Characteristics of Leachate and Their Effect on Shallow Groundwater Quality (Case Study: TPA Cipayung, Depok)

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Abstract. The problems arising from landfill activity is leaked leachate that is not absorbed well into leachate stabilization pond which furthermore contaminates shallow groundwater around landfill, include Cipayung landfill. The aims of this study is to determine the characteristics of leachate and their effect on shallow groundwater quality around landfill based on temperature, pH, Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen (TN), Mercury (Hg), and fecal coliform. Data were analyzed based on leachate samples at influent point, effluent point, and 7 sampling points of residents’ well with distance variation every 100 meters within 300 meters radius having leachate stabilization pond as benchmark. According to the standard of Indonesia’s Ministry of Environment and Forestry law No. 59 of 2016, the results showed that leachate quality was still above the standard of BOD, COD, and Total Nitrogen parameters; 4178.0 mg/L, 70556.0 mg/L and 373.0 mg/L for influent point, and 3142.0 mg/L, 9055.2 mg/L, and 350 mg/L for the effluent point. Pollution Index of shallow groundwater is between lightly and moderately contaminated. This study showed that the further the distance between sampling point and leachate stabilization pond is, the lower the Pollution Index is.

1. Introduction
One of the problems that arise from landfill activity is a possibility of leaked leachate that is not absorbed well into leachate stabilization pond, especially in areas with high rainfall. Leachate is a liquid that permeates through solid waste that contains dissolved and suspended elements or liquid that pass through the landfill which are mixed and suspended with substances or materials in the landfill. The characteristics of leachate is related to the level of environmental pollution that can be caused and influenced by various factors, such as the composition of waste, landfill age, seasons, hydrological conditions and activities in the landfill [1]. In practice, leachate in Cipayung landfill in Depok was not fully accommodated in the pipes and gathered in leachate stabilization pond, but leak into the soil and contaminate shallow groundwater in residential areas. Shallow groundwater is a groundwater located above the first waterproof layer, which in Depok City, the average depth of shallow groundwater is ranged from 10 meters to 30 meters [2]. Leaked leachate cause shallow groundwater used by residents to change color and is not safe for consumption, however this water is commonly used for daily needs such as drinking water consumptions, washing, bathing, toilet and other similar activities. This study aims to determine the characteristics of Cipayung landfill leachate and their effect on shallow groundwater quality of residential around landfill based on quantitative measurement such as...
temperature, pH, Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen, Mercury and Fecal coliform.

In this study, 7 water samples of shallow groundwater from residents’ well and leachate samples at influent point and effluent point were taken once which procedure is according to SNI 6989.59: 2008 about Water and Wastewater. Determination of sampling location is using purposive sampling by taking 3 straight lines having leachate stabilization pond as benchmark, where line A is Kampung Bulak Barat area, line B is Kampung Benda Barat area, and line C is Pasir Putih area with distance variation of 100 meters, 200 meters and 300 meters within 300 meters radius.

The results of this study were descriptively comparatively analyzed; (1) Influent point and effluent point leachate data is compared to the standard of Indonesia’s Ministry of Environment and Forestry law No. 59 of 2016 on quality standard for business and / or landfill activities to know the leachate characteristics, (2) Result data of shallow groundwater’s samples are compared to Government Regulation No. 82 of 2001 on Water Quality Management and Water Pollution Control to determine the shallow groundwater quality of residential’ well around the landfill, and (3) Shallow groundwater quality data will be calculated by Pollution Index (IP) according of Ministry of Environment Decree No. 115 of 2003.

2. Materials and methods

2.1. Description of study area

The location of this study is at influent point and effluent point of leachate stabilization pond in Cipayung landfill, and 7 sampling points at the groundwater of local residential area within 300 meters radius. The sampling points that were used in this study are considered to represent the condition of Cipayung landfill leachate, whereas the location that is selected in this study is based on groundwater flow obtained from interpolation of the groundwater surface point. Figure 1 shows the area of sampling location and Table 1 shows the sampling coordinates that were used in this study.

![Figure 1. Area of Sampling Location](image)

2.2. Data collection and analysis

Leachate sampling was conducted at the influent point and effluent point of stabilization pond and carried out on the same day as shallow groundwater sampling. The method used in groundwater sampling method is according to SNI 7989.58: 2008 about Water and Wastewater – Part 58: Groundwater Sampling Method. After that, pH and temperature were directly tested at the site, whereas for other parameters (TSS, BOD, COD, TN, Mercury and Fecal coliform), samples were preserved and stored for laboratory testing.
The method which used for each test is using pH meter for measuring pH value (SNI 6989.11 : 2004), thermometer for temperature measurement (SNI 6989.23 : 2005), TSS measurement according to SNI 6989.3:2004, BOD measurement according to SNI 6989.72:2009, COD measurement according to SNI 6989.2:2009, TN measurement according to HACH 399, Mercury measurement according to SNI 6989.78:2011, and fecal coliform measurement according to Most Probable Number Method.

### Table 1. Sampling Coordinates of Leachate and Shallow Groundwater

| Sampling point | Sampling location | Latitude; Longitude |
|----------------|-------------------|---------------------|
| S1             | Leachate stabilization pond influent | 6°25'11.60"S; 106°47'14.42"E |
| S2             | Leachate stabilization pond effluent | 6°25'11.94"S; 106°47'13.55"E |
| A200           | Line A area within 101-200 meters | 6°25'14.99"S; 106°47'19.59"E |
| A300           | Line A area within 201-300 meters | 6°25'17.35"S; 106°47'22.02"E |
| B100           | Line B area within 0-100 meters | 6°25'08.97"S; 106°47'15.85"E |
| B200           | Line B area within 101-200 meters | 6°25'06.20"S; 106°47'17.45"E |
| B300           | Line B area within 201-300 meters | 6°25'05.40"S; 106°47'19.037"E |
| C200           | Line C area within 101-200 meters | 6°25'12.004"S; 106°47'9.564"E |
| C300           | Line C area within 201-300 meters | 6°25'11.480"S; 106°47'4.270"E |

3. Results and Discussion

#### 3.1. Characteristics of leachate

Leachate quality measurement from leachate stabilization is used as a basic consideration for pollutant sources of leachate into shallow groundwater. The influent point (S1) and effluent point (S2) are used as sampling points to determine leachate quality changes before and after processing in stabilization pond, before being discharged into water body. Table 2 shows the result of parameter testing for leachate at influent and effluent point in stabilization pond.

### Table 2. Result of Leachate Samples Testing

| Parameter   | Standard [3] | Influent Point (S1) | Effluent Point (S2) |
|-------------|--------------|---------------------|---------------------|
| Temperature (°C) | Deviation 3º | 34,8                | 33,8                |
| TSS (mg/L)   | 100          | 70                  | 63                  |
| pH           | 6 – 9        | 7,8                 | 8,4                 |
| BOD (mg/L)   | 150          | 4178,0              | 3142,0              |
| COD (mg/L)   | 300          | 70556,0             | 9055,2              |
| TN (mg/L)    | 60           | 373,3               | 350                 |
| Hg (mg/L)    | 0.005        | 0,00161             | 0,00072             |
| Fecal coliform | -           | 9500               | 18000               |

As the table shows, the values of BOD, COD and TN at S1 and S2 exceed the quality standard that is permitted. Cipayung landfill is a mature landfill because its age has been more than 10 years. This is evidenced by its low BOD₅/COD value ratio which is only 0.06, which normally exhibit BOD₅/COD value ratio from 0.05 to 0.2 [1]. It can happen because the composition of mature landfill generally contains humic and fulvic acid that can’t be deciphered. The stabilization pond can reduce the levels of BOD, COD and fecal coliform present in leachate. As the table shows, the level of those parameters in effluent point is lower than influent point, but it still exceeds the standard quality limit, but for fecal coliform value, leachate stabilization pond does not decrease but increase it. Increasing the value of fecal coliform indicated that leachate water treatment has failed. Fecal coliform is included in the type of anaerobic bacteria that can breed without the presence of oxygen. Increasing number of fecal coliform at the effluent point is possible due to aerator in the leachate stabilization pond in Cipayung.
landfill that is not used optimally. Supposedly, the aerator can create the stabilization pond rich in oxygen to prevent anaerobic bacteria growing, but it does not. So, the pond conditions become anoxic and let anaerobic bacteria, including fecal coliform to grow and breed. The BOD and COD value that still exceed the quality standard indicate that the amount of organic matter in leachate is significantly high, so it requires a lot of oxygen to be biodegrade by aerobic microorganisms and to oxidize organic material chemically (non-biodegradable) [4]. The decomposition of organic matter is a natural event, where if a water body is contaminated by organic matter then the bacteria will be able to dissolve the dissolved oxygen in the water during the biodegradable process, so that the natural water biota will die and the state of the water body becomes anaerobic, reyealing bad odor.

High TN value may be caused by irregular processing time on leachate stabilization pond, where the aerator in leachate stabilization pond is not operated on a daily basis. Lack of aeration causes aerobic bacteria die and the wastewater treatment process that is not optimal, also causes leachate water become odor and the color gets black [5].

3.2. Shallow groundwater quality
Testing of shallow groundwater use parameters of leachate quality standard, i.e. temperature, pH, TSS, BOD, COD, TN, Mercury, and added with fecal coliform. The equation of leachate and shallow groundwater samples parameters test was done so the results can be compared based on the same parameters. Table 3 shows the result of shallow groundwater quality testing.

| Parameters | pH  | TSS | BOD (mg/L) | COD (mg/L) | TN (mg/L) | Mercury (μg/L) | Temperature (°C) | Deviation (°C) | Fecal Coliform |
|------------|-----|-----|------------|------------|-----------|----------------|------------------|---------------|----------------|
| Standard   | 6-9 | 50  | 2          | 10         | -         | 0.001          |                   |               |                |
| A-200      | 7.2 | 8   | 52.8       | 78.0       | 5.6       | 0.000125       | 30.6             |               | 2300           |
| A-300      | 7.1 | 1   | 90.5       | 14.0       | 2.8       | 0.00022        | 37.8             |               | 6.8            |
| B-100      | 7.4 | 5   | 63.2       | 84.7       | 6.2       | 0.000031       | 28.8             |               | 4.5            |
| B-200      | 6.9 | 7   | 44.9       | 56.5       | 5.7       | undefined      | 28.3             |               | 6.1            |
| B-300      | 7.2 | 1   | 41.6       | 51.7       | 2.5       | undefined      | 31.7             |               | 0              |
| C-200      | 6.6 | 6   | 42.3       | 62.0       | 5.2       | 0.000283       | 32.1             |               | 4.5            |
| C-300      | 7.4 | 1   | 22.7       | 30.0       | 3.3       | undefined      | 30.3             |               | 1.8            |

Figure 2 and Figure 3 shows the graphic of each other parameter. All standard that used for shallow groundwater quality comparison is standard of Government Regulation No. 82 of 2001 design of water class I. As the figure 1 shows, the normal temperature range is 24° C – 30° C with 3° C deviation, but as the graph shows, temperature exceeds the limit at some points. This high temperature can be caused by the natural influences of the depth of the water and seasons occurring at the time when the sampling is taken, as well as the human influence of waterproof surface construction and the release of warm water [6]. Overall, the pH value decreases with the distance from the benchmark to the furthest point at 300 m radius. Changes in pH values are still within the limit quality range, which is 6 -9. These different pH values correlate with the solubility of metal in the water, where the solubility of metal will be higher at low pH values or in acid conditions, Figure 2 shows the pH values variations.
Figure 2. Correlation between Temperature, pH value, TSS and BOD parameters with distance
Like the Figure 2 shows, TSS value fluctuates but is still below the permitted TSS standard of 50 mg/L, which means that the tested shallow groundwater quality is still good and not polluted by leaked leachate of Cipayung landfill. BOD values indicates the amount of oxygen needed by bacteria when stabilizing decomposable organic material under aerobic conditions, where the organic material serves as food for bacteria and energy obtained from oxidation process [7]. As the graph at Figure 3 shows, BOD values of all tests exceed the permitted quality standard of 2 mg/L, but it can be seen that even
all BOD values exceed the quality standard, the values are decreases as the distance gets further. COD values are always higher than BOD values, because COD values are derived from organic and inorganic materials of microbial degradation that accumulate in groundwater [8]. At the graph at Figure 3, COD value is decreasing along with the distance, just like BOD value. Although the values decrease, but COD concentration at all sampling points are exceed the permitted water quality standard. For the TN value, graphic at Figure 3 shows that all sampling point results are above the standard, but the value decreases as the distance gets further.

The content of mercury in shallow groundwater may be derived from leachate landfill whose garbage is mixed with hazardous and toxic garbage [9]. The graph at Figure 3 shows that mercury values of all sampling points are below permissible quality standards, indicating that shallow groundwater is not polluted by mercury. Apart from leaked leachate factor, mercury in shallow groundwater can also be caused by pH values in the water itself. At the acidic pH values, mercury can dissolve easily, and at the alkaline pH values, mercury may precipitate or slightly dissolve [10]. At some sampling point, such as B-200, B-300 and C-300, mercury values are undefined, this is probably due to alkaline pH values (above 7.0), so that the mercury precipitates and is undetectable. Fecal coliform is a bacterial indicator of pathogen contamination in water. This is because the number of colonies must be related with the presence of pathogenic bacteria. The standard quality of fecal coliform is 100 MPN/100 mL, which means that in 100 mL of sample water, there is maximum of 100 colony forming unit. The graph at Figure 3 shows that the fecal coliform index number exceeds the quality standard at point A-200, that is 2300 MPN/100 mL. It is probably because point A-200 is the source of water at waste management unit of Cipayung landfill, although there is no septic tank on this site, but the distance is closest to the leachate stabilization pond, also from landfill.

3.3. Pollution Index (PI)
The Pollution Index (PI) is used to determine the level of pollution relative to the permitted water quality parameters of Ministry of Environment Decree No. 115 of 2003. Water quality status is calculated by using the formula in accordance with the calculation of PI methods. PI calculation results of shallow groundwater quality status can be seen in Table 4 below. Overall, there are 2 points where the water quality status is lightly contaminated (range 1.0 < PI < 5.0) and 5 points of moderately contaminated (range 5.0 < PI < 10).

| Point | PI  | Status            |
|-------|-----|-------------------|
| A-200 | 6.140777 | Moderately contaminated |
| A-300 | 3.283034 | Lightly contaminated |
| B-100 | 6.210206 | Moderately contaminated |
| B-200 | 5.67031  | Moderately contaminated |
| B-300 | 5.537416 | Moderately contaminated |
| C-200 | 5.625227 | Moderately contaminated |
| C-300 | 4.582264 | Lightly contaminated |

4. Conclusions
The conclusions of this research are that the influent point and effluent point of leachate stabilization pond Cipayung landfill exceeded the quality standard on BOD, COD, and TN parameters, i.e. 4178.0 mg / L, 70556.0 mg / L and 373.3 mg / L for influent point and 3142.0 mg / L, 9055.2 mg / L, and 350
mg / L for the effluent point. While other parameters such as temperature, TSS, pH, and mercury are still below the quality standard. Fecal coliform increased from 9500 MPN / 100 ml at the point of influent to 18000 MPN / 100 ml at the effluent point. The further the distance between the sampling point and the leachate stabilization pond of Cipayung landfill is, the lower the Pollution Index is, which are in between lightly and moderately contaminated with 2 points of lightly contaminated (range 1.0 < PI < 5.0, and 5 points of moderately contaminated (range 5.0 < PI < 10). Further processing of leachate Cipayung landfill is needed considering some sampling parameters still exceed the permitted quality standard. There is also a need for repairing on leachate pipe in Cipayung landfill to minimize the contamination caused by leaked leachate.

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