysis Result | Quality Standard |
|-----|------------|------|-----------------|------------------|
| 1   | pH         | -    | 5.5             | 6-9              |
| 2   | COD        | mg/L | 364             | 275              |
| 3   | BOD5       | mg/L | 146             | 150              |
| 4   | TSS        | mg/L | 316             | 100              |

Table 4: Data on waste reduction in the third tub

| No. | Parameters | Unit | Analysis Result | Quality Standard |
|-----|------------|------|-----------------|------------------|
| 1   | pH         | -    | 6.7             | 6-9              |
| 2   | COD        | mg/L | 338             | 275              |
| 3   | BOD5       | mg/L | 110             | 150              |
| 4   | TSS        | mg/L | 123             | 100              |

Table 4 shows that the decrease in COD, BOD, TSS, and pH levels has decreased during the wetland process. The pH and BOD5 values are appropriate with the wastewater quality standards of Provincial Regulation No.5 of 2012. The efficiency of eliminating wastewater content depends on the concentration and time held in the reactor. The longer time, so higher the level of content absorption of the wastewater. The sufficient submerged time will provide opportunities for contact between microorganisms and wastewater. Microorganisms will break down organic material contained in wastewater into simpler compounds. Plants will use it as nutrients. In contrast, aquatic plants’ root system will produce oxygen, which can be used as an energy source/catalyst for a series of metabolic processes for microorganism life [12]. It is strengthened by [13] that pollutant decrease in wastewater that uses aquatic plants is a collaboration between plants and microbes in these plants. It is explained that plant roots will absorb these pollutants after being degraded by microorganisms into simpler compounds.

The addition of 2 kinds of plants in wetland construction can change pH conditions in rizosfer. On noonday, ammonia is produced as a breakdown nitrogen compound, which contributes to pH increasing. In contrast, in the noon, there is carbon dioxide release, causing the pH to decrease. Therefore, the pH of waste can be acid in the noon and base in the noonday. This condition can be shown in Figure 1.

3.1. pH
pH (potential Hydrogen) is an important parameter that can determine acid/base level in the water. pH is also a term used universally to assert acidity or alkalinity from solution [14]. The liquid waste’s pH value before being processed in the filter is 4.2, then becomes 6.7 after testing. The pH value has fulfilled the environmental quality standard stipulated by Provincial Regulation No. 5, 2012. Based on the observations, the pH value in wastewater has changed in the effluent. Wastewater always increases to be more base. Plants carry out photosynthesis by taking H + and releasing OH, causing an increase in pH. In acidic and base pH conditions, the
plants can adjust and neutralize pH conditions [15].

In the wetland construction reactor, the COD concentration decreased significantly with the length of submerged. COD values decreased from 1818 mg/L to 338 mg/L. If given a longer treatment at the time of submerged, the value will be close to the standard quality standard, 275 mg/L. Besides that, the presence of microorganisms in the reactor that degrade most of the organic matter in the wastewater affects the BOD and COD concentration at the beginning of the research. So that, this condition also causes the COD to decrease.

3.2. BOD

The decrease in BOD was quite significant from the original sample of 920 mg/L after filtering three filters with a wetland construction to be 110 mg/L. Testing the BOD concentration of tofu wastewater by planting cattail (Thypa latifolia) and Phragmites australis plants caused a decrease in organic matter concentration in the construction wetland through the oxidation process by aerobic bacteria that grew around the rhizosphere. With the conditions of the rhizosphere area, which is rich in oxygen, it causes aerob bacteria development in the area. The acclimatization process of plants at the beginning of the experiment will allow microorganisms to grow and adapt. Thus the growth of microorganisms has reached an exponential growth phase. Based on the BOD test results of the three filters, there was a maximum decrease.

3.3. TSS

The TSS concentration of tofu wastewater states the number of solids suspended in tofu wastewater in the form of insoluble particles that comes from the washing, boiling, filtering, and pressing processes of soybeans, which can cause turbidity. These particles form into serviceable organic parts that will compose sedimentation at the bottom of the tub. Also, decompose by microbes in the cattail plant’s rhizosphere (Thypa latifolia) Phragmites australis plant. Figure 2 shows a decrease in TSS concentration before testing 2425 mg/L to 123 mg/L, so the TSS results did not fulfill the standards required by the Regional Regulation yet with a value of 100 mg/L.

4. Conclusion

Tofu liquid-waste processing uses a wetland construction with the Regional Regulation of Central Java Province Number 5 of 2012. Prerequisite is the pH value of 6.7 fulfills the requirements
(pH 6-9), COD with a value of 338 mg/L does not satisfy the criteria, BOD5 with a value of 146 mg/L is fulfilling the requirements, TSS with a value of 123 mg/L is not fulfill the requirements.

The value of pollutant levels from tub 1 to tub 3 decreased due to the addition of cattail (Thypa latifolia) and Phragmites australis plants and time variations.

Acknowledgments
The authors express their gratitude to the Ministry of Education and Culture, Republik Indonesia, for the research funding through the scheme of Penelitian Tesis Magister with research grant contract number: 133.72/A.3-III/LPPM/IV/2020.

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