BIOREMEDIATION OF TOFU INDUSTRY LIQUID WASTE USING EFFECTIVE MICROORGANISM-4 (EM4) SOLUTION

(CASE STUDY OF TOFU SENTOSA INDUSTRY, YOGYAKARTA)

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Abstract

Liquid waste produced from the tofu industry contains high contaminants such as BOD, COD, TDS, pH, and TSS, which can pollute the environment. Therefore, pollutants should be decreased before being discharged into the environment. Tofu waste treatment is constrained by adequate technology and high costs. Biological treatment is one of the best treatments, a waste treatment process by utilizing microorganisms. This research used the intermittent anaerobic-aerobic process and was conducted on a laboratory scale using a tank made of glass 25 cm long, 20 cm wide, 15 cm high, and a tank of 30 cm long and 15 cm wide 15 cm high. The treatment process in this research used samples adding EM4 solution with a concentration of 1/20 and samples without EM4. The stages of the research were carried out consisting of preliminary research, core research, and further research. Preliminary research used 1/20 (5%) concentration of EM4 and was fermented for four days at room temperature. As a result, the pH value decreased from 6 to 4, and the presence of a white layer above the surface. The average pollutant reduction efficiency value in the sample with Effective Microorganism-4 (EM4) and without the Effective Microorganism-4 (EM4) was tested at different duration times for each parameter. The efficiency reduction value of the sample with EM4 of BOD was 87.14%, COD 74.68%, TSS 15.88%, and TDS -17.91%, while in the sample without EM4 of BOD value was 76.54%, COD 67.78%, TSS 22.77%, TDS -16.78% with a time process of 41st day.

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1. Introduction

The home industry is an economic activity of the community that processes raw goods into raw materials into semi-finished goods, and finished goods or goods that are more profitable. The sector has positive and negative impacts on the environment. The tofu industry is a home industry that harms solid waste and liquid waste. Waste discharged into the aquatic environment continuously can cause odors and aesthetic disturbances and damage marine ecosystems. Tofu waste treatment is constrained by adequate technology and high costs. Therefore, the alternative tofu industry must be able to process liquid tofu waste at a low cost, easy, fast, and safe destruction when discharged into the environment. Biological treatment is one of the best treatments, a waste treatment process by utilizing microorganisms.

Microorganisms that can be used to treat liquid tofu waste are microorganisms found in Effective Microorganism-4 (EM4) because EM4 consists of 95% of Lactobacillus sp (lactic acid bacteria) bacteria. The rest contains several microorganisms such as photosynthetic bacteria (Rhodopseudomonas sp.), fermented fungi (Saccharomyces sp), Actinomycetes, and yeast (Yeast). Lactic acid bacteria ferment organic matter into lactic acid, which accelerates the overhaul of organic matter, and is assisted by fermenting fungi (Saccharomyces sp) to ferment organic matter into simpler organic compounds.

This research on biological wastewater treatment was carried out using an EM4 activator with an anaerobic-aerobic intermittent system. The bacteria in EM4 are aerobic bacteria that require free oxygen in degrading organic compounds. The aerobic system is open, so oxygen supply will be faster in reducing pollutant levels and optimizing environmental conditions so that organic matter-eating bacteria can grow well.

2. Methodology

2.1 Material

The material used to treat liquid tofu waste is EM4. This research was conducted on a laboratory scale using a tank made of glass measuring 25 cm long, 20 cm wide, and 15 cm high and a tank measuring 30 cm long, 15 cm wide, and 15 cm high. Operational samples used in each treatment were 6 liters and 3 liters. This research used an intermittent system. The principle of the intermittent system is to drain wastewater from the anaerobic tank to the aerobic tank. The discharge flowing into the tank is regulated using a faucet. Wastewater has flowed continuously with a downward flow, a flow pattern from top to bottom. The reactor scheme can be seen in Figure 1.

Figure 1. Anaerobic and Aerobic reactor

2.2 Research

The stages of the research carried out consisted of preliminary, core, and further research. Preliminary research is mixing 1/20(5%) concentration of EM4 solution, fermented for four days at room temperature. This process aims to breed microorganisms and activate microorganisms present in EM4 from a dormant condition so that microorganisms can work efficiently and optimally when mixed into liquid waste. The active EM4 in the leading research is the primary material for mixing tofu liquid waste. The leading research was carried out for the 41st day with various treatments.

Tofu liquid waste at a certain volume was added with EM4 solution with a concentration of 5%. Tofu waste liquid with 5% EM4 refers to the optimum dose in previous studies (Jasmiyati et al., 2010). The method for measuring and analyzing each parameter is potentiometry, gravimetry, 5daytes, and closed reflux titrimetry. Measurements of pH and TDS every day, while measures of BOD, COD, and TSS every Monday, and after the 20th-day measurements were made on days 21, 23, 27, 28, 30, 34, 37, and 41 to see changes in quality at specific intervals.

2.3 Parameter Analysis

2.3.1 pH (Acid and base levels)

Hydrogen ion concentrations (pH) are parametrically crucial for water and wastewater quality. Quality standards set 6-9.

2.3.2 Total Suspended Solid (TSS)

Suspended substances usually consist of organic and inorganic substances that hover in the water; physically, this substance is the cause of turbidity in water.

2.3.3 Total Dissolve Solid (TDS)

TDS or total dissolved solid is the amount of solid substance dissolved in water; the lower the TDS, the better the water quality.

2.3.4 Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) measures water pollution by organic substances that can naturally be oxidized and result in reduced dissolved oxygen in the water.

$$\text{COD as } MgO_2 = \frac{(A - B) \times N \times 8000}{\text{sample}} \quad (1)$$

Where :

A = ml FAS for blank
B = ml FAS for sample
N = Normality FAS

$$DO\ (mg/l) = \frac{\text{vol. } Na_2S_2O_3 \times \text{Normalitas } Na_2S_2O_3 \times 8 \times 1000}{\text{Vol.Sample}} \quad (2)$$

2.3.5 Biochemical Oxygen Demand (BOD_5)

Biochemical Oxygen Demand (BOD_5) is a dissolved oxygen (DO) derivative parameter that has a significant role in the sustainability of water ecosystems. The main reason is that if the BOD_5 value is too large, it will cause the effect of competition for oxygen needs between the oxidation process of organic matter and the process of respiration of aquatic living things so that marine life can be disrupted.

$$BOD_{5\ days\ 20°C} = \frac{(DO_0 - DO_5) - (B_0 - B_5)(I - p)}{P} \quad (3)$$

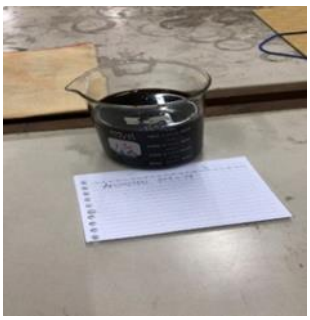
Where :

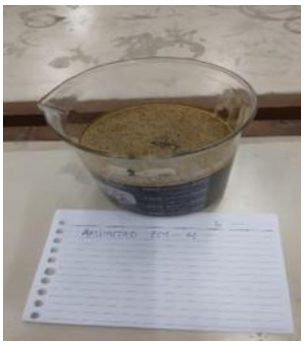
B_0 = DO 0 day blank (mg/l)
B_5 = DO 5 days blank (mg/l)
DO_0 = DO 0 day sample (mg/l)
DO_5 = DO 5 days sample (mg/l)
p = dilution figure

3. Results & Discussion

EM4, which has a pH value of > 4, has actively characterized, smells good (smells of glucose), and has a white layer above the surface of the EM4 solution (Isa, 2008). Preliminary research is mixing 1/20 (5%) of EM4 and fermenting for four days at room temperature. As a result, the pH value decreased from 6 to 4, and the presence of a white layer above the surface. This indicates that EM4 is ready for research, as shown in Table 1.

Table 1. Conditions of Effective Microorganism-4 (EM4) Solution During the Acclimation Process

Days	The State of the Solution during Acclimatization	Figure
Day-1	On the first day of acclimatization of Effective Microorganism-4 (EM4), the solution is dark brown, smells like glucose, pH 6	
Day-2	The second day of acclimatization Solution Effective Microorganism-4 (EM4) is dark brown with a slight white layer, has a sour smell, pH 5	

Days	The State of the Solution during Acclimatization	Figure
Day-3	On the third day of acclimatization Effective Microorganism-4 (EM4) solution is dark brown, there is many white coating on the surface, smells like acid, pH 4	

3.1 Main Research

Before conducting the research using EM4, the measurement results of the characteristics of industrial liquid waste tofu can be seen in Table 2.

Table 2. The first characteristics of Tofu industrial liquid waste

No	Parameter	Unit	Rate	Quality Standard*
1	BOD	mg/L	7272.83	150
2	COD	mg/L	9125.76	300
3	TSS	mg/L	1260	200
4	TDS	mg/L	2000	2000
5	Ph		4.39	6.0-9.0

3.2 Analysis of BOD_5 (Biochemical Oxygen Demand)

The experiment's results using EM4 indicated that BOD_5 drastically decreased from 5653.44 mg/l to 85.28 mg/l during the 37th day, while the experiment without using EM4 decreased from 3882.24 mg/l to 74 mg/l during the 28th day. That can be seen in Table 3 and in Figure 2.

Table 3. Analysis of BOD_5 measurement

Day-	Sample Inlet EM4 (mg/l)	Sample Outlet EM4 (mg/l)	Sample Inlet without EM4 (mg/l)	Sample Outlet without EM4 (mg/l)
1	6987.6	5653.44	3337.92	3882.24
6	4960	1364	3610.88	1785
13	4625.93	557.76	5146.08	713.3
20	4117.14	244.28	4173.44	511,44
21	4173.35	146.68	4292.1	373.92
23	4122.62	157.36	4440.3	612.24
27	4090.32	88.92	4623.84	671.84
28	4935.06	128.44	4426.24	74
30	4448.6	191.44	3643.04	770.1
34	4727.52	207.24	4282.35	735.48
37	4590.18	85.28	4663.05	298.56
41	3937.12	204.69	3617.25	223.56

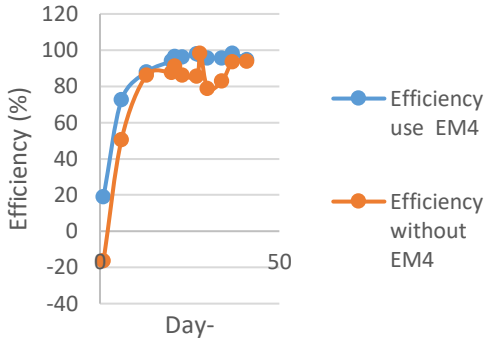


Figure 2. Efficiency graph of effective microorganism-4 (EM4) and no effective microorganism-4 (EM4) solution in BOD_5 removal

Table 3 shows the decrease in BOD_5 value for samples that used Effective Microorganism-4 (EM4) solution and without an Effective Microorganism-4 (EM4) solution. The experiment using the EM4 solution shows that the reduction efficiency of BOD_5 reached the highest value of 98.14%, which occurred on the 37th day. In comparison, the experiment without EM4 reached the highest value of 93.82% on the 28th day. This decrease in BOD_5 levels could be due to the effectiveness of lactic acid bacteria (Lactobacillus sp.) present in EM4.

3.3 Analysis of COD (Chemical Oxygen Demand)

The experiment's results using EM4 indicated that COD drastically decreased from 10800 mg/l to mg/l 1066.28 during 41th day, while experience without using EM4 decreased from 7120 mg/l to 1308.32 mg/l during 21 days. That can be seen in Table 4 and in Figure 3.

Table 4. Analysis of COD measurement

Day-	Sample Inlet EM4 (mg/l)	Sample Outlet EM4 (mg/l)	Sample Inlet without EM4 (mg/l)	Sample Outlet without EM4 (mg/l)
1	16800	10800	7200	7120
6	9669.6	4740	6370.56	3488.64
13	8986,4	3250.4	7571.52	1988.48
20	8658	1924	6772.48	1385.28
21	9235.2	1635.4	7003.36	1308.32
23	8911.2	1706.4	7432.82	1744.32
27	8486.4	1414.4	7425.6	1626
28	8663.2	1272.96	6789.12	1874.08
30	9520	1599.36	7463.68	2056,32
34	8629.2	1542.24	7196.12	1652.4
37	8812.8	1321.92	7197.12	1468.8
41	7516.4	1066.28	6362.72	1503.28

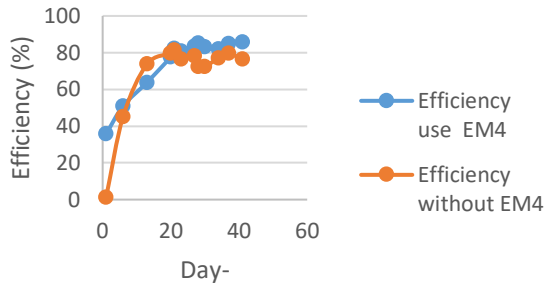


Figure 3. Efficiency graph of effective microorganism-4 (EM4) and no effective microorganism-4 (EM4) solution in COD removal

Table 4 shows the decrease in COD value in samples with Effective Microorganism-4 (EM4) solution and without Effective Microorganism-4 (EM4) solution. The experiment using EM4 solution shows that the reduction efficiency of COD reached the highest value of 85.81%, which occurred on the 41th day, while the experiment without EM4 reached the highest value of 81.32% on 21st day. The decrease in COD value can also be caused by the length of treatment time; the longer the tofu liquid waste is treated, the more significant the decrease in COD levels (Ulum, Mumu, & Kancitra, 2013). The decrease in COD value mainly occurs in the anaerobic reactor, which is not too large (Wuri Arini, 2013). In the anaerobic phase, organic matter that is difficult to decompose is degraded into simpler and toxic metabolites (Balapure, 2016). Chemical decomposition reactions of organic compounds that microorganisms can degrade are (Takwayana, 2012):

$$CXHYOZ + Cr_2O_7^{2-} + H^+ \rightarrow CO_2 + H_2O + Cr^{3+} \quad (4)$$

The reaction shows that the organic matter is oxidized by potassium bicarbonate to gas in the form of CO_2 and H_2O and with several chromium ions.

3.4 Analysis of TSS (Total Suspended Solid)

The results of the experiment using EM4 indicated that TSS drastically decreased from 318.67 mg/l to mg/l 46.67 during the 20th day, while experience without using EM4 decreased from 110.67 mg/l to 26.67 mg/l during the 20th day. That can be seen in Table 5 and in Figure 4.

Table 5. Analysis of TSS measurement

Day-	Sample Inlet EM4 (mg/l)	Sample Outlet EM4 (mg/l)	Sample Inlet without EM4 (mg/l)	Sample Outlet without EM4 (mg/l)
1	144.00	318.67	49.30	110.67
6	180.00	530.00	193.33	83.33
13	116.67	140.00	270.00	70.00
20	373.33	46.67	276.67	26.67
21	353.33	116.67	233.33	86.67
23	223.33	113..33	210.00	140.00
27	206.67	36.67	403.33	60.00
28	826.67	173.33	846.67	226.67
30	280.00	293.33	253.33	320.00
34	406.67	86.67	433.33	60.00
37	286.67	200.00	246.67	100.00
41	233.33	100.00	473.33	186.67

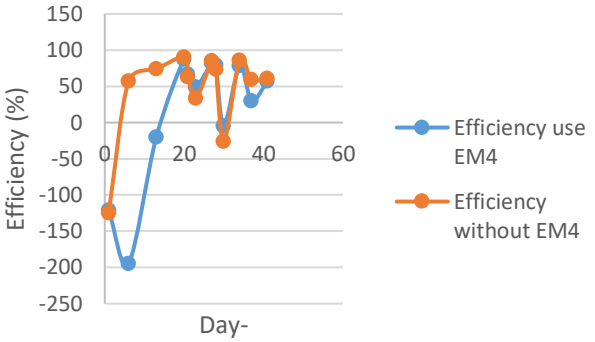


Figure 4. Efficiency graph of effective microorganism-4 (EM4) and no effective microorganism-4 (EM4) solution in TSS removal

Table 5 shows the decrease of TSS value in samples using Effective Microorganism-4 (EM4) solution and without an Effective Microorganism-4 (EM4) solution for 41th day, the bioremediation process decreased, and the levels increased unstable. The experiment using the EM4 solution shows that the reduction efficiency of COD reached the highest value of 87.50%, which occurred on the 20th day, while the experiment without EM4 reached the highest value of 90.36% on the 20th day. The increase in TSS occurs because nitrogen compounds contained in tofu liquid waste are formed in suspended material; besides, ammonia can be absorbed into the suspended material to settle to the bottom of the water (Effendi, 2003). The coagulation process slowly, and small particles in the waste will fall and become sediment (Abas Sato, 2015).

3.5 Analysis of TDS (*Total Dissolved Solids*)

The experiment's results using EM4 indicated that TDS drastically decreased from 1231 mg/l to mg/l 1164 during 3rd day, while experience without EM4 decreased from 1349 mg/l to 1330 mg/l during 3rd day. That can be seen in Table 6 and Figure 5.

Table 6. Analysis of TDS measurement

Day-	Sample Inlet EM4 (mg/l)	Sample Oulet EM4 (mg/l)	Sample Inlet without EM4 (mg/l)	Sample Outlet without EM4 (mg/l)
1	1598	1349	1221	1231
2	1668	1338	1238	1206
3	1718	1330	1234	1164
6	1310	1573	1225	1264
7	1190	1437	1156	1345
8	1206	1533	1178	1337
9	1230	1544	1172	1394
10	1219	1542	1166	1386
13	1163	1518	1183	1438
14	1178	1573	1193	1471
15	1176	1487	1185	1433
16	1207	1459	1210	1412
17	1219	1455	1219	1407
20	1237	1541	1220	1411
21	1265	1595	1231	1469
22	1243	1495	1254	1443

Day-	Sample Inlet EM4 (mg/l)	Sample Oulet EM4 (mg/l)	Sample Inlet without EM4 (mg/l)	Sample Outlet without EM4 (mg/l)
23	1252	1466	1257	1452
24	1285	1432	1271	1452
27	1220	1508	1209	1450
28	1240	1505	1219	1479
29	1244	1478	1222	1453
30	1202	1488	1176	1467
31	1241	1451	1194	1449
34	1275	1519	1224	1472
36	1278	1503	1204	1520
37	1222	1503	1196	1516
38	1248	1478	1217	1499
41	1197	1543	1192	1486

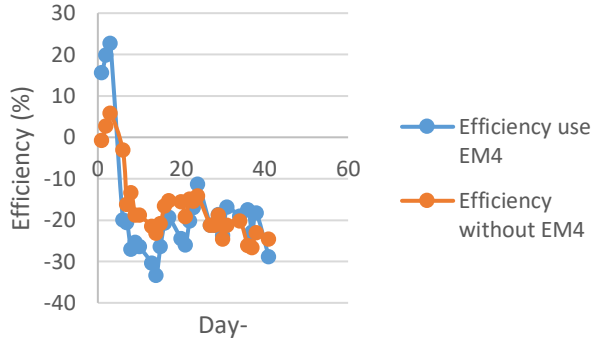


Figure 5. Efficiency graph of effective microorganism-4 (EM4) and no effective microorganism-4 (EM4) solution in TDS removal

Table 6 shows the decrease of TDS value in samples that used Effective Microorganism-4 (EM4) solution and without the Effective Microorganism-4 (EM4) solution for 41th day of the bioremediation process. The experiment using EM4 solution shows that the reduction efficiency of COD reached the highest value of 22.58%, which occurred on 3th day, while the experiment without EM4 reached the highest value of 5.67% on 3th day.

The explanation shows the most reduction in TDS levels during the processing process was in samples with EM4 solution, 1330 mg/l, and samples without EM4 solution, 1164 mg/l. The decrease in TDS value occurred due to the length of residence time. The longer the processing tofu liquid waste, the more maximal it would be to reduce the TDS value in liquid tofu waste.

3.6 Analysis of pH

The experiment's results using EM4 indicated that pH drastically increased from 3.38 to 7.29 during 3th day, while experience without using EM4 increased from 3.38 to 7.5 during 6th day. That can be seen in Table 7 and in Figure 6.

Table 7. Analysis of pH measurement

Day-	Sample Inlet EM4 (mg/l)	Sample Oulet EM4 (mg/l)	Sample Inlet without EM4 (mg/l)	Sample Outlet without EM4 (mg/l)
1	3..37	3.38	3.12	3.22
2	3.45	3.3	3.47	3.51
3	3.28	3.92	3.1	7.29
6	3.39	7.5	3.55	8.04
7	3,54	7.6	3.45	8.48
8	3.46	7.88	3.33	8.15
9	3.39	8.04	3.47	8.37
10	3.27	8.36	3.46	8.34
13	3.67	8.64	3.48	8.48
14	3.38	8.48	3.46	8.17
15	3.73	8.14	3.55	8.17
16	3.75	8.69	3.62	8.72
17	3.5	8.54	3.36	8.56
20	3.62	8.35	3.52	8.06
21	3.6	8.45	3.55	8.08
22	3.51	8.4	3.38	8.23
23	3.43	8.59	3.5	8.11
24	3.51	8.75	3.45	8.4
27	3.84	8.61	3.77	8.06
28	3.65	8.6	3.7	7.64
29	3.73	8.93	3.63	7.86
30	3.61	8.57	3.72	7.88
31	3.41	8.46	3.45	7.67
34	3.55	8.44	3.47	7.93
36	3.51	8.63	3.44	8.27
37	3.51	8.57	3.61	7.99
38	3.48	8.61	3.39	8.24
41	3.48	8.48	3.58	8.4

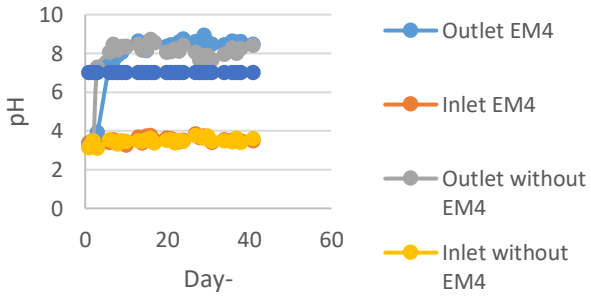


Figure 6. Comparison of pH values using Effective Microorganism-4 (EM4) and without Effective Microorganism-4 (EM4)

Table 7 shows the increase in pH value from acid to normal in samples using Effective Microorganism-4 (EM4) solution and without an Effective Microorganism-4 (EM4) for the 41th day of the bioremediation process. The initial pH value for the sample that used EM4 solution was 3.38, and without the EM4 solution was 3.22. The pH value of samples using EM4 solution and without EM4 solution increased erratically. The increased pH in tofu liquid waste used EM4 was due to microorganisms in EM4, which remodeled the remaining organic matter from liquid tofu

waste. The increase in pH in tofu waste without EM4 solution was caused by temperature. The bioremediation process is carried out in an open place that gets heat intensity from sunlight so that the surface temperature rises. When the water's surface temperature rises, carbon dioxide's solubility will decrease so that the pH will increase.

4. Conclusion

There is a difference in the decrease in pollutant value samples with Effective Microorganism-4 (EM4) solution and without the Effective Microorganism-4 (EM4) solution with the duration of time. The average pollutant efficiency value in the sample with Effective Microorganism-4 (EM4) solution and without the Effective Microorganism-4 (EM4) solution with a different duration of time for each parameter being tested. The efficiency value of the sample with EM4 of BOD was 98.14%, COD 85.81%, TSS 87.50%, and TDS 22.58%, while in the sample without EM4 of BOD value was 93.82%, COD 81.32%, TSS 90.36%, TDS 5.67%.

References

Astuti, L. P. (2018). Kemampuapn Beberapa Tumbuhan Air dalam Menurunkan Pencemaran Bahan Organik dan Fosfat untuk Memperbaiki Kualitas Air. *Jurnal Teknologi Lingkungan*.

Firmaniar, E. (2017). *Pengaruh Pemberian Campuran EM4, Tetes Tebu dan Limbah Cair Tahu sebagai Pupuk Organik Caur Terhadap Pertumbuhan Tanaman Bayam Merah (Alternanthera Amoena Voss)*.

Hidayat Nur, S. A. (2017). Evaluation of Two-Stage Biological Treatment With Attached Filter Media on Treatment of Tofu Processing Wastewater. *Journal of Applied Environmental Sciences*, *Volume 11,*

Kesehatan, P. M. (2017). *Standar Baku Mutu Kesehatan Lingkungan dan Persyaratan Kesehatan Air untuk Keperluan Higiene Sanitasi*. Nomor 32.

Meriatna. (2018). Pengaruh Waktu Fermentasi dan Volume Bio Aktivator EM4 (Effective Microorganisme) pada Pembuatan Pupuk Organik Cair (POC) dari Limbah Buah- buahan. *Jurnal Teknoligi Kimia*.

Ningrum, I, H. 2018. Studi Penurunan COD dan Amonia Pada Limbah Cair Tinja Menggunakan Biofilter Anaerob Media Sarang Tawon [skripsi]. Medan : Universitas Sumatera Utara

Rahadi, B, Wirosoedarmo, R, dan Harera, A. 2018. *Sistem Anaerobik-Aerbik Pada Pengolahan Limbah Industri Tahu Untuk Menurunkan Kadar BOD, COD dan TSS.* Jurnal Sumber Daya Alam dan Lingkungan

Rahayu, N. S. (2011). *Kemampuan upflow Anaerobic Fixed Bed (UAFB) Reaktor dalam Mempertahankan Kondisi Optimum dalam Penyisihan Senyawa Organik pada Biowaste Fasa Cair Tanpa Menggunakan Pengaturan pH*.

Silalahi, F, T. 2018. Pengolahan Limbah Cair Tahu Dengan Bioreaktor Anaerob Satu Tahap dan Dua Tahap Secara *Batch* [skripsi]. Medan : Universitas Sumatera Utara

Adsorben Untuk Mengurangi kadar Fenol Dalam Air Limbah. *Jurnal Teknik Pomits*, Vol. 2, No. 1: 116-120.

Wardhana, W. A. (2004). Dampak Pencemaran Lingkungan. *Yogyakarta*.

Widjajanti, E. (2009). Penanganan Limbah Laboratorium Kimia. Jurusan Pendidikan Kimia FMIPA UNY. *Yogyakarta*.

Wulan, T. S. (2016). Analisis Kualitas Air Sumur Masyarakat Kelurahan Lalolara Kecamatan Kambu. *Universitas Haluoleo*.accessed April 8, 2012, *Listrik Dinamis*,