Correlation analysis of leachate in final disposal sites on groundwater and surface water quality

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Abstract. The Final Disposal Site (TPA) is where waste is disposed of at the end of its life cycle. The contamination of groundwater and surface water caused by leachate is one type of pollution generated by TPA. The goal of this research is to determine the level of groundwater and surface water pollution, as well as the correlation of leachate to groundwater and surface water in West Lombok's Final Disposal Site, which is located in Kebon Kongok Hamlet, Suka Makmur Village, Gerung District. The analysis method utilized in this research is the pollution index method and the analysis which consists of a correlation test. The results of the analysis of groundwater pollution levels from samples of resident wells were classified as adequate condition, lightly polluted, and moderate polluted. Meanwhile, surface water is classified as moderately polluted. The results of the TSS correlation test analysis on groundwater turbidity have a positive direction and a strong correlation with a value of 0.643. The results of leachate TSS analysis against surface water TSS have a positive direction and a moderate correlation with a value of 0.357 as well as the COD of leachate against COD of surface water with a value of 0.257. The results of the analysis of leachate BOD to surface water BOD indicate that there is a moderate correlation with a value of 0.475. This is in line with the pollutant index which has a moderate polluted value. Referring to the findings, it is recommended that the urgency of zero waste should be implemented by all parties, not only the government but also all levels of society.

Keywords: Pollution Index, Final Disposal Site, Pollution Correlation Analysis

1. Introduction

Pollution of groundwater and surface water cannot be avoided if the leachate produced by the landfill is not managed properly. Until now, leachate from landfills is still a source of problems in the majority of cities in Indonesia. This happens because generally leachate has not received optimal management and processing to become an effluent that is safe to flow into the environment [1]. Organic waste produces leachate which has the potential to cause a foul redolence as a result of percolation (water seepage in the soil) and infiltration of rainwater, groundwater, runoff, or flood water that goes to and
through the landfill site [2]. In contrast to inorganic waste, which is waste that does not decompose easily such as plastic, food wrappers, paper, bottles, and drinking glasses [3].

The Final Disposal Site (TPA) is a place where waste reaches its final stage in its management. TPA must be isolated safely both from the aspect of location and management so as not to cause pollution or disturbance to the surrounding community. One form of pollution caused by landfills is groundwater and surface water pollution is caused by leachate. Leachate is a liquid that seeps through piles of garbage carrying dissolved or suspended materials, especially the results of the decomposition process of waste material [4], which must be treated effectively before being safely disposed of into the environment [5]. This liquid is very dangerous because it contains high concentrations of organic compounds and inorganic compounds formed in landfills [6]. The waste management system at the TPA generally still uses an open dumping system. Open dumping is a waste disposal system in which waste is placed on open land and stacked for a long time without any treatment of the waste [7]. Deteriorating soil quality and decreasing quantity of vegetation are serious consequences of open waste disposal which have resulted in increasing public concern [8].

Field surveys conducted in Final Disposal Site of West Lombok District, known as TPA Kebon Kongok, Suka Makmur Village, showed that there are still many settlers who utilized groundwater for daily needs such as cooking, bathing, watering plants, and other activities, while surface water is used by the community to irrigate their rice fields. Government Regulation of the Republic of Indonesia Number 81 of 2012 concerning the Management of Household and Similar Waste [9] states that the construction of a landfill must meet the requirements where the landfill must be constructed more than 1 km from the settlement by considering leachate pollution, odors and vector spread. In fact, around the TPA Kebon Kongok, there have been permanent settlements up to huts at a distance of fewer than 200 meters from the garbage dump. The distance between leachate and groundwater is about 100 meters, while the distance between leachate and surface water is exceedingly proximate. Groundwater and surface water are used by the community for daily needs such as washing and watering plants, while surface water is used to irrigate the community's rice fields. Seeing this condition, a study was accomplished to further review and analyze the correlation between leachate and groundwater and surface water in the area around the TPA Kebon Kongok.

2. Method

2.1 Research Location

This research was conducted in Kebon Kongok Hamlet around the Regional Final Disposal Site (TPAR) Kebun Kongok Suka Makmur Village, Gerung District.

Figure 1. Research Sites
2.2 Tools and Materials

The tools and materials used in this study were groundwater and surface water samples. UTM Geo Map Application for determining the coordinates of the sampling location then pursued with processing these coordinates in spatial data analysis.

2.3 Data Collection Method

The data collection method utilized in this research was a field observation for primary data, then the data was obtained from the test results at the West Nusa Tenggara Provincial Department of Environment and Hygiene Office (DLHK). The results of field observations and test results were analyzed utilizing the water pollution index method and correlation analysis was carried out with the analysis of statistical software. The type of data needed were data on the quality of leachate, groundwater and surface water to analyze the level of groundwater pollution. In this research, there were X variables of leachate water quality, Total Suspended Solid of leachate (TSS of Leachate) as X1, Total Suspended Solid of Groundwater (TSS of Groundwater) as X2, Biological Oxygen Demand (BOD) as X3, Chemical Oxygen Demand (COD) as X4 and Y variables of groundwater quality Y1 (turbidity) and surface water Y2 (TSS), Y3 (BOD), and Y4 (COD).

2.4 Method

The data analysis method used to analyze the level of groundwater and surface water pollution is by using the pollution index method or water pollution index. The pollution index is one of the methods applied to determine the status of water quality. The level of water quality possible to be determined in polluted conditions or adequate conditions by comparing with the quality standards that have been set. (Sheftiana et al., 2017). To analyze the correlation of leachate quality to groundwater and surface water, correlation analysis was applied which consists of classical assumption test and correlation test.

The formula used to calculate the pollution index (IP):

\[
IP_j = \sqrt{\frac{(C_i/L_{ij})_M^2 + (C_i/L_{ij})_R^2}{2}}
\]  

(1)

- \( IP_j \): Index of Pollution (j)
- \( C_i \): Parameter Test Result Concentration
- \( L_{ij} \): Parameter Concentration According to Water Quality Standard
- \( (C_i/L_{ij})_M \): Maximum Value \( C_i/L_{ij} \)
- \( (C_i/L_{ij})_R \): Average Value \( C_i/L_{ij} \)

a. If the parameter concentration value decreases, it indicates that the level of pollution is increasing, for example, DO. Determine the theoretical value or the maximum value of \( C_{im} \) (e.g. for DO, then \( C_{im} \) is a saturated value). In this case, the \( C/L_{ij} \) value of the measurement results is replaced by the calculated \( C/L_{ij} \) value, namely:

\[
(C_i/L_{ij}) = \frac{C_{im} - C_i \text{ (measurement results)}}{C_{im} - L_{ij}}
\]  

(2)

b. If standard value has a range for \( C_i \leq L_{ij} \) average
The status of water quality is based on the calculation of the pollution index as follows [10]:

\[
(C/L_{ij})_{\text{recent}} = \frac{C_i - (L_{ij})_{\text{average}}}{(L_{ij})_{\text{average}} - \text{minimum}}
\]

\[
(C/L_{ij})_{\text{recent}} = \frac{C_i - (L_{ij})_{\text{average}}}{(L_{ij})_{\text{average}} - \text{maximum}}
\]

The status of water quality is based on the calculation of the pollution index as follows [10]:

### Table 1. Determination of Water Quality Status IP Method.

| No | IP score | Description         |
|----|----------|---------------------|
| 1  | 0 – 1.0  | Adequate condition  |
| 2  | 1.1 – 5.0| Lightly polluted    |
| 3  | 5.1 – 10 | Moderately polluted |
| 4  | >10      | Heavily polluted    |

3. Results and Discussions

3.1 Analysis of Groundwater Quality Status Using Pollution Index Method

Pollution index is one of the methods used to determine the status of a water quality. The status of water quality presents the level of condition of the quality of the source water by comparing the quality standards that have been set. As an index-based method, this pollution index method is constructed based on two quality indices. The first is the average index \( I_A \) which shows the average pollution level of all observation parameters. The second is the maximum index \( I_M \) which indicates the maximum pollution level.

Figure 2 establishes the Decree of the Minister of Environment [10], based on the pollution index, it can be seen that there are two wells whose pollution indexes are tranquility classified as adequate condition, which are in November and February with pollution indexes respectively 0.81 and 0.88. In December, the pollution index of resident’s well 1 was classified as lightly polluted with a pollution index value of 3.63, while in January the pollution index was classified as moderately polluted with a pollution index value of 5.1. This was due to the high total coliform and *E.coli* values from the residents’ wells.
From Figure 2, based on the pollution index, it is evident that there is one well which was stated as heavily polluted, namely in November with a pollution index of 0.43. In December and January, the pollution index of citizen 2 wells was classified as lightly polluted with a pollution index value of (respectively 4.6 and 4.49), while in February the pollution index value was classified as moderately polluted. This was because the total value of coliform and *E. coli* were higher than groundwater 2 in January and groundwater 1 for the period February. In addition, the cause of contamination of wells is the distance between the landfill and the well does not meet government regulations, where the landfill must be built more than 1 kilometre from settlements.

From Figure 4 (1) can be seen that physically the residents’ well is constructed of concrete and does not have a cover and sometimes smelly. The smell arises because the location of the well is quite close to the final disposal site, which is approximately 900 meters. From Figure 4 (2), the water in beaker glass shows well water that looks quite clear physically. This was confirmed by the test result from the aspect
of turbidity, pH, Total Dissolved Solid (TDS), color, Fe and Zn content were still within the Environmental Quality Standard (EQS) limits. Even so, the test result of the content of Total Coliform and *E.coli* were very high and exceeds the safe limits set by the government, namely 1100 CFU/100 ml and 23,400 CFU/100 ml (EQS limit is 50 CFU/100 ml for Total coliforms and 0 CFU/100 ml for *E.coli* [11]).

3.2 Analysis of Surface Water Quality Status Based on Pollution Index

Pollution index is one of the methods used to determine the status of water quality of the water sources. The status of water quality shows the level of water quality conditions of water sources in polluted conditions or good conditions by comparing with the quality standards that have been set.

Figure 5 shows that the majority of the pollution index values in each period are 5 and above, which are 5.96 in November, 5.71 in January and 6.16 in February. Based on the Decree of the Minister of Environment No. 115 of 2003[10], the pollution index of $5.0 < P_{ij} < 10$ is categorized as moderately polluted. However, there is one period that is still classified as lightly polluted, which is surface water 1 in December with a pollution index value of 4.78.

![Figure 4. Resident’s Well (1) The Water in a Beaker Glass (2).](image1)

![Figure 5. The Results of Surface Water Analysis 1.](image2)
From Figure 6 it can also be seen that the majority of the pollution index values are categorized as moderately polluted, which are 5.58 in November, 5.4 in December and 6.23 in February. However, in January, surface water 2 was still classified as lightly polluted with a pollution index value of 4.53.

Figure 6. The Results of Surface Water Analysis 2.

Figure 7 (1) shows that surface water is brownish in color, but that the color can shift to brownish black at times due to its proximity to the leachate outflow. Furthermore, river water samples taken from locations near the leachate outlet showed that the water was physically not clear and brown in color as Figure 7 (2). From the test results, the parameters showed results that did not meet the EQS standard, which are BOD levels, DO levels, Total Phosphate, Ammonia, Nitrite, and Fe. Moreover, the test results of the content of Total Coliform and E.Coli were very high and exceeds the safe limits set by the government, namely 116000 CFU/100 ml each (EQS limit is 5000 CFU/100 ml for Total coliforms and 0 CFU/100 ml for E-coli) [12].

Figure 7. Surface Water (1) River Water Sample in a Beaker Glass (2)

3.3. Correlation Test
The correlation test aims to determine the level of closeness of the correlation between variables expressed by the correlation coefficient (R) [13]. The type of correlation between variables X and Y can be positive and negative. The basis for deciding on the correlation test is if the significance value is <0.05 then it is correlated otherwise, if the significance value is >0.05 then it is determined as not correlated [14]. The degree of correlation test [15]:

1) The Pearson linear correlation value of ±0.1 indicates a small effect.
2) The Pearson linear correlation value of ±0.3 represents the medium effect.
3) The Pearson linear correlation value of ±0.5 indicates a large effect.

3.3.1. **TSS Correlation Test Results of Leachate on Turbidity of Groundwater**

The Pearson correlation value of 0.643 indicates that the TSS correlation coefficient of 0.643 is positive and has a strong correlation, according to the results of the analysis. While a positive association suggests that the greater the TSS value, the higher the turbidity value, and vice versa, a negative relationship shows the opposite. This corresponds to the value of the pollution index, which indicates that citizen 1's wells and residents 2's wells are both minimally polluted. The water in citizen 1's well is physically clear, but it has the potential to turn brown at times. Citizen 2's well's water is physically clear and brownish in appearance.

| Table 2. Correlation of Leachate on Turbidity of Groundwater. |
|-----------------|-----------------|-----------------|
| Correlation     | X1              | Y1              |
| X1 Pearson Correlation | 1               | .643            |
| Sig. (2-tailed) | .085            |                 |
| N               | 8               | 8               |
| Y1 Pearson Correlation | .643            | 1               |
| Sig. (2-tailed) | .085            |                 |
| N               | 8               | 8               |

3.3.2. **TSS Correlation Test Results for Leachate to TSS Surface Water**

The Pearson correlation value for the association between leachate TSS and surface water TSS is 0.357, indicating a medium correlation, based on the results of the investigation above. While the positive association shows that the higher the TSS level in leachate, the higher the TSS level in surface water, This corresponds to the pollution index value, which indicates that surface water 1 and 2 are moderately polluted. Surface water 1 is physically brownish in hue, although it has the potential to turn green at times. The condition of surface water 2 is physically brownish in hue, but the water gets black at times.

| Table 3. Correlation of Leachate to TSS Surface Water |
|-----------------|-----------------|-----------------|
| Correlation     | X2              | Y2              |
| X2 Pearson Correlation | 1               | .357            |
| Sig. (2-tailed) | .385            |                 |
| N               | 8               | 8               |
| Y2 Pearson Correlation | .357            | 1               |
| Sig. (2-tailed) | .385            |                 |
| N               | 8               | 8               |
3.4. *Results of the BOD Correlation of Leachate Water to BOD Surface Water*

The Pearson correlation value of 0.475 indicates a moderate association between the BOD of leachate and the BOD of surface water, which is consistent with the pollution index value, which indicates that surface water 1 and surface water 2 have moderate contamination indexes. The first surface water 1 is brownish in color, but it can turn black at times.

**Table 4. Correlation of Leachate Water to BOD Surface Water.**

| Correlations               | X3   | Y3   |
|----------------------------|------|------|
| Pearson Correlation        | 1    | .475 |
| Sig. (2-tailed)            | .234 |      |
| N                          | 8    | 8    |

3.5. *COD Correlation Test Results Leachate to COD Surface Water*

The Pearson correlation value for COD of leachate and COD of surface water is 0.257, indicating that there is a correlation between the two, however it is moderate. Surface water 1 and surface water 2 are moderately polluted, which corresponds to the pollution index value. The physical hue of surface water 1 is brownish, but it can turn green at times. Surface water 2 is physically brownish, yet it turns black at times.

**Table 5. Correlation of Leachate Water to COD Surface Water**

| Correlations               | COD  | CODY |
|----------------------------|------|------|
| Pearson Correlation        | 1    | .257 |
| Sig. (2-tailed)            | .539 |      |
| N                          | 8    | 8    |

4. **Conclusion**

The investigation of the correlation between leachate and groundwater and surface water yielded a positive and strong correlation, with the positive direction indicating that the greater the TSS value, the higher the turbidity value, and vice versa. The correlation analysis between leachate TSS and surface water TSS, on the other hand, shows a medium correlation, with a positive link indicating that the greater
the TSS value in leachate, the higher the TSS level in surface water. This corresponds to the pollution index value, which indicates that surface water 1 and 2 are moderately polluted. Surface water 1 has a physically brownish color. The findings of the analysis of BOD of leachate with BOD of surface water revealed a moderate correlation, while COD of leachate with COD of surface water revealed a medium correlation, similar to TSS of leachate with surface water, which indicated a positive correlation direction. Overall, referring to the findings, it is recommended that the urgency of zero waste should be implemented by all parties, not only the government but also all levels of society.

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