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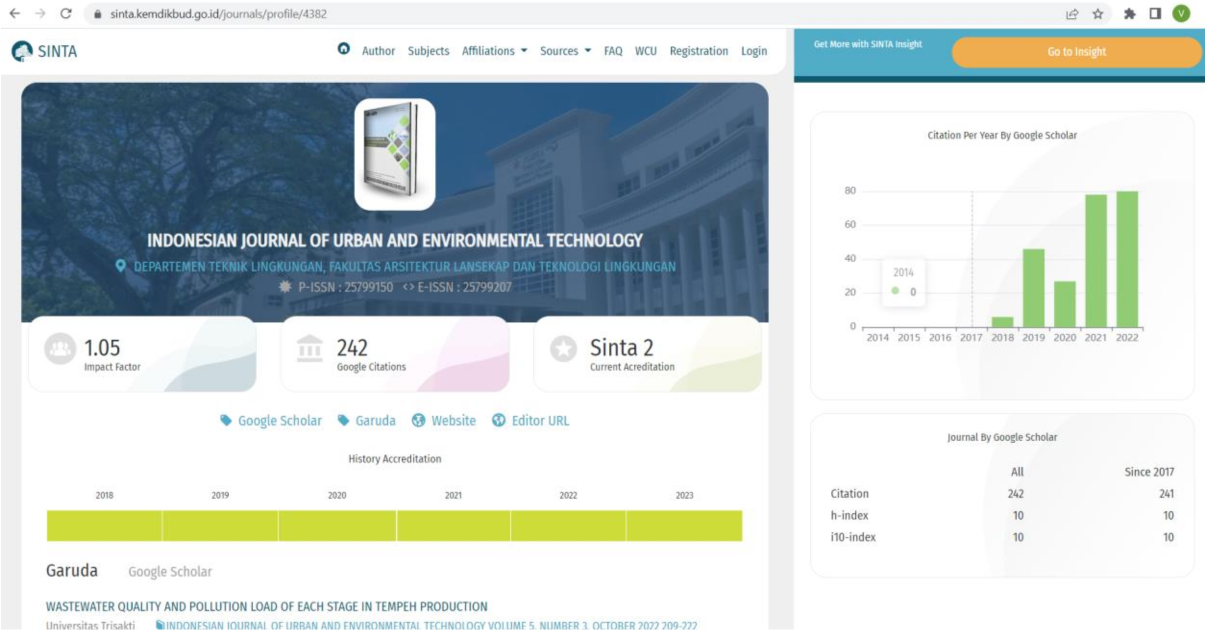

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Articles

WASTEWATER QUALITY AND POLLUTION LOAD OF EACH STAGE IN TEMPEH PRODUCTION
Vita Pramaningsih, Hansen Hansen, Sarva Mangala Praveena, Ucik Ika Fenti Styana
209-222
PDF
| Abstract views: 191 | PDF Download: 57 |
https://doi.org/10.25105/urbanenvirotech.v5i3.12838

ANALYSIS OF RESIDUAL CHLORINE CONCENTRATION IN DISTRIBUTION NETWORK OF DRINKING WATER SUPPLY AT ISTANA DIENG II RESIDENCE OF MALANG, EAST JAVA, INDONESIA
Moh. Zainal Bahrudin, Anie Yulistyorini, Titi Rahayuningsih
223-239
PDF
| Abstract views: 121 | PDF Download: 56 |
https://doi.org/10.25105/urbanenvirotech.v5i3.12463

SIMULTANEOUS ELECTROCOAGULATION - PHOTOCATALYTIC SCENARIO TO ENHANCE HYDROGEN PRODUCTION IN LIQUID WASTE TREATMENT: A BRIEF OVERVIEW
Reno Pratiwi, Slamet Slamet, Dina Asmaul Chusniyah, Widia Yanti
240-265
PDF
| Abstract views: 120 | PDF Download: 41 |
https://doi.org/10.25105/urbanenvirotech.v5i3.14447

THE INFLUENCE OF ENVIRONMENTAL POLICIES ON SELECTING INVESTMENT LOCATIONS
Anita Sitawati, Herika Muhammad Taki, Rezkia Dewi Andajani

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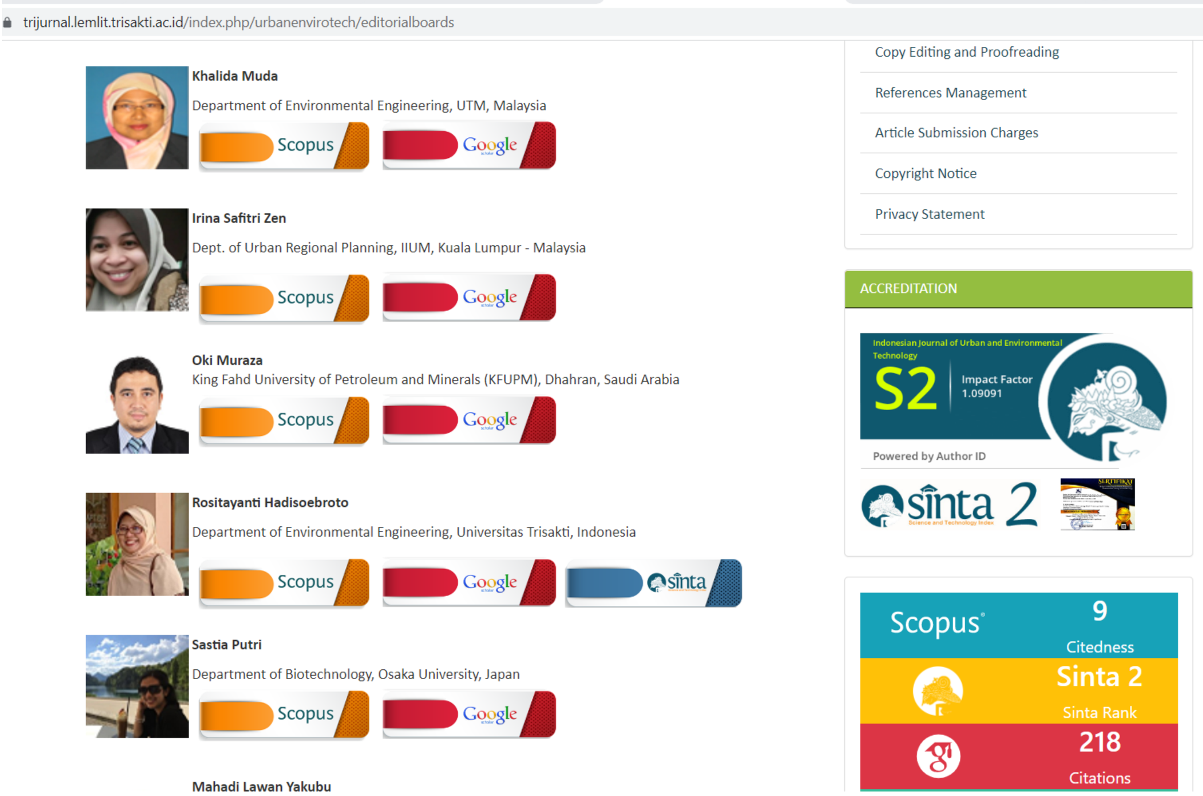

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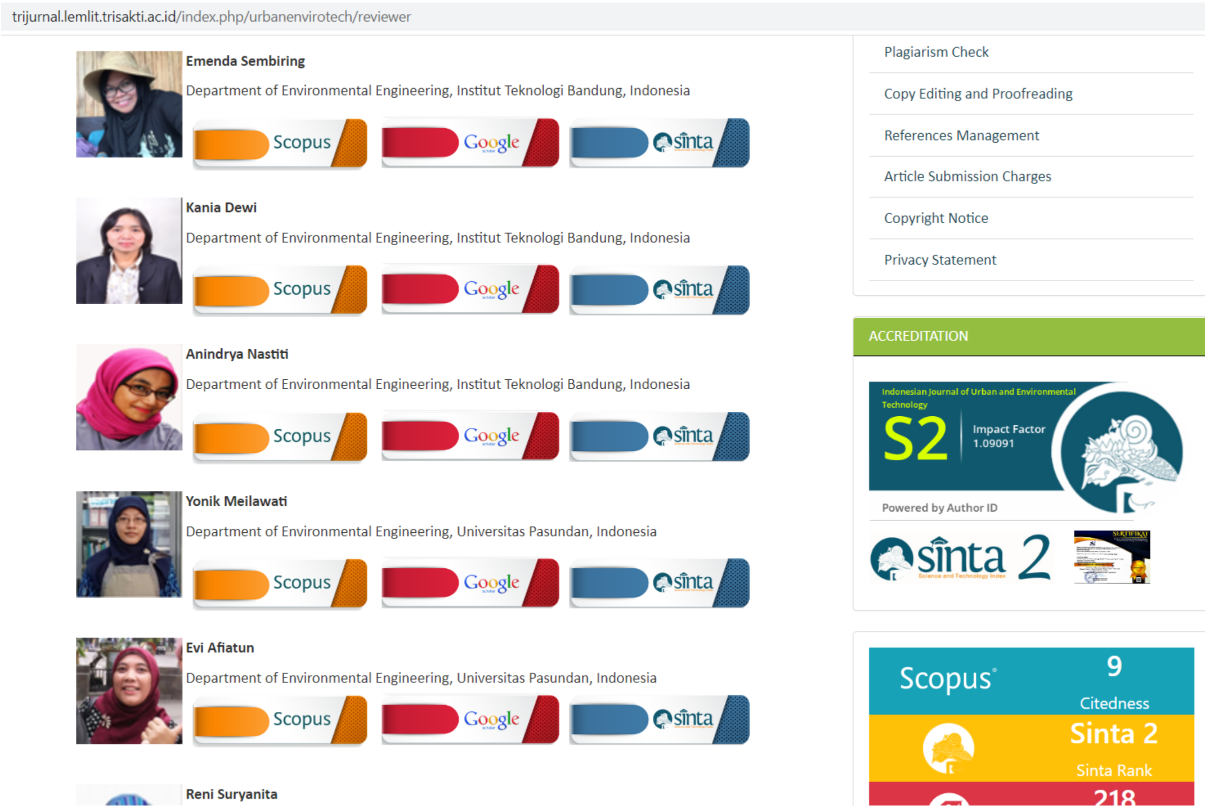

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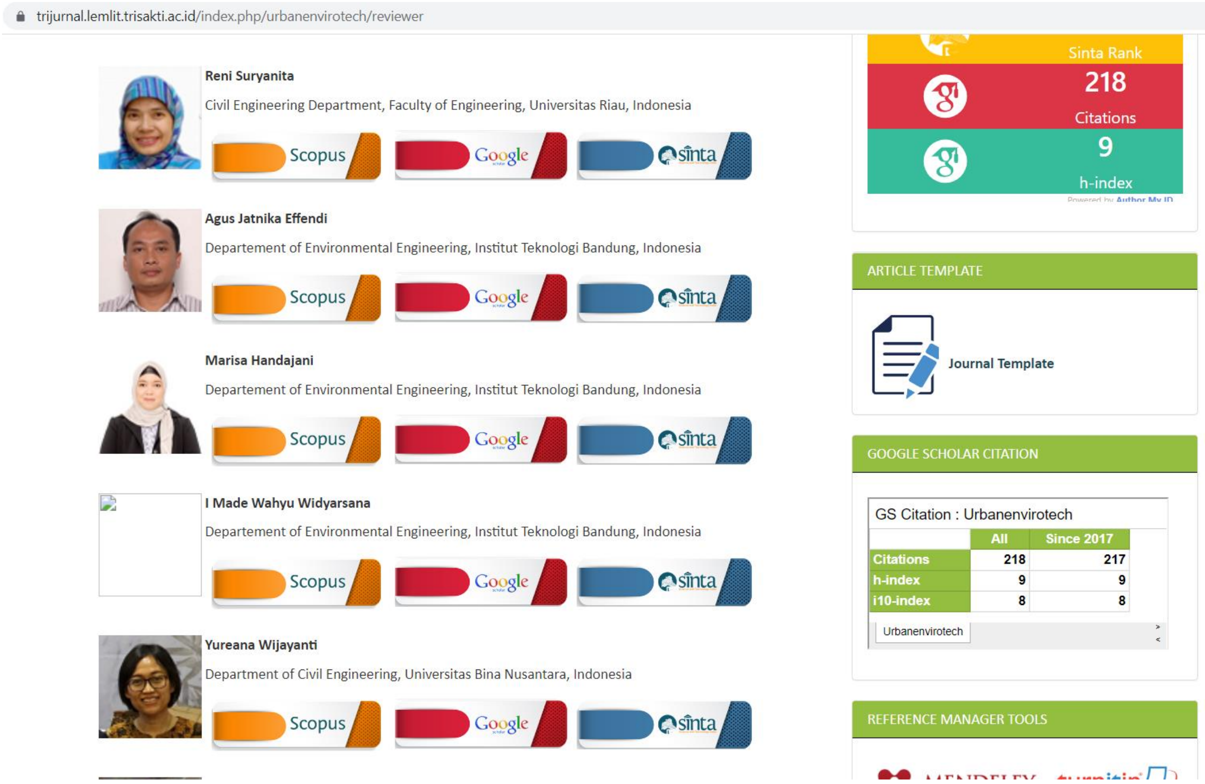
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WASTEWATER QUALITY AND POLLUTION LOAD OF EACH STAGE IN TEMPEH PRODUCTION

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ABSTRACT

Aim: This study is purpose to understand the chemical and physical characteristics and pollution load in each step of tempeh wastewater: washing, boiling, soaking and mixing. However, wastewater from tempeh production is discharge to river directly which considered as environmentally damaging. However, the characteristics of wastewater from tempeh production and its level of environmental impacts to environment are limitedly studied. **Methodology and Results:** Tempeh wastewater was analyzed in chemical and physical parameters. Chemical characteristics analyzed are pH, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The physical parameter analyzed is Total Suspended Solid (TSS). Pollution load calculated by deviation maximum pollution load and pollution load existing. Result of this study findings indicated that the highest BOD 299.40 mg/L and COD 540.66 mg/L was found in soaking step compared to other steps in tempeh production. Highest TSS 655.20 mg/L was found in boiling step. The pH values in all steps were acidic 4 and 5. Allocation Pollution load of: TSS overall exceeded the capacity, BOD and COD overall exceeded the capacity except in washing step (BOD 304.39 kg/day and COD 857.78 kg/day). **Conclusion, significance and impact of study:** The Highest TSS of tempeh wastewater processes was in boiling step while the highest organic matter was detected in soaking. Further for whole pH were acidic and exceeded the standard. Allocation of pollution load for TSS, BOD and COD exceed the standard except for BOD and COD in washing waste. Overall tempeh wastewater needs treatment to prevent river pollution.

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- Biological oxygen demand (BOD)
- Chemical oxygen demand (COD)
- pH
- Pollution load
- Total suspended solid (TSS)

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1. INTRODUCTION

Tempeh is one of traditional and favorite foods in Indonesia from soybean fermentation. Tempeh is a healthy food holds more protein, dietary fibre and vitamins (Wijaya, 2019). Soybean is a protein source in foods production that a lot kind of processed as fermented (tempeh, natto, miso, soy sauce) and unfermented (soy milk and tofu) (Chua and Liu, 2019; Puspawati and Soesilo, 2018). Tempeh is produced by fermentation, it improved nutritional value, enhance proteins, carbohydrates and lipids (Santhirasegaram *et al.,* 2016). It's also low cost, health promoting and sustainable food production technology to produce protein-rich foods (Ahnan-winarno *et al.,* 2021). Many home industries produce tempeh in Indonesia.

In general, tempeh production is conducted at household scale without wastewater treatment to treat their waste. Subsequently tempeh production wastewater is streamed directly into drainage and lastly to river. The direct discharge of tempeh production wastewater without any treatment has affected the river water quality which is used as raw drinking water supply in Samarinda. Furthermore, Karang Mumus River that through the Samarinda City has indicated Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) have exceeded the what standards which the source of pollution load capacity comes from domestic activities such tempeh production (Pramaningsih *et al.,* 2020).

Soybean wastewater such as tempeh has high organic matter and COD content (Guo *et al.,* 2018). Wastewater treatment to reduce COD can produce a bioenergy as biogas from methane. It is mean if use traditional or minimum treatment will be wasted the bioenergy (Yu *et al.,* 2017). Soybean Processing Waste (SPW) in anaerobic digestion treatment can produce biogas. SPW/hay ratio give significant effect on daily cumulative methane (Zhu *et al.,* 2014). Thus, the study aims to identify the chemical and physical characteristics and pollution load in each processes of tempeh production. Understanding of tempeh wastewater characteristics will be able to provide guidance on wastewater treatment and potential to produce biogas from methane.

2. RESEARCH METHODOLOGY

Tempeh production process consists of: (1) soybeans boiled and soaked overnight then washed, (2) breaking soybean to be two parts then the skin separate by washing it, (3) fermentation process and packaging, (4) keep Tempeh around two days to get good product. Detail of

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tempeh production processes and point source of wastewater chose to measure, show in Figure 1. Tempeh wastewater samples were collected was taken from each processes that produce a lot of wastewater: washing, boiling, soaking and mixing (mixing waste from all process) in tempeh production.

Tempeh wastewater was analyzed for chemical and physical characteristic. The chemical characteristics analyzed are pH, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). pH was measured using pH meter, BOD using SNI 6989.72:2009 method and COD using SNI 6989.2: 2019 method. The physical parameter analyzed is Total Suspended Solid (TSS) and analyzed using SNI 6989.3: 2019 method. Furthermore discharge was calculate by batch system at the time of production run in the morning. This is a home industry that run production just in the morning every day.

The physical and chemical parameters were compared with the standards from region government regulation of East Kalimantan Province No. 2 Years 2011 regarding water quality management and water pollution control (Goverment regulation, 2011). Pollution load was calculated using the Indonesian Ministry of Environmental No. 110 Years 2003 about Guidelines for Determination of Load Capacity Water Pollution in Water Source (State Minister of Environment, 2003) as in Equation 1.

$$Pollution\ Load\ Existing\ =\ Q\ x\ C \tag{1}$$

Pollution Load Existing (kg/day)

Q = Discharge (m^3/sec)

C = Concentration of pollution (mg/L)

Load Capacity Water Pollution is counted by calculate maximum pollution load from standard concentration of pollution was regulation allowed. Afterward obtained allocation of pollution load by calculate deviation maximum pollution load and pollution load existing. If obtained minus it means the load capacity water pollution has exceeded.

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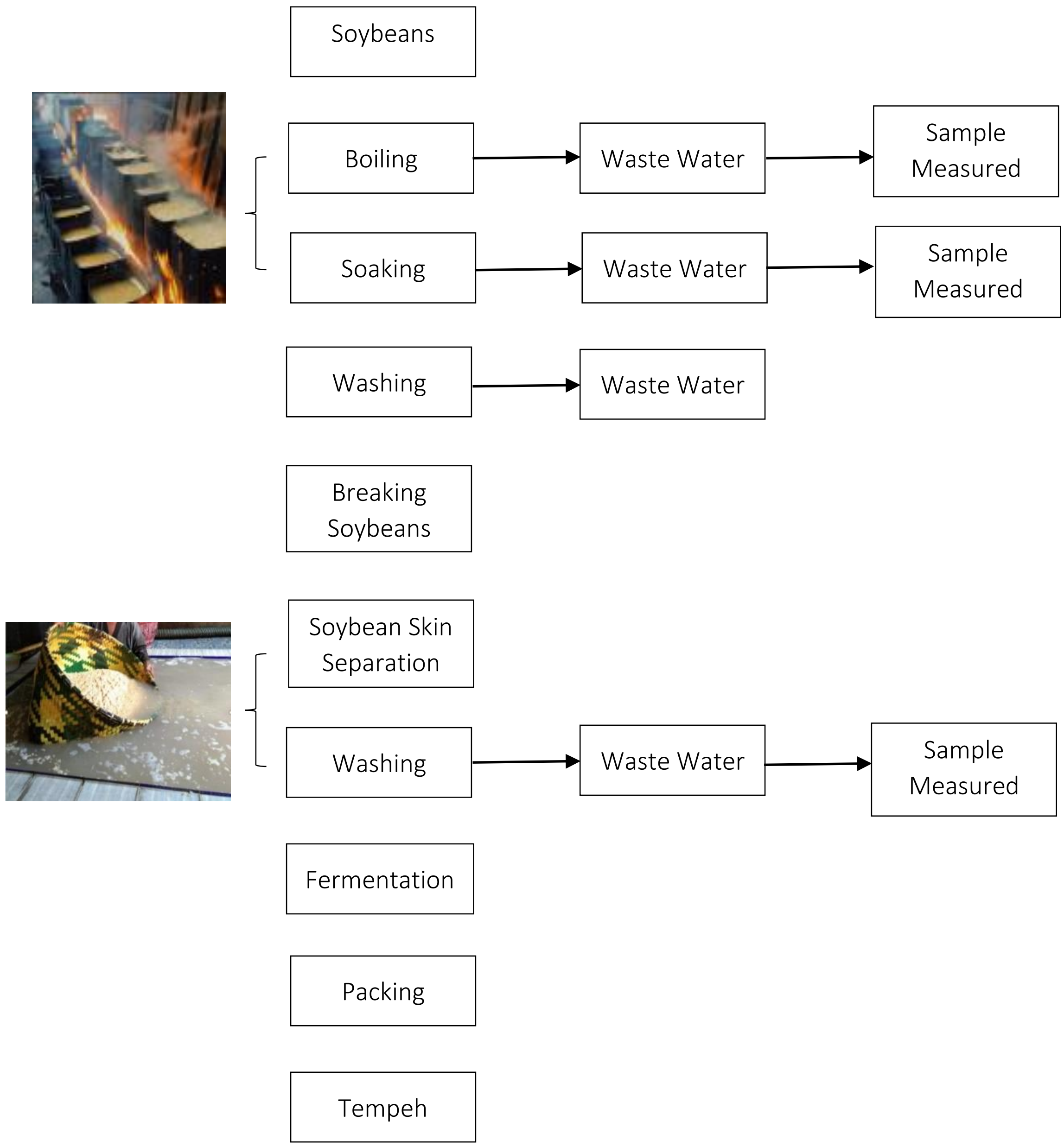

Figure 1 Tempeh production processes and samples measured

3. RESULTS AND DISCUSSION

3.1 Wastewater Quality of TSS, BOD, COD and pH

Table 1 shows the Total Suspended Solid (TSS) in each step processing from washing to mixing included result of mixing waste from all process. TSS contents in all processes have exceed the

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 5, Number 3, page 209-222, October 2022
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what standard and the highest TSS was in boiling process (655,2 mg/L). TSS affect to the water quality of turbidity in the water body as river. It is impact to inhibit the penetration sunlight to the water body and disturb photosynthesis in the waters caused decrease Dissolved Oxygen (DO) (Puspawati and Soesilo, 2018; Seroja, Effendi and Hariyadi, 2018). The biological degradation process of organic matter was determined by DO contents (Wang *et al.*, 2019).

Table 1 Total suspended solid (TSS) contents

Source of Tempeh Wastewater	TSS (mg/L)	Standard (mg/L)
Washing	223.20	200
Boiling	655.20	200
Soaking	370.00	200
Mixing	194.40	200

Table 2 shows BOD contents in Tempeh wastewater in each process of tempeh production. BOD content in boiling, soaking and mixing waste from all process exceed the standard except in washing process and the highest BOD was in soaking process indicating that the organic matter soaking is high in tempeh wastewater (Wang and Serventi, 2019). BOD content in waste water means organic matter pollutant (Mamun, Lee and An, 2018).

Table 2 Biological oxygen demand (BOD) contents

Source of Tempeh Wastewater	BOD (mg/L)	Standard (mg/L)
Washing	114.77	50
Boiling	174.65	50
Soaking	299.40	50
Mixing	264.47	50

Table 3 shows COD level in each process of tempeh wastewater and mixing waste from all process. COD content in boiling, soaking and mixing waste from all process exceed the standard except in washing process and highest COD was showed in soaking. Moreover, COD and BOD values are similar as oxygen demand to degrade organic matter in difference process (Mamun, Lee and An, 2018; Wang and Serventi, 2019; Pramaningsih *et al.,* 2020). Soaking wastewater contain of higher organic matter than others.

Table 3 Chemical Oxygen Demand (COD) Contents

Source of Tempeh Wastewater	COD (mg/L)	Standard (mg/L)
Washing	200.72	100
Boiling	351.54	100
Soaking	540.66	100
Mixing	403.02	100

Table 4 shows TSS, BOD and COD contents in each tempeh processing step. The highest TSS in boiling process while the highest of BOD and COD is in soaking process. It is similar with the other researcher, where wastewater of soybean food in each step processing has difference characteristic especially in soaking and cooking water have high COD and BOD [15]. The others source of tempeh wastewater have low of pollutants, it can be treated by minimum treatment to get the standard. Then the wastewater high organic matter can be reduced by aerobic or anaerobic digestion. Soybean wastewater characterized is high organic was composed soluble protein and carbohydrates, with high COD (Guo *et al.*, 2018). Reducing COD of Soybean wastewater used hybrid system by direct feeding is more affective without dilution (Song *et al.*, 2019). Soybean wastewater treatment by anaerobic digester produce methane about 55% and COD removal about 80% (Yu, 2015). Anaerobic digestion processes from tempeh wastewater treatment produced methane 8720 mL and COD removal 67.7% (Fransiscus and Simangunsong, 2021). The other soybean wastewater treatment to reduce COD use biological process using *Aspergillus niger* pelletization technology found 98.11% COD removal (Zhang, Zhang and Diao, 2017).

BOD and COD content in the wastewater will impact to the Dissolved Oxygen (DO) that it is support the healthy aquatic ecosystem. Beside that DO content also influence the biological organic degradation process changes in aerobic or anaerobic organisms work (Wang *et al.*, 2019). Decreasing of DO due to the organic matter had increased in the water (Raudsepp *et al.*, 2019). Organic matter from the waste of human activities or industries influence to river water quality especially for BOD and COD will be high (Pramaningsih *et al.*, 2020).

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Table 4 TSS, BOD and COD contents in each soybean processes

Source of Tempeh Wastewater	TSS (mg/L)	BOD (mg/L)	COD (mg/L)
Washing	223.20	114.77	200.72
Boiling	655.20	174.65	351.54
Soaking	370.00	299.40	540.66
Mixing	194.40	264.47	403.02

The content of pH in each soybean processing step is showed in Table 5. The lowest pH was showed in soaking and mixing at 4.0 and can influence microalgae life in wastewater treatment. Low pH and sufficiently phosphorous resources determine efficient COD removal by microalgae (Song *et al.*, 2019) but pH adjustment to neutral at 7.0 guaranteed growth of microalgae (Song *et al.*, 2020). COD removal by reactor is effective in pH at 7.0-7.4 (Guo *et al.*, 2018).

Table 5 pH contents in each soybean processes

Source of Tempeh Wastewater	pH	Standard
Washing	5	6
Boiling	5	6
Soaking	4	6
Mixing	4	6

3.2 Pollution Load of TSS

Pollution load existing, maximum pollution load and allocation pollution load of TSS from tempeh industry wastewater showed in Table 6, 7, and 8. Pollution load existing is amount of a polluting element contained in water or wastewater. Maximum pollution load is the standard maximum polluting allowed in wastewater discarded to the environment. Pollution load was calculated by multiplication of discharge and the pollutant concentration. Deviations of both are allocation of pollution load that will be allowed while getting positive value and need improvement while getting negative value. It used for monitoring water pollution source before discarded to the river or environment.

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Table 6 Pollution load of TSS existing

Source of waste	Discharge (m^3/sec)	TSS existing (mg/L)	Pollution Load existing (kg/day)
Washing	0.10	223.20	1928.45
Boiling	0.05	655.20	2830.46
Soaking	0.05	370.00	1598.40
Mixing	0.20	194.40	3359.23

Table 7 Maximum pollution load of TSS

Source of waste	Discharge (m^3/sec)	TSS standard (mg/L)	Maximum Pollution Load (kg/day)
Washing	0.10	100	864
Boiling	0.05	100	432
Soaking	0.05	100	432
Mixing	0.20	100	1728

Table 8 Allocation pollution load of TSS

Source of waste	Discharge (m^3/sec)	Pollution Load existing (kg/day)	Maximum Pollution Load (kg/day)	Allocation of Pollution Load (kg/day)
Washing	0.10	1928.45	864	-1064.45
Boiling	0.05	2830.46	432	-2398.46
Soaking	0.05	1598.40	432	-1166.40
Mixing	0.20	3359.23	1728	-1631.23

Highest Pollution load existing in mixing wastes source but the highest allocation of pollution load happened in boiling wastewater. It is depend on TSS concentration and discharge from source. Boiling wastewater of soybean also has high nutrient as nitrogen (Hokamura *et al.*, 2017). Nitrogen effect to the eutrophication in the water (Wang *et al.*, 2019) that makes blooming algae in the surface water and disturb penetration sunlight for photosynthesis. It is impact to decrease of dissolved oxygen then dangerous for aquatic life. Overall of pollution load in wastewater from each stage exceed the maximum pollution load as wastewater tempeh production. It is mean not requirement to the environment and need treatment to improve wastewater quality of TSS. It is showed in allocation pollution load get negative value and

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pollution load capacity for TSS content in tempeh wastewater was exceed the standard. High TSS will influence turbidity in the water increase (Seroja, Effendi and Hariyadi, 2018). TSS in the water prevent penetration sunlight that affect photosynthesis process (Puspawati and Soesilo, 2018; Seroja, Effendi and Hariyadi, 2018).

3.3 Pollution Load of BOD

Pollution load existing, maximum pollution load and allocation pollution load of BOD from tempeh industry wastewater showed in Table 9, 10, and 11.

Table 9 Pollution load of BOD existing

Source of waste	Discharge (m^3/sec)	BOD existing (mg/L)	Pollution Load existing (kg/day)
Washing	0.10	114.77	991.61
Boiling	0.05	174.65	754.49
Soaking	0.05	299.40	1293.41
Mixing	0.20	264.47	4570.04

Table 10 Maximum pollution load of BOD

Source of waste	Discharge (m^3/sec)	BOD Standard (mg/L)	Maximum Pollution Load (kg/day)
Washing	0.10	150	1296
Boiling	0.05	150	648
Soaking	0.05	150	648
Mixing	0.20	150	2592

Table 11 Allocation pollution load of BOD

Source of waste	Discharge (m^3/sec)	Pollution Load existing (kg/day)	Maximum Pollution Load (kg/day)	Allocation of Pollution Load (kg/day)
Washing	0.10	991.61	1,296	304.39
Boiling	0.05	754.49	648	-106.49
Soaking	0.05	1,293.41	648	-645.41
Mixing	0.20	4,570.04	2592	-1,978.04

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Highest Pollution load existing and allocation of pollution load of BOD happened in mixing waste. All pollution loads have exceeded the standard except washing stage. Oxygen in the water depends on between photosynthesis, degradation organic matter and aeration processes (Ali and Khairy, 2016). BOD is measure dissolved oxygen consumed by microorganisms for degradation process in the wastewater (Bhateria and Jain, 2016). The high discharge and pollution load existing of BOD affect to the high value of BOD allocation pollution load. Discharge of mixing waste is highest that effect increasing pollution load due to high organic matter degradable. Discharge kind of wastewater influence water quality (Elsayed *et al.*, 2019) and pollution load.

3.4 Pollution Load of COD

Pollution load existing, maximum pollution load and allocation pollution load of COD from tempeh industry wastewater showed in Table 12, 13, and 14.

Table 12 Pollution load of COD existing

Source of waste	Discharge (m^3/sec)	COD existing (mg/L)	Pollution Load existing (kg/day)
Washing	0.10	200.72	1734.22
Boiling	0.05	351.54	1518.65
Soaking	0.05	540.66	2335.65
Mixing	0.20	403.02	6964.19

Table 13 Maximum pollution load of COD

Source of waste	Discharge (m^3/sec)	COD standard (mg/L)	Maximum Pollution Load (kg/day)
Washing	0.10	300	2592
Boiling	0.05	300	1296
Soaking	0.05	300	1296
Mixing	0.20	300	5184

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Table 14 Allocation pollution load of COD

Source of waste	Discharge (m^3/sec)	Pollution Load existing (kg/day)	Maximum Pollution Load (kg/day)	Allocation of Pollution Load (kg/day)
Washing	0.10	1,734.22	2,592	857.78
Boiling	0.05	1,518.65	1,296	-222.65
Soaking	0.05	2,335.65	1,296	-1,039.65
Mixing	0.20	6,964.19	5,184	-1,780.19

Highest pollution load and allocation pollution load of COD occur in mixing waste, similarly BOD pollution load. It meaning that oxygen needed to organic and inorganic matter degradation by biological and chemical processes. COD usually as important indicator of water pollution for organic matter in the water (Zhang *et al.*, 2020). Kind of wastewater has high COD contents and suspended solid have high organic matter (Apandi *et al.*, 2019). Nutrient and organic pollution load was reduced by microalgae found COD and BOD removal up to 75% and 82% (Usha *et al.*, 2016).

4. CONCLUSION

In identification result of wastewater quality of pH values in all tempeh processing steps were acidic and have exceeded the standard. Highest BOD and COD were showed in soaking step due to there is high organic matter. It has potential to get biogas in wastewater treatment by anaerobic digestion. Then the highest TSS was showed in boiling step due to there is turbulence process during boil of the soybean. Pollution load in parameters have exceed the standard except in washing waste. These findings indicated that tempeh production wastewater is capable to impact the aquatic life balance. Wastewater from tempeh industry should be treated in order to reduce its impact in aquatic environment.

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