Analysis of Leachate Quality Status, Rainfall Intensity and Pollution Index at the Final Processing Site of Talumelito Waste

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Abstract

This study aims to analyze the quality of leachate based on quality standards, examine the relationship between rainfall intensity and leachate quality, and assess the level of leachate pollution at the Talumelito TPA. The research employs a descriptive quantitative approach by collecting primary and secondary data. Primary data were obtained from leachate sample testing, while secondary data included rainfall intensity from the Gorontalo Climatology Station. The leachate samples, taken from the inlet and outlet of the reservoir on December 11, 2024, were tested for pH, BOD, COD, TSS, N-Total, Mercury, and Cadmium at LPPT UGM Yogyakarta and the UPTD Regional Health Laboratory Center of Gorontalo Province. The results indicate that from 2022 to 2024, five parameters at the inlet (pH, BOD, COD, TSS, N-Total) and four at the outlet (BOD, COD, TSS, N-Total) exceeded the quality standards set by PerMenLHK No. 59 of 2016. However, Mercury and Cadmium at the inlet and pH, Mercury, and Cadmium at the outlet met the standards. Rainfall intensity ranged from 9 mm (2023) to 235 mm (2022), but it did not significantly impact the leachate quality. Pollution index analysis using the IP and Storet methods showed an average IP value of 4.2, indicating light pollution, while the Storet classification placed the water quality in Class C (-18), meaning moderate pollution. These findings highlight the need for improved leachate treatment and management to mitigate environmental impacts at Talumelito TPA.

Keywords: Leachate Water Quality Standard, Rainfall Intensity, Pollution Index, Talumelito Landfill.

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Introduction

The final waste processing site, hereinafter abbreviated as TPA, is a place to process and return waste to the environmental media safely for humans and the environment. Sorting waste from its source (for example, households) will be more effective in reducing the amount of waste that will be transported to Temporary Disposal Sites and Final Waste Processing Sites (Kurniawan & Santoso, 2020). However, in its implementation, the participation and effectiveness of waste management by the community are still not optimal. Judging from waste sorting, many people still dispose of waste without knowing which waste is organic and which waste is inorganic (Handayani & Agussalim, 2023).

Align with research from Munawaroh (2013), waste containing pollutants, both organic and inorganic, undergoes natural decomposition, but the results of this decomposition are dissolved among the piles of waste. The pile of waste will produce a liquid known as leachate. Leachate contains organic materials and heavy metals (Damsir et al., 2016). Rainwater can carry pollutants from the results of waste decomposition into the leachate reservoir. If these

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pollutants are not managed properly, leachate will pollute the soil, groundwater, and surface water around the Final Processing Site (TPA) (Puspitarini et al., 2023).

According to previous research conducted by Raheem (2022), Leachate treatment at the Piyungan TPA in the maturation pond, aeration pond, anaerobic pond and outlet pond. The heavy metals contained exceed the quality standards of Government Regulation No. 82 of 2001, Permen LHK No. 59 of 2016, and the Food and Agriculture Organization: Water Quality for Agriculture. Irrigation and Drainage Paper 29 rev.1, 1985. As well as the distribution of heavy metals through leachate which goes directly to the river without any processing and is still relatively high so that it disturbs the environment around the Piyungan TPA (Dari & Suhartini, 2024).

Previous research was also conducted by Sari & Afdal (2017) at the Air Dingin final waste disposal site in Padang City, leachate at the landfill has COD and BOD values and Pb heavy metal content which is quite high and has exceeded the quality standards at several points. Based on these results, it can be seen that the function of the leachate control pond at the Air Dingin landfill is still ineffective. Talumelito landfill is a final waste processing site in Talumelito Village, Telaga Biru District, Gorontalo Regency, Gorontalo Province. Talumelito landfill is a regional provincial landfill formed based on the Gorontalo Governor Regulation which refers to Law No. 18 of 2008 concerning Waste Management.

Until now, Talumelito landfill serves seven work areas, namely Gorontalo City, Bone Bolango Regency, Gorontalo Regency, Gorontalo Police, Bank Indonesia, Lupoyo Village, and Tenggela housing based on initial data obtained from Talumelito landfill, the volume of waste has continued to increase since the landfill was first opened. This is evidenced by the graphic data on the volume of waste entering the Talumelito TPA from 2012 to 2021 in three working areas, namely Gorontalo City, Gorontalo Regency, and Bone Bolango Regency. The increase in the volume of waste at the Talumelito TPA has caused an increase in waste disposal cells because the 4 waste disposal cells at the Talumelito TPA are starting to fill up.

According to direct observations, the waste generated at the TPA produces leachate which is channeled into the reservoir that has been provided, which is getting fuller every day and can have a negative impact on the environment (Scott et al., 2005). Based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.59 / Menlhk / Setjen / Kum.1 / 7/2016, the characteristics of leachate at the Talumelito TPA are determined by several parameters, such as pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total N, Mercury, and Cadmium.

Leachate produced in the landfill is formed from rainwater seepage that wets the pile of garbage (Mujaddid, 2019). The concentration of leachate in the landfill is influenced by several factors, one of which is the amount of rainfall (Monice & Perinov, 2016). Based on the description of the background, the author is motivated to conduct research to analyze the quality of leachate according to quality standards, the relationship between rainfall intensity and pollution index at the Talumelito final waste processing site, Gorontalo Regency.

Methods

Research Design

This type of research is quantitative descriptive by collecting secondary data and primary data from the results of leachate sample examinations at the Talumelito TPA compared to the

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Volume 6, Issue 1 (Page 1-18)
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parameter values in PerMenLHK Number 59 of 2016 concerning leachate quality standards for businesses and/or activities at final waste processing sites and secondary data on rainfall intensity obtained from the Gorontalo Climatology Station and calculating the pollution index using the IP and Storet methods. The results of this study, researchers hope, can provide valuable information related to the importance of leachate processing, rainfall intensity and pollution index in the Talumelito TPA environment.

Research Variables

The variables in this study are leachate parameters, rainfall intensity and pollution index that occur in the Talumelito TPA. The operational definition of the variables is as follows: (1) 7 parameters in PerMenLHK Number 59 of 2016 concerning leachate quality standards for businesses and/or activities of final waste processing sites; (2) Rainfall intensity at the time of the study, leachate sampling at the Talumelito TPA, Gorontalo Regency; (3) Leachate pollution index is the ability of leachate to pollute the environment around the Talumelito TPA. To determine the status of polluted environmental quality, namely calculating the IP method and the storet method (Yusnita & Triajie, 2021).

Data Collection Technique

The data collection technique used is primary data, which is carried out by taking and examining leachate samples at the inlet and outlet by measuring 7 leachate quality standard parameters based on PerMenLHK Number 59 of 2016. Taking leachate samples at the inlet and outlet.

Table 1. Sampling Tools and Materials

No	Name Of Tools and Materials	Total	Function
1	Sample bottle	4 pieces	Leachate sample container
2	Coll box	2 pieces	Temporary storage place for leachate samples
3	APD	1 pairs	Personal protective equipment
4	Label	4 pieces	Sample ID
5	Camera	1 pieces	Research documentation tools
6	Ice pack	1 pieces	Media that helps neutralize room temperature

Leachate sampling procedure; (1) prepare tools and materials and use PPE; (2) rinse the sample bottle 3 times with leachate sample; (3) leachate sample taken from the inlet channel is put into the sample bottle and labeled according to the collection code; (4) leachate sample taken from the outlet channel is put into the sample bottle and labeled according to the collection code; (5) after filling the sample, the bottle that has been filled with the sample is put into a cool box with a freezing temperature of <-18°C then taken to the laboratory to carry out leachate quality standard examination.

Secondary data consists of: (1) leachate quality data from 2022 to 2024, there are 7 leachate quality examination data at the inlet and 8 data at the outlet. With 7 to 8 repetitions obtained from the UPTD TPA Talumelito, this data will complement the primary data; (2) Rainfall data at the time of leachate sampling at the Talumelito TPA from 2022 to 2024 obtained from the Gorontalo Climatology Station; (3) The amount of waste generated at the Talumelito TPA obtained from the Talumelito TPA UPTD.

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Volume 6, Issue 1 (Page 1-18)
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Data Analysis Techniques

Primary data analysis was conducted at LPPT UGM Yogyakarta and UPTD of the Regional Health Laboratory Center of Gorontalo Province; (1) The quality of leachate at the inlet and outlet was compared with the leachate quality standards for businesses and/or activities at final waste processing sites by PerMenLHK Number 59 of 2016; (2) The relationship between rainfall and leachate quality was analyzed using a table of rainfall intensity categories; (3) The pollution index was calculated based on leachate quality with leachate quality standards in PerMenLHK Number 59 of 2016 and Leachate Classification in KepmenLH No. 115 of 2003.

In this study, the author presents data in the form of narratives, numbers and images. The data presented will make it easier to understand the condition of leachate quality, the effect of rainfall and pollution index at the Talumelito final waste processing site (Hidayat, 2020). Information on the presentation of leachate quality data and rainfall intensity data is shown in Table 2.

Table 2. Test Result Code Description

Location	Leachate Sampling Time	Test Result Code No.
Inlet dan Outlet	16 March 2022	I
	7 November 2022	II
	9 December 2022	III
	18 May 2023	IV
	24 October 2023	V
	20 November 2023	VI
	25 April 2024	VII
	8 August 2024	VIII
	11 December 2024	IX

Based on Table 2, the sampling time is coded to make it easier to analyze, in the 2022 sampling on May 16, November 7 and December 9, the codes were I, II and III. In 2023, May 18, October 24 and November 20 were given codes IV, V and VI. In 2024, April 25, August 8 and December 11 were given codes VII, VIII and IX. Rainfall intensity can be categorized as low to very high as shown in Table 3.

Table 3. Rainfall Intensity Categories

Category	Intensitas Curah Hujan
Low	: 0 – 100 mm
Medium	: 101 – 300 mm
High	: 301 – 500 mm
Very High	: > 500 mm

Source. Gorontalo Climatology, 2024

Based on the rainfall categories shown in Table 3, there are categories of low rainfall from 0-100 mm, medium 101-300 mm, high rainfall 301-500 mm and very high rainfall > 500 mm. The water quality status based on the results of the Pollution Index calculation using the IP method is shown in Table 4.

Table 4. Evaluation of the Pollution Index Value of the IP Method

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No.	IP Score	Quality Status
1	0,0≤ PIj ≤ 1,0	Meets Quality Standards (Good)
2	1,0 < PIj ≤ 5,0	Light Pollution
3	5,0 < PIj ≤ 10	Moderate Pollution
4	PIj > 10	Heavy Pollution

Source: Decree of the Minister of Environment No. 115 of 2003

Water quality status based on the results of the Storet Method Pollution Index calculation by classifying water quality into four classes, namely: (1) Class A: very good: score 0 = meets quality standards; (2) Class B: good: score -1 to -10 = light pollution; (3) Class C: moderate: score -11 to - 30 = moderate pollution; (4) Class D: bad: score ≥ -31 = heavy pollution

Results and Discussion

Laboratory Analysis Results of Leachate Quality Status at Inlet and Outlet at Talumelito Landfill in 2022-2024.

The results of laboratory analysis of leachate taken from the inlet and outlet of the Talumelito TPA leachate reservoir tank shown in tables 5 and 6 show several parameters that do not meet the leachate quality standards. The results of the leachate quality analysis at the inlet at the Talumelito TPA are shown in Table 5.

Table 5. Results of Leachate Water Quality Examination at the Reservoir Inlet in 2022-2024

No.	Parameter	Quality standards		YEARS 2022			YEARS 2023			YEARS 2024		
				I	II	III	IV	V	VI	VII	VIII	IX
		Mark	Unit	INLET								
1	pH	6-9	-	-	7.42	7.54	7.24	9.31	8.45	7.6	7.54	9.5
2	BOD	150	mg/L	-	1450	1330	2510	3400	2080	1440	3950	177
3	COD	300	mg/L	-	2780	3160	4470	6790	4030	2950	7690	1238
4	TSS	100	mg/L	-	18	32	544	480	210	59	19	89.5
5	N Total	60	mg/L	-	640	100	635	100	1300	810	2316	700
6	Merkuri	0,005	mg/L	-	0.00012	< 0.00005	0.00036	0.00013	0.00012	0.00027	0.00086	0.0032
7	Kadmium	0,1	mg/L	-	0.0007	0.0025	0.0007	0.0013	0.0016	0.0008	0.0012	<0.01
Information:		Does not meet leachate quality standards according to the Minister of Environment and Forestry Regulation Number P.59/Menlhk/Setjen/Kum.1/7/2016										

Based on Table 5, there are several parameters such as pH in results V and IX, BOD, COD and N-Total in results II to IX, TSS in results IV, V and VI which exceed the quality standards of PerMenLHK Number 59 of 2016 concerning Leachate Quality Standards for Businesses and/or Activities of Final Waste Processing Sites, while for Mercury and Cadmium in results I to IX are still below the quality standards. The results of the leachate quality analysis at the outlet at the Talumelito TPA are shown in Table 6.

Table 6 Results of Leachate Water Quality Examination at the Reservoir Outlet in 2022-2024

No	Parameter	Quality Standard		Years 2022			Years 2023			Years 2024		
				I	II	III	IV	V	VI	VII	VIII	IX
		Mark	Unit	Outlet								
1	pH	6-9	-	8.93	7.36	8.52	8.31	7.7	8.62	8.62	8.35	8.7
2	BOD	150	mg/L	1320	1560	1040	983	1120	1970	588	266	145
3	COD	300	mg/L	2640	3380	1760	1670	2300	3970	1140	546	609

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Volume 6, Issue 1 (Page 1-18)
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4	TSS	100	mg/L	52	30	58	92	148	110	313	19	41.5
5	N Total	60	mg/L	287	537	< 50	550	1260	480	135	246	400
6	Merkuri	0,005	mg/L	> 0.00005	0.00016	< 0.00005	0.00031	0.00028	0.00027	0.00034	0.00037	0.0004
7	Kadmium	0,1	mg/L	0.0031	0.0002	0.0008	0.0003	0.0024	0.0005	0.0004	0.0002	<0.01
Information:		Does not meet leachate quality standards according to the Minister of Environment and Forestry Regulation Number P.59/Menlhk/Setjen/Kum.1/7/2016										

Based on Table 6, there are several parameters such as BOD in results II to VIII, COD in results I to IX, TSS in results V, VI and VII and Total N in results I, II, IV to IX which exceed the quality standards of PerMenLHK Number 59 of 2016 concerning Leachate Quality Standards for Businesses and/or Activities of Final Waste Processing Sites, while for pH in results I to IX, BOD in results IX, TSS in results I to IV, VIII and IX, N-total in results III and Mercury and Cadmium in results I to IX are still below the quality standards. The following are the Results of the Analysis of 7 Parameters compared to the Quality Standards according to the Regulation of the Minister of LHK Number 59 of 2016.

pH

The pH value of leachate at the inlet and outlet shown in Figure 1, the average pH value still meets the quality standards (Yulis., 2018). The pH value that does not meet the quality standards is found in results V and IX at the inlet point, namely 9.31 and 9.5 where the pH range of 6 - 9 is the optimal pH value for biological life.

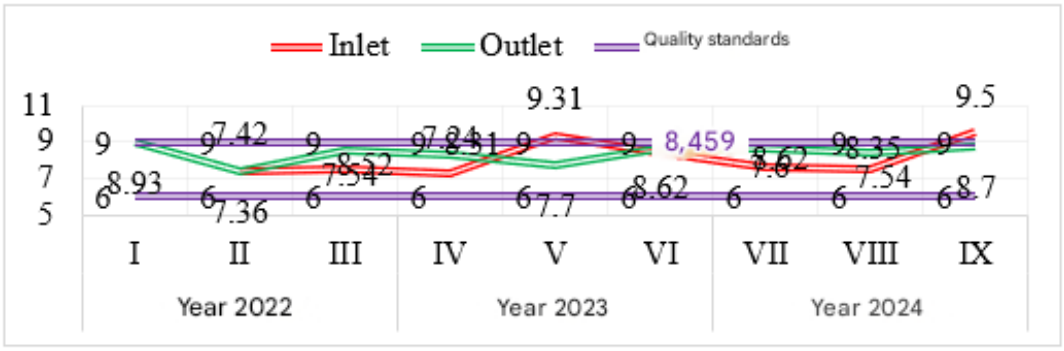

Figure 1. Graph of pH Analysis Results

Biochemical Oksigen Demand (BOD)

The analysis results shown in Figure 2 are the BOD values at the inlet of results II to IX with the smallest value in results IX, namely 177 mg/L and the largest in results VIII, namely 3950 mg/L and the outlet of results I to IX with BOD values that meet the quality standards are in the IX test, namely 145 mg/L and those that do not meet the quality standards according to PerMenLHK No. 59 of 2016 or exceed 150 mg/L, namely in the results of the I VIII waste test. The results shown in Figure 2 show a decrease during the leachate management process, but on average it still does not meet the ideal quality standards, namely 150 mg/L.

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Volume 6, Issue 1 (Page 1-18)
ISSN: 2709-0248

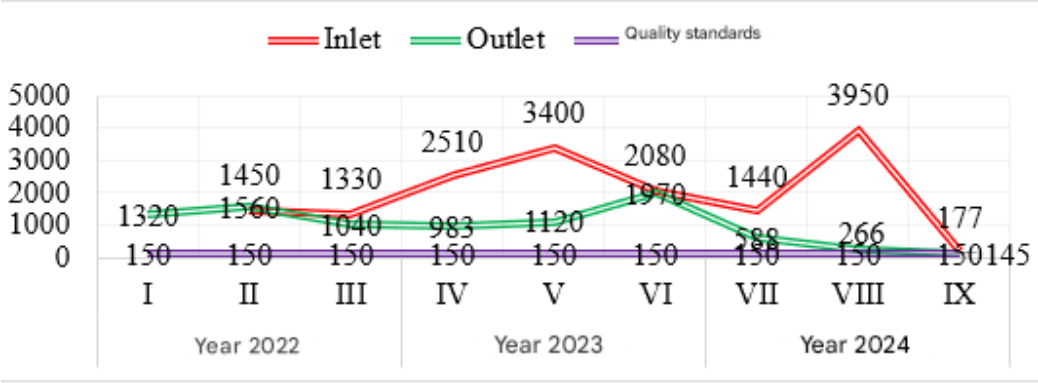

Figure 2. Graph of BOD Level Analysis Results

Chemical Oxigen Demand (COD)

The results of the COD level analysis shown in Figure 3 at the inlet and outlet results I to IX do not meet the quality standards according to PerMenLHK No. 59 of 2016, which has a quality standard value of 300 mg/L. The smallest COD level test at the leachate inlet was 1238 mg/L in result IX, while the largest COD level was 7690 mg/L. The test results at the outlet (processing has been carried out) the smallest COD level was 546 mg/L and in result VI with the largest COD level of 3970 mg/L. The processing process has been carried out, but the COD level in leachate still does not meet the quality standards (Ivontianti et al., 2021).

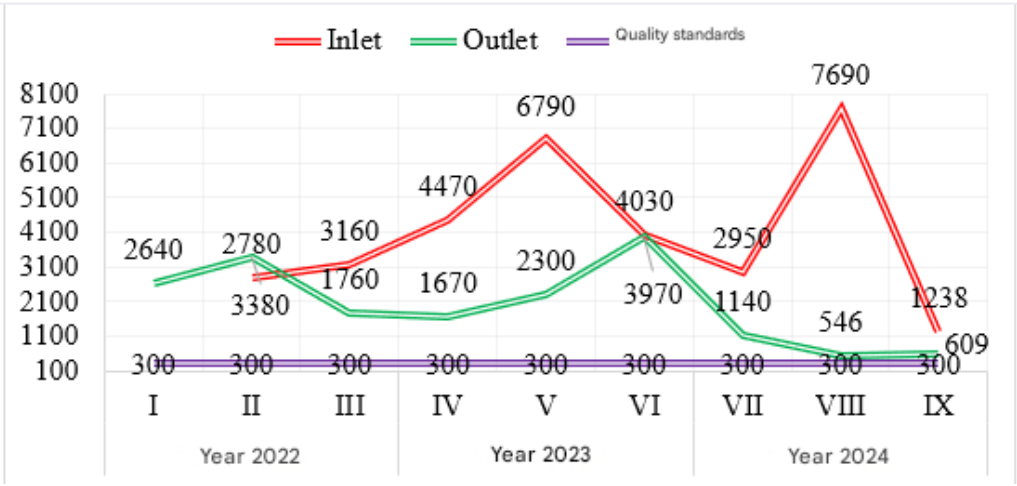

Figure 3. Graph of COD Content Analysis Results

Total Suspended Solid (TSS)

The average TSS content of Talumelito landfill leachate still meets the quality standard with a content below 100 mg/L as shown in Figure 4 At the inlet location, the value of II is 18 mg/L, III is 32 mg/L, VII is 59 mg/L, VIII is 19 mg/L and IX is 89.5 mg/L still meets the quality standard while IV, V and VI results still exceed 100 mg/L, which is the TSS quality standard value that has been set. Meanwhile, the analysis results at the leachate outlet results I, II, III, IV, VIII and IX still meet the quality standard, namely 52 mg/L, 30 mg/L, 58 mg/L, 92 mg/L, 19 mg/L and 41.5 mg/L, but in results V, VI, and VII the TSS content is high, namely 148 mg/L, 110 mg/L and 313 mg/L.

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Volume 6, Issue 1 (Page 1-18)
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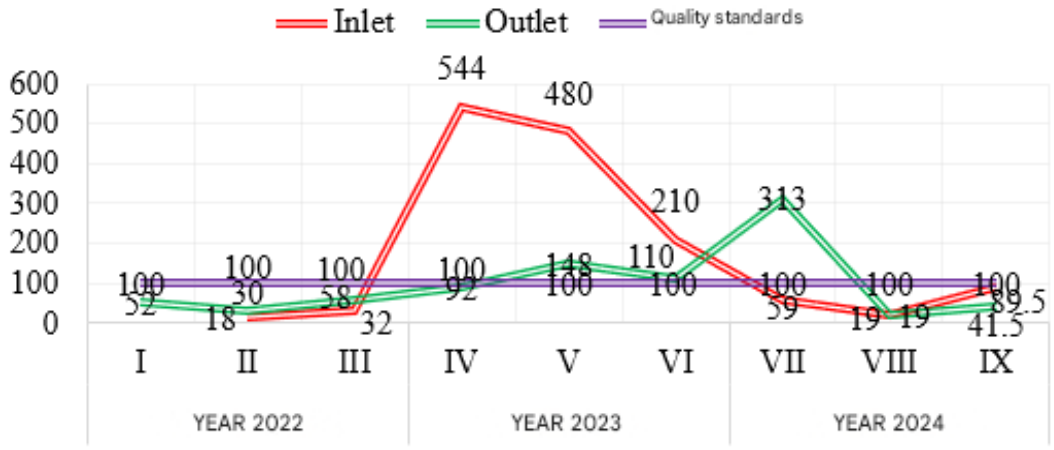

Figure 4. Graph of TSS Content Analysis Results

N-Total

The results of the N-Total analysis shown in Figure 5 at the leachate inlet from 2022 to 2024 still exceed the required quality standard of 60 mg/L. The highest N-Total content in result VIII is 2316 mg/L, while the lowest is in results III and V, which is 100 mg/L. Meanwhile, at the outlet of the N-Total leachate from the Talumelito TPA, the highest content is in result VIII, which is 1260 mg/L, while the lowest is in result III, which is 50 mg/L, which means it meets the quality standard.

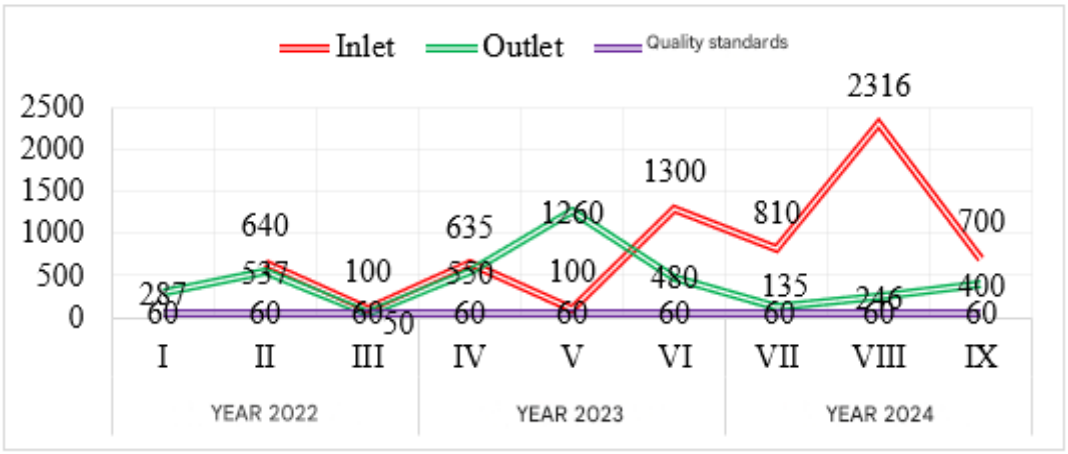

Figure 5. Graph of N-Total Analysis Results

Mercury

The mercury levels in leachate at the inlet and outlet of the Talumelito landfill are still below the quality standards, which means they still meet the requirements for discharge into the environment. The results of the analysis of mercury levels in leachate at the inlet and outlet are shown in Table 7.

Table 7. Results of Mercury Content Analysis

Ket	Mecury								
	I	II	III	IV	V	VI	VII	VIII	IX
Inlet		0.00012	0.00005	0.00036	0.00013	0.00012	0.00027	0.00086	0.0032

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Outlet	0.00005	0.00016	0.00005	0.00031	0.00028	0.00027	0.00034	0.00037	0.0004
Quality standards	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005

Based on the results of the analysis of mercury levels shown in Table 7, at the inlet from results I to IX with the smallest level of 0.00005 mg/L in test II and the largest of 0.0032 mg/L in test IX still meets the quality standards. At the outlet from test results I to IX with the smallest level of 0.00005 in test II and the largest of 0.00037 mg/L in test VIII still meets the quality standards of PerMenLHK No. 59 of 2016, which is below 0.005 mg/L.

Cadmium

Cadmium levels in leachate at the inlet and outlet of the Talumelito landfill are still below the quality standard, which means they still meet the requirements for discharge into the environment. The results of the analysis of cadmium levels in the air ducts at the inlet and outlet are shown in Table 8.

Table 8. Results of Cadmium Content Analysis

Inf	**Cadmium**								
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**
Inlet		0.0007	0.0025	0.0007	0.0013	0.0016	0.0008	0.0012	<0.01
Outlet	0.0031	0.0002	0.0008	0.0003	0.0024	0.0005	0.0004	0.0002	<0.01
Quality standards	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Based on the results of the analysis of cadmium levels of leachate at the inlet and outlet of the Talumelito TPA shown in Table 8 At the inlet results I to IX with the smallest levels of 0.0007 mg/L and the largest 0.01 mg/L or not detected in the test because it is less than 0.01 which means it still meets the quality standards. At the outlet results I to IX with the smallest levels of 0.0002 mg/L and the largest 0.01 mg/L or not detected in the test because it is less than 0.01 which means it still meets the quality standards of PerMenLHK No. 59 of 2016, which is below 0.1 mg/L.

The Relationship Between Rainfall Intensity and Leachate Quality at the Talumelito Final Waste Processing Site.

The intensity of rainfall during sampling I to IX based on data from the Gorontalo Climatology Station is included in the low to medium rainfall category. The relationship between rainfall and leachate quality at the inlet and outlet of the Talumelito TPA is shown in tables 9 and 10. The results of the analysis of the relationship between rainfall intensity and leachate quality at the inlet at the Talumelito TPA are shown in table 9.

Table 9. Results of the Analysis of the Relationship between Rainfall Intensity and Leachate Quality at the Inlet Reservoir at the Talumelito TPA.

Location	**Test Results to-**	**Rainfall Intensity**		**Leachate Parameters**						
		Mark	**Category**	**pH**	**BOD**	**COD**	**TSS**	**N-Total**	**Mercury**	**Cadmium**
Inlet	I	235	Intermediate	-	-	-	-	-	-	-
	II	143	Intermediate	7.42	1450	2780	18	640	0.00012	0.0007
	III	96	Low	7.54	1330	3160	32	100	< 0.00005	0.0025
	IV	153	Intermediate	7.24	2510	4470	544	635	0.00036	0.0007
	V	9	Low	9.31	3400	6790	480	100	0.00013	0.0013
	VI	216	Intermediate	8.45	2080	4030	210	1300	0.00012	0.0016

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	VII	198	Intermediate	7.6	1440	2950	59	810	0.00027	0.0008
	VIII	119	Intermediate	7.54	3950	7690	19	2316	0.00086	0.0012
	IX	214	Intermediate	9.5	177	1238	89.5	700	0.0032	<0.01
Information:		Does not meet leachate quality standards according to the Minister of Environment and Forestry Regulation Number P.59/Menlhk/Setjen/Kum.1/7/2016								

Based on table 9 the rainfall intensity is categorized as low to medium. The results of the analysis show that rainfall does not affect the quality of leachate at the inlet. The quality of pH parameters in leachate with low rainfall intensity of 9 mm and medium rainfall of 214 mm exceeds the established quality standards. In the BOD parameter with the largest content of 3950 mg/L and the smallest 177 mg/L, the rainfall category at the time of sampling was 119 mm and 214 mm. In the COD parameter with medium rainfall of 143 mm, the result of IX is the smallest 1238 mg/L and the largest 7690 with a rainfall intensity of 119 mm. In the TSS parameter with the smallest value of 18 mg/L and the largest 544 mg/L with rainfall intensity in the medium category of 143 mm and 153 mm.

In the N-Total parameter with the smallest value in results III and V, namely 100 mg/L with low rainfall intensity compared to when the medium rainfall the N-total value increased. In the mercury parameter with the smallest value in result III, namely 0.00005 mg/L with low rainfall and the largest value in medium rainfall, namely 0.0032 mg/L in the IX result and in the cadmium parameter with the smallest value in results II and IV, namely 0.0007 mg/L with medium rainfall and the largest value in low rainfall, namely 0.0025 mg/L. The results of the analysis of the relationship between rainfall intensity and leachate quality at the outlet at the Talumelito TPA are shown in the table 10.

Table 10. Results of the Analysis of the Relationship between Rainfall Intensity and Leachate Water Quality at the Storage Outlet at the Talumelito TPA

Location	**Test Results-**	**Rainfall Intensity**		**Leachate Parameters**						
		Mark	**Kategori**	**pH**	**BOD**	**COD**	**TSS**	**N-Total**	**Mercury**	**Cadmium**
Outlet	I	235	Intermediate	8.93	1320	2640	52	287	> 0.00005	0.0031
	II	143	Intermediate	7.36	1560	3380	30	537	0.00016	0.0002
	III	96	Low	8.52	1040	1760	58	< 50	< 0.00005	0.0008
	IV	153	Intermediate	8.31	983	1670	92	550	0.00031	0.0003
	V	9	Low	7.7	1120	2300	148	1260	0.00028	0.0024
	VI	216	Intermediate	8.62	1970	3970	110	480	0.00027	0.0005
	VII	198	Intermediate	8.62	588	1140	313	135	0.00034	0.0004
	VIII	119	Intermediate	8.35	266	546	19	246	0.00037	0.0002
	IX	214	Intermediate	8.7	145	609	41.5	400	0.0004	<0.01
Information:		Does not meet leachate quality standards according to the Minister of Environment and Forestry Regulation Number P.59/Menlhk/Setjen/Kum.1/7/2016								

Based on Table 10, rainfall intensity is categorized as low to medium. The results of the analysis show that rainfall does not affect the quality of leachate at the outlet. The quality of pH parameters at the leachate outlet with low to medium rainfall intensity meets the established quality standards. In the BOD parameter with the largest content of 1970 mg/L and the smallest 145 mg/L, the rainfall category at the time of sampling was 216 mm and 214 mm. In the COD parameter with medium rainfall, namely 119 mm, result III is the smallest 546 mg/L and the largest 3970 mg/L with a rainfall intensity of 216 mm.

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In the TSS parameter with the smallest value of 19 mg/L and the largest 148 mg/L with rainfall intensity in the medium category, namely 119 mm and low 9 mm. In the N-Total parameter with the smallest value in result III, namely 50 mg/L with low rainfall intensity. In the mercury parameter with the smallest value in results I and III, namely 0.00005 mg/L with low rainfall of 96 mm and medium 235 mm and the largest value in medium rainfall is 0.00037 mg/L in result VIII and in the cadmium parameter with the smallest value in results II and VIII, namely 0.0002 mg/L and the largest value is 0.0024 mg/L.

Pollution Index at Talumelito Landfill 2022 – 2024

Based on the data from the laboratory examination of leachate at the Talumelito landfill, the Pollution Index was calculated using the IP Method and the Storet Method. This calculation uses data from the test results of 7 leachate parameters at the outlet of the reservoir from 2022 to 2024. This calculation aims to determine the Level of Leachate Pollution at the Talumelito Landfill in 2022, 2023 and 2024, so that the average and final values can be concluded. The calculation was carried out on the results of the leachate test at the outlet because the leachate at the outlet has gone through various processes so that it is expected to be safe to be discharged into the environment. The results of the 2022 Pollution Index Calculation Analysis using the IP method are shown in Table 11.

Table 11. Results of Leachate IP Calculation at Outlets in 2022

No.	Parameter	Quality standards (Lij)		Data (Cij)			Ci/Lij			Ci/Lij New		
		Min	Max	I	II	III	I	II	III	I	II	III
1	pH	6	9	8.93	7.36	8.52	0.953	0.093	0.680	0.953	0.093	0.680
2	BOD	-	150	1320	1560	1040	8.800	10.400	6.933	5.722	6.085	5.205
3	COD	-	300	2640	3380	1760	8.800	11.267	5.867	5.722	6.259	4.842
4	TSS	-	100	52	30	58	0.520	0.300	0.580	0.520	0.300	0.580
5	N Total	-	60	287	537	50	4.783	8.950	0.833	4.399	5.759	0.833
6	Mercuri	-	0.005	0.00005	0.00016	0.00005	0.010	0.032	0.010	0.010	0.032	0.010
7	Cadmium	-	0.1	0.0031	0.0002	0.0008	0.031	0.002	0.008	0.031	0.002	0.008
Ci/Lij, Avg										2.480	2.647	1.737
Ci/Lij, Max										5.722	6.259	5.205
Pollution Index (IPj)										4.410	4.805	3.880

The results of the analysis in table 11 show that the pollution index in 2022 is 4.4, 4.8 and 3.8 with an average value of 4.3, which means that the leachate quality status is lightly polluted as shown in table 12

Table 12. Results of Leachate Pollution Status in 2022

Test Result Code	Mark	Pollute Status
I	4.4	Light Pollution
II	4.8	Light Pollution
III	3.8	Light Pollution
Average	4.3	Light Pollution

The results of the Pollution Index Calculation Analysis in 2023 using the IP method are shown in table 13.

Table 13. Results of Leachate IP Calculation at Outlets in 2023

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No.	Parameter	Quality standards (Lij)		Data (Cij)			Ci/Lij			Ci/Lij New		
		Min	Max	IV	V	VI	IV	V	VI	IV	V	VI
1	pH	6	9	8.31	7.7	8.62	0.540	0.133	0.747	0.540	0.133	0.747
2	BOD	-	150	983	1120	1970	6.553	7.467	13.133	5.082	5.366	6.592
3	COD	-	300	1670	2300	3970	5.567	7.667	13.233	4.728	5.423	6.608
4	TSS	-	100	92	148	110	0.920	1.480	1.100	0.920	1.851	1.207
5	N Total	-	60	550	1260	480	9.167	21.000	8.000	5.811	7.611	5.515
6	Mercury	-	0.005	0.00031	0.00028	0.00027	0.062	0.056	0.054	0.062	0.056	0.054
7	Cadmium	-	0.1	0.00003	0.0024	0.0005	0.000	0.024	0.005	0.000	0.024	0.005
Ci/Lij, Avg										2.449	2.923	2.961
Ci/Lij, Max										5.811	7.611	6.608
Pollution Index (IPj)										4.459	5.765	5.120

The results of the analysis in table 13 show that the pollution index in 2023 was 4.4, 5.7 and 5.1 with an average value of 5.1, which means that the leachate quality status is moderately polluted, as shown in table 14.

Table 14. Results of Leachate Pollution Status in 2023

Test Result Code	Value	Status Contamination
IV	4.4	Light Pollution
V	5.7	Moderately Soiled
VI	5.1	Moderately Soiled
Average	5.1	Moderately Soiled

The results of the Pollution Index Calculation Analysis in 2024 using the IP method are shown in table 15.

Table 15. Results of Leachate IP Calculation at Outlets in 2024

No.	Parameter	Quality standards (Lij)		Data (Cij)			Ci/Lij			Ci/Lij New		
		Min	Max	VII	VIII	IX	VII	VIII	IX	VII	VIII	IX
1	pH	6	9	8.62	8.35	8.7	0.747	0.567	0.800	0.747	0.567	0.800
2	BOD	-	150	588	266	145	3.920	1.773	0.967	3.966	2.244	0.967
3	COD	-	300	1140	546	609	3.800	1.820	2.030	3.899	2.300	2.537
4	TSS	-	100	313	19	41.5	3.130	0.190	0.415	3.478	0.190	0.415
5	N Total	-	60	135	246	400	2.250	4.100	6.667	2.761	4.064	5.120
6	Mercury	-	0.005	0.00034	0.00037	0.0004	0.068	0.074	0.080	0.068	0.074	0.080
7	Cadmium	-	0.1	0.0004	0.0002	0.001	0.004	0.002	0.010	0.004	0.002	0.010
Ci/Lij, Avg										2.132	1.349	1.418
Ci/Lij, Max										3.966	4.064	5.120
Pollution Index (IPj)										3.184	3.028	3.756

The results of the analysis in table 15 show that the pollution index in 2024 was 3.1, 3.0 and 3.7 with an average value of 3.3, which means that the leachate quality status is lightly polluted as shown in table 16.

Table 16. Results of Leachate Pollution Status in 2024

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Test Result Code	Value	Pollute Status
VII	3.1	Light Pollution
VIII	3.0	Light Pollution
IX	3.7	Light Pollution
Average	3.3	Light Pollution

The results of the Pollution Index Calculation Analysis in 2022-2024 using the Storet Method are shown in Table 17.

Table 17. Results of the Storet Method Calculation of Leachate at Outlets in 2022-2024

No.	Parameter	Quality standards (Lij)		Data (Cij)									Max	Min	Average	Scor		
		Min	Max	I	II	III	IV	V	VI	VII	VIII	IX				Max	Min	Avg
1	pH	6	9	8.93	7.36	8.52	8.31	7.7	8.62	8.62	8.35	8.7	8.93	7.36	8.345556	0	0	0
2	BOD	-	150	1320	1560	1040	983	1120	1970	588	266	145	1970	145	999.1111	-2	0	0
3	COD	-	300	2640	3380	1760	1670	2300	3970	1140	546	609	3970	546	2175.75	-2	-2	0
4	TSS	-	100	52	30	58	92	148	110	313	19	41.5	313	19	102.75	-4	0	0
5	N Total	-	60	287	537	50	550	1260	480	135	246	400	1260	50	443.125	-4	0	0
6	Mercury	-	0.005	0.00005	0.0002	0.00005	0.00031	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004	0.00005	0.000229	-2	-2	0
7	Cadmium	-	0.1	0.0031	0.0002	0.0008	0.00003	0.0024	0.0005	0.0004	0.0002	0.001	0.0031	0.00003	0.000954	0	0	0
Total Scor																**-18**		

Water quality status based on the results of the Storet Method Pollution Index calculation by classifying water quality into four classes, namely: (1) Class A: very good: score 0 = meets quality standards; (2) Class B: good: score -1 to -10 = lightly polluted; (3) Class C: moderate: score -11 to - 30 = moderately polluted; (4) Class D: bad: score ≥ -31 = heavily polluted. Based on the results of the analysis in table 4.11, the leachate pollution index at the outlet on average using the Storet method, from 2022 to 2024 the total score is -18, which means that the leachate quality at the Talumelito TPA can be classified as class C or moderately polluted.

Discussion

This study was conducted to analyze the quality standards of leachate, the effect of rainfall and pollution index at the Talumelito final waste processing site. This final waste processing site is a place where waste generated by prolonged community activities accumulates and causes various significant changes in people's lives and the surrounding environment (Utari et al., 2022). The accumulation of waste to produce leachate is one of the environmental problems in the TPA if it is not managed properly (Sari., 2023). Based on the results of the study, several parameters were found that did not meet the quality standards set by the Ministry of Environment and Forestry (Royani et al., 2021). According to the Regulation of the Ministry of Environment and Forestry Number 59 of 2016 concerning leachate quality standards for businesses and/or activities at final waste processing sites, there are 7 leachate quality parameters, namely pH, BOD, COD, TSS, N-TOTAL, Mercury and Cadmium.

From the results of laboratory analysis conducted by TPA Talumelito and the Author at the LPPT UGM Yogyakarta laboratory and the Gorontalo Province Labkesda with test location points at the inlet and outlet of the leachate reservoir at TPA Talumelito from 2022 to 2024, there were 5 parameters at the inlet and 4 parameters at the outlet that did not meet the established quality standards and 2 parameters at the inlet and 3 parameters at the outlet that met the quality standards. Based on the results of the analysis of leachate quality at the inlet and outlet of the reservoir at TPA Talumelito in 2022 - 2024, including: (1) The pH at the inlet point in tests V and IX is above the set quality standard, which is in the range of 6-9, while at

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Volume 6, Issue 1 (Page 1-18)
ISSN: 2709-0248

the outlet point it meets the quality standard. pH can reduce or deactivate enzyme activity in microorganism cells which will affect the metabolism of microorganisms, low pH can also complicate the process of sludge formation (Sari, et al., 2023); (2) BOD at the inlet point in all test results from II to IX did not meet the set quality standard or was above 150 mg/L, while at the outlet point in the last test by the researcher it still met the quality standard.

If the BOD level is high, it means that the water contains a lot of organic material. BOD is a measure of the amount of oxygen needed by microorganisms to decompose organic material in water. The higher the BOD value, the greater the potential for water pollution; (3) COD at the inlet and outlet points in all test results from I to IX did not meet the set quality standard or was above 300 mg/L. This shows that organic matter that is difficult to degrade biologically is more than organic matter that is easily degraded biologically; (4) TSS at the inlet point in the 2022 test results still meets the quality standards, which then in 2023 the TSS levels increased beyond the set quality standards of 100 mg/L, but in 2024 testing was carried out by the TPA and Researchers, TSS levels were below the quality standards while at the outlet point in testing V-VII the TSS levels did not meet the quality standards but in testing VIII and IX by the Talumelito TPA and Researchers the TSS levels decreased so that they were safe and met the set quality standards.

TSS can be an indicator of the level of water pollution and solid contamination in leachate, the higher the TSS value, the higher the level of pollution (Sufra et al., 2024). TSS content has a close relationship with water clarity. The lower the TSS levels, the higher the dissolved oxygen and clarity values (Dewa, et al, 2016); (5) N-Total at the inlet point is found in the test results from II to IX does not meet the set quality standards or is above 60 mg/L, while at the outlet point in 2022 the III test results of N-total are below the quality standards, namely <50 mg/L, but after re-testing in 2023 and 2024 the N-Total levels do not meet the set quality standards.

Talumelito TPA has carried out a leachate treatment process which on average decreases from inlet to outlet but the average N-Total levels still do not meet the quality standards, which means that they do not meet the requirements for discharge into the environment and can pollute the environment where total nitrogen is an important nutrient for plants and animals if excess nitrogen in the waters can cause low dissolved oxygen levels and have a negative impact on the lives of organisms and plants; (6) Mercury at the inlet and outlet points in the test results I to IX still meets the quality standards of PerMenLHK No. 59 of 2016, which is below 0.005 mg/L; (7) Cadmium at the inlet and outlet points in test results I to IX still meets the quality standards of PerMenLHK No. 59 of 2016, namely below 0.1 mg/L.

After analyzing the leachate quality status according to PermenLHK Number 59 of 2016, the next step was to analyze the intensity of rainfall with the quality of leachate at the Talumelito TPA. Based on the rainfall intensity data shown in tables 4.3 and 4.4, the rainfall range at the Talumelito post is categorized as low to moderate rainfall. In the 2022 and 2023 tests, the rainfall intensity was in the low to moderate rainfall category, while in 2024, 3 tests were carried out, the rainfall intensity was in the moderate rainfall category. After being analyzed, there was no significant effect on the intensity of rainfall with the quality of leachate at the Talumelito TPA, this is because during low or moderate rainfall, the leachate quality parameter values were not determined.

Based on the results of the analysis of leachate quality at the outlet that has gone through the leachate treatment process, calculations were carried out to determine the environmental pollution status at the Talumelito TPA using the IP method and the Storet method based on the

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Volume 6, Issue 1 (Page 1-18)
ISSN: 2709-0248

Leachate Classification in KepmenLH No. 115 of 2003. The calculation of the IP method is divided into 3 according to the year of testing. In 2022 with an average IP value of 4.3 which means lightly polluted, then in 2023 with an average IP of 5.1 which means lightly polluted, while in 2024 with an average IP value of 3.3 which means lightly polluted. If the average of the entire IP value from 2022 to 2024 is 4.2, it means that the environmental pollution status at the Talumelito TPA is lightly polluted. Meanwhile, for the calculation of pollution using the storet method, from the results of test I in 2022 to the results of test IX in 2024, a score of -18 was obtained which is shown in table 4.11 which means that the quality status is in class C or moderately polluted.

Recommendation

To prevent an increase in environmental pollution status due to leachate containing chemical compounds that are harmful to the environment and the community around the Talumelito TPA, various preventive efforts need to be made by the Government, especially the UPTD Talumelito TPA. The efforts that must be made include: (1) Carrying out activities and/or reactivating the organic and non-organic waste sorting place/process at the TPA to reduce the amount of waste dumped into the shelter; (2) Creating partnerships by collaborating between the Regency/City Environmental Service and Certain Business Entities that can assist in sorting activities at TPS3R, TPST and Waste Bank so that they can be used properly so that only residual waste enters the Talumelito TPA; (3) Carrying out regular maintenance on the leachate reservoir, such as sediment at the inlet of the reservoir, which if not cleaned will inhibit the entry of leachate into the next processing tank and can inhibit the leachate quality monitoring process at the inlet; (4) Providing technical training facilities to certain employees on monitoring and processing leachate at the TPA so that it is safe to be disposed of into the environment; (5) Providing facilities in the form of tools and materials needed in the leachate processing process and should be carried out periodically by maximizing the processing process physically, chemically and biologically; (6) Creating partnerships by collaborating between the Government, Certain Business Entities and Researchers in finding solutions to reduce the environmental pollution status at the Talumelito TPA.

For example, collaboration is supporting experimental research such as that conducted by Fazdli in 2023 with research related to leachate treatment at the Gampong Jawa Banda Aceh TPA using the trickling filter and rotating biological contactor (RBC) processes with research results able to reduce the levels of COD, BOD, TSS parameters in leachate samples according to quality standards. However, this method has not been able to reduce the levels of turbidity parameters according to the predetermined quality standards, or research conducted by Manoppo in 2024 on the application of eco-enzymes to reduce biological oxygen demand levels in leachate at the Talumelito final processing site (TPA) where the results of the study showed that increasing eco-enzyme concentrations were directly proportional to the decrease in BOD levels, with different percentages of BOD reductions in contact times. The results of this study are expected to help treat leachate at the TPA.

Conclusion

Results of the Analysis of Leachate Quality at the inlet and outlet of the Talumelito TPA with testing on 7 parameters from 2022 to 2024, there were 5 parameters at the inlet, namely pH, BOD, COD, TSS, and N-Total that did not meet the quality standards. At the outlet point, there were 4 parameters, namely BOD, COD, TSS, and N-Total that did not meet the quality standards. Meanwhile, those that met the quality standards (PerMenLHK No. 59 of 2016

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Volume 6, Issue 1 (Page 1-18)
ISSN: 2709-0248

concerning leachate quality standards for businesses and/or activities at final waste processing sites), there were 2 parameters at the inlet, namely Mercury and Cadmium and 3 parameters at the outlet, namely pH, Mercury and Cadmium.

The intensity of rainfall at the Talumelito rain post is categorized as light to medium rainfall with the lowest rainfall of 9 mm in 2023 and the highest medium of 235 mm in 2022 which is associated with leachate water quality does not affect the decrease in the parameters tested. The pollution index calculated using the IP and Storet methods with an average evaluation value in the IP method in 2022 was 4.3, in 2023 it was 5.1 and in 2024 it was 3.3 if the average IP value is 4.2 which means the quality status is lightly polluted while in the Storet method the water quality is classified as class C which means moderately polluted with the final score obtained being -18.

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