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Regional Case Study

Characteristics of Domestic Wastewater from Shopping Centres, Office Buildings, and Hospitals in Jakarta, Indonesia

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Abstract

Understanding the characteristics of domestic wastewater is crucial for designing effective wastewater treatment facilities that comply with regulatory standards. This study examined key parameters, including pH, BOD, COD, TSS, oil and grease, ammonia nitrogen, and total coliform, outlined by Indonesia's Ministry of Environment and Forestry (MoEF) under their regulation. Samples were collected monthly over a 12-month period from three types of facilities: shopping centers, office buildings, and hospitals. The results indicated significant variability among the sites. The shopping center recorded the highest concentrations of BOD and TSS, with values of 231 mg/L and 366 mg/L, respectively, while the hospital showed elevated COD levels, reaching 725 mg/L. Its processing requires a wastewater treatment plant that aims to reduce various parameters that exceed the threshold based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.68 /Menlhk/Setjen/Kum I/8/2016 on Domestic Waste Quality Standards. These findings underscore the need for tailored wastewater treatment approaches based on facility type to mitigate environmental impacts and maintain water quality standards.

Keywords: Domestic wastewater; BOD; COD; shopping center; office building; hospital

1. Introduction

With a population of 273 million in 2021, Indonesia, like other developing nations, faces several problems (Ratnasari et al., 2022). One of those problems is domestic refuse pollution (Dehghani et al., 2021). Water pollution in Indonesia is intensified by insufficient sanitation infrastructure and management, resulting in approximately 20 million tons of domestic garbage discharged daily, obstructing rural development and sustainability initiatives (Bachri et al., 2024). Population expansion intensifies domestic wastewater pollution owing to heightened waste generation, insufficient sanitation infrastructure, and low public awareness, resulting in environmental degradation and health hazards (Wong et al., 2007). Domestic wastewater originates from various businesses and human activities, encompassing biodegradable waste produced by establishments such as restaurants, offices, hotels, residences, shopping centers, and hospitals (Mubin et al., 2016). Black water and greywater are the two categories into which domestic wastewater is often separated. The wastewater from toilets that has a high concentration of nitrogen, phosphorus, and organic matter is called black water. All additional wastewater from the sink, shower, and laundry that is not from the toilet is referred to as grey water (Widyarani et al., 2022).

Domestic wastewater contains harmful inorganic and organic components that can endanger aquatic organisms, highlighting the need for effective treatment methods to protect water resources and ecosystems (Koul et al., 2022). Pollution from domestic wastewater creates excessive concentrations of pollutants (such as oil and grease) that exceed quality limits, obstruct sunlight, interrupt photosynthesis, and severely destroy aquatic ecosystems (Fikri et al., 2021). Eutrophication, alterations in water quality, and a notable decrease in fish variety and abundance are all results of persistent domestic wastewater pollution, suggesting that environmental degradation is still occurring in the impacted ecosystems (Sinclair et al., 2023). Moreover, pathogenic bacteria that pose risks to human health are frequently identified in domestic wastewater (Prasetyo, 2022). With more than 80% of domestic water pollution being improperly discharged into the environment, the challenge of domestic water pollution is a concern for Indonesia and the entire world (du Plessis, 2022).

An increase in the volume of domestic wastewater leads to pollution of surface waters, as domestic wastewater discharged without prior treatment can exceed the capacity and carrying capacity of surface waters (Hidayah et al., 2018). Pollution is clearly visible in many areas, affecting water quality and ecosystem health. According to research on river pollution in Indonesia, namely in the Larangan/Premulung River in Sukoharjo Regency, Central Java Province, the upstream portion can no longer withstand medium-to-severe pollutant loads in accordance with quality requirements (Edi Minarno et al., 2022). This issue certainly requires prompt and appropriate measures to reduce the burden of surface water pollution and in terms of reducing wastewater pollution levels, the Indonesian government through the Ministry of Environment and Forestry (MoEF) has issued standard quality benchmarks for domestic wastewater through Ministerial Regulation No. P.68/Menlhk-Setjen/2016 regulates the maximum allowable values for various parameters (Ministry of Environment and Forestry, 2016).

To meet the government quality standards, domestic wastewater must be treated before being discharged into surface water. Some of these technologies are standard (like sand filtration, coagulation/flocculation, precipitation, biodegradation, activated carbon adsorption), non-conventional methods (advanced oxidation, biosorption, bio/nanofiltration, biomass, adsorption on non-conventional solids), and established methods (evaporation, oxidation, incineration, solvent extraction, membrane separation, membrane bioreactors, electrochemical treatment, ion exchange) (Koul et al., 2022). To achieve successful treatment, features such as wastewater volume, composition, peak flow rate, and retention duration must be considered during the design of domestic wastewater treatment units (Neles et al., 2020). The activated sludge method stands as the leading technology for sewage treatment, effectively removing organic carbon and nutrients through the processes of microbial metabolism and proliferation (Valipour et al., 2014).

The study examines the characteristics of domestic wastewater, focusing on pH levels, COD (Chemical Oxygen Demand), BOD (Biochemical Oxygen Demand), Ammonia, and TSS (Total Suspended Solid) concentration, which vary across different activities (Khashroum, 2024). BOD is the amount of oxygen required by organisms for the decomposition of organic matter (Hidayah et al., 2018). The amount of organic matter contamination in water increases with the BOD value (Djoharam et al., 2018). Chemical oxygen demand (COD) measures the concentration of reducing substances in water, serving as a key metric for assessing organic pollution and water quality (Che et al., 2022). Ammonia nitrogen refers to nitrogen that exists in the form of ammonia (NH_3) in water or wastewater. Water containing ammonia nitrogen, or NH_3, is a crucial indicator of water quality as it shows the extent of organic contamination and has an impact on aquatic ecosystem health (Chanchaldas, 2023). Water quality assessment generally involves measuring the concentration of ammonia nitrogen expressed in milligrams per liter (mg/L). Effectively managing domestic wastewater pollution in surface water is essential. Domestic wastewater contains substantial levels of ammonia nitrogen (62.8%), chemical oxygen demand (45.6%), and biochemical oxygen demand (BOD) (12.6%) (Omar et al., 2024). From several sources, domestic wastewater contains an average of 500 mg/L dissolved solids, 220 mg/L suspended solids, 100 mg/L oil and grease, 220 mg/L BOD, 500 mg/L COD, and 25 mg/L N-NH_3 (Aristiami and Widiasa, 2015).

Domestic wastewater from various building activities has several differences in several parameters. Activities involving large crowds have the potential to generate significant amounts of domestic wastewater and require special treatment. The author highlights the characteristics in shopping centers, office buildings, and hospitals because these areas are linear with the current development of the city, which also affects the amount of domestic waste generation. Where it is known that non-household areas contribute as much as 25% as surface water pollutants (Wirawan, 2020). In addition to solid waste and industrial wastewater, the management and treatment of domestic wastewater are equally significant. Limited information on the properties of domestic wastewater generated by diverse building activities might be a constraint. The right building of wastewater treatment facilities at the source of the wastewater can help to solve the problem. The availability of data on wastewater quality features must be considered while designing an adequate domestic wastewater treatment system for the area. This study seeks to assess the quality and quantity of domestic wastewater generated by various sources, including shopping centers, office buildings, and hospitals.

2. Methods

This section describes the research location, time, and analysis technique. Three types of domestic wastewater from shopping centers, office buildings, and hospitals were collected for this study.

2.1. Location and Research Period

The samples under examination were collected from the wastewater input pipe before starting the domestic wastewater treatment process. Primary data gathering is used to analyze the parameters of domestic wastewater. The first place to take a sample of domestic wastewater was a shopping center in Bekasi City. This shopping center once included a wastewater treatment system equipped with fixed biological system. This shopping center is among the biggest in Bekasi, with domestic wastewater originating from toilets, cleaning activities, prayer rooms, and restaurant operations. For the second placement, domestic wastewater samples were gathered from one of office building also in Bekasi City. Around eighty employees use this office to work for eight hours a day. Domestic wastewater is generated from toilets, sinks, the kitchen, and praying room. This office building has been operational since 1999 until now. To treat the domestic wastewater produced, this building is also equipped with a sewage treatment plant using an extended aeration system. For the third sample, it was taken from domestic wastewater from a hospital located in the South Tangerang area. This hospital provides outpatient services, inpatient care, surgical operations, a pharmacy, a kitchen, laundry, and administrative activities. In its operations, all the above activities become sources of domestic wastewater, therefore special attention is needed to manage it. Domestic wastewater from hospitals may have characteristics that differ from other domestic wastewater due to specific sources such as infectious wastewater. Other factors, such as the presence of disinfectants, may also be found in the domestic wastewater of hospitals. For this reason, data regarding the characteristics of domestic wastewater from hospitals is essential so that the design of the sewage treatment plant as a wastewater processing facility can fulfil its function properly. The parameter test values of each site were obtained from primary data by sampling 2000 mL once a month for each site without specific classification of its domestic effluent characteristics, with a sampling duration of 12 (twelve) consecutive months.

2.2. Examination of Domestic Wastewater

The method for examining domestic wastewater is conducted by testing samples taken from the point before the domestic wastewater treatment process, and analyzing the characteristics of domestic wastewater is done through the collection of primary data. Wastewater sampling is conducted for laboratory testing using the grab sampling method. This test is conducted to measure several parameters, including pH levels, BOD, COD, total suspended particle, oil and grease, ammonia, and total coliform.

The standard procedure for the analysis of domestic wastewater led to the determination of the following parameters: pH, the pH measurement in this study uses SNI 06-6989, 11-2019 (Ismaini et al., 2023). For the examination of BOD concentration values, it is conducted in the laboratory using the SNI 6989.72:2009 standard (Badan Standarisasi Nasional, 2009). The Chemical Oxygen Demand (COD) testing in wastewater is conducted using the reflux method with a UV-Vis Spectrophotometer in accordance with the Indonesian National Standard (SNI) 6989.2:2019 (Mustofa and Febriyana, 2024). The TSS parameter value is also necessary to understand the characteristics of domestic wastewater. In this study, the value of total suspended solids (TTS) is determined in line with the regulatory reference SNI 6989.3:2019 (Putri and Arisalwadi, 2023). Oil and grease (IKM.KHT-68), Ammonia concentration (IKM.KHT-108 FIA Spektrofotometri), and total coliform (SM APHA Ed. 23rd 9221.B,9221.C-2017). In this study, samples and measurements of domestic wastewater parameters were conducted by a private laboratory.

2.3. Analysis of Data

The selection and operation of treatment methods may be influenced by the concentrations and ratios of different water quality indices in the influent of domestic wastewater treatment. Therefore, it is essential to use statistical methods like mean and standard deviation to conduct systematic analyses on water quality parameters of wastewater, such as pH, BOD, COD, TSS, oil and grease, Ammonia, total coliform, and quantity of domestic wastewater generated from shopping centers, office buildings, and hospitals. Descriptive statistical analysis of the data generated in Microsoft Excel is conducted using SPSS 25 software. Descriptive analysis is conducted by calculating the mean concentration of each effluent parameter. Parameters with mean concentrations beyond the quality requirement were recognized as critical effluent parameters. The concentration of each critical parameter was established using the average value from thirty-six domestic wastewater samples. The analysis of data relies on descriptive statistical processing and is presented via tables and graphs.

3. Result and Discussion

This section will examine the concentration of pollutant factors in domestic wastewater generated from various sources, including shopping center, offices, and hospitals. The reported test findings will highlight the distinctive characteristics of wastewater from these specific sources.

3.1. Domestic Wastewater Examination Result

The evaluation of biodegradability is essential for refining wastewater treatment operations, as it guides the choice of efficient microbial consortia and improves the elimination of pollutants like COD and BOD (Dhall et al., 2012). Table 1 presents the findings of laboratory analyses conducted on domestic wastewater samples collected from three distinct locations: a shopping center, an office, and a hospital. The total number of domestic wastewater samples assessed was thirty-six samples, where samples were taken every month and sampling was conducted over a period of 12 months.

From the examination data result as shown in Table 1 and Table 2 below, main characteristics of domestic wastewater parameters include ammonia, total coliform, pH, COD, BOD, TSS, and oil & grease. In these circumstances, study is needed to establish the most practical and efficient processing techniques for lowering pollutant levels until they are safe to release into surface water and fulfill predefined quality criteria.

Table 1. Laboratory examination results for parameters domestic wastewater

No	Parameter	Units	Quality Standards *	Average Concentration								
				Office			Hospital			Shopping Center		
1	pH		6 - 9	5.50	-	7.80	6.46	-	7.48	5.46	-	7.35
2	BOD5	mg/L	30	70.45	-	85.36	11.01	-	138.00	111.00	-	231.00
3	COD	mg/L	100	210.56	-	265.47	44.02	-	725.47	317.00	-	660.00
4	Total Suspended Solid (TSS)	-	30	64.00	-	93.00	77.72	-	237.60	105.00	-	366.00
5	Oil and Grease	mg/L	5	4.10	-	6.00	0.86	-	10.40	1.00	-	4.60
6	Ammonia Nitrogen (NH3N)	mg/L	10	6.50	-	13.00	0.01	-	35.75	14.00	-	57.00
7	Total Coliform	MPN/100 mL	3000	20,000	-	26,000	2,750	-	435,200	12,000	-	84,000

**Quality Standards Minister of Environmental Regulation P.68/Menlhk-Setjen/2016*

Table 2. Average concentration value of buildings domestic waste water

No	Parameter	Units	Quality Standards	Average Concentration		
				Office	Hospital	Shopping Centre
1	pH	-	6 - 9	6.71	7.03	6.21
2	BOD5	mg/L	30	76.34	72.76	157.75
3	COD	mg/L	100	243.32	328.64	449.00
4	Total Suspended Solid (TSS)	mg/L	30	73.14	147.04	239.33
5	Oil and Grease	mg/L	5	4.51	3.27	2.80
6	Ammonia Nitrogen (NH3N)	mg/L	10	9.48	11.37	35.00
7	Total Coliform	MPN/100 mL	3000	23,076.92	140,877.30	36,583.33

**Quality Standards Minister of Environmental Regulation P.68/Menlhk-Setjen/2016*

3.2. Important Domestic Wastewater Parameters

Refer to Quality Standards Minister of Environmental Regulation P.68/Menlhk-Setjen/2016 domestic waste water should be monitored with 7 (seven) parameters. The important of domestic wastewater from shopping center, office building, and hospital as follow.

3.2.1. pH

In accordance with PermenLHK No. 68 of 2016 quality standards for domestic waste water, the recommended pH value is 6-9. Some samples of domestic wastewater have pH values below the standard, but none of these samples have values above it. Below is the fluctuation graph of the pH values obtained from the tested domestic wastewater samples.

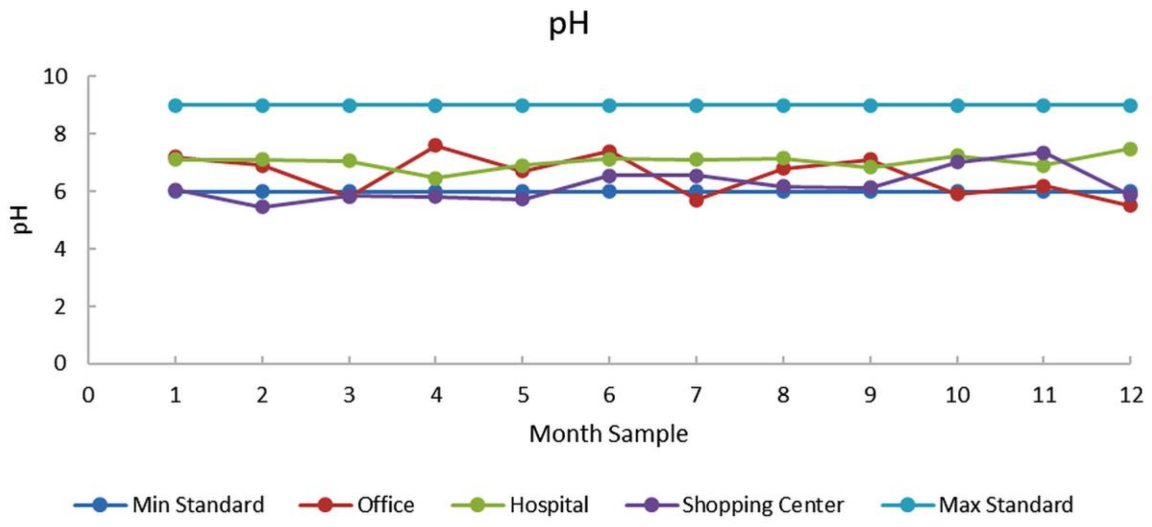

Figure 1. pH concentration fluctuation

Figure 1 illustrates that the pH values of domestic wastewater mostly adhere to standards, with most analyzed samples showing pH values beyond six, signifying their neutrality. The pH value of domestic wastewater should be maintained at around 6.5, since deviations from this range might interfere with the biochemical processes critical for efficient biological purification in wastewater treatment (Saboski and Swanson, 1981). Domestic wastewater typically shows a pH range of 6 to 8, driven by organic matter and chemical constituents. Research shows that altering pH levels may improve the efficacy of wastewater treatment processes. Modifying the pH to 7 during anaerobic hydrolysis fermentation significantly improves the liberation of carbon substrates from particulate organic waste (Zhu et al., 2022). Domestic wastewater treatment with chlorine affects the resulting pH. When chlorine is added to wastewater treatment, the pH tends to become acidic because the chlorine in the water is hydrolyzed to form Ca(OH)2 and HOCl compounds, where chlorine serves to kill bacteria still present in the wastewater and can help lower the pH when domestic wastewater is discharged to surface water (Yolanda and Heriyanti, 2024). Variations in pH levels in domestic wastewater influence microbial activity and community composition, resulting in diminished microbial populations and hindered organic matter decomposition, hence undermining the efficacy of wastewater treatment (Wang et al., 2022).

3.2.2. BOD5

The BOD level in domestic wastewater shows the extent of organic pollution, which can affect water quality and treatment efficiency. The higher the BOD value, the longer the treatment time needed to meet the established quality standards (Zulfikar et al., 2022). Among several tested domestic wastewater samples, the majority had concentrations above the domestic wastewater discharge quality standards. Among the three sources of domestic wastewater samples from different activities, it was found that the BOD concentration from the shopping center had a higher average concentration than the others, reaching 157.75 mg/L.

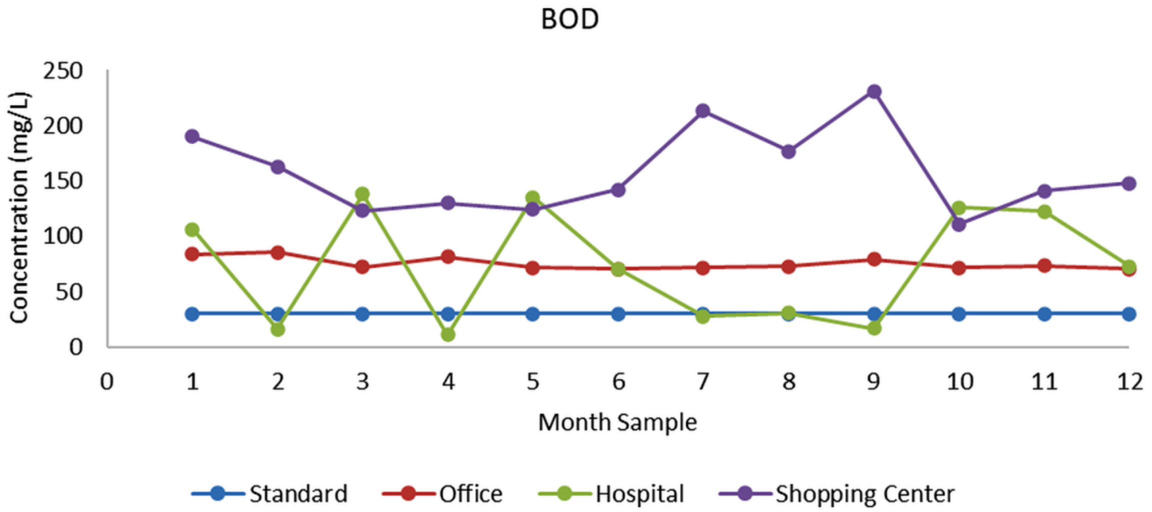

Figure 2. BOD5 concentration fluctuation

Figure 2 illustrates that all samples of domestic wastewater from shopping centers, offices, and hospitals have BOD concentrations that are above the regulatory threshold. Therefore, domestic wastewater treatment facilities must have the capability to significantly reduce BOD concentrations. Domestic wastewater with high BOD levels shows organic pollution that leads to reduced dissolved oxygen, water quality disturbances, and adverse effects on aquatic ecosystems and biodiversity (Maddah, 2022). Effective domestic wastewater treatment is important to reduce BOD before being discharged into the environment. To reduce pollution levels from domestic wastewater having high BOD concentrations, biological treatment applications can be used, either through anaerobic or aerobic processes. The decrease of the BOD value is an indicator of the improvement of the waste water quality in a better way, if there is a comparison of the waste water conditions before the aeration treatment (Pramyani and Marwati, 2020). When oxygen is present, aerobic microbes will oxidize organic compounds to form new cells and more stable forms that will produce CO_2, NH_3, and H_2O+ new cells (Utami et al., 2019). Decreasing BOD (Biological Oxygen Demand) concentration also indicates that the organic matter in wastewater is mostly easily decomposable organic matter (Yolanda and Heriyanti, 2024). For example, domestic wastewater treatment plants using anaerobic biofilter technology have shown high efficiency in reducing BOD concentrations, achieving reductions of up to 80% (Sumiyati et al., 2018). Hydraulic Retention Time (HRT) in the wastewater treatment process can also affect the percentage of BOD reduction efficiency. Over time and with technological advancements, it is certainly possible to explore other methods for lowering BOD concentrations in wastewater (Zulfikar et al., 2022).

3.2.3. COD

Assessing the wastewater samples for COD concentration revealed that domestic wastewater samples from shopping centers had the highest average COD concentration value. Figure 3 illustrates the concentration of COD in samples of domestic wastewater collected from shopping centers, offices, and hospitals The wastewater samples taken from hospitals had a lower COD concentration, and the wastewater samples from office buildings had the lowest concentration with an average value of 243.32 mg/L. The high COD levels in domestic wastewater can cause oxygen depletion in water bodies, harm aquatic life, and potentially lead to waterborne diseases in humans through contaminated water sources (Edokpayi et al., 2017).

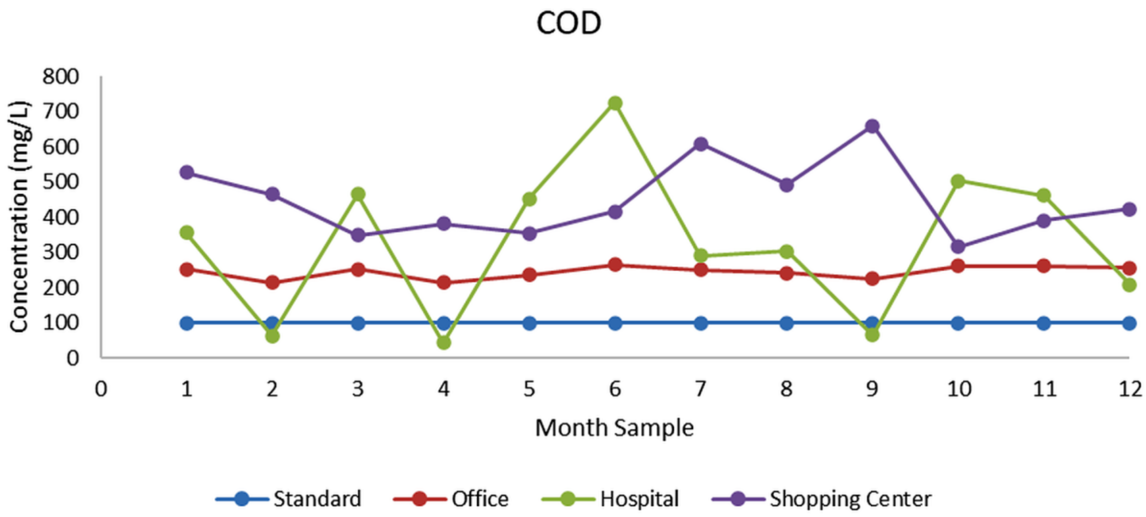

Figure 3. COD concentration fluctuation

Chemical oxygen demand (COD) significantly originates from domestic wastewater, particularly from daily human activities. COD in domestic wastewater arises from various organic and inorganic materials. COD is influenced by the amount of organic and also inorganic compounds contained in the wastewater discharged (Paśmionka et al., 2022). Activities such as cooking, washing hands, washing cooking utensils, cleaning the floor, and washing with detergent can cause an increase in COD concentration in domestic wastewater (Haryani et al., 2020). Various treatment methods can effectively reduce chemical oxygen demand (COD) in domestic wastewater. These methods include the use of hybrid reactors, phytoremediation, filtration techniques, and innovative materials such as fly ash. Each approach has shown a significant reduction in COD levels, contributing to environmental sustainability.

3.2.4. Total Suspended Solid (TSS)

Total Suspended Solids (TSS) in domestic wastewater contribute to physical pollution, affecting water quality by reducing light penetration and disrupting aquatic ecosystems, which leads to harmful environmental impacts (Fikri et al., 2021). From figure 4 below, the TSS concentration value of the domestic wastewater sample from the shopping center reaches 350 mg/L. This value has exceeded the maximum value required by the government, which is 30 mg/L. When treating domestic wastewater, hydraulic retention time (HRT) has a big effect on the TSS level. Longer HRT leads to higher removal rates, as shown by a study where TSS removal went from 17.3% to 50.4% with HRT changes from 1 to 8 hours (Zulfikar et al., 2022).

TSS in domestic wastewater can consist of sludge, fine sand, and microorganisms, and if not treated, can negatively affect water quality (Anurogo et al., 2023). TSS parameter reduction can use the method of suspended solids capture by fungal filamentous structures is a possible mechanism for total suspended solids (TSS) reduction in treated biosolids (Alam et al., 2003). Based on the studies of Alam et al. (2003) a reduction of the TSS parameter using the method of treatment with filamentous fungi in domestic wastewater where the method can reduce TSS higher with a maximum value of 98.8%.

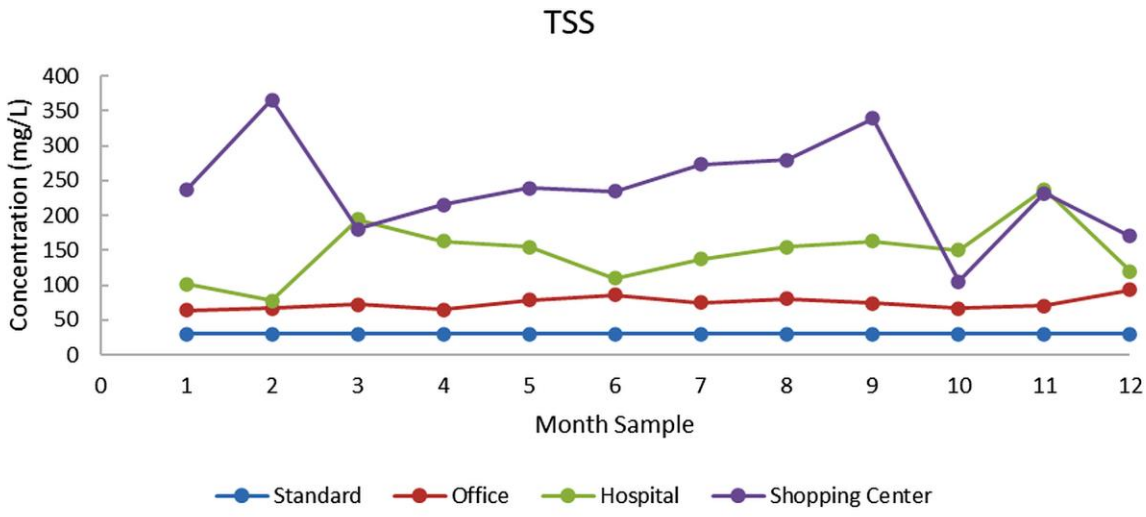

Figure 4. TSS concentration fluctuation

3.2.5. Oil and Grease

Untreated domestic wastewater entering aquatic habitats may result in oil and fat accumulation on the surface, hence elevating BOD and COD levels and obstructing the biodegradation process by microorganisms (Doraja et al., 2012). The presence of oil and grease in residential wastewater presents considerable environmental issues. Oil and grease in residential wastewater stem from kitchen operations. The sample testing findings showed that most oil and fat content values in the domestic wastewater post-grease trap were below the standard, as seen in Figure 5. The use of a grease trap for the separation of oil and fat in domestic wastewater is a successful measure, achieving an oil and fat separation efficiency of 93.48% inside the domestic wastewater system (Al-Gheethi et al., 2019).

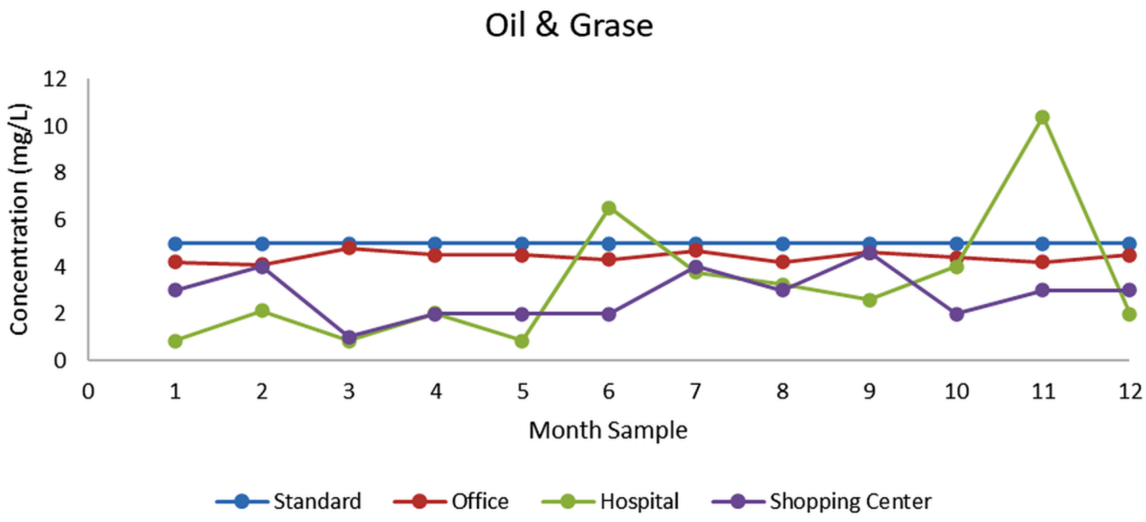

Figure 5. Oil & Grease concentration fluctuation

Excessively high levels of oil and grease in domestic wastewater may lead to worse waste quality, diminish processing efficiency, and result in environmental issues such as eutrophication (Ishak et al., 2022). Oil and grease in residential wastewater limit processing efficiency by producing emulsions, increasing turbidity, and complicating the removal of organic and inorganic contaminants, so lowering the overall performance of wastewater treatment. High concentrations of oil and grease may also create issues in the functioning of sewage treatment facilities, such as foaming, blockage, and increased maintenance needs, which in turn impair maintenance efficiency (Jasim and Aljaberi, 2023).

3.2.6. Ammonia Nitrogen

The ammonia nitrogen concentration in domestic wastewater originates from human excrement, mostly due to the decomposition of organic substances and urea elimination. Nitrogen compounds provide considerable environmental difficulties, causing efficient treatment strategies. Excess ammonia nitrogen may induce eutrophication in aquatic systems, resulting in detrimental algal blooms and oxygen depletion (Cruz, 2020). In the samples taken from the three buildings, the test results showed that the average domestic wastewater had ammonia concentrations above the standard.

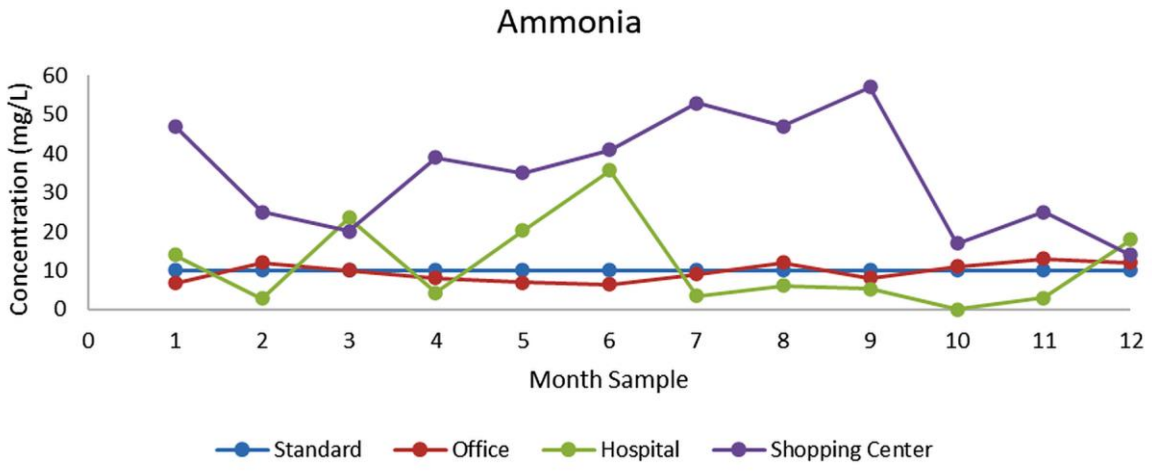

Figure 6. Ammonia concentration fluctuation

The samples collected from the three buildings reveal, as seen in figure 6, that the average domestic wastewater shows ammonia concentrations above the statutory limits. The test findings show low and steady ammonia concentrations in the domestic wastewater samples from the office building. Simultaneously, the domestic wastewater from the hospital and shopping center shows moderate to elevated ammonia concentrations. Elevated ammonia concentrations in domestic wastewater often originate from human excrement, organic refuse, and cleaning products. Ammonia may also be generated via the breakdown of organic matter and the use of fertilizers in agricultural activities, leading to elevated amounts of ammonium nitrogen (Marek et al., 2021). The treatment of domestic wastewater is essential for the elimination of ammonia nitrogen, which is vital for mitigating environmental damage. An effective treatment approach may markedly decrease ammonia concentrations, thereby averting ecological disruptions. This traditional technique transforms ammonia into nitrogen gas (N_2), efficiently eliminating reactive nitrogen from wastewater (Cushing, 2022).

Monitoring ammonia nitrogen concentrations in domestic wastewater is essential for safeguarding public health and environmental integrity. Numerous novel techniques have arisen, using modern technologies and predictive models to improve monitoring precision and care efficacy (Omar et al., 2024). This sensor employs surface plasmon resonance (SPR) to achieve a remarkable sensitivity in detecting ammonia concentrations. Research demonstrated an impressive accuracy level of 94.09% through the application of gold nanoparticles in the sensor's development (Ficrah Huda, 2023).

3.2.7. Total Coliform

The presented graph illustrates as seen in figure 7 the temporal distribution of total coliform contamination at four separate locations: Standard, Office, Hospital, and Shopping Center. This data is analyzed based on monthly samples measured in MPN/100 ml, which is the standard method for estimating the number of coliform bacteria in water (Ukpong and Udechukwu, 2015). The hospital samples showed a significant increase in total coliform, showing a potential water sanitation issue at this healthcare facility. Elevated total coliform levels may result from contaminated sources or deficiencies in the sanitation system (Zubaidah et al., 2024). Conversely, offices and shopping centers show more stable pollution levels, which are often below acceptable standards.

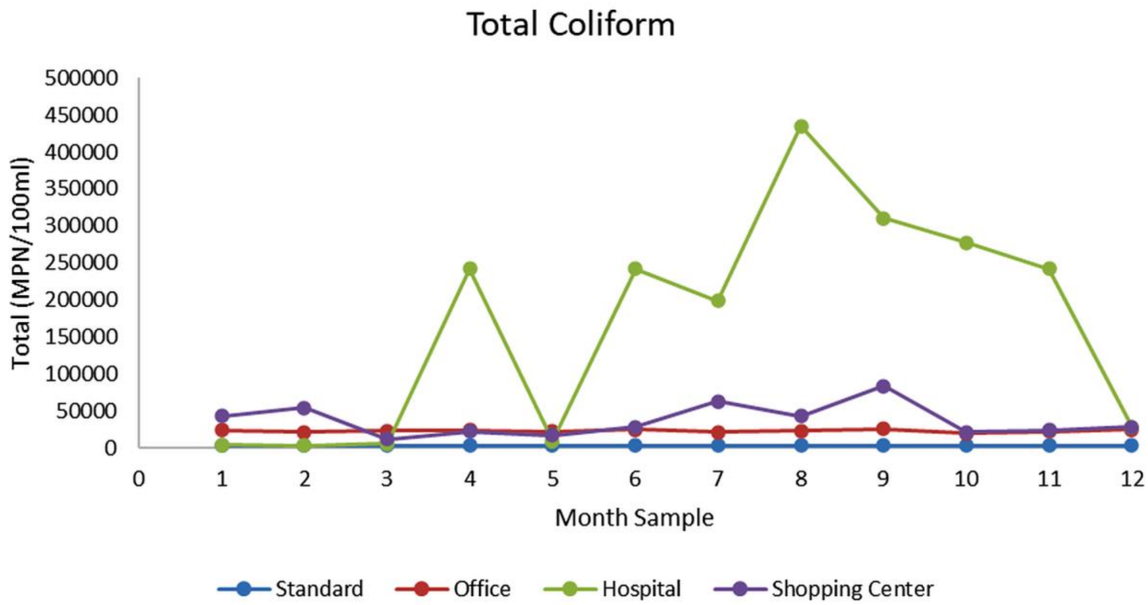

Figure 7. Total Coliform concentration fluctuation

The presence of Total Coliform in domestic wastewater signifies fecal pollution, with test samples in the research revealing levels that above environmental quality guidelines. This may provide health hazards and assess the inadequacies of domestic wastewater treatment (Lusiana et al., 2020). The concentration of total coliform in wastewater must be decreased to prevent environmental pollution and mitigate the transmission of waterborne diseases. Research shows that chlorine may lower coliform levels by 98.55%, hence necessitating the disinfection procedure to comply with the Total Coliform quality criteria established by environmental legislation (Mulyati et al., 2022).

3.3 The Implementation of Domestic Wastewater Treatment Technologies

The design procedure for sewage treatment plant facilities may be conducted with the availability of domestic wastewater characteristic data. In the design of domestic wastewater systems, the technology for wastewater treatment must be identified. Furthermore, the sequence of domestic wastewater treatment process and flow diagram must be suitable. The appropriateness of the flow process diagram will influence the efficacy of the treatment system, ensuring that contaminants are effectively removed before the effluent is discharged. Furthermore, attention must be directed on the prospects for future development and the use of sustainable methods to improve environmental protection.

The treatment of domestic wastewater begins with the process of separating non-biodegradable solids, such as trash or other objects. Separation is conducted by adding a basket strainer or rod strainer to the sewage treatment plant (STP) inlet pipeline. The separated waste is then collected and set aside. In addition to solids, domestic wastewater containing oil also requires processing in the pretreatment phase. Grease traps are designed to block fats, oils, and grease (FOG) from wastewater, thereby preventing these substances from entering the STP and causing problems in the biological process. Grease traps can efficiently decrease the concentrations of oil and grease in effluent. A research showed that grease traps eliminated 43% to 52% of oil and fat from restaurant effluent (Wong et al., 2007). A further investigation shown that modified grease traps attained a decrease of up to 83.20% in oil and grease content across different contact durations (Rachmawati et al., 2021).

The operational basis of a grease trap leverages the disparity in specific gravity between oil and water in wastewater. The grease trap functions by allowing wastewater to pass through a chamber where fats, oils, and grease (FOG) ascend to the surface, therefore obstructing their entry into the STP system. The grease trap may function both automatically, using a scraper on the top, and manually, where the operator performs oil removal. Wastewater will thereafter enter the equalization unit, which functions as the preliminary phase of wastewater treatment. The equalization unit helps the equalization of residential wastewater by balancing flow and pollutant concentration to enhance treatment efficiency, maintain constant conditions for biological processes, and improve the overall quality of the effluent (Eko and Romayanto, 2006). To regulate wastewater flow, planners may include pumps based on the design capacity, which may be outfitted with control valves and flow meters. The equalization of pollutant concentration is achieved by stirring the wastewater in the equalization unit. This may be carried out via agitators, water movement via pumps, or aeration through a blower unit. The equalization unit's volume is designed to manage flow at peak loads. An effective equalization method helps stabilize the wastewater load sent to the biological treatment system. This may avert overload problems in the domestic wastewater treatment process that may impair the biological process.

The biological processes in a sewage treatment facility are categorized into three phases: anaerobic, anoxic, and aerobic. The anaerobic process in domestic wastewater treatment employs microbes to decompose organic materials, generating methane and decreasing sludge volume, thereby enhancing treatment efficiency (McCarty and Smith, 1986). The anaerobic process has COD removal efficiencies ranging from 74% to 65% at different hydraulic retention durations, showing successful treatment of domestic wastewater inside the system (Khan et al., 2023). The attributes of influent in domestic wastewater are crucial for assessing the viability of biological treatment methods. For influent ratios of moderate to strong residential wastewater with a BOD_5/COD ratio between 0.23 and 0.69, biological treatment techniques may be applicable (Alsaqqar et al., 2023). This includes the execution of operations like biological treatment and sophisticated filtering techniques, which may enhance the quality of the effluent.

The amalgamation of anaerobic and aerobic biofilters in wastewater treatment facilities has shown efficacy in diminishing biochemical oxygen demand (BOD) values (Handriyono and Rukmi, 2022). The integration of these two processes produces successful outcomes in the treatment of domestic wastewater. The anaerobic biofilter technique facilitates interaction between anaerobic decomposer bacteria and contaminants in wastewater in the absence of oxygen. The anaerobic technique is also cost-effective since it does not need substantial electrical power. Technological developments in this technique provide alternate treatments to minimize dimensions and hydraulic retention time via the use of interconnected growing medium. Presently, often used anaerobic wastewater treatment medium is the plastic honeycomb media (wasp nest) composed of PVC, which functions as a substrate for microbial adhesion. This may enhance the anaerobic breakdown of organic contaminants in wastewater, achieving a COD reduction effectiveness of up to 79.11% during a retention period of 96 hours (Said and Firly, 2018).

Aerobic treatment is used as a subsequent treatment after the anaerobic biofilter. Diverse media, such as aerobic granular sludge (AGS), expanded polystyrene (EPS), and bio-balls, have been investigated for their efficacy in wastewater treatment. Every media type offers distinct benefits and obstacles, influencing the overall efficacy of the aerobic system. Aerobic granular sludge (AGS) serves as an efficient medium for wastewater treatment, exhibiting stable granules with diameters ranging from 2.0 to 5.0 mm, and attaining removal efficiencies of 84.4% for COD, 99.6% for ammonia nitrogen, and 81.7% for total phosphorus in the treatment of domestic wastewater (Halim et al., 2019). Aerobic granules serve as an efficient wastewater treatment medium, showing significant pollutant removal efficacy (e.g., 91.0% COD, 98.6% NH_4) in low dissolved oxygen environments, while using 27.9% less aeration energy than traditional approaches (Zuo et al., 2021). The Moving Bed Biofilm Reactor (MBBR) is an advanced aerobic wastewater treatment device that employs biofilm carriers to improve microbial proliferation and treatment efficacy. The MBBR system has reached a COD removal efficiency of up to 93% and an NH_4^+-N removal efficiency of 95% under optimal circumstances (KOZAK et al., 2022)

The biological process is the treatment of domestic wastewater that uses the activity of decomposing microorganisms. After the biological process, the wastewater enters the sedimentation stage to separate the treated water from the microorganisms that are still carried along with the wastewater. The sedimentation process in wastewater treatment employs tanks (horizontal, radial, or upward flow) to facilitate the settling of denser sediments while lighter substances migrate toward the exit, hence enhancing treatment efficiency (García et al., 2013). The sedimentation process in wastewater treatment encompasses coagulation and flocculation phases, markedly improving the separation of the solid phase. This procedure may eliminate up to 90% of total suspended particles and enhance the overall treatment efficiency at the wastewater treatment facility (Maciołek et al., 2018).

The sedimentation process must have a return activated sludge (RAS) system using pumps. The RAS system enhances sedimentation properties in the primary sedimentation tank, resulting in improved maintenance efficiency and decreased energy usage (Gupta and Anjali, 2017). Research on wastewater treatment performance indicates that RAS influences waste quality, with maximum removal efficiency attained at a RAS level of 90% of the influent flow in the WWTP (Rafati et al., 2018). Active sludge in the RAS system denotes the segment of treated sludge that is recirculated to the aeration tank in domestic wastewater treatment.

The next procedure applicable to the domestic wastewater treatment system is filtration. The sand and activated carbon filtration system efficiently eliminates suspended particles and microorganisms via physical and biological mechanisms. Crucial determinants influencing efficacy in the filtering process include sand particle size, filtration rate, and backwash frequency. The filtering process achieved a total suspended solids (TSS) removal efficiency of 79.01% and a chemical oxygen demand (COD) removal rate of 77.84%, showing compliance with certain wastewater quality criteria (Utari and Herdiansyah, 2020). Filtration is used to enhance the quality of wastewater effluent for recycling applications. The wastewater filtration process employs fiber filtration (FF) and ultrafiltration (UF) as pre-treatment stages, efficiently eliminating suspended particles and bacteria, so keeping consistent reverse osmosis (RO) feed water quality and attaining a significant reduction in turbidity for safe water reuse (Chan and Wu, 2022).

The comprehensive procedure of domestic wastewater treatment consists of many stages designed to meet the quality criteria established by the government. A disinfection method is essential to diminish the coliform count in wastewater prior to its environmental release. The wastewater disinfection procedure is crucial for safeguarding water resources and preventing disease transmission. Diverse approaches are used, each showing distinct processes and varying degrees of efficacy. The wastewater disinfection process encompasses chemical methods (chlorine, chlorine dioxide, ozone), physical methods (ultraviolet light, micro-electrolysis, ultrasonic), and combined methods (UV-chlorine), each exhibiting distinct mechanisms and efficacy in eradicating harmful microorganisms to guarantee water safety (Chan and Wu, 2022). The chlorine disinfection procedure for wastewater is often used, with an effective dosage of 40 mg/L for the inactivation of SARS-CoV. Ozone at 1000 ppmv and ultraviolet radiation at 1048 MJ/cm^2 also efficiently inactivate SARS-CoV-2 (Milani and Bidhendi, 2022).

This research revealed that the test parameter values from domestic wastewater samples collected from shopping malls were elevated in comparison to other sites. Consequently, meticulous planning is essential when developing home wastewater treatment systems for retail complexes. The design of domestic wastewater treatment systems for shopping center cannot be compared to those for other locations. Domestic wastewater treatment facilities for shopping centers should have pretreatment systems to mitigate non-biodegradable contaminants. Implementing such measures not only helps in compliance with environmental regulations but also promotes sustainability within the community.

This research has limitations as the samples taken were each from only one location. Therefore, it is possible for further research in the future to add reference data regarding the characteristics of domestic wastewater. This additional data could enhance the understanding of regional variations and improve the accuracy of treatment methods. Future studies could involve collecting samples from various urban and rural settings to capture a broader spectrum of wastewater characteristics. This approach would allow researchers to analyze how factors such as population density, industrial activity, and climate variations impact wastewater quality. Additionally, integrating advanced analytical techniques could provide deeper insights into the specific pollutants present, thereby facilitating the development of more effective treatment strategies tailored to diverse environments. Ultimately, this expanded research could lead to improved sustainability practices in wastewater management across different regions.

4. Conclusions

Based on the tests carried out, the results show that BOD and TSS have the highest values in the shopping center location, for COD parameter, the highest is found in the hospitals. Meanwhile, the office site has a lower value of domestic waste parameter than the other two sites. However, in all three locations, this study shows that all tested parameters exceed the quality standard value of domestic waste standards according to the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.68/Menlhk/Setjen/Kum I/8/2016 on Domestic Waste Quality Standards. Therefore, the use of STP is an absolute water necessity for a commercial building. The reduction of these pollutant parameters can be adjusted according to their respective characteristics. The implementation of planning for domestic wastewater treatment installations can be conducted with several combinations of treatment processes. This is adjusted according to their respective characteristics. Research indicates that domestic wastewater treatment systems may be chosen and tailored to specific field circumstances. Factors to consider in the design include land availability, electrical power capacity, elevation, bearing capacity of the receiving surface water, and the costs associated with the wastewater treatment process.

The understanding of wastewater characteristics from the three activities in this research might inform the design of analogous development functions in other regions. Subsequently, an assessment may be made to determine the suitability of constructing structures such as shopping centers, office buildings, and hospitals in the vicinity, or whether specialized management of the resultant domestic wastewater is required.

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