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Identification of Tempeh Wastewater Quality and Analysis of Producers' Behavior Towards Waste Management in Plaju Ulu, Palembang, South Sumatera, Indonesia

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Abstract: The development of the household-scale tempeh industry in Plaju Ulu has the opportunity to disrupt the balance of the environmental ecosystem if it is not balanced with treatment. This study aims to identify the stages of the tempeh production process that have the potential to cause environmental pollution and to identify the behavior of tempeh producers in waste management. These efforts are necessary to immediately prevent the impacts caused by waste and to serve as a basis for determining the appropriate treatment methods. Quantitative methods were used for the identification of BOD, COD, TSS, and pH. A qualitative method was used to find out the behavior of producers. The results showed that the soaking stage produced a pH level of 3.830; TSS 22,350 mg/L; COD 27,214.1 mg/L, and BOD 224 mg/L. The washing stage produces a pH of 4.530; TSS 787.5 mg/L; COD of 1,187.2 mg/L, and BOD of 7 mg/L. The boiling stage produces pH 5.3; TSS 1,165 mg/L; COD 45,332.8 mg/L, and BOD 295 mg/L. The separation stage of soybean produces TSS 117 mg/L; COD 676,320; BOD 400 mg/L and pH level 6.930. The watering stage produces a BOD level of 160 mg/L, COD 269,84; TSS 32,3. Tempeh producers have been aware of the importance of the waste management process to maintain environmental balance, but as many as 81% of producers still dispose of waste.
Keywords: wastewater, environment, behavior

1. Introduction

Tempeh is one of Indonesia's local foods made by adding tempeh yeast in the form of *Rhizopus oligosporus* for the fermentation process of soybeans [1]. The tempeh production process includes soaking, processing to break and remove the skin and seeds of soybeans, washing, boiling, drying, cooling, inoculation, packaging, and incubation [2]. The characteristics of waste from the tempeh production process are classified into physical properties such as total solids, temperature, odor, and color, and chemical properties, including organic compounds such as proteins, carbohydrates, fats, and oils, as well as gases [3]. Tempeh production must be carried out with good production management to ensure that the resulting tempeh meets standardized quality [4].

During the production process, raw soybeans go through soaking, boiling, and fermentation stages, which release organic compounds such as proteins, carbohydrates, fats, and oils, contributing to changes in BOD and COD values [5]. Suspended solids from soybean skins and fermentation residues contribute to TSS [6]. As for pH, the fermentation process, which involves organic compounds, undergoes hydrolysis into organic acids, which can lower the pH of the liquid waste [7].

Many people argue that waste from household-scale food industry production activities is not too harmful to the environment and does not interfere with people's daily activities. What the community feels is only seen as a short-term impact but if activities in household-scale industries are not balanced with good environmental management activities, it will disrupt the balance of the environmental ecosystem in the long term [8]. Industrial waste disposal must comply with environmental management standards and the environmental management efforts that should be implemented by industrial actors [9].

The role of the community in environmental management activities is related to the obligations of community groups in maintaining environmental sustainability [10]. These efforts can be carried out through social supervision activities by making local rules, providing suggestions and proposals related to waste treatment systems, and complaining about obstacles to the delivery of information that is important for the success of environmental conservation programs. The management of tempeh liquid waste faces challenges in implementation, influenced by several factors such as the knowledge of tempeh producers, education level, economy, government involvement, and community participation [11]. Environmental changes, including advancements in technology, and social, cultural,

economic, and environmental factors, have a significant impact on the quality of life and the development of tempeh production areas [12]. The social status of the community greatly influences environmental balance. This social status is viewed from education, occupation, and income [13].

One example of the household tempeh industry that needs to be studied further in terms of environmental management is Plaju Ulu Village, Plaju District, Palembang City. The development of the household-scale tempeh industry in the Plaju Ulu Village area, Palembang City currently shows a fairly high level of production activity. This of course requires raw materials to be processed which contributes to an increase in the amount of waste produced.

The tempeh industry in Plaju Ulu has been established since 1952 and until now has marketed its products mostly in the upstream part of Palembang City. In the early days of the establishment of this area, tempeh production was carried out individually, but since 2021 have joined a legal entity group, namely the Plaju Bersinar Group. Tempeh producers still use simple equipment and methods for the tempeh production process. The rest of the soaked water and soybean stew are still dumped in the sewers, this causes the water conditions to be affected biologically and physically. The condition of the sewer water that does not flow and is black sometimes causes an unpleasant odor that interferes with the activities of other residents.

Tempe producers in Plaju Ulu produce tempeh using an average of 50 kg of soybeans and an average water usage of 1,115 liters per day per producer. This production generates an average of 1,000 liters of wastewater per day. Household-scale industrial activities have the opportunity to disrupt the balance of the environmental ecosystem if they are not balanced with waste treatment from each stage of existing production activities. Efforts to identify the quality of wastewater and the behavior of tempeh producers need to be carried out to immediately prevent the impact caused by waste disposal and also become the basis for determining the right wastewater treatment method.

2. Material and Methods

2.1. Materials

This study uses a mixed methods approach to find out the complete research subject. This approach is aimed at providing better knowledge of the problem to be researched. There are two types of research methods used in this study, namely quantitative and qualitative methods. Quantitative methods were used to obtain data related to the identification of wastewater content including BOD, COD, TSS, and pH from each stage of tempeh production. Qualitative methods were used to find out more clearly how the behavior of tempeh producers towards the management of tempeh wastewater in the Plaju Bersinar Group and the influencing factors in the process of managing tempeh wastewater.

2.2. Methods

2.2.1. Sample collection and preparation

The data collection of this research was carried out in RW 02 Plaju Ulu Village, Plaju District, Palembang City. This location was chosen by the researcher because it is one of the locations of the household industry that has been operating for a long time in Palembang City and the laboratory test of tempeh wastewater content was carried out at the Palembang Public Health Laboratory Center with the time of the research in July-September 2024. The population of this study is tempeh producers of the Plaju Bersinar Group located in Plaju Ulu Village, Plaju District, Palembang City. The total population of this study is 27 people. The identification stage of community behavior in waste management around the tempeh industry was carried out using structured interviews, while the determination of the research sample used the total sampling method where the number of informant samples in the interview was equal to the number of population.

2.3. Experimental variable and analytical procedures

2.3.1 Tempeh Wastewater Sampling

Tempeh wastewater sampling uses The Indonesian National Standard (SNI) 6989.59:2008 regarding wastewater sampling methods. The sampling stage is carried out using instant or grab sampling. The containers used to take waste samples are made of glass or polyethylene (PE) and polypropylene (PP) plastic materials by the standards that have been set. The wastewater sample was taken from one of the tempeh producers' kitchens. Wastewater sample points were taken in 5 stages of tempeh making that produce waste, namely in the process of boiling, soaking, washing, separating soybean shells, and final washing. Here is a sample point diagram of the parameters tested on each production process.

2.3.2 Laboratory Tests

Data collection through laboratory tests is used to test the conformity of wastewater samples with standards. The waste samples taken will be tested at the Palembang Public Health Laboratory Center. The waste content tested includes pH using the SNI 6989.11.2019 method, Biological Oxygen Demand (BOD) using SM APHA 24rd Ed., Sec 5210 D, 2022 method, Chemical Oxygen Demand (COD) using SNI 6989.2:2019 method, and Total Suspended Solid (TSS) using SNI 6989.3:2019 method.

2.3.3 In-Depth Interviews

In this study, interviews were conducted in-depth with tempeh producers. This process was carried out to find out the form of community behavior towards wastewater management in Plaju Ulu.

2.4. Data Analysis

Waste samples are taken from each stage of the process. The tested waste parameters include BOD, COD, TSS, and pH with quality standards by the Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2014 concerning Wastewater Quality Standards for Soybean Processing Activities or Businesses. The analysis of interview data in this study is categorized as inductive qualitative research. Data processing in the form of tempeh artisan behavior towards wastewater management is also carried out with an interactive and sustainable model that has been developed [14], which includes data presentation, data reduction, data verification, and conclusion.

3. Results and Discussion

3.1 Analysis of pH Content of Tempeh Wastewater

The pH analysis of tempeh wastewater was carried out to evaluate the acidic or alkaline characteristics of the waste produced during the tempeh production process. The analysis was carried out at the Palembang Health Laboratory Center (BBLK), certified by KAN using the SNI 6989.11.2019 method. The results of the wastewater pH laboratory test from each stage of tempeh production are presented in Figure 1. as follows.

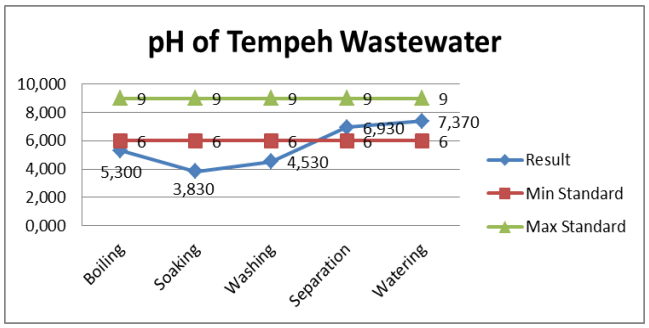

Figure 1. Laboratory test results from each stage of tempeh production

Based on Figure 1. shows a graph of the results of the tempeh wastewater pH laboratory test from each stage of production. The results showed that the soaking, washing, and boiling stages of soybeans had pH values below the standard according to the Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2014 concerning wastewater quality standards for soybean processing activities or businesses. The pH level of the soaking waste is 3.830; The pH of the washing waste is 4.530; and the boiling waste level is 5.300. The pH level of the waste in the three stages of production is classified as acidic while the pH level for the soybean husk separation stage and the final watering are 6.930 and 7.370 respectively, which are classified as normal.

During the soybean soaking process, microorganisms such as lactic acid bacteria can multiply. These microorganisms ferment the carbohydrates in soybeans into lactic acid which can lower the pH of wastewater. The soaking stage is generally carried out on soybeans before fermentation, both heated and unheated [7]. In unheated soybeans, the soaking process triggers natural acid fermentation, which increases acidity until the final pH reaches 4.5.

The soybean washing stage also produces wastewater with a low or acidic pH, in this process the soybeans absorb the ignition water which can remove the solutes in the soybeans such as organic compounds and minerals. The pH value is an essential factor for water conditions because acidic or alkaline conditions will affect the biological activity of microorganisms in the water [15].

The production stage of separating soybean husks and final watering produced tempeh wastewater with pH values of 6.690 and 7.730 respectively. This value is categorized as a neutral pH by the quality standards that have been set. The cause of tempeh wastewater becoming neutral is caused by several factors, such as natural buffering, microorganisms that have used acid, acid deposition, and water mixing. The neutral pH condition of tempeh wastewater is an indicator that the fermentation stage is at an equilibrium point where the acidic properties produced have been neutralized. At the soaking stage, the pH of the waste decreases and after that stage, the pH will increase to 7 [16].

3.2 Analysis of Biochemical Oxygen Demand (BOD) Content of Tempeh Wastewater

Biochemical Oxygen Demand is a parameter to assess the burden of sewage pollution and the impact of wastewater disposal on the quality of water bodies, BOD is used as an indicator to measure the amount of oxygen used by microorganisms to digest organic substances that decompose in water. High BOD levels in waters due to tempeh wastewater can cause the loss of aquatic biota due to low oxygen levels [17]. The results of the wastewater BOD laboratory test from each stage of tempeh production are shown in Figure 2.

Based on Figure 2. indicates that the boiling, soaking, separation of soybean husks, and final watering stages have BOD values above the standard. Meanwhile, the soybean washing stage showed that the BOD level was below the threshold. The standard value that has been set by the government is 150 mg/L.

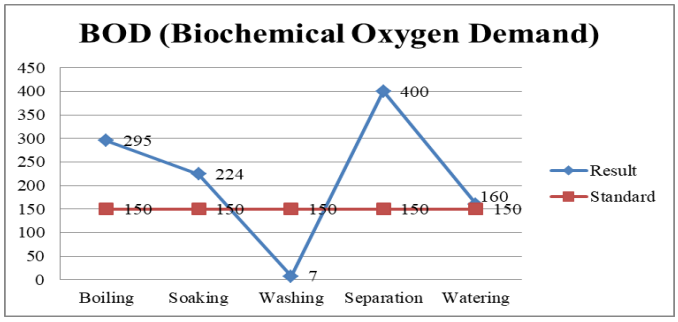

Figure 2. The results of the wastewater laboratory test from each stage of tempeh production

The boiling stage of soybeans showed a BOD level of 295 mg/L. Soybeans contain a lot of organic matter such as protein, fat, and carbohydrates andthese ingredients are a food source for microbes. This can cause the BOD content of tempeh wastewater to be high and exceed the predetermined threshold. The soybean soaking stage also shows results above the set standard of 224 mg/L.

The soybean soaking stage contains a lot of organic matter that tends to increase the BOD content in wastewater [5]. The soybean washing stage shows the results of BOD levels that are by the set standards, this is in line with research which shows that the BOD content at the boiling, soaking, and mixing stages of soybeans exceeds the standard except for the washing stage [18].

At the stage of separating soybean shells and final watering, the resulting BOD levels did not meet the standards. In order, the BOD level at the soybean husk separation stage was 400 mg/L, while at the final watering, it was 160 mg/L. Soybean shells and residues contain high organic levels, these organic matter tend to increase oxygen levels for the decomposition stage of organic matter which has the potential to increase BOD levels in tempeh wastewater [19].

3.3 Analysis of Chemical Oxygen Demand (COD) Content of Tempeh Wastewater

Chemical Oxygen Demand can show the amount of organic pollutants in water bodies [20]. COD measurements can be carried out directly to improve wastewater treatment efficiency where higher COD levels indicate oxidized organic matter in oxidized samples and reduce ocean oxygen [21]. The results of the COD laboratory test of wastewater from each stage of tempeh production in Figure 3. are as follows.

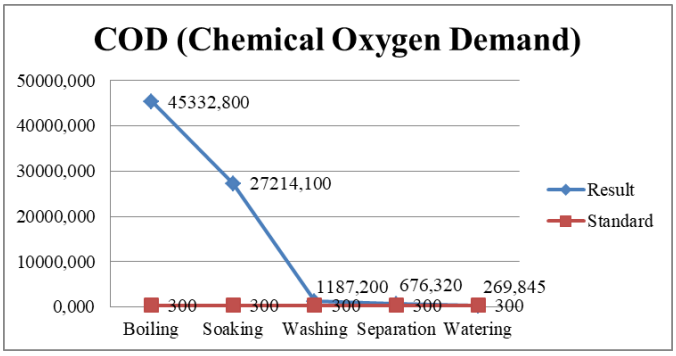

Figure 3. Results of laboratory tests of wastewater from each stage of tempeh production

The COD level of soybean boiling waste showed the highest yield of 45,332.8 mg/L. The COD level of soybean soaking waste showed results of 27,214.1 mg/L, washing waste of 1,187.2 mg/L, soybean husk separation waste of 676.32 mg/L, and watering stage of 269.845. This shows that the wastewater from the production process contains very high levels of organic matter and will cause a decrease in dissolved oxygen levels in the water body. A decrease in oxygen levels can occur due to oxidation from microorganisms so that the water is in anaerobic conditions [22].

Soybean boiling is the stage where many organic compounds and other substances are released into the water, causing the COD content to be higher compared to other processing stages. According to Sari [21], the wastewater from soybean boiling contains protein, carbohydrates, fats, water, and ash. The results of laboratory tests show that the waste produced exceeds the threshold and has the potential to pollute the environment if it has been discharged into the water body in Plaju Ulu area.

BOD is the oxygen used by microorganisms to break down organic matter, while COD is the oxygen required to oxidize both organic and inorganic materials in waste. According to Abdalla and Hammam [23], COD values can be used to estimate BOD, but this correlation may vary depending on the type of waste being tested.

3.4 Analysis of TSS (Total Suspended Solids) Content of Tempeh Wastewater

Total Suspended Solids levels are suspended in water bodies with a size of > 1µm. Turbidity level is defined as an optical property that is determined based on the intensity of light that can be absorbed by materials in the water, in addition to water turbidity due to the suspension of organic and inorganic materials on water bodies [22]. The results of the TSS laboratory test of wastewater from each stage of tempeh production in Figure 4. are as follows.

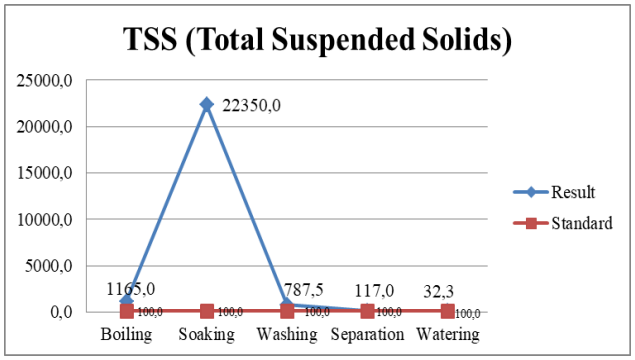

Figure 4. Results of laboratory tests of wastewater from each stage of tempeh production

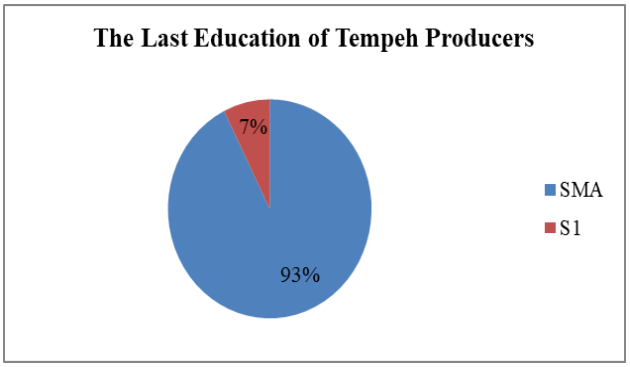

Figure 5. Diagram comparing the educational background of tempeh producers

Based on Figure 4. It shows that the stages of boiling, soaking, washing, and separating soybean husks, have TSS values above the standard. At the boiling stage of soybeans, tempeh waste is produced with a Total Suspended Solid (TSS) level of 1,165 mg/L. Furthermore, the soaking stage produces waste with the highest TSS level, which is 22,350 mg/L. At the washing stage, the level of TSS in waste reaches 787.5 mg/L. The separation stage of soybean husks produces waste with a TSS level of 117 mg/L.

High levels of Total Suspended Solid (TSS) in a body of water can block the penetration of sunlight into the water, high levels of TSS not only affect water quality but also damage the balance of the ecosystem as a whole [6]. The final watering production stage produces waste with a TSS level of 32,300 mg/L. The discharge is in normal condition and safe to be disposed of in water bodies. The final watering stage produces the lowest TSS value compared to other production stages because at this stage it contains few solid particles and does not interfere with the process of oxygen transfer into the water body. The high TSS levels in wastewater are influenced by high organic matter, so TSS can be minimized by reducing the organic content in tempeh wastewater [24].

3.5 Analysis of Tempeh Producers' Behavior Towards Wastewater Management

3.5.1 The Correlation Between Education Level and Waste Treatment Awareness

Tempeh wastewater management can run well if accompanied by awareness of environmental sustainability involving the wider community. One of the factors that affects this awareness is the level of education. The condition of the education level of tempeh producers of the Plaju Bersinar Group is presented in Figure 5.

Figure 5 shows that most of the tempeh producers in the Plaju Bersinar Group have completed their education up to the secondary level. The number of tempeh producers who are high school graduates is 93% of the total or as many as 25 people. Based on the results of interviews with tempeh producers, the limited access to higher education makes producers only complete education up to the secondary level. Tempeh producers argue that the skills or abilities required to produce tempeh do not require formal education equivalent to that of a university. The ability to make tempeh is obtained through the inheritance of knowledge from previous generations.

The percentage of tempeh producers who have received education up to university is 7% or equivalent to 2 tempeh producers. Based on the results of the interview, tempeh producers with the last educational background of senior high school and universities consider that tempeh wastewater management is an important thing that must be done.

However, in practice, it was found that most tempeh producers do not manage wastewater properly and still dispose of waste into drainage. The imbalance between the consciousness of craftsmen and their practices in the field is caused by several things. First, lack of access to knowledge related to the implementation of safe and environmentally friendly wastewater treatment technology. Second, wastewater treatment requires additional costs so that it can reduce profits from sales. Third, tempeh producers do not have more time to implement waste treatment sustainably and the existing time is only used for selling and producing tempeh. The factors that hinder the implementation of wastewater management consist of the lack of knowledge of tempeh producers, education level, economic conditions, government, and law enforcement involvement, and the role of the community[11].

3.5.2 Tempeh Wastewater Disposal Practice at the Plaju Bersinar Group

Data collection was carried out based on the results of in-depth interviews with tempeh producers. Data related to tempeh Wastewater disposal is presented in Figure 6.

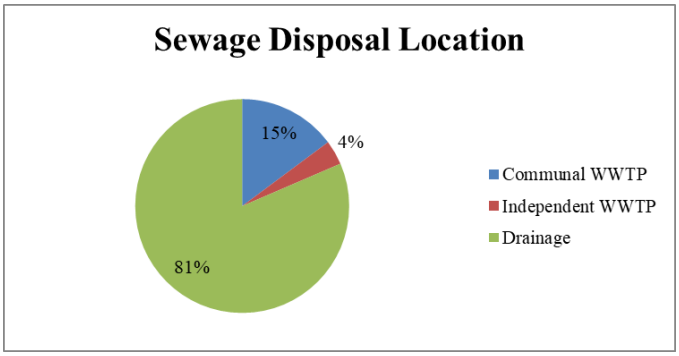

Figure 6. Diagram comparing waste disposal practices at the Plaju Bersinar Group

Based on Figure 6, it shows that as many as 81% or 22 tempeh producers dispose of Wastewater directly into drainage without any further processing stage. Based on the results of the interview, it was shown that most craftsmen threw waste into the drainage because they did not know the impact caused. In addition, limited costs and densely populated residential conditions are the reasons for the lack of wastewater treatment facilities at the location. This shows the need for education to increase the awareness of tempeh producers regarding the dangers that can be caused by the practice of disposing of wastewater into drainage. The importance of awareness for business actors will affect their survival in the future [25].

The practice of disposing of Wastewater to the communal Wastewater Treatment Plant (WWTP) has been carried out by 15% of tempeh producers or the equivalent of 4 producers. The WWTP at this location represents contributions from surrounding companies related to the implementation of Social and Environmental Responsibility. The existence of this facility encourages tempeh producers to start switching to environmentally friendly waste treatment, even though the number of tempeh producers involved is still small. In daily practice, producers in managing waste find challenges, where the carrying capacity of WWTP is still very limited to manage all wastewater produced from tempeh production houses. According to Puspitasari et al.[26], communal WWTP is a Wastewater treatment instrument that is used together in one centralized area so that it has a positive impact on producers and the nearby environment.

Based on direct observation in the field, there is only 1 tempeh producer, or 4% of all members who are still actively using independent WWTP to process tempeh wastewater. Although the percentage is still relatively low, the tempeh producers have shown efforts to treat waste sustainably. The implementation of WWTP development in this region also faces challenges, namely the difficulty of finding an area for development due to the type of area which is a densely populated settlement, and the lack of open land.

According to Sonalitha et al. [27], The appropriate behavior of the community in managing tempeh wastewater is behavior that supports environmentally friendly principles, such as waste separation, utilization, efficient processing, and not disposing of it indiscriminately. Education and outreach are also very important to ensure that the community has a good understanding of the impacts of tempeh wastewater and how to manage it wisely.

4. Conclusion

Based on the research that has been carried out, it can be concluded that the soybean soaking stage produces tempeh wastewater that is not by the standard with a pH level of 3.830; TSS 22,350 mg/L; COD 27,214.100 mg/L, and BOD 224 mg/L. The level of waste produced from the washing stage that is not by the standard includes a pH of 4.530; TSS of 787.5 mg/L; COD of 1,187.2 mg/L, and BOD levels that have met the standard of 7 mg/L. The soybean boiling stage produces wastewater that is not by the standard, namely pH 5.3; TSS 1,165 mg/L; COD 45,332.8 mg/L, and BOD 295 mg/L. The level of waste produced from the separation stage of soybean husks that is not by the standard includes TSS 117 mg/L; COD 676.320; BOD 400 mg/L and the pH level that is by the standard is 6.930. The final watering stage that is not by the standard is the BOD level of 160 mg/L.

Tempeh producers have been aware of the importance of the tempeh wastewater management process to maintain environmental balance but as many as 81% of producers still dispose of tempeh wastewater without direct treatment to drainage. This research can be used as a reference in the development of appropriate technology innovations to manage tempeh wastewater in Plaju Ulu, so that it can minimize the impact caused by the disposal of waste into the environment.

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