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Regional Case Study

The Impact of the Sarimukti Landfill's on the Water Quality of the Cipanawuan River

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Abstract
Sarimukti Landfill operations use a controlled landfill system. The Cipanawuan River is affected by the operational impact of this Landfill. This study aims to identify the effect of leachate from the Sarimukti Landfill on the water quality of the Cipanawuan River. The research method calculates water quality status based on the Decree of the State Minister for the Environment No. 115 of 2003 concerning Guidelines for Determining Water Quality Status. River water quality standards are based on Appendix VI of Government Regulation No. 22 of 2021 concerning implementing Environmental Protection and Management. Water quality parameters identified are parameters that exceed quality standards. Based on the water quality status calculation shows a decrease in water quality from upstream to downstream of the river. The downstream part has been heavily polluted, indicating that there is influence from Sarimukti Landfill operations. Based on the research results, Sarimukti's Treatment Plant's flowing quality for TSS, BOD, and COD is needed to meet quality standards. This can affect water quality, and there is a relationship between the influence of Sarimukti Landfill operations on the water quality of the Cipanawuan River, which is near the Landfill.

Keywords: Cipanawuan river; sarimukti landfill; water quality status; pollution

1. Introduction

Sarimukti Landfill still uses a controlled landfill system, based on the Indonesian National Standard 192454-2002 concerning Urban Waste Management Operations, controlled landfill is an open dumping system that is improved, namely covering waste with a layer of compacted soil after the landfill is full or reaches a specific period. The controlled landfill system has the potential to contaminate groundwater because the waste disposed of in the landfill will decompose along with rainwater to produce leachate (Widyasari et al., 2013). Sarimukti Landfill received 2,000 tons of waste from the Greater Bandung area (Aljaradin & Persson, 2012). Sarimukti Landfill began operating in May 2006 and is planned to stop at the end of 2024. Leachate parameters need to meet quality standards based on the Minister of Environment and Forestry Forestry Regulation No. 59 of 2016 concerning Leachate Quality Standards for Businesses and/or Activities of Waste Final Processing Sites, namely Total Suspended Solid (TSS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). Leachate reaches water sources, which can cause pollution to these water sources (Aljaradin & Persson, 2012). Contaminants are carried by water movement through the soil, contaminating soil, groundwater and river water (Kassenga & Mbuligwe, 2009).

Landfills have a high risk of polluting various pollutants in the environment. Some research results show the distribution of organics and heavy metals in sediments and their relationship with

physical and hydrological parameters in the waters that leachate input causes the metal content in river sediments to increase (Maramis et al., 2005). River water is generally used for several things, such as; drinking water supply, both domestic and non-domestic, agricultural irrigation, hydroelectric power, infrastructure activities, tourism, recreation, and other functions that economically use water (Venkatramanan et al., 2018). Leachate pollution will disrupt the river's function so that water treatment costs are required to meet the required standards.

Water pollution that occurred around the Sarimukti Landfill area is still being investigated. There is news about water around the landfill that cannot be used for daily needs, which is important for further research. The Cipanawuan River has its headwaters at Gunung Pasir Susuru and empties into the Citarum River with a meeting point downstream of the Citarum Rajamandala bridge. The Cipanawuan River passes through the Sarimukti Landfill area, and the downstream part, which is the research location, is close to the Sarimukti Treatment Plant location.

The Cipanawuan River empties into the Cirata Reservoir, which has the important function of supplying electrical energy needs in the Java-Bali region and being a place for aquaculture and agricultural irrigation (Handayani, 2017). Cirata Reservoir, which has been operating for 30 years, needs better water quality. The search results concluded that the reservoir water had experienced heavy pollution and sedimentation. The water in the Cirata Reservoir has also been polluted by heavy metals caused by the waste of some industries in the Citarum River basin. One of the pollutant sources comes from the Sarimukti Landfill, where the leachate is disposed of through the Cipanawuan River. On the other hand, the impact of decreasing water quality in the Cirata Reservoir is inseparable from the quantity and quality of water from the Citarum River and its tributaries, the water source for the Cirata Reservoir (Wahyudiana, 2019).

The West Java Environmental Service monitors and measures the quality of river water, which is the leachate drain or Sarimukti Landfill liquid waste in West Bandung Regency. The measurement results show that these rivers are heavily polluted. The activity occurred at several river points, outlets, or sewers near the leachate holding ponds. Preliminary monitoring and measurements occurred at the meeting point of the Cipicung and Cipanawuan Rivers, which are in Cinagrog Village, Sarimukti Village, and Cipatat District. Samples of the Cipanawuan River water, which were brown and taken in the river's upper reaches, showed very high levels of organic and inorganic substances; the inorganic substances contained chemicals. The results of sample measurements at the Cipanawuan River flow point in 2017 were BOD 7.34 mg/l, TSS 56 mg/l, and Lead 0.05 mg/l. The data also shows Sarimukti's Treatment Plant malfunctioning (Mulyatna, 2017).

This study aimed to identify the effect of leachate from the Sarimukti Landfill on the water quality of the Cipanawuan River. The benefits of this research are to become primary data for better Sarimukti Landfill management, especially in leachate management, improving the water quality of the Cipanawuan River, and this research can recommend efforts to control water pollution of the Cipanawuan River, which empties into the Cirata Reservoir caused by the operational activities of the Sarimukti Landfill.

2. Methods

The research method begins with identifying problems regarding the pollution of the Cipanawuan River due to leachate originating from Sarimukti Landfill operations. Location of sampling point 1 (upstream) is located before Sarimukti Landfill at coordinates 107.35335; -6.797316667, and sampling point 2 (downstream) after Sarimukti Landfill and close to Sarimukti's Treatment Plant at coordinates 107.34905; -6.806216667. The location of the sampling points is presented in **Figure 1**.

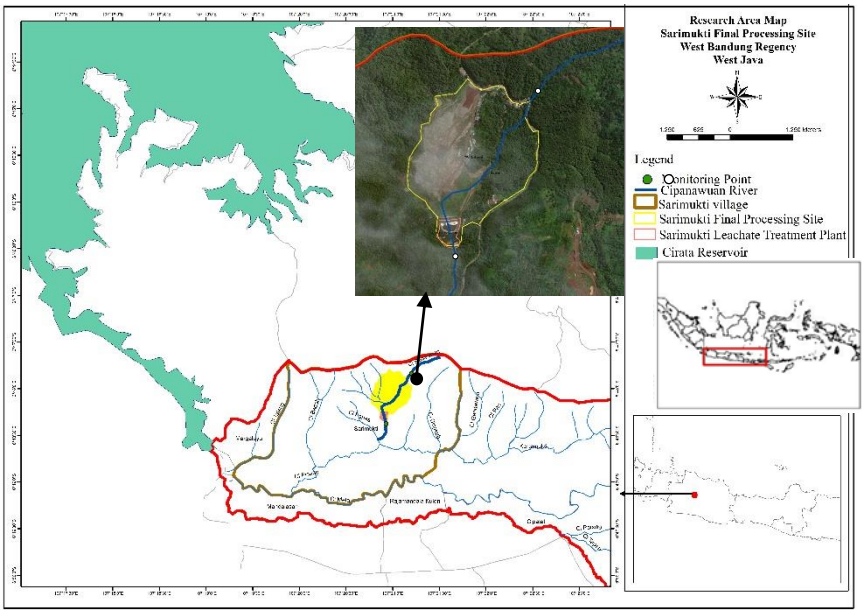


Figure 1. Map of the location of the Cipanawuan River points

This study uses secondary data from the West Java Environmental Service from 2012 to 2019 during the rainy and dry seasons. Data collection for eight years aims to determine the water quality trend in the Cipanawuan River yearly. The data is processed to determine the status of water quality based on the Decree of the State Minister for the Environment No. 115 of 2003 concerning Guidelines for Determining Water Quality Status. Water quality status is the level of water quality conditions indicating polluted or good conditions in a water source at a specific time by comparing it with the stipulated water quality standards. Determination of water quality status is carried out by the Pollution Index Method.

Management of water quality based on this Pollution Index can provide input to decision-makers in order to be able to assess the quality of water bodies for a designation and take action to improve quality if there is a decrease in quality due to the presence of pollutant compounds. Classification of Pollution Index Values can be seen in **Table 1**. Classification of Pollution Index Values can be seen in **Table 1**.

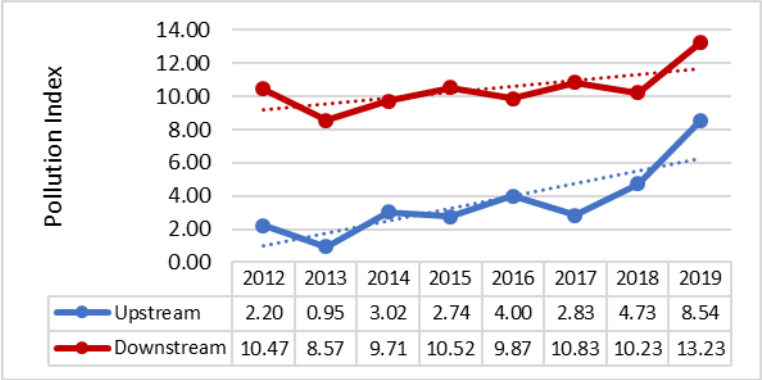
Table 1. Classification of pollution index values

Pollutant Index Value	Water quality
$0 \leq PIj \leq 1.0$	Meet Quality Standards (Good Condition)
$1.0 < PIj \leq 5.0$	Lightly Polluted
$5.0 < PIj \leq 10$	Moderately Polluted
$PIj > 10$	Severely Polluted

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

3. Results and Discussion

The value of the water quality status of the Cipanawuan River from 2012 to 2019 can be seen in Figure 2. The upstream part of the river, located before the Sarimukti Landfill Pollution Index value, has a value with the classification of Lightly Polluted to Moderately Polluted. In contrast, the downstream part of the river, located after Sarimukti's Treatment Plant, includes the Pollution Indicator for Heavy Polluted category. This proves that Landfill operations affect the water quality of the Cipanawuan River.



	2012	2013	2014	2015	2016	2017	2018	2019
Upstream	2.20	0.95	3.02	2.74	4.00	2.83	4.73	8.54
Downstream	10.47	8.57	9.71	10.52	9.87	10.83	10.23	13.23

Figure 2. Graph of the Cipanawuan River pollution index

The results of the calculation of the Pollution Index show that from upstream to downstream, the value of the Pollution Index over the last eight years has tended to increase even though, in several years, there have been fluctuations in water quality.

On average, the water quality condition in the upstream part is in the category of lightly polluted, while in the downstream part, the average is heavily polluted. The upstream part has an IP value with a lowest value of 0.95 to the highest value of 8.54, and the downstream part has an IP value with the lowest value of 8.57 to the highest value of 10.52. The trend line of the pollution index value in the upstream and downstream parts shows that from 2012-2019 it has increased, causing a decrease in the water quality of the Cipanawuan River.

The condition of river water in the upstream in 2012 with an IP value of 2.2 (lightly polluted) while in the downstream section with an IP value of 10.4 (severe polluted), the increase in IP was due to increased levels of free NH_3N, Nickel, BOD and COD; in 2013 the upstream part experienced a decrease with an IP value of 0.9 (meeting quality standards) while the downstream section with an IP value of 8.5 (moderately polluted) decreased from the previous year due to a decrease in Sarimukti Landfill waste generation; in 2014 the upstream part with an IP value of 3.1 (lightly polluted) while the downstream part with an IP value of 9.7 (moderately polluted); in 2015 the upstream part with an IP value of 2.7 (lightly polluted) while the downstream part with an IP value of 10.5 (severely polluted) the increase in IP was due to increased levels of TDS, free NH_3N, chloride, BOD, and COD; in 2016 the downstream with an IP value of 4 (lightly polluted) while the downstream with an IP value of 9.8 (moderately polluted); in 2017 the upstream part with an IP value of 2.8 (lightly polluted) while the downstream part with an IP value of 10.8 (severely polluted); in 2018 the upstream part with an IP value of 4.7 (lightly polluted) while the downstream part with an IP value of 10.2 (moderately polluted); and in 2019 the upstream section was relatively high with an IP value of 8.5 (moderately polluted) while the downstream experienced a very large increase with an IP value of 13.32 (severely polluted).

The IP value in 2019 increased quite a lot due to the significantly increased levels of TDS, TSS, Chloride, BOD, COD, Fecal Coliform, and Detergent in that year due to increased plastic waste generation so that many scavengers around the Landfill (close to the upstream monitoring point)) which sorts plastic waste and then washes it so it can be recycled, causing the detergent concentration value to be relatively high compared to other years. **Table 2** shows the increase in waste generation at the Sarimukti Landfill from 2012-2019.

Table 2. Increase in waste generation

Year	Waste Generation		
	ton/year	kg/year	kg/day
2012	466,670	466,670,000	1,278,548
2013	480,009	480,009,000	1,315,093
2014	409,431	409,431,000	1,121,729
2015	402,523	402,523,000	1,102,803
2016	601,885	601,885,000	1,649,000
2017	585,168	585,168,000	1,603,200
2018	584,000	584,000,000	1,600,000
2019	698,907	698,906,690	1,914,813

Source: West Java Environmental Service, 2022.

Based on the table, it can be seen that there has been an increase in waste generation from 2012 of 466,670 ton/year or 1,278,548 kg/day to 698,907 ton/year or 1,914,813 kg/day. There was an increase in the waste generation of around 232.237 ton/year or 636.265 kg/day or 33% for eight years or 4.15%/year. An increase in a waste generation will increase the leachate generation rate and concentration. Waste generation at the Sarimukti Landfill shows that from 2012-2019 it tends to increase even though there has been a decrease in waste generation for several years. Factors causing the accumulation of waste are large volumes of waste, limited transportation facilities, relatively long distances to landfills, making it less effective, ineffective waste management, and suboptimal waste processing technology (Kahfi, 2017). Based on the results of field observations, leachate seepage originated from piles of garbage around the study site, which directly entered the river. This will reduce the water quality because leachate seepage will pollute the river. The 2012-2019 Sarimukti Landfill leachate quality, which did not meet quality standards, has been compared with the Minister of Environment and Forestry Regulation No. 59 of 2016 concerning Leachate Quality Standards for Landfill Businesses and/or Activities is then related to the water quality of the Cipanawuan River which can be seen in **Figure 3**.

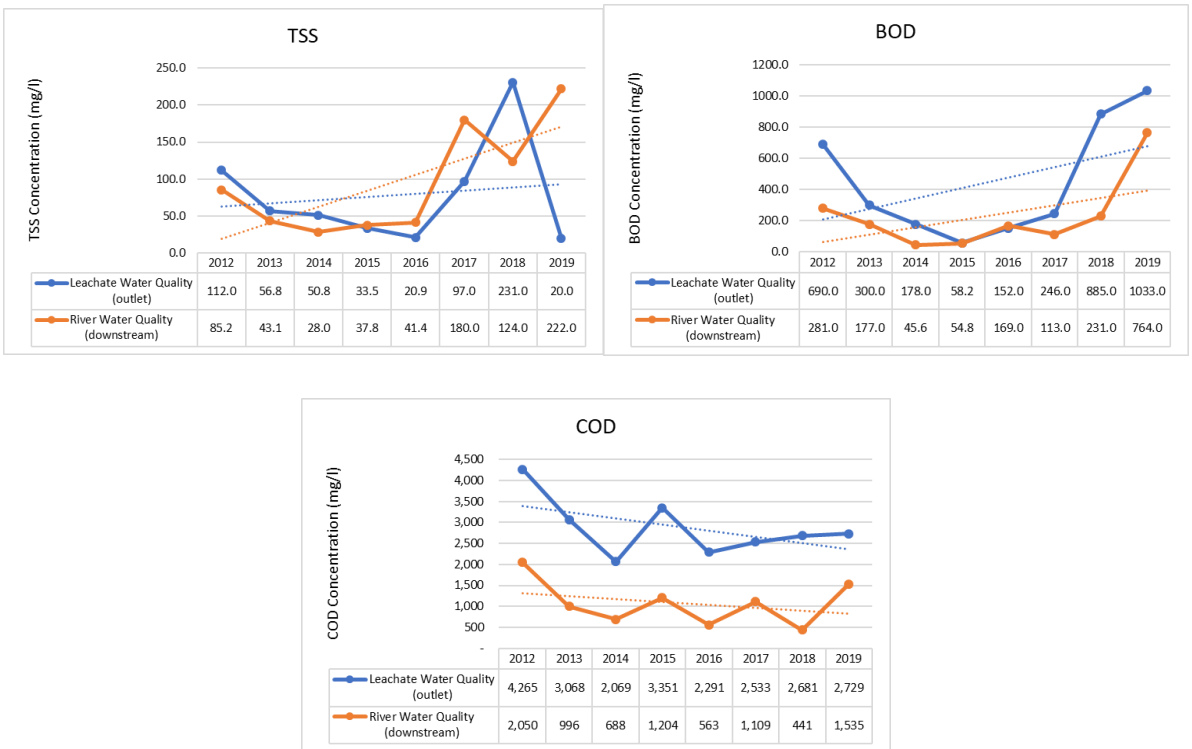


Figure 3. The linkage of leachate quality to Sarimukti Landfill in 2012-2019
Source: West Java Environmental Service, 2022.

Comparison results with leachate quality standards according to the Minister of Environment and Forestry Regulation No. 59 of 2016 concerning Leachate Quality Standards for Businesses and/or Activities at Waste Final Processing Sites, there are five regulated parameters, and there are three parameters that exceed the quality standards. From the results of leachate quality in Figure 3.

The concentration of TSS in leachate water quality has a range with the lowest value of 20.0 mg/l and the highest value of 231.0 mg/l, which, when compared with the TSS quality standard of 100.0 mg/l then in In 2012 and 2018, the concentration was not appropriate, while in river water quality it has a range with the lowest value of 28.0 mg/l and the highest value of 222.0 mg/l so that every year the value does not comply with the quality standard. The trend line for TSS concentration in the outlet and downstream sections shows that from 2012-2019 it has increased, which has caused a decrease in the water quality of the Cipanawuan River. It can be concluded that the TSS parameter concentration for the water quality of the Cipanawuan River is significantly and quite strongly affected by the leachate quality of Sarimukti's Treatment Plant; the TSS concentration of the Cipanawuan River originates from solids that are in the leachate seepage around the river (sand, silt, and clay) or suspended particles in water (sedimentation erosion or domestic sewage).

The BOD parameter in 2012-2019, the concentration of BOD in leachate water quality has a range with the lowest value of 58.2 mg/l and the highest value of 1,033.0 mg/l which, when compared with the BOD quality standard of 150.0 mg/l, only in 2015 was the concentration is appropriate, while river water quality has a range with the lowest value of 45.6 mg/l and the highest value of 764.0 mg/l so that every year the value is not by the quality standard. The trend line for BOD concentration in the outlet and downstream sections shows that from 2012-2019 it has increased, causing a decrease in the quality of the Cipanawuan River water originating from the Sarimukti Landfill operation. The concentration of BOD originating from Sarimukti Landfill operations has significantly and substantially impacted the water quality of the Cipanawuan River. However, the water quality of the Cipanawuan River is still very high in concentration value; it can be concluded that the concentration of the BOD parameter does not only affect the Treatment Plant from the operational results of the Sarimukti Landfill but also comes from leachate seepage of garbage heaps which undergo an oxidation process in water which is influenced by various factors, so BOD value will also be affected.

The COD parameter in 2012-2019, the COD concentration in leachate water quality has a range with the lowest value of 2.069 mg/l and the highest value of 4.265 mg/l which, when compared to the COD quality standard of 300.0 mg/l, then in every year the value is not by quality standards, while river water quality has a range with the lowest value of 441.0 mg/l and the highest value of 2.050 mg/l so that every year the value does not comply with the quality standard. The trend line for COD concentration at the outlet and downstream shows that from 2012-2019 it has decreased. The COD concentration originating from the Sarimukti Landfill operation had an insignificant but quite substantial impact on the water quality of the Cipanawuan River. However, the water quality of the Cipanawuan River still has a very high concentration value. It can be concluded that the COD parameter concentration not only affects leachate seepage from Sarimukti Landfill operations but also comes from the oxidation process in waters, which is influenced by various factors, so the COD value will also be affected. This shows that Sarimukti Landfill operations affect the water quality of the Cipanawuan River.

It can be concluded that the concentration of pH and Cadmium in Sarimukti's Treatment Plant from 2012-2019, the inlet and outlet sections have met quality standards based on Minister of Environment and Forestry Regulation No. 59 of 2016.

The quality results of the BOD concentration decreased almost every year between the inlet and outlet, but all of them still exceeded the quality standard. The BOD concentration at the outlet decreased quite well to 58.2 mg/L and met the quality standard. Moreover, the results of the quality of the COD concentration from 2012-2019 each year exceed the quality standards, but between the inlet and outlet sections each year, there is always a reasonably good decline. Effluent removal efficiency on parameters that exceed the quality standard can be seen in **Table 3**.

Table 3. The efficiency of elimination of effluent parameters that exceed quality standards

Removal Efficiency (%)								
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
TSS	4.3	19.1	25.6	9.5	64.6	94.9	11.5	-5.3
BOD	2.1	12.0	40.9	87.2	80.7	96.2	0	0
COD	3.4	14.4	19.7	28.2	50.4	78.9	21.1	43

Source: West Java Environmental Service, 2022.

Sarimukti's Treatment Plant consists of a Stabilization Pond, a Collecting Tub, an Anaerobic Buffle Reactor (ABR) Pool, Aerobic Ponds 1 and 2, Sedimentation Ponds and Land Treatment. The TSS parameter effluent removal results that exceed the leachate quality standard from the inlet to Sarimukti's Treatment Plant outlet from 2012 to 2019 are 4.3% to 94.9%, for BOD parameters are 2.1% to 96.2%, and for COD parameters are 3.4% to 78.9%. The manager increased Sarimukti's Treatment Plant repairs in the effluent allowance from 2012 to 2019.

The West Java Environmental Service stated that efforts to increase Sarimukti's Treatment Plant by repairing anaerobic and aerobic ponds and adding chemical and biological processing units had been carried out. Sarimukti's Treatment Plant with biological processing did not show optimal results, as seen from the physical condition of leachate, the quality of leachate at the inlet to outlet of the Treatment Plant which did not experience a significant decrease in pollutant parameters due to high organic load and discharge and problems with processing units that did not meet the criteria required (Safria, 2022). The treatment system used is effective enough to reduce the effluent value of each parameter, but it needs to be improved again to be more optimal in operation to remove the pollutant content contained in the leachate. Research that has been conducted to determine the quality of water in rivers that are tributaries of the Citarum River in West Java province is presented in **Table 4**. This table shows that the quality of tributaries of the Citarum River is in the Heavily Polluted category.

Table 4. Research on river water quality using the pollution index method

Research Place	**Research Result**	**Reference**
Cibaligo River, Cimahi City, West Java	Heavily Polluted	(Anggraini, 2021)
Cimahi River, Cimahi City, West Java	Heavily Polluted	(Rafianto, 2021)
Cibabat River, Cimahi City, West Java	Heavily Polluted	(Alfaroby, 2021)
Cibeureum River, Cimahi City, West Java	Heavily Polluted	(Hermawan, 2021)
Cisangkan River, Cimahi City, West Java	Heavily Polluted	(Rosmeiliyana, 2021)
Cikapundung River, Bandung Regency, West Java	Heavily Polluted	(Wardhani, 2022)
Gampong Jawa Landfill, Banda Aceh City	Heavily Polluted	(Darnas, 2020)
Kali Asem River, Bantar Gebang Landfill, Bekasi City, West Java	Heavily Polluted	(Kurniasari, 2020)

Table 5 identification of sources of water pollution in the Cipanawuan River compared to field conditions, so that it can be seen that the sources of pollution in the Cipanawuan River only come from the operational Sarimukti Landfill and the waste that has covered the Cipanawuan River. Identification of pollutant sources can be seen in **Table 5**.

Table 5. Identification of pollutant sources

Parameter	**Identification of Pollutant Sources**
BOD, COD	Koda (2017) in his research stated that COD and BOD are indicators for determining leachate quality. Landfill activity is a source of BOD pollutants. Based on observations at the Sarimukti Landfill, organic contaminants in water cause high BOD and COD values, possibly due to leachate seepage in the leachate column or from piles of garbage.

Parameter	**Identification of Pollutant Sources**
TSS	TSS originates from all solids (sand, silt, and clay) or suspended particles in water (sedimentation erosion, domestic waste, and landfill activities) and can be in the form of living (biotic) components such as phytoplankton, zooplankton, bacteria, fungi. , or dead (abiotic) components such as detritus and inorganic particles (Rinawati, 2016). Based on the results of observations at the Sarimukti Landfill, high TSS levels in leachate were affected by the considerable growth and death of bacteria in the form of suspended matter from degradation in young waste.
TDS	The primary sources of TDS in waters are overflow from agriculture, household and industrial waste (Rinawati, 2016). Based on observations at the Sarimukti Landfill, the high TDS level in leachate is due to the accumulation of decomposition results of organic and inorganic waste stockpiled in the Landfill.
Nitrite	The natural source of nitrite is the nitrogen cycle, while human activity comes from using nitrogen fertilizers, industrial waste and human organic waste (Setyowati, 2016). Based on observations, nitrite levels, aside from the nitrogen cycle process, also come from organic wastes due to landfill operations.
NH_3N	Ammonia in water comes from urine and faeces, oxidation of organic substances microbiologically and from industrial wastewater and community activities (Putri et al., 2019). Based on the observation results, ammonia levels come from landfill operations with a controlled landfill system. Waste covered with soil will have low oxygen levels, so it undergoes a waste decomposition process.
Oil and Fat	Oil and grease are parameters of wastewater quality standards for various business and/or industrial activities, hotels, healthcare facilities, slaughterhouses, landfills, and domestic waste (Zaharah et al., 2017). Based on observations, the parameters for oil and grease come from domestic waste buried in landfills.
Detergent as MBAS	Sources of detergent pollution in waters can come from domestic waste. Domestic waste comes from daily household activities, such as washing using detergents and deodorizers (Suastuti et al., 2015). Based on observations, detergent contamination comes from domestic waste that enters landfills.
Metal (Cu, Cd, Pb, and Zn)	These metals can accumulate in the body of organisms with a prolonged susceptibility to an accumulated toxic status or originate from weathering of pipes and natural contaminants from weathering of rocks from erosion of mineral rocks, dust, mining, smelting, batteries and cables (Suyani, 2015). Based on observations, metal parameters originate from the accumulation of decomposition results of organic and inorganic waste stockpiled in landfills, pollutant materials from the surrounding community, or are influenced by high organic and inorganic pollutant materials or a high volume of waste.
Faecal Coliform	Faecal coliform is coliform bacteria from human or animal faeces (Aswan et al, 2017). Based on the observations, the parameters of faecal coliform come from human and animal activities around the Cipanawuan River and Sarimukti Landfill.

4. Conclusion

Fifteen water quality parameters exceed the quality standards in the Cipanawuan River, namely: TDS, TSS, Nitrite, free NH_3N, Copper (Cu), Lead (Pb), Zinc (Zn), Nickel (Ni), Chloride (Cl^-), Sulfur (H_2S), BOD, COD, DO, Oil and Fat, Detergent as MBAS, and Fecal Coliform. This can be seen from the high parameter concentration values exceeding quality standards. The Pollution Index of the Cipanawuan River for the upstream part tends to be included in the lightly polluted category. However, the downstream part every year is categorized as being moderately polluted towards heavily polluted—most of the water pollutant sources for the Cipanawuan River impact Sarimukti Landfill operations. The leachate quality of Sarimukti Landfill tends to be poor, especially in the parameters of TSS, BOD, and COD, because the concentration is always high. Therefore, the Sarimukti Landfill has a significant and quite strong influence on the Cipanawuan River, so the treatment system must be improved again to remove pollutants effectively on leachate.

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