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MORALITY BEFORE KNOWLEDGE

The effectiveness of photomediation of *apu (Pistia stratiotes L.)*, water hyacinth *(Eichhornia crassipes)* and water bamboo *(Equisetum hyemale)* plant on reducing bod levels in tofu factory waste water

Nafi Ayu Widyaningrum[1]*
[1] *Public Health Study Program, General Achmad Yani College of Health Sciences, Cimahi, West Java, 10430, Indonesia.*
*Correspondence: nafiayu0899@gmail.com

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ABSTRACT
Background: The increase in BOD in tofu wastewater is caused by soybeans as a raw material for tofu so that tofu wastewater contains protein, carbohydrates, fats and amino acids. These organic materials affect the high phosphorus, nitrogen, and sulfur in the water, so that the wastewater produced contains organic matter. tall one. **Methods:** The research design used was an experimental research type with Pretest-Posttest with Control Group. Data was collected by examining samples at the Cimahi City Environmental Laboratory. **Findings:** BOD levels of tofu factory wastewater before treatment were 4860 mg/L, the high levels of BOD can be overcome by plant phytoremediation. This study aims to determine the effectiveness of phytoremediation of *apu* wood *(Pistia stratiotes L.)*, water hyacinth *(Eichhornia crassipes)* and water bamboo *(Equisetum hyemale)* on reducing BOD levels in tofu factory wastewater. **Conclusion:** The results of the statistical test using thetest Dependent T and One Way Anova. The results of statistical tests using T Dependent showed that there was a significant difference before after giving water cabbage plants with p value= 0.035, while the results showed no significant differences before after giving water hyacinth plants with p value= 0.059 and water bamboo plants with p value= 0.074 to decrease the BOD levels of tofu factory wastewater. While the results of thestatistical test One Way Anova showed that there was a significant difference after the administration of water cabbage, water hyacinth and water bamboo plants with p value= 0.022 to the decrease in BOD levels of tofu factory wastewater. The most effective use of plants in reducing BOD levels in tofu factory wastewater is water cabbage, this plant can reduce BOD levels in tofu factory wastewater by 33.26%. **Novelty/Originality of this article:** This research can be used for tofu factory wastewater treatment by utilizing water cabbage plants with the phytoremediation method.

KEYWORDS: BOD level; phytoremediation of water cabbage; water hyacinth and water bamboo; wastewater.

1. Introduction

Wastewater is the liquid waste from a business or activity. Wastewater can originate from both domestic and industrial sources (Asmadi & Suharno, 2012). Industrial wastewater generally results from the use of water in production processes, which functions as a coolant, transporting products or raw materials, processing water, and for washing and rinsing products (Ahmad & Adiningsih, 2019). Industrial wastewater is the

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liquid waste from a process or industrial activity whose presence in an environmentally undesirable location has no economic value and is therefore often discarded (Billah et al., 2020). Wastewater is a major water pollution problem in Indonesia, a problem that remains unresolved. One cause of water pollution is tofu factories. Many tofu factories discharge their waste directly into the environment without prior treatment (Chandra, 2006). This has negative impacts, including decreased water quality and water pollution due to untreated discharge into rivers, which causes cloudy river water, unpleasant odors, and pollution problems that damage the environment (Fachrurozi et al., 2010).

According to Febriningrum & Nur (2021), the BOD (Biochemical Oxygen Demand) figure is the amount of oxygen needed by aerobic microorganisms to decompose almost all dissolved or suspended organic matter in water. The decomposition of organic matter is a natural process, a body of water is polluted by organic matter, then during the decomposition process microorganisms can use up the dissolved oxygen in the water (Dewa & Idrus, 2017). This can result in the death of fish in the water. In addition, the lack of oxygen can change the condition to anaerobic so that it can cause a foul odor (Dewi & Akhari, 2020). The increase in BOD in tofu wastewater is caused by several factors, namely because in the tofu production process using soybeans as the raw material for tofu so that tofu wastewater has a protein content of 40-60%, carbohydrates 25-50%, fat 10% and amino acids, These organic materials affect the high levels of phosphorus, nitrogen, and sulfur in the water (Marian & Tuhuteru, 2019). So that the resulting wastewater is a thick liquid containing high organic matter (Istighfari et al., 2018). The presence of organic compounds contained in tofu wastewater causes tofu wastewater to have a BOD (Biological Oxygen Demand) level that exceeds the wastewater quality standard (Hapsari et al., 2018).

Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning Wastewater Quality Standards explains that the wastewater quality standard for soybean processing businesses and/or activities, with a BOD parameter for soy sauce processing, is 150 mg/L, for tofu processing, 150 mg/L, and for tempeh processing, 150 mg/L. Wastewater quality standards are used to measure the limits or levels of pollutants and/or the tolerable amount of pollutants in wastewater to be discharged or released into the water environment by a business or activity (Herlambang, 2002). Research on wastewater quality, such as the results of Hermayanti & Proklamasiningsih (2004), found that the BOD value for tofu industrial wastewater before treatment was 228.10 mg/L. Meanwhile, according to research by Hikmah et al. (2019), the BOD level in tofu wastewater before treatment was 3200 mg/L. Therefore, the BOD level exceeds the maximum limit stipulated in the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 concerning Wastewater Quality Standards. This is because the wastewater is discharged directly into the river without prior treatment (Himma, 2017).

One way to address high BOD levels is by treating wastewater. Wastewater treatment can be carried out physically, chemically, or biologically. One biological treatment process uses plants (Irhamni et al., 2017). This waste management can be done using the phytoremediation method. According to Khaer & Nursyafitri (2019), phytoremediation is a method of reducing or eliminating toxic substances in wastewater using plant media or using plants to extract, eliminate, and detoxify pollutants in the environment. Phytoremediation methods that have been widely used include the *apu* wood plant *(Pistia stratiotes L.)*, water hyacinth *(Eichhornia crassipes)*, and water bamboo *(Equisetum hyemale)* (Margowati & Abdullah, 2016). The *apu* wood plant (*Pistia stratiotes L.*) is often used to decompose wastewater concentrations through the phytoremediation process (Ningrum, 2018). This plant has the potential to reduce high levels of organic wastewater pollutants (Nigrum et al., 2020). It absorbs nutrients from water, can grip mud with its root tufts, and is used to clean very dirty river water (Ni'mah et al., 2019). In industry, it is used to absorb toxic elements in wastewater (Fachrurozi et al., 2010). Water hyacinth *(Eichhornia crassipes)* is often used for wastewater treatment due to its high efficiency (Nugraha & IW, 2015). Water hyacinth can reduce BOD levels and capture heavy metal pollutants and organic compounds in wastewater (Dewi & Tauny, 2020). Water bamboo *(Equisetum hyemale)* has stems with a high silicate content, which is useful for binding particles absorbed by the plant's roots (Nurfadillah et al., 2017). This plant performs quite well in wastewater treatment, absorbing various concentrations of pollutants, including organic matter and toxic compounds (Nugraha & Hari, 2015).

In a study by Oktavia et al. (2016) the *apu* wood plant is used as phytoremediation to reduce BOD levels in tofu wastewater by 92.70% for 7 days, in the study of Pamungkas (2016) the water hyacinth plant can reduce BOD levels in tofu wastewater by 97.31% for 7 days and in the study of Ratnasari (2008) the water bamboo plant can reduce BOD levels in tofu wastewater by 89.99%. So the variation in the differences in *apu* wood, water hyacinth and water bamboo plants greatly influences the phytoremediation method to reduce BOD levels in tofu wastewater. This research will be conducted at the tofu factory "X". The tofu factory "X" in the process of producing tofu with 384 kg/day of soybeans produces 1-1.6 m3 of wastewater originating from the tofu production process that uses water, starting from washing, soaking, cooking, filtering and molding. The BOD level of tofu factory wastewater before treatment was 4860 mg/L. This wastewater can have a negative impact on the environment, such as emitting a foul odor from the degradation of protein residues into ammonia. This odor can spread over a radius of several kilometers due to the wastewater being discharged through drains and directly into rivers without prior treatment. This tofu factory is also located near residential areas and directly adjacent to a river.

Tofu wastewater is very dangerous to humans due to the large number of hazardous and toxic substances contained in the wastewater, such as bacteria, which can transmit disease and cause health problems such as itching and several skin conditions. Therefore, appropriate management methods are needed to address these problems. Based on this, researchers were interested in observing the effectiveness of phytoremediation using pumice, water hyacinth, and water bamboo plants on reducing BOD levels in tofu factory wastewater, which will be treated for 7 days. This difference in use can influence BOD reduction in tofu factory wastewater. Based on the description in the background above, the research problem can be formulated as follows, "Do the *Apu* Wood Plants *(Pistia stratiotes L.)*, Water Hyacinth *(Eichhornia crassipes)* and Water Bamboo *(Equisetum hyemale)* Have Phytoremediation Effectiveness in Reducing BOD Levels in Tofu Factory Wastewater.

2. Methods

2.1 Research paradigm

Tofu is a popular food not only in Indonesia but also in other Asian countries. It is a source of vegetable protein. In addition to its protein content, tofu is recognized as a nutritious food containing substances such as fat, vitamins, and minerals (Rijal, 2016). The tofu industry produces wastewater that is usually discharged directly into water bodies without prior treatment. This can lead to water pollution, as tofu wastewater contains high levels of dissolved organic matter and will rot if left to stand for several days in open areas (Rismawati et al., 2020).

Tofu factory wastewater is produced from the washing, boiling, pressing, and molding processes. Because soybeans are used in the tofu production process, tofu wastewater contains organic matter and the resulting quantity is very high (Riyanto, 2019). The presence of organic compounds in tofu wastewater causes tofu wastewater to have a BOD (Biological Oxygen Demand) level that exceeds wastewater quality standards (Riyanto, 2011). The use of variations of *apu* wood *(Pistia stratiotes L.)*, water hyacinth *(Eichhornia crassipes)*, and water bamboo *(Equisetum hyemale)* as phytoremediators of BOD levels in tofu wastewater was carried out by placing the tofu wastewater in a container planted with *apu* wood, water hyacinth, and water bamboo plants.

The pumice tree *(Pistia stratiotes L.)* is often used to decompose wastewater concentrations through phytoremediation. This plant has the potential to reduce wastewater pollutants with high organic content (Rosmala, 2019). The water hyacinth plant *(Eichhornia crassipes)* is often used to treat wastewater because it is able to treat wastewater with a high level of efficiency, so that water hyacinth can reduce BOD levels, capture heavy metal pollutants and organic content in wastewater (Romansyah et al., 2019). The water bamboo plant *(Equisetum hyemale)* has stems with a high silicate content, which is useful for binding particles absorbed by the plant's roots. This plant has quite good performance in wastewater treatment, namely it can absorb various levels of pollutant concentrations, including organic substances and toxic compounds (Ruhmawati et al., 2017). Based on the research paradigm above, it can be described in a research conceptual framework as follows:

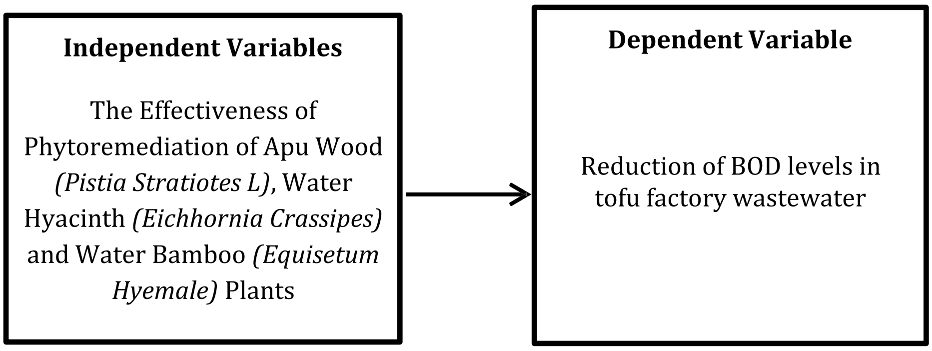

Fig 1. Research conceptual framework

2.2 Research design, research hypothesis, and research variables

The research design used was a true experimental study. This study involves conducting an experiment to determine the symptoms that arise as a result of a particular treatment or experiment. This experimental study employed a true experimental design with a pretest-posttest with a control group (Sari & Al Jauhari, 2016).

The hypotheses in this study are as follows. Null Hypothesis (Ho), there is no difference in the reduction of BOD levels in tofu factory wastewater with the addition of *apu* wood, water hyacinth, and water bamboo plants. Alternative Hypothesis: There is a difference in the reduction of BOD levels in tofu factory wastewater with the addition of *apu* wood, water hyacinth, and water bamboo plants. The independent variables in this study are variations of *Apu* Wood *(Pistia stratiotes L.)*, Water Hyacinth *(Eichhornia crassipes)* and Water Bamboo *(Equisetum hyemale)*. Dependent variables: the dependent variable in this study is the decrease in BOD levels in tofu wastewater.

Table 1. Operational definitions

No	Variable	Conceptual Definition	Operational Definition	How to Measure	Measuring Instrument	Measurement Results	Measuring Scale
1.	*Apu* Wood *(Pistia stratiotes L.)*, Water Hyacinth *(Eichhorni a crassipes)* & Water Bamboo *(Equisetum hyemale)*	The pumice plant is often called watercress or water cabbage. This plant has thick, rose-like leaves. (Rijal, 2016). Water hyacinth is an aquatic weed that grows approximately 90 cm tall, with smooth, green leaves. (Khaer & Nursyafitri, 2019). Water bamboo has cylindrical, hollow, tapering	The number of types of plants that will be used for tofu factory wastewater treatment with the specified plants are *Apu* Wood, Water Hyacinth & Water Bamboo.	Observation	There isn't any	Different types of aquatic plants	Nominal

		green stems. (Ratnasari, 2008)					
2.	BOD levels of tofu factory wastewater	The nature of the content of wastewater pollutants that cannot be observed physically and the chemical parameters that determine the pollutant	BOD content value in tofu factory wastewater in mg/L units	Laboratory examination	Spectrophotometry	BOD levels in mg/L of tofu factory wastewater	Ratio

2.3 Population and research sample

The population is all subjects (humans, animals, experiments, laboratory data, etc.) that will be studied and meet the specified characteristics (Sattuang, 2020). The population that will be used in this study is all tofu factory wastewater in West Batujajar Village. The sample is a portion of the population that is expected to be representative of the population (Sattuang, 2020). The sample of this study is tofu factory wastewater at the inlet section located in West Batujajar Village. The sample size determined in this study is based on the number of treatments (t) of 3 (three) and 1 (one) control. In each treatment, each uses Kayu *Apu*, Water Hyacinth and Water Bamboo plants with 100 liters of tofu factory wastewater with a contact time of 7 days. To determine the number of repetitions (r) the following formula is used (Sayow et al., 2020):

$$t(r-1) \geq 6 \quad \text{(Eq. 1)}$$
$$3\,(r\ -\ 1) \geq 6$$
$$3r - 3 \geq 6$$
$$3r \geq 9$$
$$r \geq 3$$

The number of treatments in this study was 3 treatments and was repeated 3 times.

2.4 Data collection

The data collection technique was carried out by measuring the BOD (Biological Oxygen Demand) levels in tofu factory wastewater that had been treated with various plants, namely pumice, water hyacinth, and water bamboo, which were contacted for seven days by measuring during the research, and examined at the Cimahi City Regional Environmental Laboratory. The research instruments used in this study were: stationery and observation sheets, used to record the results of observations and measurements. Thermometer and pH Meter, used to measure the temperature and pH of tofu factory wastewater during treatment. Laboratory tools, used to measure BOD levels in tofu factory wastewater. Cameras, used to document the research process. Validity and reliability test of research instruments: in this study, validity and reliability tests were not carried out.

2.5 Research procedures

Determining the problem to be studied in this stage the researcher begins by searching through various libraries and accurate information news. Literature study is carried out by searching for theories and literature that have been proposed from various library sources such as health books, journals and the internet. Then, researchers conducted a preliminary study on phytoremediation of variations in the number of Kayu *Apu*, water hyacinth and water bamboo plants which will be used as research and survey materials to the tofu factory in Batujajar Barat Village, West Bandung Regency which will be used as a place for sampling tofu factory wastewater.

Table 2. Research tools

No	Tool	Amount
1.	30 L Water Jerry Can	3 pieces
2.	Large Bucket Volume 15 L	10 pieces
3.	Dipper	1 piece
4.	Thermometer and pH Meter	1 piece
5.	Sample Bottle	11 pieces
6.	Calendar	1 piece
7.	Stationery	1 piece
8.	Scales	1 piece

The tofu factory wastewater used for the study was 10 liters per bucket, so the required tofu wastewater for the study was 100 liters. The *apu* wood, water hyacinth, and water bamboo plants were each 250 grams per bucket. The *apu* wood and water hyacinth plants used had the criteria of 6-8 leaves, a plant/root height of 10-20 cm, and the water bamboo plants used had the criteria of 10-60 cm in length. All plants used must be green and fresh. Implementation stage: The steps in conducting the study included: research preparation, preparing research tools and materials for collecting tofu factory wastewater samples. Research sampling uses 100 liters of tofu factory wastewater samples were collected using jerry cans. The tofu factory wastewater samples were placed in each bucket, each 10 liters in each bucket, and each bucket was labeled with information on the treatment and repetition.

Each bucket was given or placed with pumice, water hyacinth, and water bamboo plants that had previously been acclimatized for 7 days and 1 was not given or placed with pumice, water hyacinth, and water bamboo plants which acted as a control. Tofu factory wastewater was contacted with pumice, water hyacinth, and water bamboo plants according to the specified contact time, which was 7 days. Measuring temperature, pH, and BOD levels in each treatment and control, measured on day 0 (zero) and day 7 (seven). pH and temperature measurements were carried out using a thermometer and pH meter, while BOD levels were checked at the Cimahi City Regional Environmental Laboratory. This experiment was carried out with 3 (three) repetitions. Conducting data collection and data analysis. Final stage: making and compiling a research report. Presenting research results. Improving the results of the research report.

2.6 Data processing and analysis

After data collection, the raw data must be processed to produce information that can ultimately be used to address the research objectives. To ensure accurate data analysis, there are four stages in data processing (Riyanto, 2011): Then editing steps is the activity of checking that the collected data is complete, relevant, and accurate. For coding, assignment or creation of codes for each piece of data, such as converting numerical data to categorical data. The last is closing and cleaning. Closing is the process of entering coded data into a computer program for statistical analysis. Then clining is the activity of rechecking the entered data for errors.

Univariate analysis is an analysis that describes data that will be created individually or in groups. The purpose of descriptive analysis is to systematically describe factual and accurate data regarding the facts and relationships between the phenomena being investigated or researched. This analysis is used to describe the dependent variable, namely the decrease in BOD levels of tofu factory wastewater and the independent variable, namely the variation of *apu* wood, water hyacinth and water bamboo plants (Setiyono & Gustaman, 2017). Bivariate analysis: bivariate analysis is carried out to see the relationship between the independent variables (variations of *apu* wood, water hyacinth and water bamboo plants) with the dependent variable (decrease in BOD levels). In this study, bivariate analysis was carried out using two tests, namely the Dependent T Test and the Anova Test, based on the results of the data normality test in this study showed that seen from the comparison of skewness and standard error the results were below two so that the data was normally distributed, it can be concluded that this study used the Dependent T test and the Anova test. The Dependent T test was carried out to analyze the pretest and posttest data of pH, Temperature and BOD levels of each treatment. The Anova test was carried out to determine the differences in pH, Temperature and BOD levels in each treatment group, namely the treatment by contacting *apu* wood, water hyacinth and water bamboo plants with tofu factory wastewater.

3. Result and Discussion

3.1 Discussion results

3.1.1 Description of pH, temperature and BOD levels for each treatment of pumice, water hyacinth and water bamboo plants

Based on Table 3, the results of the pH measurements of tofu factory wastewater before treatment showed an average pH of 4.30, while the results of the pH measurements after treatment showed the lowest average of 6.36 in the water hyacinth treatment group and the highest average pH of 6.76 in the water bamboo treatment group. The results of temperature measurements before and after treatment.Results of pH measurements before and after treatment.

Table 3. Results of pH measurements before and after treatment

Treatment Group	Before Treatment			After Treatment		
	Mean	SD	Min- Max	Mean	SD	Min- Max
Apu Wood	4.30	0.00001	4.3 – 4.3	6.50	0.1732	6.3-6.6
Water Hyacinth	4.30	0.00001	4.3 – 4.3	6.36	0.1528	6.2-6.5
Water Bamboo	4.30	0.00001	4.3 – 4.3	6.76	0.1528	6.6-6.9
Control	4.30	0.00001	4.3 – 4.3	6.70	0.00001	6.7-6.7

Based on table 4, the results of the tofu factory wastewater temperature measurements before treatment obtained an average result of 26.50°C. Meanwhile, the results of temperature measurements after treatment obtained the lowest average result of 25.33 °C in the treatment group of pumice and water bamboo plants and the highest average temperature of 23.50°C in the treatment group of water hyacinth plants. The results of the BOD level measurements for each treatment of pumice, water hyacinth and water bamboo plants.

Table 4. Results of temperature measurements before and after treatment

Treatment Group	Before Treatment			After Treatment		
	Mean	SD	Min- Max	Mean	SD	Min- Max
Apu Wood	26.50	0.00001	26.5 – 26.5	25.33	0.5778	25.0 – 26.0
Water Hyacinth	26.50	0.00001	26.5 – 26.5	25.50	0.5000	25.0 – 26.0
Water Bamboo	26.50	0.00001	26.5 – 26.5	25.33	0.5774	25.0 – 26.0
Control	26.50	0.00001	26.5 – 26.5	25.16	0.2887	25.0 – 25.0

Based on table 5, the results of the BOD level measurement of tofu factory wastewater before treatment were obtained with an average result of 4860 mg/L. Meanwhile, the results of the BOD level measurement after treatment obtained the lowest average result of 3243.33 mg/L in the pumice wood treatment group and the highest average BOD level of 4046.67 mg/L in the water bamboo plant treatment group.

Table 5. Results of BOD level examination before and after treatment

Treatment Group	Before Treatment			After Treatment		
	Mean	SD	Min- Max	Mean	SD	Min- Max
Apu Wood	48.60	0.0001	48.60 – 48.60	3243.33	534.821	28.40-38.50
Water Hyacinth	48.60	0.0001	48.60 – 48.60	3710.00	508.626	32.40-42.50
Water Bamboo	48.60	0.0001	48.60 – 48.60	4046.67	405.010	36.40-44.50
Control	48.60	0.0001	48.60 – 48.60	4620.00	0.0001	46.20-46.20

3.1.2 Differences in pH, temperature and biochemical oxygen demand (BOD) levels in tofu factory wastewater before and after treatment with pumice, water hyacinth and water bamboo plants

The bivariate analysis used to determine the differences in pH, temperature and biochemical oxygen demand (BOD) levels in tofu factory wastewater before and after treatment with pumice, water hyacinth and water bamboo plants was a dependent t-test.

Table 6. Average distribution of differences in pH levels in tofu factory wastewater before and after treatment

Treatment Group		Mean	SD	SE	P value
Apu Wood	Before	4.30	0.17	0.1000	0.002
	After	6.50			
Water Hyacinth	Before	4.30	0.15	0.0882	0.002
	After	6.36			
Water Bamboo	Before	4.30	0.15	0.0882	0.001
	After	6.76			

Based on table 6, it was found that the average pH value of tofu factory wastewater in the treatment of *apu* wood, water hyacinth and water bamboo was 4.30, while the average after treatment using *apu* wood plants for 7 days was 6.50, water hyacinth was 6.36 and water bamboo was 6.76 with an average difference between the pH value before and after the treatment of *apu* wood of 0.1000, water hyacinth of 0.0882 and water bamboo of 0.0882 with a standard deviation of *apu* wood treatment of 0.1732, water hyacinth of 0.1528 and water bamboo of 0.1528. The results of statistical tests were obtained in the treatment of *apu* wood and water hyacinth with a p value= 0.002 at alpha 5% (0.05) so it can be concluded that there is a significant difference between the pH value before and after treatment using *apu* wood and water hyacinth plants. In the water bamboo treatment with a p value= 0.001 at alpha 5% (0.05), it can be concluded that there is a significant difference between the pH value before and after treatment using water bamboo plants.

Table 7. Average distribution of differences in temperature levels in tofu factory wastewater before and after treatment

Treatment Group		Mean	SD	SE	P value
Apu Wood	Before	26.50	0.5774	0.3333	0.073
	After	25.33			
Water Hyacinth	Before	26.50	0.5000	0.2887	0.074
	After	25.50			
Water Bamboo	Before	26.50	0.5774	0.3333	0.073
	After	25.33			

Based on table 7, it was found that the average temperature value of tofu factory wastewater in the treatment of *apu* wood, water hyacinth and water bamboo was 26.50°C, while the average after treatment using *apu* wood plants for 7 days was 25.33°C, water hyacinth was 25.50°C and water bamboo was 25.33 with an average difference between the temperature values before and after the treatment of *apu* wood of 0.3333, water hyacinth was 0.2887 and water bamboo was 0.3333 with a standard deviation of apu wood treatment of 0.5774, water hyacinth was 0.5000 and water bamboo was 0.5774. The results of statistical tests were obtained in the treatment of *apu* wood and water bamboo with a p value= 0.073 at alpha 5% (0.05) so it can be concluded that there is no significant difference between the temperature values before and after treatment using *apu* wood and bamboo plants. In the water hyacinth treatment with a p value= 0.074 at alpha 5% (0.05), it can be concluded that there is no significant difference between the temperature values before and after treatment using water hyacinth plants.

Table 8. Distribution of average differences in BOD levels in tofu factory wastewater before and after treatment

Treatment Group		Mean	SD	SE	P value
Apu Wood	Before	4860.00	534.821	308.779	0.035
	After	3243.33			
Water Hyacinth	Before	4860.00	508.626	293.655	0.059
	After	3710.00			
Water Bamboo	Before	4860.00	405.010	233.833	0.074
	After	4046.67			

Based on table 8, it was found that the average BOD content of tofu factory wastewater in the treatment of pumice, water hyacinth and water bamboo was 4860.00 mg/L, while the average after treatment using pumice plants for 7 days was 3243.33 mg/L, water hyacinth was 3710.00 mg/L and water bamboo was 4046.67 mg/L with the average difference between the BOD content values before and after the pumice treatment of 308.779, water hyacinth was 293.655 and water bamboo was 233.833 with a standard deviation of the pumice treatment of 534.821, water hyacinth was 508.626 and water bamboo was 405.010. The statistical test results obtained in the treatment of pumice wood with a p value= 0.035 at alpha 5% (0.05) it can be concluded that there is a significant difference between the BOD levels before and after treatment using pumice wood plants. In the treatment of water hyacinth with a p value= 0.059 at alpha 5% (0.05) it can be concluded that there is no significant difference between the BOD levels before and after treatment using water hyacinth plants. In the treatment of water bamboo with a p value= 0.075 at alpha 5% (0.05) it can be concluded that there is no significant difference between the BOD levels before and after treatment using water bamboo plants.

3.1.3 Differences in pH, temperature and biochemical oxygen demand (BOD) levels in tofu factory wastewater in each treatment of pumice, water hyacinth and water bamboo plants

The bivariate analysis used to determine the differences in pH, temperature and biochemical oxygen demand (BOD) levels in tofu factory wastewater in each treatment of *apu* wood, water hyacinth and water bamboo plants was a one-way ANOVA test.

Table 9. Analysis of the effectiveness of pumice, water hyacinth and water bamboo plants on pH levels

Treatment Group	Mean	SD	Min-Max	P value
Apu Wood	2.20	0.1732	2.0-2.3	
Water Hyacinth	2.06	0.1528	1.9-2.2	0.027
Water Bamboo	2.46	0.1528	2.3-2.6	
Control	2.40	0.0001	2.4-2.4	

Based on table 9, the average pH value of tofu factory wastewater in the treatment using pumice plants was 2.20 with a standard deviation of 0.1732, the average of the treatment group using water hyacinth plants was 2.06 with a standard deviation of 0.1528, the average and mean of the treatment group using water bamboo plants was 2.46 with a standard deviation of 0.1528, while the average and mean of the control group was 2.40 with a standard deviation of 0.0001. The results of the statistical test obtained a p value= 0.027 at alpha 5% (0.05) so it can be concluded that there is a significant difference after giving three plant treatments and the control group on the pH value of tofu factory wastewater.

Table 10. Analysis of the effectiveness of pumice, water hyacinth and water bamboo plants in reducing BOD levels

Treatment Group	Mean	SD	Min-Max	P value
Apu Wood	1616.67	534.821	1010-2020	
Water Hyacinth	1150.00	508.626	610-1620	0.022
Water Bamboo	813.33	405.010	410-1220	
Control	240.00	0.0001	240-240	

Based on table 10, the average BOD level of tofu factory wastewater in the treatment using pumice plants was 1616.67 mg/L with a standard deviation of 534.821, the average of the treatment group using water hyacinth plants was 1150.00 mg/L with a standard deviation of 508.626 mg/L, the average and mean of the treatment group using water bamboo plants was 813.33 mg/L with a standard deviation of 405.010, while the average and mean of the control group was 240.00 mg/L with a standard deviation of 0.0001. The results of the statistical test obtained a p value= 0.022 at alpha 5% (0.05) so it can be concluded that there is a significant difference after administering three plant treatments and the control group to reduce BOD levels in tofu factory wastewater.

3.1.4 The most effective use of plants is between pumice, water hyacinth and water bamboo in reducing BOD levels in tofu factory wastewater

Based on table 11, the results of the highest reduction in BOD levels in tofu factory wastewater were obtained from the pumice plant treatment group with an effectiveness percentage of 33.26%, while the lowest reduction in BOD levels in tofu factory wastewater was obtained from the water bamboo plant treatment group with an effectiveness percentage of 16.73%.

Table 11. Percentage of plant use in reducing BOD levels in tofu factory wastewater

Treatment Group	Before	After	Difference (mg/L)	Effectiveness (%)
Apu Wood	4860	3243.33	1616.67	33.26
Water Hyacinth	4860	3710.00	1150	23.66
Water Bamboo	4860	4046.67	813.33	16.73
Control	4860	4620.00	240	4.9

According to Sattuang (2020), determining the effectiveness (%) of reducing BOD levels can be calculated by:

$$\text{Effectiveness}= \frac{\text{level before}}{\text{level after level before}} \times 100\% \quad \text{(Eq. 2)}$$

3.2 Discussion

3.2.1 Description of pH, temperature and BOD levels for each treatment of apu wood, water hyacinth and water bamboo plants

The pH of tofu wastewater before and after the study was 4–6.7. According to Ningrum et al (2020) an abnormal pH will disrupt plant metabolism, tofu wastewater has acidic pH characteristics, this will hinder the process of decomposition of organic substances. The changing pH concentration during treatment was caused by the *apu* wood, water hyacinth and water bamboo plants through the process of photosynthesis by utilizing the concentration of CO2 in the tofu factory wastewater, in this photosynthesis process the *apu* wood, water hyacinth and water bamboo plants will absorb the reaction of CO2 with the elements in the tofu factory wastewater, so that this photosynthesis process can increase the pH to neutral. Temperature: the temperature of tofu wastewater before and after the study was 26-25°C. The temperature of wastewater has a major influence on plant metabolism to help the process of plant photosynthesis so that it can produce oxygen which can help the process of decomposition of organic matter with plant roots. Temperature is also influenced by the surrounding environment. BOD levels: the *apu* wood plant is one of the aquatic weeds that has long, dense, finely branched roots and an extensive root system. (Sumantri, 2017). The pumice tree *(Pistia stratiotes L.)* is a phytoremediator plant, meaning it has the ability to process waste, including heavy metals, organic, and inorganic substances. The pumice tree is able to grip mud with its roots and absorb excess nutrients that cause pollution. This absorption occurs due to the chelating agent, or phytochelatin, excreted by the pumice tree's root tissue (Suyono, 2012).

Water hyacinth is a weed that lives floating in water. Water hyacinth is a type of aquatic plant that easily grows in polluted waters, developing and growing very quickly, making it useful for humans to address pollution (Zumani et al., 2015). Water hyacinth, as a biofilter, is thought to accelerate water evaporation through evapotranspiration. The evapotranspiration process that occurs will support the rate of uptake of nutrients and organic matter needed for photosynthesis through the mechanism of water absorption through the root hairs. High photosynthetic activity will also produce high levels of oxygen, thereby increasing the dissolved oxygen in liquid waste. Water hyacinth supplies oxygen to wastewater through its roots and increases the amount of dissolved oxygen in the wastewater, thus stimulating the activity of microorganisms in decomposing contaminants (Zahro & Nisa, 2020). Water bamboo plants grow easily anywhere, are easy to care for, and are resistant to various external influences. Water bamboo plants have stems with a high silicate content, which is useful for binding particles absorbed by the plant's roots. Water bamboo plants have photosynthetic results in the form of high oxygen, thus enriching the oxygen content in the water, which will be used by aquatic biota to decompose wastewater in the water (Zulkoni, 2018). Based on the results of the BOD level examination in tofu factory wastewater carried out before and after treatment, namely on day 0 and day 7, it showed that the BOD level before treatment was 4860 mg/L. From the results of the BOD examination after treatment with the use of pumice, water hyacinth and water bamboo plants for 7 days with 3 repetitions, the lowest BOD level after treatment was 3243.33 mg/L and the highest BOD level was 4046.67 mg/L.

3.2.2 Differences in pH, temperature and biochemical oxygen demand (BOD) levels in tofu factory wastewater before and after treatment with pumice, water hyacinth and water bamboo plants

Based on the results of the Dependent T Test that the use of pumice wood and water hyacinth as phytoremediation media obtained a p value at pH of pumice wood and water hyacinth of 0.002 and in water bamboo of 0.001 which showed results smaller than alpha 5%, it can be concluded that there is a significant difference after giving treatment of pumice wood, water hyacinth and water bamboo. This is in line with the research of Nurfadillah et al. (2017) that there is a significant difference in the decrease in pH in wastewater, changes in pH are caused by the process of biodegradation of organic materials, so that in the process of decomposition of organic materials it will affect the pH value. Based on the results of the Dependent T-Test, the use of pumice and water hyacinth as phytoremediation media yielded a p-value of 0.073 for pumice and water bamboo, and 0.074 for water hyacinth, indicating a result greater than the 5% alpha value. It can be concluded that there was no significant difference after the treatment of pumice, water hyacinth, and water bamboo.

This aligns with research by Oktavia et al. (2016) that temperature in phytoremediation is influenced by environmental conditions. Based on the results of the Dependent T-Test, the use of pumice and water hyacinth as phytoremediation media yielded a p-value of 0.035 for pumice, 0.059 for water hyacinth, and 0.074 for water bamboo. The test results showed that the results for pumice were less than the 5% alpha value, thus concluding that there was a significant difference after the treatment of pumice. While the test results on water hyacinth and water bamboo showed that water hyacinth and water bamboo were greater than alpha 5%, it can be concluded that there was a significant difference after the treatment of water hyacinth and water bamboo plants. This is in line with the research of Nurfadillah et al. (2017) who stated that the absence of differences in water hyacinth and water bamboo plants was due to the saturation of water plants as absorbents which resulted in BOD levels not decreasing rapidly.

3.2.3 Differences in pH, temperature and biochemical oxygen demand (BOD) levels in tofu factory wastewater in each treatment of pumice, water hyacinth and water bamboo plants

Based on the results of the One-Way ANOVA test for pH, the p-value obtained was 0.027. The statistical test results obtained a p-value of 0.027, which is less than the 5% alpha value. Therefore, it can be concluded that H0 is rejected, meaning there is a significant difference after the addition of pumice, water hyacinth, and water bamboo plants on the pH level of tofu factory wastewater. This is in line with the research of Ni'mah et al. (2019), which explains that the significant increase in pH is caused by the biochemical activity of microorganisms found in plant roots. During photosynthesis, aquatic plants absorb CO2 from the wastewater, resulting in an increase in water pH or neutralization. Based on the results of the One-Way ANOVA test for temperature, the p-value obtained was 0.647. The statistical test results obtained a p-value of 0.647, which is less than the 5% alpha value. Therefore, it can be concluded that H0 is accepted, meaning there is no significant difference after the addition of pumice, water hyacinth, and water bamboo plants on the temperature level of tofu factory wastewater.

This is in line with the research of Billah et al. (2020) explained that the temperature in the phytoremedation process is influenced by the environment, which will affect metabolism and photosynthesis. Therefore, increases and decreases in temperature will indirectly affect the absorption rate of aquatic plants in wastewater. Based on the results of the One-Way ANOVA test, the p-value obtained was 0.022. The statistical test results obtained a p-value of 0.022, which is less than the 5% alpha value. Therefore, it can be concluded that H0 is rejected, meaning there is a significant difference after the addition of *apu* wood, water hyacinth, and water bamboo plants in reducing BOD levels in tofu factory wastewater. This is in line with the research of Rismawati et al. (2020) which found a significant difference between the addition of *apu* wood plants and the reduction of BOD levels in tofu factory wastewater. Research by Sari et al. (2016) explained that treating tofu factory wastewater with *apu* wood plants can reduce BOD levels.

This is in line with the research of Ningrum et al. (2020) that there is a significant difference in the provision of water hyacinth plants in reducing BOD levels in tofu factory wastewater. According to Dewi & Tauny (2020) explained that providing treatment with water hyacinth plants in tofu factory wastewater can reduce BOD levels. This is also in line with the research of Nugraha & Hari (2015) that there is a significant difference in providing water bamboo plants in reducing BOD levels in tofu factory wastewater. According to Margowati & Sugeng (2016) explained that providing treatment with water bamboo plants in wastewater can reduce BOD levels. Providing treatment with *apu* wood, water hyacinth and water bamboo plants in tofu factory wastewater can reduce BOD levels. This occurs because the provision of these plants has a good role in supporting the rate of absorption of nutrients which are the result of the decomposition of organic matter by microbes and utilized in the process of photosynthesis. The higher the photosynthetic activity, the higher the dissolved oxygen produced, which will trigger an increase in the performance of microorganisms in degrading existing organic compounds. Oxygen produced by photosynthesis can be used to decompose organic matter in wastewater. Meanwhile, the plant's root system produces oxygen, which can be used as an energy source for a series of metabolic processes for microorganisms. The roots of pumice, water hyacinth, and water bamboo also play an active role in reducing BOD levels in tofu factory wastewater.

3.2.4 The most effective use of plants is between pumice, water hyacinth and water bamboo in reducing BOD levels in tofu factory wastewater.

Based on the analysis results in Table 11, the average BOD reduction in the pumice treatment group was 33.26%, the water hyacinth treatment group was 23.66%, the water bamboo treatment group was 16.73%, and the control group was 4.9%. Based on plant observations during the study, pumice plants had better phytoremediation capabilities than water hyacinth and water bamboo. During the phytoremediation process, the water hyacinth plants began to wilt on the second day, while the water bamboo plants began to wilt on the third day, and the pumice plants began to wilt on the fifth day. On the seventh day, some of the stems and leaves of the water hyacinth and water bamboo plants turned brown, and the roots began to fall off. While the leaves of the pumice plants showed little color change, the roots remained firm and white due to the absorption of organic elements from the tofu factory wastewater.

The most effective plant used to reduce BOD levels in tofu factory wastewater is the pumice plant. The reduction in BOD levels is also influenced by the presence of pumice plants covering the surface of the wastewater. The presence of pumice plants can absorb organic matter contained in the wastewater because they have wider leaves to cover the water surface. The denser the leaves, the more organic matter is absorbed and the less organic matter that must be degraded by microorganisms. The less organic matter that must be degraded by microbes, the higher the oxygen content in the wastewater (Fachrurozi et al., 2010). Dissolved oxygen in the wastewater also increases due to the supply of oxygen from plant photosynthesis. The reduction in BOD levels can also be caused by the process of phytodegradation. Organic contaminants are absorbed through the roots and decomposed through metabolic processes in plants. The reduction in pollutants can be caused by the process of phytovolatization, which is the absorption of pollutants by plants after processing and released as water vapor into the atmosphere. This process is appropriate for organic contaminants (Rismawati et al., 2020).

4. Conclusion

Based on the results of the conclusions that have been made, it can be concluded: the picture of the pH before treatment shows an average pH of 4.30 while the results of pH measurements after treatment obtained the lowest average result of 6.36 in the water hyacinth treatment group and the highest average pH of 6.76 in the water bamboo treatment group. The picture of the temperature before treatment shows an average of 26.50°C. While the results of temperature measurements after treatment obtained the lowest average result of 25.33°C in the pumice and water bamboo treatment groups and the highest average temperature of 23.50°C in the water hyacinth treatment group. The BOD level in tofu factory wastewater obtained the results of measurements before being given treatment showed an average of 4860 mg/L. While the results of measurements of BOD levels after being given treatment showed the lowest average result of 3243.33 mg/L in the pumice wood treatment group and the highest average BOD level of 4046.67 mg/L in the water bamboo treatment group. Based on the results of the Dependent T-Test, the pH of pumice and water hyacinth was 0.002 and that of water bamboo was 0.001, indicating a result lower than the 5% alpha value. It can be concluded that there was a significant difference after the treatment of pumice, water hyacinth, and water bamboo.

The p-value for pumice and water bamboo was 0.073 and that of water hyacinth was 0.074, indicating a result higher than the 5% alpha value. It can be concluded that there was no significant difference after the treatment of pumice, water hyacinth, and water bamboo. The p-value for the BOD content of pumice was 0.035, for water hyacinth it was 0.059, and for water bamboo it was 0.074. The test results showed that the pumice was lower than the 5% alpha value, indicating a significant difference after the treatment of pumice. And the results on water hyacinth and water bamboo show that the results on *apu* wood are greater than alpha 5%, it can be concluded that there is no significant difference after giving the treatment of water hyacinth and water bamboo plants. Based on the results of the statistical test, p value= 0.027 is smaller than alpha 5%, it can be concluded that H0 is rejected, which means there is a significant difference after giving *apu* wood, water hyacinth and water bamboo plants to the pH level of a tofu factory wastewater. Based on the results of the statistical test, p value= 0.647 is smaller than alpha 5%, it can be concluded that H0 is accepted, which means there is significant difference after giving *apu* wood, water hyacinth and water bamboo plants to the temperature level of tofu factory wastewater. Based on the results of the statistical test, p value= 0.022 is smaller than alpha 5%, it can be concluded that H0 is rejected, which means there significant difference after giving *apu* wood, water hyacinth and water bamboo plants to a reduce the BOD level of tofu factory wastewater. The most effective plant used in reducing BOD levels in tofu factory wastewater is the pumice plant with a reduction in BOD levels of 33.26%.

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Biography of Author

Nafi Ayu Widyaningrum, Public Health Study Program, General Achmad Yani College of Health Sciences, Cimahi.

- Email: nafiayu0899@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A