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Physical and Chemical Properties of Wastewater Discharged from Tofu Industries in Banda Aceh City, Indonesia.

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ABSTRACT

Tofu which is produced by grinding soy bean produces high amount of wastewater, and is considered as one of the most polluting food-industrial effluent due to its high values of organic pollutants. Prior to discharge into the environment, the organic pollutants in the tofu waste should be removed through waste treatment process. Knowledge about the properties of the wastewater is crucial in designing the waste treatment system. This paper investigates the physical and chemical properties of untreated wastewater discharged from tofu industries in Banda Aceh, Indonesia. The parameter of BOD, COD, MLSS, PO4-P NH3-N, Turbidity and pH were analyzed based on the standard method, approved by the EPA, for the examination of water and wastewater. The COD and BOD of wastewater from tofu processing facilities in Banda Aceh were ranging from 5000-8500 and 3500-4500 mg/L, respectively. The amount of other parameters such as MLVSS, ammonia, and turbidity were above the threshold that allowed by the government of Indonesia. Site investigation shows that in Banda Aceh city, the tofu waste has been disposed into the environment without any treatment, causing bad odours and pollution of the surface, ground water, and river. Anaerobic method can be used for tofu waste treatment because the method produces biogas and at the same time reducing organic content in waste.

Keywords: Wastewater, Tofu, Biochemical oxygen demand, Chemical oxygen demand, Wastes management, anaerobic.

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INTRODUCTION

Nowadays, food industry is continuously developing along with the increasing incomes of the population. With the increasing number of food industries will considerably increase the waste produced in the process. Upon being discharged into the environment, the waste should be processed through phases of processing, depends on the characteristic of the wastes. Wastes coming from the foodstuff usually contain a quite high organic compounds. Physical, chemical, and biological characteristics of the waste should be studied by the engineer before designing the waste treatment system. One of the wastes containing a quite high organic compounds is coming from tofu industrial processing.

The management of wastes produced by food industries such as tofu industry is currently one of the most serious and controversial issues faced by local government. The government is required to propose the waste management systems that fulfill the hierarchy of options (i.e. prevention, reduce, reuse, recycling, recovery, and disposal). A good waste management system will protect environmental health by reducing the negative impact of the waste and finding the environmental-friendly use of the waste. Improving environmental protection through the optimization of waste management practices is the typical focus of waste management policies and technologies in countries where strong legislation has been well established and immediate health concerns have been controlled [1-3].

Tofu is a very popular food in Indonesia because of its associated health benefits and acceptable price. Tofu is produced by grinding of soy bean, cooking (boiling), filtration, protein coagulation, preservation, and packaging. Although tofu industries discharge a lot of wastes, only a small percentage of tofu waste has been utilized as nutritious feed for livestock, the remainder being incinerated and/or reclaimed as industrial waste, thereby contributes to serious pollution problems [4].

Many factors have been considered in order to select the treatment process of the wastes. One of them is waste characterization. Characterization of the waste has proven helpful in order to determine the treatment process. The characterization of the waste is fundamental in order to improve the waste treatment system. This paper discusses the physical and chemical properties of tofu waste from some tofu industries in Banda Aceh city, Indonesia.

METHODS

The tofu wastes were obtained from local tofu factories in Banda Aceh city. Five representative samples of tofu wastes) from local tofu industries (e.i. Tahu Lampaseh Aceh, Tahu Lampaseh Aceh, Tahu MKS, Tahu Sumedang and Tahu Meurah Jaya) were analyzed by using various methods. All examinations were made in accordance with the procedure given in Standard Methods for the Examination of Water and Wastewater, approved by the EPA (Environmental Protection Agency).

RESULTS AND DISCUSSION

Tofu manufacturing is one of the traditional oriental food processes using soy bean as the raw material. A typical process consists of soy bean grinding, cooking and boiling, first filtering, protein coagulating, second filtering, preserving, washing, drying and packaging. The wastewater from soybean processing is characterized by its high chemical oxygen demand (COD) and biochemical oxygen demand (BOD) values derived from the high protein content. Table 1-5 shows the characteristic of wastewater from local tofu industries in Banda Aceh (e.i. Tahu Lampaseh Aceh, Tahu Lampaseh Aceh, Tahu MKS, Tahu Sumedang and Tahu Meurah Jaya).

Source of Tofu Industrial Waste

Tofu industrial waste is a waste produced in the processing of tofu or upon washing the soybean. Tofu industrial waste is generally divided into 2 (two) types of waste, i.e. solid waste and liquid waste. Solid waste of tofu manufacturing consists of dirt from washing the soybean (pebbles, soil, soybean skin, and other solids stuck on the soybeans) and residuals of the filtered soybean pulps called as tofu dregs. Solid waste consists of dirt are coming from the initial process (washing) of the tofu raw materials and usually it is produced in a small

amount (0.3% of the raw materials). While the solid waste consists of tofu dregs is produced during the filtering process of the soybean pulps. The quantity of tofu dregs produced is approximately 25%-35% from the tofu product yielded [5]. The impact of solid waste towards the environment is a minor one, as it can be directly utilized as livestock fodder. Tofu dregs have a quite economical price if compared with the concentrated fodder. Tofu solid waste can be processed into various kinds of product with good selling price. Tofu solid waste contains a high amount of protein as it can be utilized as flour or snacks.

The tofu liquid waste in the tofu processing is coming from the process of soaking, washing the soybean, washing the equipment required for the tofu processing, filtering, and pressing/moulding the tofu. Most of the liquid wastes produced by the tofu manufacturing are viscous fluid separated from the tofu clods which is called as whey [5]. This fluid contains protein, suspended solids or solutes. The compounds contained in this type of waste will undergo a physical, chemical, or biological change which generates toxic compounds. These compounds can be a medium for the growth of germs hazardous to humans. Over time, the colour of wastewater will change into a dark brown and it smells rotten. The rotten smell will cause air pollution and respiratory disease. If being discharged into the rivers without treatment, the waste will pollute the river; and if being reused, it will cause various kinds of disease.

MLSS (Mixed Liquor Suspended Solids)

The MLSS measures the total concentration of mixed liquor suspended (non-soluble) solids in wastewater. The data is important in for examination of the operational behavior and solids inventory of the system and it is used to determine when the waste is discharge or for recycle. The value of MLSS from the tofu wastewaters in Banda Aceh are ranging from 1,050-3,130 mg/l. As can be seen from Table 4, the highest value of MLSS is at wastewater from Tahu Sumedang.

BOD (Biochemixal Oxygen Demand) and COD (Chemical Oxygen Demand)

The BOD measures the quantity of oxygen required by bacteria to biologically oxidize organic material under aerobic conditions. The BOD test involves the value of dissolved oxygen (DO) at initial and after five days of incubation at 20^{o}C. The measurement method attempts to replicate the oxidation found in the environment. The BOD value can be in mg/L or in lbs/day. While in the COD analyses, the sample is reacting with excess oxidizing agent under acidic conditions, and nearly all organic compounds can be fully oxidized to carbon dioxide. The value of BOD and COD are critical in the wastewater analyses, since the can show the amount of polluted organic materials in the water system. Usually there is a good correlation betwen COD and BOD value. Its ratio can give the information whether the waste can be treated biologically or not.

The COD and BOD of wastewater from tofu processing facilities in Banda Aceh is ranging from 5000-8500 and 3500-4500 mg/L, respectively. Those high value of organic compounds can cause bad odours, pollution of the surface, ground water, and river. Other parameters such as MLSS, PO4-P NH3-N, Turbidity, and pH are also above the standard for wastewater. Site investigation showed that in Banda aceh city, the tofu waste has been disposed into the environment without any treatment. Tofu-processing waste is acidic (pH about 4-5) during the tofu preparation acetic acid as added for coagulation. There is no hazardous chemical added to tofu during the production process, hence it makes the tofu waste basically non-toxic, thus can be effective treated biologically. However, without any treatment, bad smell will appear after 2 days, due to the degradation of ammonia compounds [4]. The management of tofu waste is very important to be socialized for tofu manufacturing owner. Government involvement is also very necessary to encourage the owner to treat their waste and keep the environment clean.

Ammonia (NH3-N)

Ammonia from tofu wastewater in Banda Aceh is ranging from 33-129 mg/l. The highest concentration of NH3-N is at Tahu Sumedang (i.e 129.3 ppm). High amount of ammonia will be responsible for eutrophication in the waterways or river. The nitrogen contained in ammonia will serve as a nutrient that stimulates the productivity of algae and other water plants. The eutrophication is responsible in accelerating the extreme growth of alga, which impacts to the bad taste and odour of water. Moreover, ammonia is also consuming oxygen from the water system during its oxidation to nitrite and nitrate, thus will reduce the oxygen in the water, causing problem for fish and other animals in inhaling the oxygen.

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Treatment of Tofu Processing Waste

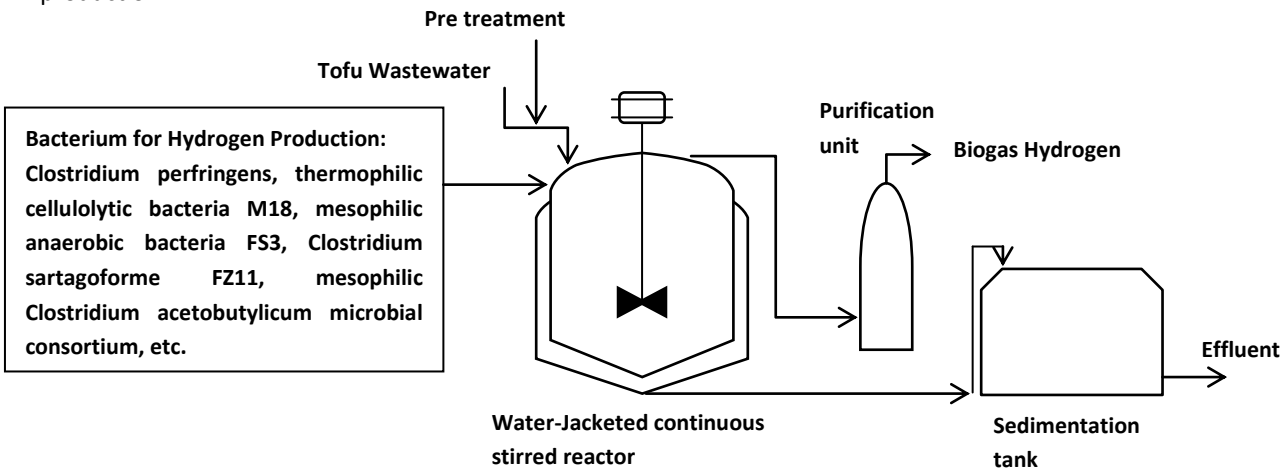
Usually, the treatment method of tofu processing waste is by biological degradation. Most probably because the waste is high degradable due to its high value of BOD and COD ratio. It is, however, often prohibitively expensive in densely populated areas due to the high space requirement of this method. Chemical coagulation is an option to remove most of the organics from the water colloids [6]. The treatment of tofu waste using supersonic irradiation of the substrate suspension on the methane fermentation performance has been studied, and finds that the supersonic wave irradiation is effective to enhance the methane yield [7].

Anaerobic digestion is a well-known technique that has been widely applied to the organic waste treatment since it transforms organic carbon in the waste into biogas (methane and hydrogen) and reduces the amount of biosolids to be disposed of [8-10]. The process is gaining attention in the effective treatment of low quality food waste and its competent biogas yield which can be used directly for electric power generation. However, it has a complex process and does not exist independently, and requires additional equipments, such as pre-treatment, wastewater treatment, and composting process [11].

Tofu Liquid Waste Treatment to Produce Hydrogen Gas

Hydrogen can be produced by using the organic waste as raw material. Microorganism can produce hydrogen through photosynthesis or fermentation process. Fermentation is preferable as it is technically simpler than the photosynthesis. Fermentation produces hydrogen from the carbohydrate materials contained in the waste. Hydrogen-yielding-bacteria has the ability to form the a heat resistant endospore during the heating process and helps to eliminate the hydrogen-consuming-bacteria which cannot form a spore such as methanogen, and allows the growth of the bacteria forming the spores, for example Clostridium species [12-14].

Fermentative H_2 production in batch and continuous modes using a thermophilic mixed culture has been done by Kim and Lee [15]. The maximal H_2 production rate (12.0 l H_2/l/day) and yield (2.3 mol H_2/mol glucose equivalent) are obtained at HRT 4 h and pH 5.5. Although this method is still in laboratory scale, the technology of yielding H_2 from the waste clearly be the perfect method to produce alternative energy. Nowadays the method of yielding H_2 from the wasted is continuously developed in order to get a product with a high concentrated of H_2. Several types of bacteria which are able to use in the H_2 yielding process are Clostridium perfringens, thermophilic cellulolytic bacteria M18, mesophilic anaerobic bacteria FS3, Clostridium sartagoforme FZ11, Clostridium acetobutylicum under mesophilic conditions and microbial consortium [16-27]. The diagram scheme of H_2 yielding process from the tofu waste can be seen on Figure 1. The types of bacteria and the certain condition (temperature, pH, F/M ratio, etc.) being used will determine the success of biogas production.



$C_6H_{12}O_6 + 2H_2O \longrightarrow 2CH_3COOH + 4H_2 + 2CO_2$

$C_6H_{12}O_6 \longrightarrow CH_3CH_2CH_2COOH + 2H_2 + 2CO_2$

$CH_3COOH + 2H_2O + Light \longrightarrow 4H_2 + 2CO_2$

Figure 1. Schematic diagram for hydrogen production from tofu wastewater

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Table 1: Characteristic of wastewater from Tahu Lampaseh Aceh

Parameter	Unit	Results
MLSS	mg/L	1,177
BOD	mg/L	3,575.5
NH_3-N	mg/L	36.1
PO_4-P	mg/L	1.81
COD	mg/L	6,500
Turbidity	NTU	387
pH	-	4.9 (28.6^oC)

Table 2: Characteristic of wastewater from Tahu Solo

Parameter	Unit	Results
MLSS	mg/L	1,150
BOD	mg/L	4,415.5
NH_3-N	mg/L	33.5
PO_4-P	mg/L	0.97
COD	mg/L	8,500
Turbidity	NTU	841
pH	-	4.85 (28.9^oC)

Table 3: Characteristic of wastewater from Tahu MKS

Parameter	Unit	Results
MLSS	mg/L	1,050
BOD	mg/L	4,390.5
NH_3-N	mg/L	39.9
PO_4-P	mg/L	1.57
COD	mg/L	7,300
Turbidity	NTU	902
pH	-	4.82 (28.2^oC)

Table 4: Characteristic of wastewater from Tahu Sumedang

Parameter	Unit	Results
MLSS	mg/L	3,130
BOD	mg/L	3,810.2
NH_3-N	mg/L	129.3
PO_4-P	mg/L	95.5
COD	mg/L	5000
Turbidity	NTU	730
pH	-	5.5 (28.5^oC)

Table 5: Characteristic of wastewater from Meurah Jaya

Parameter	Unit	Results
MLSS	mg/L	1,600
BOD	mg/L	4,520.5
NH_3-N	mg/L	64.0
PO_4-P	mg/L	2.56
COD	mg/L	6400
Turbidity	NTU	921
pH	-	5.08 (28.4^oC)

Tofu Liquid Waste Treatment for Small Scale Industry

Considering that tofu industry is a small scale industry, it requires installation of waste treatment system of which equipment is easy to use, inexpensive operational cost, good economic value, and environment friendly. Today, the method being developed is the utilization of biogas yielded from the liquid

waste treatment with anaerobic system. Every organic material if being put in the container will undergo a natural fermentation process. The process can be quickened if the container is made air-tight or in a form of air-tight tube. Besides producing fluid with no smell, the biogas being yielded can be used as an alternative fuel for cooking stove and lighting. It is very economically valuable, especially for the residents who live in the village [5].

CONCLUSION

Evaluation on waste characteristics including its chemical, biological, and physical characteristics is important to do as waste characteristics holds important role in designing a prefect method for waste treatment. Tofu waste contains a quite high organic compound and will pollute environment as well as endanger human health if being discharged into the river without undergoing waste treatment process. Based on analysis data the value of waste tofu BOD/COD ratio is above 0.5 indicating that the waste is biodegradable that it can be processed with biological method. Anaerobic method is an appropriate method to process the waste. With anaerobic method, besides yielding biogas, the waste fluid can be used as liquid fertilizer or can be mixed with the other biomass, such as vegetable waste, husks, and several other to produce solid compost. A selection of appropriate method in the tofu waste treatment system will determine the expected quality of output and the other end-product.

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