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Original Research Article

Characteristics of Wastewater Generated by the Snack Food (Cookies) Industry

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Abstract

The snack food industry is one of the major industries in Indonesia that has various types of products, one of which is snacks (cookies), which are widely consumed as snacks. This study aims to determine the characteristics of wastewater from the snack food industry (cookies). The research was conducted in three factories located in Bandung Regency, Sumedang Regency and Majalengka Regency. Primary data were collected from wastewater samples collected monthly for laboratory testing. Data analysis used descriptive statistical analysis of average concentration of wastewater parameters using Microsoft Excel software and SPSS 25 software. The main parameters of wastewater from the snack food industry (cookies) are pH, TSS, BOD, COD, ammonia, total nitrogen, and MBAS. From the comparison of the resulting BOD, COD, TSS, ammonia, and total nitrogen pollutant loads, the largest load trends occur in Factory B, Factory C, and Factory A. Failure to properly treat these crucial wastewater parameters can pose risks to the environment and surrounding communities. Thus, these vital parameters form the basis for selecting wastewater treatment plant technology to fulfil environmental standards. WWTP process recommendations that can be used are grease trap, surge tank, dissolved air flotation (DAF), anaerobic system, aerobic system, secondary clarifier, and post-treatment.

Keywords: Key parameters; snack food industry; wastewater characteristics

1. Introduction

The industry of snack food products encompasses the manufacturing of cookies, biscuits, bread, and both sweet and savory pastries. Snack foods are intended to alleviate hunger as snacks or treats and are not considered main menu items (Gemina et al., 2016). Every year, consumer interest in Indonesia regarding snack foods continues to rise. This is supported by an 8% increase in the distribution volume of snack foods from 2020 to 2021 and a 6% increase from 2021 to 2022, with the largest proportion in the cookies and crackers category (Industry Research Data, 2023).In the production process of snack foods, there is wastewater generated as a byproduct of raw material processing in the industry. The food industry, along with textiles, is known as one of the largest consumers and producers of wastewater (Pervez *et.al.*, 2021). Wastewater from the food industry originates from various operational sources in the factory, such as production processes, sanitation water for food processing, cooking and dissolving, equipment cleaning, and material transportation (Abdallh et al., 2016). Approximately 60% of wastewater comes from equipment washing, as after production, the used equipment is cleaned with chemicals requiring washing and rinsing with water (Overseas Environmental Cooperation Center, 2003).

Broadly, wastewater characteristics are grouped into physical, chemical, and biological characteristics. Physical characteristics of wastewater are related to its physical properties, such as Total Suspended Solids (TSS), temperature, density, color, conductivity, and turbidity. According to Ginting (2007), chemical characteristics of wastewater include Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, Dissolved Oxygen (DO), ammonia, nitrite, nitrogen, oil & grease, and heavy metals. Meanwhile, biological characteristics of wastewater involve the presence of microorganisms that are harmful to health. The characteristics and volume of wastewater produced by food processing industries vary according to the product and production methods (Pervez et al., 2021). Wastewater characteristics for some dairy product industries include BOD levels of 442 mg/L, COD of 8960 mg/L, TS of 797.2 mg/L, TSS of 253.6 mg/L, pH of 7.1, and total nitrogen of 120.1 mg/L (W. Qasim & Mane, 2013). Milk & cheese products have BOD levels of 4840.6 mg/L, COD 10251.2 mg/L, TSS 5802.6 mg/L, pH 6.34, and total nitrogen 663 mg/L (Cristian, 2010). Cheese products have COD levels of 23,000 – 40,000 mg/L, TS 1600 – 3900 mg/L, and total nitrogen 400 – 700 mg/L (Rajagopal et al., 2013). Sweet snack products have levels of BOD mg/L, COD 9720 mg/L, TS 763.5 mg/L, TSS 224.7 mg/L, pH 5.64, and total nitrogen 95.2 mg/L (Qasim & Mane, 2013). Fruit products have BOD levels of 860 mg/L, COD 919 mg/L, pH 5.5 – 7.2, and total nitrogen 40 mg/L (Puchlik & Struk-Sokołowska, 2017).

Generally, wastewater characteristics from the food industry contain high concentrations of organic pollutants, both in suspended and dissolved forms (Pervez et al., 2021). The presence of other pollutant parameters depends on raw materials and processing procedures (Aderibigbe et al., 2018). Wastewater from the food industry has characteristics that can biologically degrade and are non-toxic but have high concentrations of BOD, COD, and TSS (Cristian, 2010). According to Krzemińska et al., (2015), wastewater from the food industry contains suspended solids, nitrogen, oil and fat, phosphorus, chloride, and organic matter. Wastewater from food processing industries also has varying pollutant concentrations influenced by differences in raw materials and additives used in each product type (Abdallh et al., 2016).

When wastewater is discharged into the environment without treatment, it can degrade the quality of the environment. Wastewater containing nitrogen (ammonia, nitrite, nitrate) and phosphorus parameters can cause eutrophication, which is an increase in organic production in water that promotes excessive algal growth and biomass accumulation, leading to a decrease in biodiversity at all trophic levels (Burkholder, 2003). Large quantities of oil and grease parameters from food industry effluent entering water bodies can cover the water surface and inhibit the transfer of oxygen from the air into the water. This condition can lead to reduced oxygen availability in the water, resulting in the death of fish and other aquatic organisms. In addition, the decomposition of organic matter from wastewater by anaerobic bacteria into methane gas can produce unpleasant odors. (Arifudin et al., 2020). Current regulations require that effluent discharged into water bodies must be safe and not disrupt the aquatic ecosystem for fear that the water body will be used as a source of clean water for the public's daily use and pose a risk to human health.

Wastewater with high pollutant levels requires treatment before being released into the environment. To determine the appropriate wastewater treatment technology and predict environmental impacts, it is necessary to identify the characteristics of wastewater according to its source Pambudi et al., (2021). In this study, the identified wastewater characteristics were obtained from the snack food industry. The research was conducted in three factories located in Bandung, Sumedang and Majalengka regencies. The purpose of this study is to analyze the characteristics of wastewater produced by the industry as well as potential technologies in reducing wastewater parameters. This study will analyze the test results of 33 wastewater parameters for three years, so that the main wastewater parameters from the snack food industry (cookies) can be identified.

2. Methods

The method used to analyze the characteristics of wastewater from the snack food industry (bakery products) is through primary data collection, namely field observations. Wastewater samples are taken using the grab sampling method and then laboratory tests are carried out. The wastewater samples taken were 37 samples and were carried out every month from August 2020 to August 2023, which came from the wastewater inlet that entered the wastewater treatment plant (WWTP) in three snack food industry factories.

Wastewater testing was conducted in an accredited laboratory with physical, chemical, and biological testing parameters. Physical parameters included temperature, Total Dissolved Solids (TDS), and Total Suspended Solids (TSS). Chemical parameters comprised pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrate, arsenic, cobalt, barium, nickel, tin, selenium, cadmium, hexavalent chromium, total chromium, copper, iron, lead, manganese, mercury, zinc, cyanide, fluoride, nitrite, oil & grease, free chlorine, sulfide, surfactant (MBAS), phenol, total ammonia, total nitrogen, and biological parameter total coliform.

Data analysis is based on descriptive statistical processing and presentation in the form of tables and graphs. The main parameters were determined by comparing the test results of wastewater parameters with the quality standards set by the Regulation of the Minister of Environment No. 5 Year 2014 Annex XLVII Class II. Statistical data analysis of the data processed in Microsoft Excel is carried out by descriptive analysis using SPSS 25 software. Descriptive analysis is performed by determining the average concentration of each wastewater parameter. Parameters with average concentrations exceeding the quality standard were identified as key effluent parameters. The concentration for each key parameter was determined based on the average value of the 37 wastewater samples by eliminating data that deviated too much (outliers).

3. Result and Discussion

3.1. Wastewater Test Results

Table 1 shows the average values of wastewater characteristics from three light food industry factories (cookies) for 33 parameters. The average values were obtained from the laboratory testing results with a total of 37 samples. Wastewater characteristics that exceed the quality standards in all three factories are pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), oil and grease, total ammonia, total nitrogen, surfactant (MBAS), and total coliform.

Table 1. Laboratory test results for snack food industry wastewater concentration (cookies)

No	Parameter	Units	Quality Standards	Concentrations		
				Factory A	Factory B	Factory C
1	Temperature	^{0}C	40	26.20 - 30.30	25.50 - 32.50	25.50 - 30.70
2	Total Dissolved Solids (TDS)	mg/L	4000	260 - 3.310	210 - 1.079	380 - 2.110
3	Total Suspended Solids (TSS)	mg/L	400	381 - 7,780	409 - 7,820	161 - 9,290
4	pH	-	6 - 9	3,44 - 7.61	2.77 - 6.21	2.98 - 6.46
5	BOD	mg/L	150	179 - 10,689	368 - 9,551	730 - 9,250
6	COD	mg/L	300	577 - 22,848	1,028 - 29,300	3,321 - 21,990
7	Nitrate (NO3-N)	mg/L	30	0.02 - 6.00	0.26 - 9.00	0.07 - 9.00
8	Arsen (As)	mg/L	0,5	0.00 - 0.01	0.00 - 0.01	0.00 - 0.01
9	Cobalt (Co)	mg/L	0,6	0.00 - 0.04	0.00 - 0.04	0.01 - 0.04
10	Barium (Ba)	mg/L	3	0.04 - 3.00	0.03 - 3.00	0.23 - 3.00
11	Nickel (Ni)	mg/L	0,5	0.00 - 0.16	0.00 - 0.16	0.00 - 0.16
12	Tin (Sn)	mg/L	3	0.02 - 1.40	0.02 - 1.40	0.02 - 1.40
13	Selenium (Se)	mg/L	0,5	0.00 - 0.00	0.00 - 0.00	0.00 - 0.01
14	Cadmium (Cd)	mg/L	0,1	0.00 - 0.02	0.00 - 0.02	0.00 - 0.02
15	Chrom (VI)	mg/L	0,5	0.00 - 0.08	0.01 - 0.08	0.00 - 0.08
16	Total Chrom (Cr)	mg/L	1	0,00 - 0.08	0.00 - 0.08	0.04 - 0.08

17	Copper (Cu)	mg/L	3	0.10 - 1.00	0.01 - 3.00	0.01 - 3.00
18	Iron (Fe)	mg/L	10	0.30 - 8.00	0.03 - 9.00	0.03 - 9.00
19	Lead (Pb)	mg/L	1	0.10 - 0.80	0.00 - 0.08	0.01 - 0.08
20	Manganese (Mn)	mg/L	5	0.30 - 4.00	0.04 - 5.00	0.07 - 5.00
21	Mercury (Hg)	mg/L	0,005	0.00 - 0.00	0.00 - 0.00	0.00 - 0.01
22	Zinc (Zn)	mg/L	10	0.04 - 4.00	0.04 - 5.00	0.01 - 5.00
23	Cyanide (CN)	mg/L	0,5	0.00 - 0.02	0.00 - 0.01	0.00 - 0.04
24	Fluoride (F)	mg/L	3	0.05 - 3.00	0.05 - 3.00	0.05 - 3.00
25	Nitrite (NO2-N)	mg/L	3	0.00 - 0.30	0.00 - 1.65	0.01 - 2.25
26	Oil and Grease	mg/L	20	1.00 - 39.00	0.37 - 94.00	1.00 - 50.00
27	Free Chlorine (Cl_2)	mg/L	2	0.01 - 0.08	0.01 - 0.09	0.01 - 0.08
28	Sulfide (H2S)	mg/L	1	0.01 - 0.10	0.00 - 0.20	0.00 - 0.30
29	MBAS	mg/L	10	0.03 - 94.83	0.03 - 61.00	0.06 - 54.00
30	Phenol	mg/L	1	0.00 - 0.09	0.00 - 0.34	0.00 - 0.60
31	Total Ammonia (NH3-N)	mg/L	10	0.30 - 57.00	0.09 - 46.00	0.09 - 45.00
32	Total Nitrogen	mg/L	60	4.47 - 63.00	2.00 - 99.00	6.09 - 76.00
33	Total Coliform	MPN/100 mL	10000	2,100 - 42,000,000	2,800 - 47,400.000	2,800 - 10,200.000

The data resource is processed from laboratory tes results in August 2020 – August 2023
Quality Standards Minister of Environmental Regulation No. 5 of 2014 Attachment XLVII Category II

Table 2. Average Concentration Value of Snack Food (Cookies) Industry Wastewater

No	Parameter	Units	Quality Standards	Average Concentration		
				Factory A	Factory B	Factory C
1	Temperature	^{0}C	40	28.358 ± 1.106	29.156 ± 2.000	27.961 ± 1.251
2	Total Dissolved Solids (TDS)	mg/L	4000	849.406 ± 605.401	601.566 ± 222.815	786.187 ± 298.368
3	Total Suspended Solids (TSS)	mg/L	400	3656.861 ± 2325.272	3258.727 ± 2073.336	4504.428 ± 2205.854
4	pH	-	6 - 9	4.956 ± 0.792	4.458 ± 0.851	4.605 ± 0.837
5	BOD	mg/L	150	3950.538 ± 2538.165	4431.151 ± 3037.579	4294.778 ± 2406.695
6	COD	mg/L	300	11741.314 ± 5825.513	14205.380 ± 8033.730	14741.849 ± 5552.287
7	Nitrate (NO3-N)	mg/L	30	2.844 ± 1.493	3.521 ± 2.413	3.470 ± 2.304
8	Arsen (As)	mg/L	0,5	0.002 ± 0.002	0.002 ± 0.003	0.003 ± 0.003
9	Cobalt (Co)	mg/L	0,6	0.032 ± 0.014	0.031 ± 0.014	0.033 ± 0.012
10	Barium (Ba)	mg/L	3	1.539 ± 0.848	1.585 ± 1.048	1.646 ± 1.042
11	Nickel (Ni)	mg/L	0,5	0.038 ± 0.031	0.056 ± 0.036	0.063 ± 0.030
12	Tin (Sn)	mg/L	3	0.490 ± 0.322	0.575 ± 0.407	0.575 ± 0.407
13	Selenium (Se)	mg/L	0,5	0.575 ± 0.407	0.001 ± 0.000	0.001 ± 0.001
14	Cadmium (Cd)	mg/L	0,1	0.012 ± 0.004	0.012 ± 0.004	0.012 ± 0.003
15	Chrom (VI)	mg/L	0,5	0.019 ± 0.019	0.021 ± 0.022	0.023 ± 0.023

16	Total Chrom (Cr)	mg/L	1	0.042 ± 0.033	0.067 ± 0.021	0.071 ± 0.016
17	Copper (Cu)	mg/L	3	0.652 ± 0.347	0.679 ± 0.751	0.825 ± 0.878
18	Iron (Fe)	mg/L	10	4.248 ± 2.020	4.898 ± 2.811	4.782 ± 2.543
19	Lead (Pb)	mg/L	1	0.553 ± 0.152	0.057 ± 0.022	0.056 ± 0.024
20	Manganese (Mn)	mg/L	5	2.040 ± 0.792	1.743 ± 1.417	1.729 ± 1.337
21	Mercury (Hg)	mg/L	0,005	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.001
22	Iron (Zn)	mg/L	10	1.441 ± 1.039	1.957 ± 1.534	1.837 ± 1.483
23	Cyanide (CN)	mg/L	0,5	0.005 ± 0.003	0.004 ± 0.001	0.005 ± 0.006
24	Fluoride (F)	mg/L	3	1.936 ± 0.434	1.843 ± 0.732	1.828 ± 0.776
25	Nitrite (NO2-N)	mg/L	3	0.059 ± 0.082	0.128 ± 0.309	0.201 ± 0.415
26	Oil and Grease	mg/L	20	20.806 ± 12.155	24.568 ± 18.887	22.982 ± 14.754
27	Free Chlorine (Cl_2)	mg/L	2	0.018 ± 0.018	0.013 ± 0.014	0.024 ± 0.018
28	Sulfide (H2S)	mg/L	1	0.045 ± 0.033	0.044 ± 0.038	0.050 ± 0.064
29	MBAS	mg/L	10	14.211 ± 21.938	10.265 ± 9.807	10.071 ± 8.518
30	Phenol	mg/L	1	0.006 ± 0.017	0.013 ± 0.059	0.033 ± 0.123
31	Total Ammonia (NH3-N)	mg/L	10	17.926 ± 14.235	20.937 ± 14.195	20.662 ± 14.250
32	Total Nitrogen	mg/L	60	37.000 ± 14.579	45.913 ± 23.140	43.495 ± 19.052
33	Total Coliform	MPN/100 mL	10000	3387443 ± 8560350	2948769 ± 9892006	937664 ± 2575108

The data resource is processed from laboratory tes results in August 2020 – August 2023
Quality Standards Minister of Environmental Regulation No. 5 of 2014 Attachment XLVII Category II

Based on Table 1 and Table 2, the key parameters of snack food industry wastewater (Cookies) consist of pH, COD, BOD, TSS, fatty oil, ammonia, total nitrogen, MBAS, and total coliform. Under these conditions, analysis is needed to find out effective and efficient processing methods to reduce pollutant levels until they meet predetermined quality standards and are safe to discharge into water bodies.

3.2. Key Wastewater Parameters

Key parameters are waste water parameters whose average levels are high and exceed quality standards. The key parameters of snack food (cookies) industry wastewater are as follows.

3.2.1. pH

The pH quality standard for snack food industry waste is in the range 6 – 9. The pH concentration fluctuation graph for this industrial wastewater is in Figure 1.

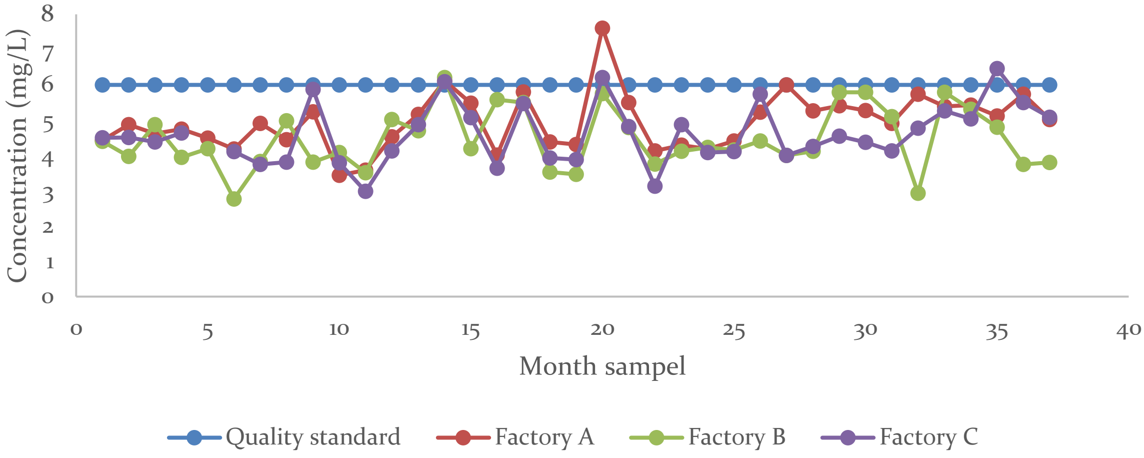

Figure 1. pH concentration fluctuation graph

Based on Figure 1, the pH values of the wastewater are predominantly below the quality standard, specifically below pH 6, indicating that this industrial wastewater is acidic. The presence of acidic liquid waste and high levels of organic compounds can cause unpleasant odors, raising concerns about potential discomfort for employees and the surrounding community near the Wastewater Treatment Plant (WWTP). A case in point is observed in the Aerobic Treatment of Palm Oil Mill Effluent, where the high COD content in liquid waste not only poses health risks but also results in unpleasant odors (Komala & Aziz, 2019). The low pH of wastewater is influenced by the process of reducing wastewater parameters, detergents and disinfectants used. Wastewater can become acidic on its own as a result of natural fermentation. Sodium hydroxide and nitric acid are the most commonly used cleaning chemicals. Sodium hypochlorite and a mixture of hydrogen peroxide and peracetic acid are used for disinfection. The pH limit of reclaimed wastewater is generally between 6 and 11. Low pH levels (pH <6) in wastewater cause corrosion of sewer networks and concrete pumping stations (Oy and Hannus, 2020).

3.2.2. COD

The Chemical Oxygen Demand (COD) value represents the equivalent amount of oxygen required to oxidize both organic and inorganic substances in a water sample through chemical means.

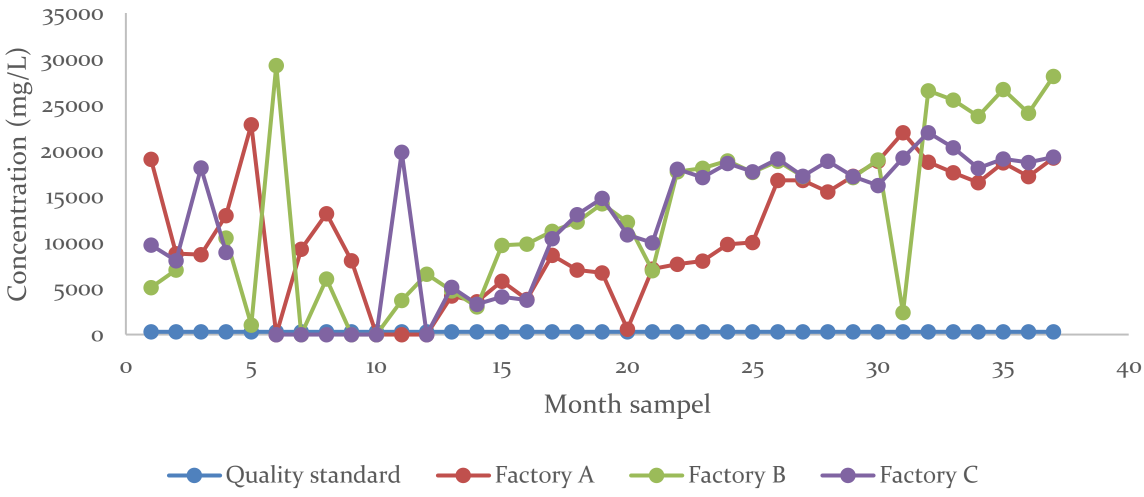

Figure 2. COD Concentration Fluctuation Graph

Based on the COD concentration graph in Figure 2, it can be observed that the COD levels in the wastewater from the light food industry producing cookies can reach around 30,000 mg/L (Factory B), which is considered high. According to Harper et al. (1971), in the food industry, BOD and COD levels are generally in the range of thousands of milligrams per liter but can reach tens of thousands in some cases, such as wastewater from cheese makers, wineries, and olive oil production. This indicates that the organic content in the wastewater from the light food industry (Cookies) is high, and effective treatment or processing units are needed to reduce COD levels before disposal into water bodies. The selection of appropriate treatment units can reduce high COD and BOD levels to meet the specified standards. One possible approach, based on the Japanese Ministry of the Environment (JME), involves the implementation of a biological treatment system such as an Anaerobic Reactor and Aeration Tank, where the removal efficiency can exceed 90%.

3.2.3. BOD

BOD (biological oxygen demand) is the amount of oxygen required by microorganisms (usually bacteria) for the aerobic degradation of organic matter (Santoso, 2018). BOD is a measure of the amount of oxygen required for the physiological stabilization of organic matter present in water and is the basis for determining the oxygen concentration in water, measuring the efficiency of treatment processes in wastewater treatment, and assessing compliance with permitted limits for wastewater discharge (Mutamim et al., 2012).

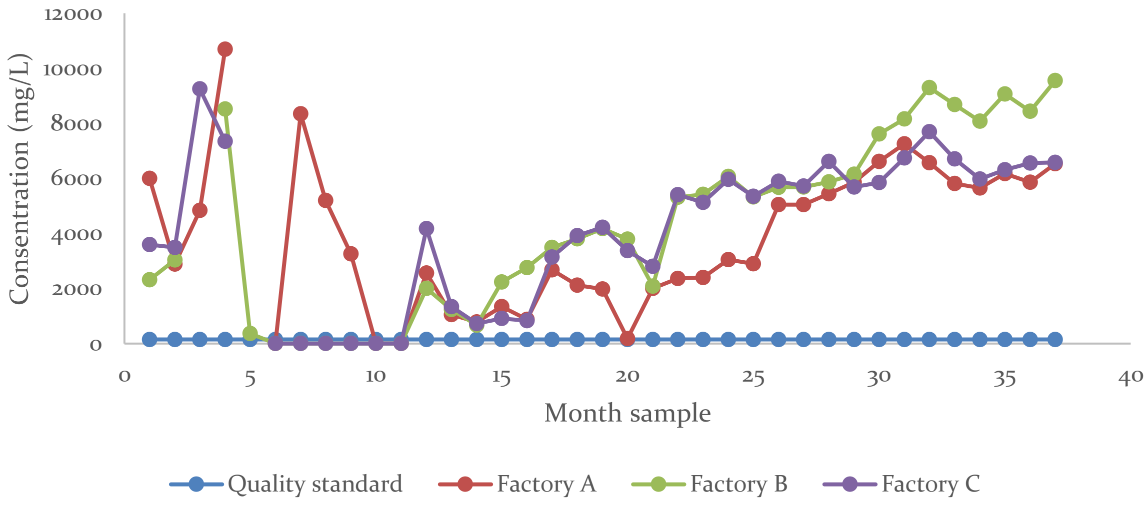

Figure 3. BOD concentration fluctuation graph

Based on the BOD concentration graph in Figure 3, it is evident that the highest concentration can fall within the range of 10,000-12,000 mg/L. This aligns with the discussion on COD concentration earlier, indicating that liquid waste from the food industry, such as the production of cookies, which often involves the use of sugar as one of its primary ingredients, can have very high BOD values. This is because sugar-rich wastewater typically contains a significant amount of organic matter and has a low availability of dissolved oxygen (Yuningsih et al., 2014).

3.2.4. TSS

In surface water inland waterways, TSS is the most prevalent water contaminant in terms of both weight and volume (Butler and Ford, 2018). Water bodies contain contaminants including metals, carbon, nitrates, and many others due to the movement of sediments in the water (Azzam et al., 2022). TSS is formed by physical processes that are mostly governed by hydrology. It can be composed of sand, silt, clay, and mineral deposits of biological components. A few of these physical processes are surface soil, bank erosion, and the aggregation of dissolved organic materials (Sagan et al., 2020).

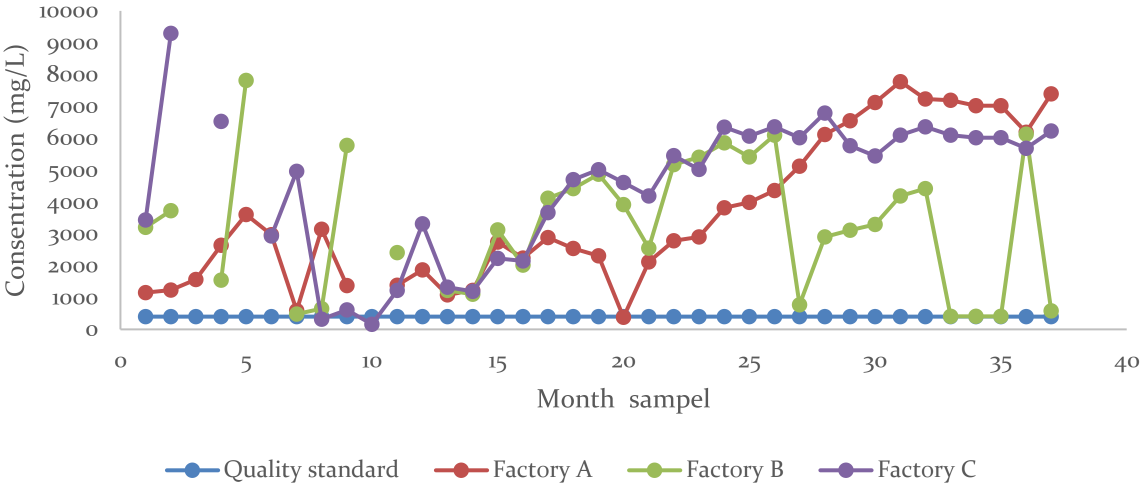

Figure 4. TSS concentration fluctuation graph

Based on the graph in Figure 4, it is observed that the TSS concentration mostly exceeds the established quality standard, with wastewater concentrations ranging from 1000-10,000 mg/L. The high TSS levels in the light food industry (cookies) may be attributed to the use of ingredients such as flour, sugar, and high concentrations of fats and oils in the production process (De Santana et al., 2018). The removal of TSS needs attention because if the removal is mainly through physical treatment and filtration processes, it generally does not significantly impact microbial metabolic activities unless a substantial portion of the TSS load is organic (Karathanasis et al., 2003).

3.2.5. Oil and Grease

Oil and grease are organic compounds that originate from nature and are insoluble in water but soluble in non-polar organic solvents. The components constituting oils and greases in each industry vary, depending on the raw materials, production processes, and additives. In the food and beverage processing industry, the main components of oils and greases come from vegetable oils and animal fats (Gunstone, 2009).

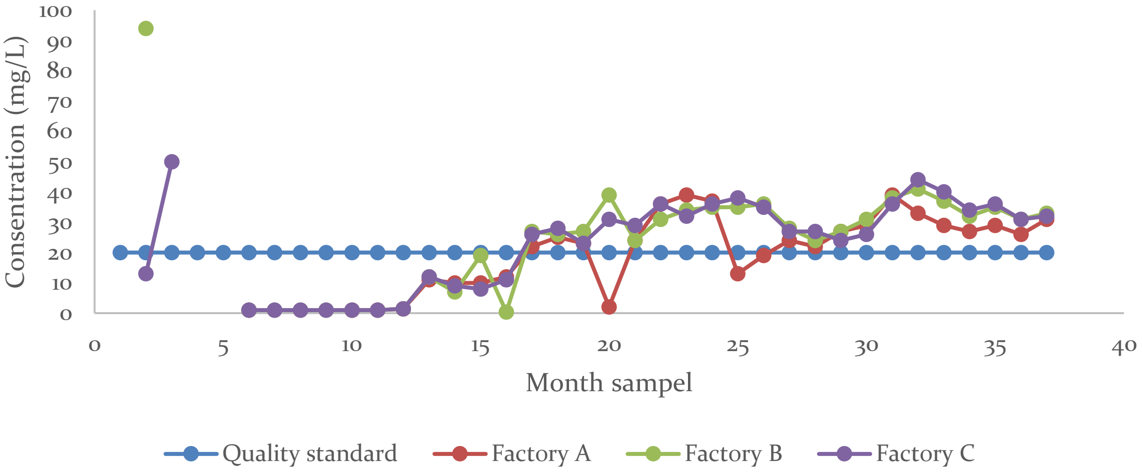

Figure 5. Oil and grease concentration fluctuation graph

Based on the graph in Figure 5, it is known that the oil and fat content in liquid waste fluctuates, with a significant portion of the oil and fat levels exceeding the set standard threshold for wastewater, which is 20 mg/L. The high content of oil and fat in the liquid waste from the light food industry is attributed to the production process using surfactants and fats as raw materials, causing the formation of emulsions of fat and oil molecules in water that are difficult to degrade (Malik et al., 2016). Wastewater from the food industry contains high levels of organic substances, and if discharged into receiving water bodies, it can lead to a decline in water and environmental quality. The resulting impacts include decay in the receiving water bodies and the foam produced by the liquid waste, which, over time, hardens and covers the surface of the receiving water bodies.

3.2.6. Ammonia

Ammonia (NH_3) is one of the organic nitrogen compounds. The ammonia content in water will affect the total nitrogen value, so the ammonia parameter is taken into account.

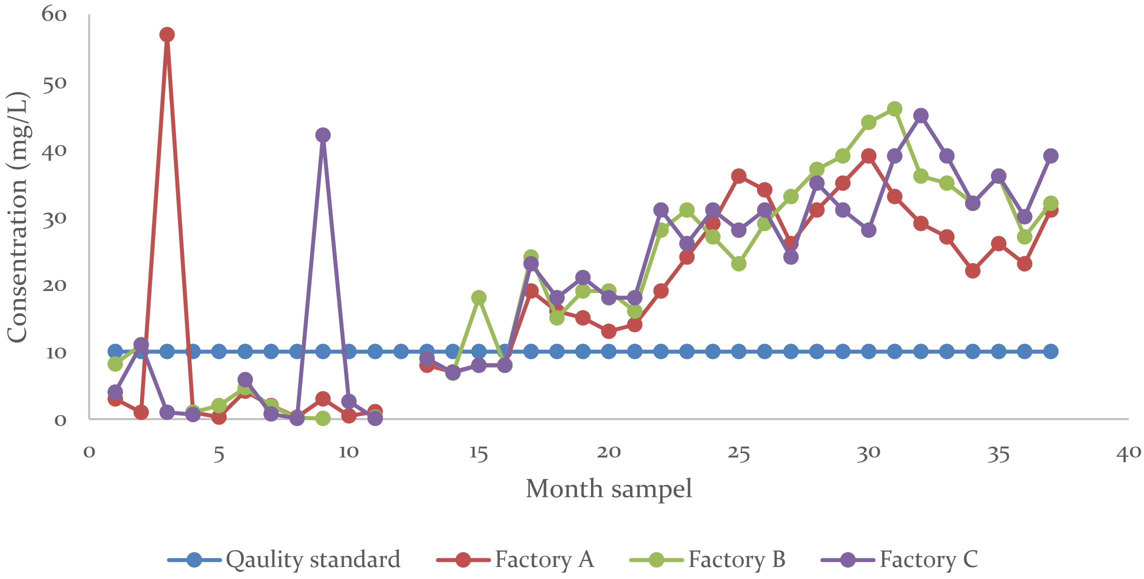

Figure 6. Ammonia concentration fluctuation graph

Based on the graph in Figure 6, it can be explained that the ammonia levels in wastewater from the food industry fluctuate within the range of 20-60 mg/L, exceeding the standard quality threshold. High ammonia levels can indicate contamination from organic substances originating from domestic or industrial waste, inversely proportional to the dissolved oxygen levels in the water. In water with excessively high oxygen content, the ammonia content tends to be relatively low (Said & Syabani, 2014). The high concentration of ammonia is due to the acidic pH conditions of the wastewater and the occurrence of high microbiological oxidation of organic matter, consistent with the conditions of pollutants such as Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) that are very high in wastewater from the light food industry (Putri et al., 2019).

3.2.7. Total Nitrogen

Total nitrogen is the total amount or concentration of nitrogen found in liquid waste or samples, surface water, and others. Nitrogen can be found in almost every body of water in various forms, depending on its oxidation state, namely NH_3, N_2, NO_2, NO_3. In wastewater, most of this nitrogen is present in the form of organic or protein and ammonia. Step by step, this organic nitrogen is converted into ammonia nitrogen. Under aerobic conditions, the oxidation of ammonia into nitrite and nitrate occurs over time (Prabowo, 2017).

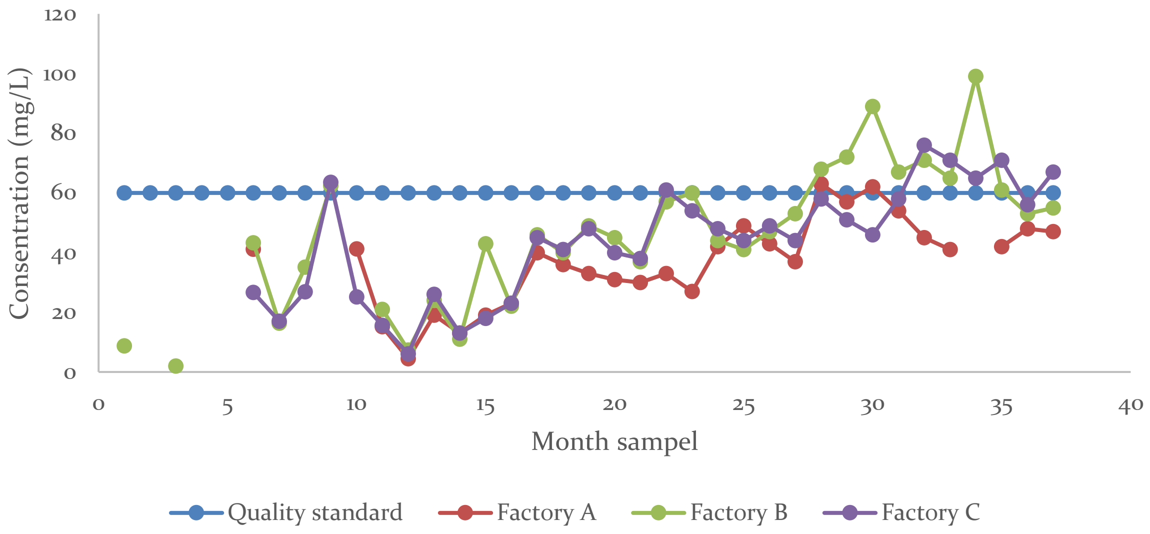

Figure 7. Total nitrogen concentration fluctuation graph

Based on the total nitrogen concentration graph in Figure 7, it can be observed that there is an increase in total nitrogen exceeding the quality standard for 12 months. This is similar to the condition of the ammonia concentration graph shown in Figure 6. According to Rambe (2017), the high BOD levels in industrial wastewater are directly proportional to the nitrite concentration, in line with the increase in nitrate and ammonia levels. This aligns with the statement by Hutagalung and Rozak (1997) that the concentration of nitrite compounds will increase as the dissolved oxygen decreases. Therefore, it is essential to note that with the increase in BOD and COD levels in industrial food wastewater, consideration must be given to nitrogen management to prevent water and its biota from pollution.

3.2.8. MBAS

The input of detergent pollutants into water can lead to water and biota pollution. The presence of detergents in aquatic environments, even in small amounts, can have negative impacts on fish (Sastrawijaya, 2009). According to Ainsworth (1996), some negative effects of high MBAS (Methylene Blue Active Substances) levels in the environment include : Formation of a film/layer on the water surface, hindering the transfer of oxygen from the air to the water; If detergent concentrations (MBAS) exceed 3 ppm, stable foam formation occurs; and The combination of polyphosphate with surfactants can increase nutrient content in water, leading to eutrophication processes that accelerate the growth of water weeds, such as water hyacinths.

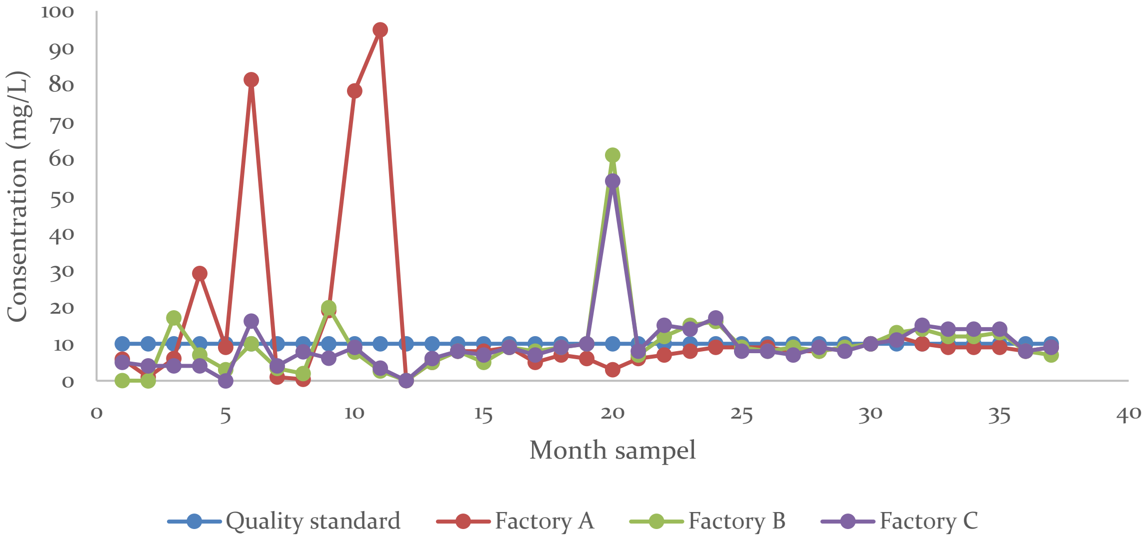

Figure 8. MBAS concentration fluctuation graph

Based on the MBAS (Methylene Blue Active Substances) concentration graph in Figure 8, it can be observed that the MBAS concentration in several months exceeds the specified quality standards. The presence of MBAS pollutants in the wastewater from the light food industry is attributed to industrial activities such as the washing of raw materials and production equipment. The presence of MBAS pollutants is indicated because they are used to bind anionic surfactants from wastewater (Triyani et al., 2013). Therefore, the high MBAS content is consistent with an increase in washing activities that use detergents containing surfactants to bind impurities on industrial equipment.

3.2.9. Coliform Total

Coliform bacteria are non-spore-forming organisms that can be either motile or non-motile. They have a rod-shaped morphology and the ability to ferment lactose to produce acid and gas at a temperature of 37°C during a 48-hour incubation period (Abdullah et al., 2019).

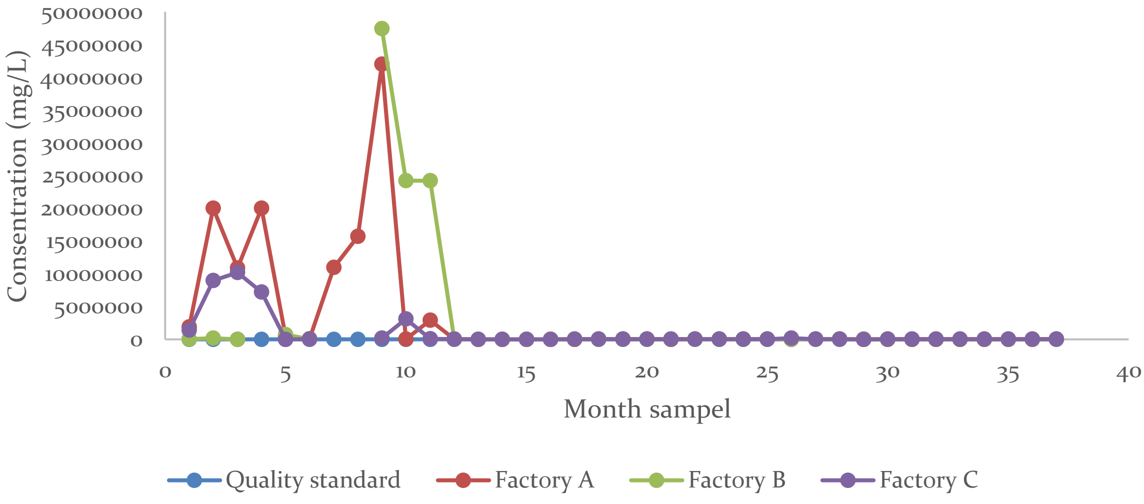

Figure 9. Total coliform concentration fluctuation graph

Based on the graph in Figure 9, it is evident that there is contamination of coliform bacteria in the wastewater sample. The wastewater test results indicate the presence of coliform bacteria in the wastewater from the light food industry. However, field conditions involve the separation of wastewater channels and different treatment processes for industrial wastewater and domestic wastewater. This suggests that there may be leakage, leading to the contamination of pathogenic bacteria from specimens of living organisms (human waste, fecal/urine) mixed in the industrial wastewater treatment plant (IPAL) containment.

3.3. Comparison of BOD Loading and COD Loading in Three Food Industries

The analysis is conducted through a comparison of the wastewater characteristics based on the pollutant loads generated from the three light food industries (Cookies), as depicted in Figure 10 and Figure 11.

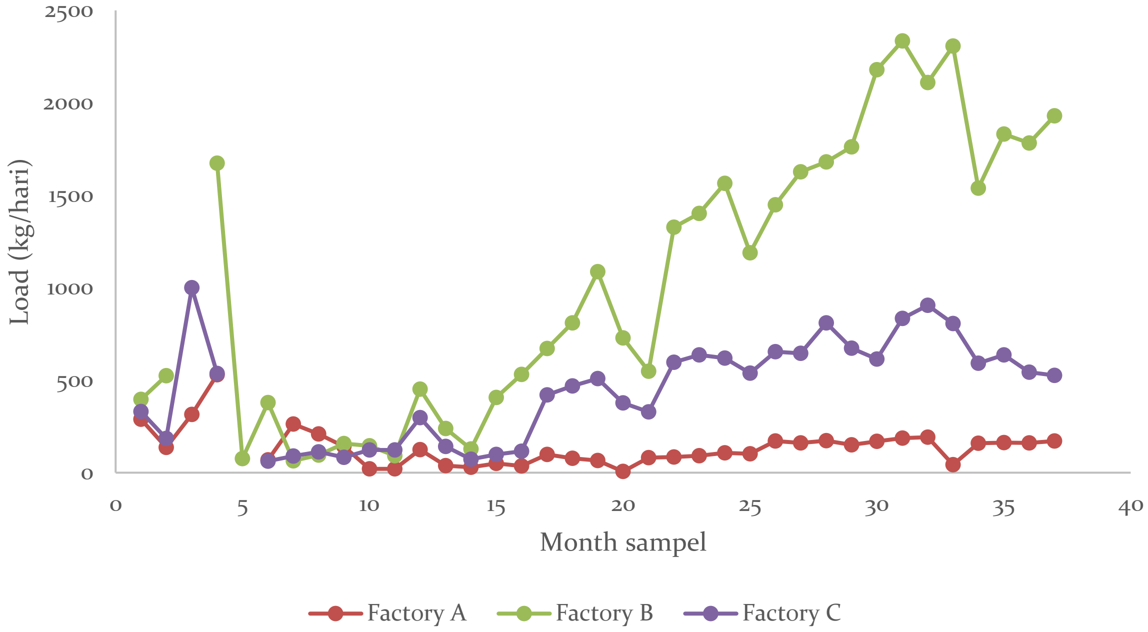

Figure 10. Fluctuation graph of bod loading in the three light snack food factories

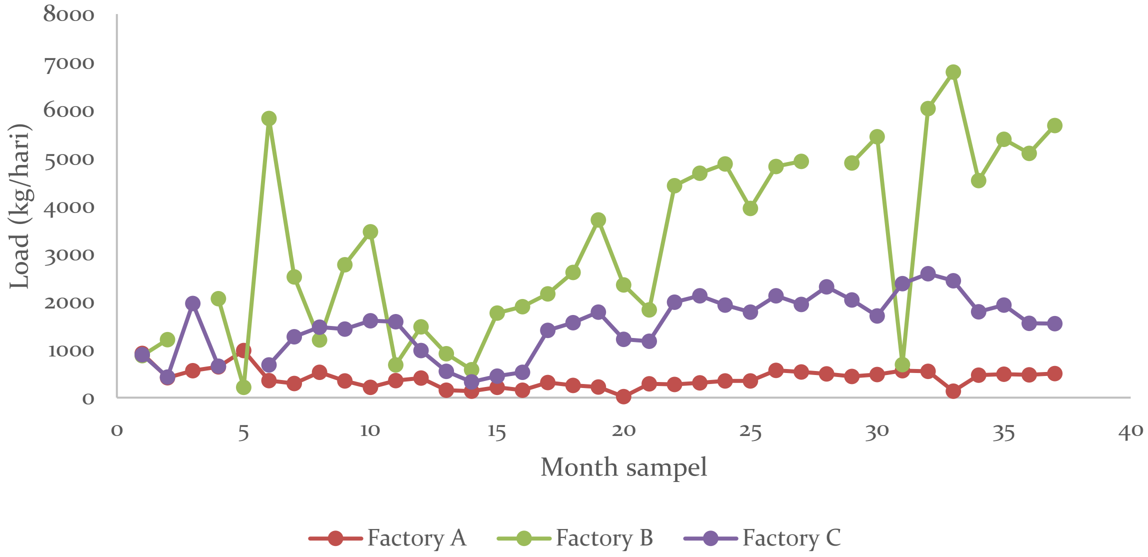

Figure 11. Fluctuation graph of cod loading in the three light snack food factories

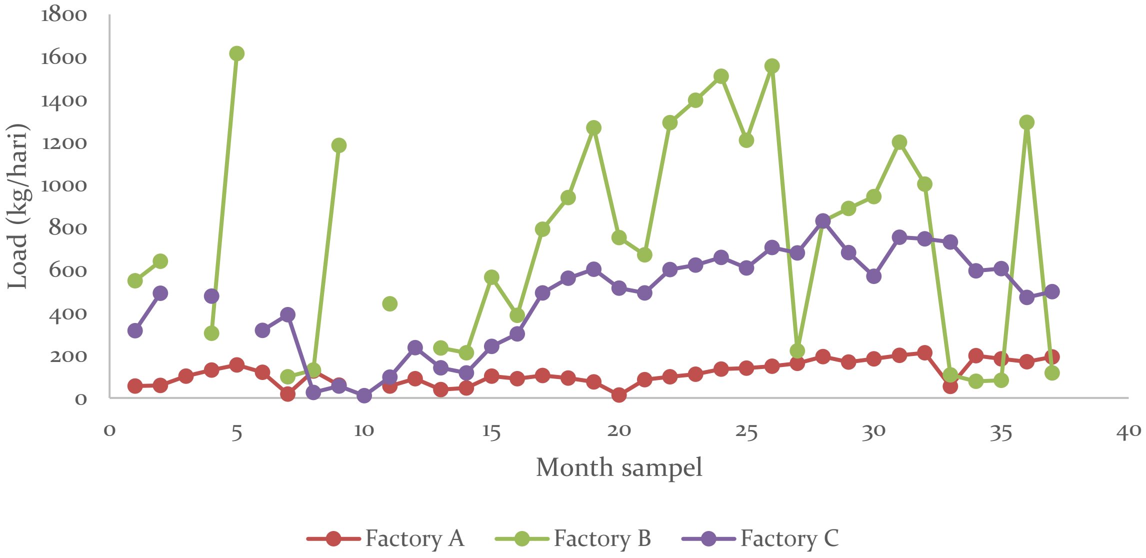

Figure 12. Fluctuation graph of tss loading in the three light snack food factories

Based on Figures 10 and 11, the BOD Loading for Factory A ranges from 6.2 to 530.1 kg/day, Factory B is 64.4 to 2335.3 kg/day, and Factory C is 62.5 to 999.9 kg/day. Meanwhile, the COD Loading for Factory A is 19.9 to 982.4 kg/day, Factory B is 212.4 to 6787.5 kg/day, and Factory C is 327.6 to 2583.3 kg/day. Reviewing the organic loads of BOD and COD for the three factories reveals significant differences influenced by the wastewater capacity or flow rate generated by each factory, which varies significantly. The wastewater flow for Factory A ranges from 7.5 to 65 m3/day, Factory B ranges from 171.3 to 286.3 m3/day, and Factory C ranges from 52.9 to 139.7 m3/day. Factory B has the highest pollutant loads compared to Factories A and C. Besides differences in wastewater flow, variations in organic loads can also be attributed to differences in the types of cookies produced in each factory and variations in the practices of the wastewater treatment plant (IPAL) operators. Differences in pollutant loads can affect the performance and types of treatment units used, where the wastewater treatment plant can function optimally if each processing unit meets standard design criteria such as Organic Loading Rate (OLR), detention time, and Hydraulic Loading Rate (HLR) (Aprilliani et al., 2023). If the incoming organic load exceeds the processing capacity of the treatment unit in the wastewater treatment plant, there will be untreated organic loads remaining, causing suboptimal processing and decreasing separation efficiency (Kothari et al., 2014).

In addition to the OLR, knowing the solid loading rate, derived from the TSS load parameter, can be used to consider the design of the sedimentation zone in the sedimentation tank, the needs for units like thickeners, Dissolved Air Flotation (DAF), Drying Beds, Filter Press, Anaerobic Sludge Digestion, and others (Qasim and Zhu, 2017). The larger the TSS (Total Suspended Solids) load contained in wastewater, the higher the by-product in the form of sludge generated, thus requiring consideration of the appropriate sludge treatment technology. Based on Figure 12, it can be observed that Plant B (77.9 – 1616.0 kg/day) has a high TSS loading compared to Plant A (13.1 – 211.5 kg/day) and Plant C (11.1 – 830.6 kg/day), consequently requiring a larger processing unit capacity and land area.

The ammonia and total nitrogen pollutant loads can be used to consider technologies to reduce nitrogen content in water. Based on the calculations in Figure 13 and Figure 14, it is known that the ammonia and total nitrogen loading, from the largest to the smallest, are plant B (ammonia 0.01 – 13.1 kg/day, TN 0.45 – 25.4 kg/day), plant C (ammonia 0.00 – 5.2 kg/day, TN 0.43 – 8.9 kg/day), and plant A (ammonia 0.01 – 3.7 kg/day, TN 0.21 – 2.0 kg/day). Differences in the pollutant loading characteristics of wastewater from the three snack food manufacturing plants can be caused by various factors, but generally, the main source of liquid waste in the snack food industry comes from the production process, raw material washing, equipment cleaning, and raw materials (GISEN, 2018). Additionally, differences in production capacity for each plant create variations in the duration and quantity of water needed for production and cleaning, ultimately resulting in different wastewater flow rates and pollutant loads for each characteristic pollutant for each plant. Apart from differences in wastewater flow rates, variations in organic loads can also be attributed to differences in the types of cookies produced at each plant and variations in the production operator's practices in operating equipment and optimizing raw material usage.

3.4. Technology for the Treatment of Wastewater from the Light Snack Food Industry

Industries, in general, will generate wastewater, and if not handled properly and appropriately, it can lead to environmental pollution in the surrounding area. Wastewater from the food industry, in particular, exhibits high levels of organic content, fats, and surfactants (Malik et al., 2016). Therefore, there are several stages in the treatment of wastewater in the light snack food industry that are commonly used, as follows.

- Grease Trap

  A grease trap functions as a separator of oil and grease from liquid waste. The grease trap operates based on the principle of the difference in density between oil and water. The oil from the liquid waste is captured, and the water is then directed through baffles into the next compartment.
- Equalization Tank

  The equalization tank functions as a reservoir for wastewater before it enters the treatment unit, ensuring that the wastewater has homogeneous characteristics and a stable flow (pretreatment). In addition, the purposes of the equalization tank are as follows:
  a. Regulating the flow rate of wastewater to be treated in the wastewater treatment plant (dividing and leveling the influent volume for chemical processes).
  b. Stabilizing organic load fluctuations to avoid shock loading on the biological treatment system and minimizing the need for additional chemicals.
  c. Leveling the pH to minimize the need for chemicals in the neutralization process.

  The equalization tank unit should be equipped with a mixer, or it can be engineered in terms of construction by positioning the inlet and outlet channels in such a way as to induce turbulence mixing effects (Arifudin et al., 2019)
- Dissolved Air Flotation (DAF)

  Dissolved Air Flotation (DAF) can be used in wastewater treatment processes in the snack food industry as it is a process that separates suspended solids, oil and grease from the liquid phase. DAF is a separation technique that uses a flotation process to remove emulsified particles. Water and air are combined in an air saturator at high pressure (300-800 kPa) to create microbubbles (Fanaie and Khiadani, 2020). Bubble agglomerates are formed when suspended particles strike and adhere to the microbubbles. The agglomerates are pulled to the surface by the buoyancy of the microbubbles, where they gradually solidify into a sludge blanket that is mechanically removed from the surface (Edzwald, 2010). The floating suspended particles coalesce to form flocs.

  The efficiency of flotation depends on the amount of air bubbles sufficient to float suspended particles. If the amount of air is insufficient, flotation will only occur partially. Meanwhile, when there is an excess of air, it will not have a significant effect. The effluent quality from the flotation unit can be related to the air-to-solids ratio or A/S ratio. This ratio is a comparison of the mass of dissolved air released to the atmosphere to the mass of suspended solids in the influent. Here are several reasons why the selection of DAF is appropriate in wastewater treatment:
  a. It can separate oil and TSS simultaneously.
  b. It can perform the Coagulation - Flocculation process and separation in a single DAF unit.
  c. It requires a smaller footprint compared to a Clarifier/Sedimentation Unit.
  d. Suitable for wastewater with oily and light sludge characteristics.

e. In terms of ease, it is easy to operate and maintain, quick in installation processes, and easy to relocate (only for Package Models).

- Anaerobic System

  Anaerobic processes produce biogas, a mixture of gases consisting primarily of carbon dioxide and methane, by converting various organic materials using microbes that exist naturally in oxygen-deficient environments. Anaerobic digesters are specialized facilities that house cultures of microorganisms that are constantly fed digestible (organic) material (Botheju and Bakke, 2011). Complex organic compounds are broken down with the help of different groups of microorganisms (bacteria and archaea) in the absence of oxygen. The rate of degradation depends mainly on the activity level of different bacteria (Krishna and Kalamdhad, 2014).

  The Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) tests are two common tests used in wastewater treatment that are based on the oxidation of organic matter. In both tests, organic matter is oxidized and the parameter value is represented by the volume of oxygen consumed. This has to do with how much oxygen is biochemically required for aerobic organisms to oxidize organic matter, as measured by the BOD test. Biodegradability and BOD are therefore strongly correlated. Instead of using the traditional aerobic BOD test, it is preferable to use a standardized anaerobic biodegradability test when using anaerobic therapy (Van Lier et al., 2008). This is divided into two further subcategories (Maddela et al., 2021).

  (a) Treatment for anaerobic suspended growth: An aerobic digester is a special type of airtight reactor where suspended activity takes place. Sludge is added constantly or sporadically. The following methods are commonly used in this treatment:

    1. Anaerobic digestion : Anaerobic digestion is used primarily for industrial wastewater and comes in two types: standard rate digesters and high rate digesters. Standard rate digesters require external heat, resulting in longer retention times, while high rate digesters provide agitation and heat, resulting in a two-stage system (Ebrahimi and Najafpour, 2016) .
    2. Anaerobic contact digester: an anaerobic contact process used primarily to treat high BOD industrial wastes. The process uses a series of sequential reactors. The wastewater and regenerated sludge are fed into these reactors where they are anaerobically digested. A clarifier is then used to separate the two layers and the resulting supernatant is discharged while the sludge settles and is prepared for reuse.
    3. Upflow anerobic sludge blankets (UASB): Digesters are used to treat various wastes such as food processing, sugar beet, brewery and winery waste by forming a granular sludge that can be further processed by anaerobic microorganisms. These digesters are three-phase separators that separate solids, liquids and gases under high turbulence conditions. The sludge blanket separates solid particles from the mixture, allowing liquid and gas to exit the UASB reactor. The treated waste is discharged to waterways and the gas is captured and reused as biofuel (Tilley et al., 2014).

  (b) Anaerobic attached growth process: Microbes that handle wastes are connected to the medium in a reactor as part of an attached growth system. Anaerobic attached growth treatment mainly involves:

    1. Anaerobic filter process: Anaerobic filter process in a special tank involves anaerobic microbes attaching to filter media, allowing wastewater to flow upwards, thereby degrading organic matter.
    2. Expanded bed process: A reactor uses a tank filled with a bed of sand, coal, or aggregates to form a biofilm. Wastewater is pumped into the bed, degraded by anaerobic microbes, and recycled to maintain flow rate.

- Aerobic System

  Aerobic wastewater treatment promotes the proliferation of aerobic microorganisms that occur naturally. These microorganisms power wastewater treatment facilities. High-energy forms of carbon are found in organic molecules. These engines run on fuel that is produced when organic components oxidize to produce carbon dioxide, a low-energy form. One of the main responsibilities of wastewater engineers is to comprehend the proper combination of aerobic bacteria, soluble organic molecules, and dissolved oxygen for the high-rate oxidation of organic carbon (Buchanan and Seabloom, 2004). here are the types of aerobic treatment:

a. Suspended Growth
   Suspended growth is an aerobic treatment process that utilizes microorganisms suspended in the wastewater to be treated. Examples include Activated Sludge, a treatment method involving the cultivation of bacteria in an aeration tank. In addition to Activated Sludge, there are Aerated Lagoons, which are aeration ponds equipped with a reactor for suspended growth without sludge recirculation.
b. Attached Growth
   Attached growth is a treatment process that utilizes microorganisms attached to a medium, forming a layer called a film. Wastewater comes into contact with this medium, leading to an aerobic process. Examples of this process include Trickling Filter and Rotating Biological Contactors (RBC).
c. Hybrid Process
   The hybrid process combines both attached and suspended growth processes. An example of this process is the Integrated Fixed Film Activated Sludge (IFAS), which combines features of Trickling Filter and suspended growth.

- Secondary Clarifier
  The Secondary Clarifier is a tank designed to separate activated sludge from biological treatment. The sludge containing still-active bacteria is recirculated back to the biological treatment unit, while the sludge containing inactive or dead bacteria is directed to the sludge treatment process. This sludge treatment step is the final stage to produce stable effluent with low concentrations of Biological Oxygen Demand (BOD) and Suspended Solids (SS).
  The type of secondary clarifier structures can be based on the treatment plant's building shape, either rectangular or circular. In some cases, a sedimentation tank is placed after the activated sludge process (Secondary Clarifier) to separate sludge particles from the clean fluid. This allows the effluent, in the form of clean water, to be discharged into the environment, provided that the nitrogen content in the effluent meets environmental discharge standards (Gerardi, 2002).
- Post-Treatment
  The Post-Treatment Unit is a facility designed to maximize the quality of the treated wastewater in a wastewater treatment plant. Post-treatment within a wastewater treatment facility is an additional or follow-up process that aims to remove remaining compounds, such as dead bacteria carried by wastewater, solids that have passed through the previous treatment, and others. Examples of post-treatment include the addition of filtration units or coagulation-flocculation-sedimentation units.

3.5. Impact of Pollution on Social, Economic, and Environmental Aspects

Units of wastewater treatment, including primary, secondary, and tertiary, are required to reduce pollutant levels that exceed quality standards, preventing environmental or water body pollution. Elevated levels of organic pollutants such as Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) in water bodies indicate low levels of dissolved oxygen, leading to oxygen deficiency (anoxia) and potential harm to fish and other aquatic biota (Salmin, 2005).

Additionally, high concentrations of Total Suspended Solids (TSS) in water bodies cause water turbidity. TSS consists of suspended solids that cause turbidity in water and do not settle directly. Excessive TSS concentrations beyond quality standards can inhibit light penetration into the water, disrupting the photosynthesis process of organisms. This disruption includes the hindered growth of phytoplankton, a food source for fish and other aquatic biota. Therefore, high TSS levels negatively impact aquatic ecosystems, and water bodies with high TSS values have lower water productivity (Wirasatriya, 2011). Consequently, this not only affects the aquatic ecosystem but also influences the decline in local economic income and public health for those who depend on the water body.

Total nitrogen, including ammonia, has different impacts when its concentration in the water body exceeds specified standards. On the positive side, there is an increase in phytoplankton production, serving as a food source for fish (Gypens et al., 2009). However, there are also negative impacts, including a decrease in dissolved oxygen content in the water, a reduction in biodiversity, and the potential emergence of harmful algal blooms (HABs), which can be detrimental to native aquatic life, causing environmental and local community harm (Risamasu & Prayitno, 2011).

The social and economic aspects fundamentally refer to the community's perception around food industries generating liquid waste, which could either be beneficial or potentially have adverse effects (Sanusi, 2000). The establishment and utilization of wastewater treatment facilities in the food industry have both direct and indirect impacts (Kodoatie, 1995). The direct impacts of these wastewater treatment facilities include:

- Reduction and adherence to the wastewater quality discharged into rivers according to the prevailing standards can maintain the environmental aesthetics around the river basin, consequently leading to a decrease in groundwater pollution that can be minimized.
- By-products from the wastewater treatment process, such as organic sludge from aerobic or anaerobic biological processes, rich in organic materials, can assist in enhancing plant growth, making the soil more fertile.

The indirect impacts manifest after the progression of wastewater treatment activities in the food industry and include:

- Creating employment opportunities and business prospects during the construction and operational phases of wastewater treatment facilities, absorbing local labor and boosting the economic status of the community residing near the treatment facility.
- The treated water from the wastewater treatment facility, meeting quality standards, can be utilized by the community for agricultural and fisheries activities, thereby expected to increase and create additional income for the people around the river basin.

4. Conclusions

Wastewater from the snack (cookies) industry has higher concentrations of several pollutant parameters than expected quality standards. The main characteristic parameters of the snack industry wastewater are pH, TSS (Total Suspended Solids), BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), ammonia, total nitrogen and MBAS (methylene blue active substance). The average concentrations of these parameters are TSS 3656.861 ± 2325.272 mg/L, pH 4.956 ± 0.792, BOD 3950.538 ± 2538.165 mg/L, COD 11741.314 ± 5825.513 mg/L, Oil & Fat 20.806 ± 12.155 mg/L, MBAS 14.211 ± 21.938 mg/L, and Total Ammonia 17.926 ± 14.235 mg/L. The difference in production capacity among the three plants resulted in different wastewater flow rates, different types of pastries produced, as well as differences in the operational practices of the production operators in operating equipment and optimizing the use of raw materials. High levels of pollutants in receiving waters cause a variety of adverse environmental effects, including damage to aquatic ecosystems and the death and reduced productivity of aquatic organisms such as fish and shrimp. Differences in pollutant loadings can affect the performance and design of wastewater treatment facilities. Recommended wastewater treatment technologies to address these parameters include grease traps, equalization basins, dissolved air flotation (DAF), anaerobic systems, aerobic systems, secondary clarifiers, and post-treatment. In addition, indirect impacts may be felt by local communities that use the water bodies as sources for aquaculture and agricultural irrigation.

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