MODELING DISPERSION OF LEACHATE BY USING MINITAB SOFTWARE AND SPATIAL ANALYSIS OF GROUNDWATER QUALITY AROUND LANDFILL

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ABSTRACT

Based on previous research, already calculation of groundwater pollution index in Jabon Landfill, where from the calculation results of 12 well points in the area around TPA, the pollution index is included moderate pollution index. Based on that information, it is necessary for modeling perception of leachate penetration, to find out how far the radius of groundwater has been polluted by landfill leachate. This modeling is use minitab 17 software. Minitab was chosen because minitab is one of the most applicable software for engineering, and minitab provides a simple to understand alternative in performing statistical analysis. This study is use a non linear regression procedure to obtain a curve fitting. In this curve fitting analysis produces a formulation that can be applied to determine radius of dispersion of leachate penetration into groundwater, and based on this formulation can calculate the groundwater pollution index in the area around the landfill. Based on the calculation of the pollution index, radius 3691 meters from the landfill is classified as a moderate pollution index with a pollution index value of 9.0495. This research also evaluates the groundwater quality by mapping approach using a geographic information system. Geographic information system is an information system designed to work with spatially referenced data or geographic coordinates. So that it can provide more information about the quality of groundwater in the area.

Keywords: Groundwater, Dispersion, Curve Fitting, Minitab 17, Leachate Penetration

1. INTRODUCTION

Soil contamination by leachate can last for a long time and take decades to return to the previous soil condition (Novianti, 2018). The leachate produced by the landfill is also difficult to control so as not to pollute the environment, although it provides strong protection for the landfill, so it is important to model leachate seepage (Mahyudin, 2017). The same thing was also expressed by (Putranto, 2011), where groundwater is basically a hidden resource, therefore the study of groundwater below requires modeling techniques in its application. Groundwater modeling describes groundwater flow processes using mathematical equations based on certain simplifying assumptions. This study uses the minitab 17 software. The minitab software was chosen *because minitab* is one of the most applicable software for use in the *engineering field,* offers a variety of data exploration, estimation, regression, and parametric and non-parametric tests and provides an easy-to-understand alternative in performing statistical analysis. (Maat, 2017) .

The method used in this research is the *curve method fittings* . This method is used to examine the relationship between distance and groundwater quality parameters. The next step is to determine the right formulation to study the dispersion of leachate penetration to groundwater in the area around the Jabon TPA. This formulation can be used to determine the level of groundwater pollution in the area around the Jabon TPA. In this study, an approach to mapping groundwater quality was also carried out. The groundwater quality mapping used is using a geographic information system. Geographic information system is an information system designed to work with spatially referenced data or geographic coordinates. Based on the problems that have been mentioned, the authors are also interested in conducting research on groundwater quality around the Jabon TPA which aims to map the distribution of groundwater quality based on geographic information system applications. so that it can provide further information regarding groundwater quality in the area.

2. RESEARCH METHOD

This modeling uses minitab 17 *software* . The method used in this study is the *curve method fittings* . *Curve* analysis *fitting* using minitab 17 software. Results from *curve* This *fitting* produces a formulation that can be applied to assess the dispersion of leachate penetration to groundwater around the Jabon TPA area. Specialized in *curve* analysis *fitting* , data that are considered *outliers are* omitted, until the data is normally distributed. Outliers need to be removed because they can increase the error variance and reduce the power of statistical tests, but it can also present a bias (Osborne & Overbay, 2014). The formulation obtained from the curve fitting was tested using the mean absolute percentage error (MAPE) method, where the MAPE target for each distance relationship with the desired groundwater quality parameter is <50% so that the model can be declared feasible.

Based on the formulation obtained, it is then possible to determine the level of groundwater pollution in the area around the Jabon TPA. The calculation of the pollution index refers to the Decree of the State Minister of the Environment Number: 115 of 2003 . How to calculate the pollution index as follows:

1. Calculate Ci/Lij, where Ci is the concentration of the parameter test results, and Lij is the parameter concentration according to the water quality standard. If the calculation result is > 1, then a new Ci/Lij calculation is performed with the formula: New Ci/Lij EC = 1 + 5 log (Ci/Lij) .
2. If the parameter concentration value decreases, it indicates that the level of pollution is increasing, for example the DO parameter. Determine the theoretical value or maximum value (Cim). In this case, the measured Ci/Lij value is replaced by the calculated Ci/Lij value, namely:

   New Ci = $\frac{\text{Cim} - \text{Ci}}{\text{Cim} - \text{Lij}}$ .... equation 1

   so that New Ci/Lij = $\frac{\text{Ci baru}}{\text{Lij}}$ .... equation 2
3. Determine the average and maximum values of the entire Ci/Lij ((Ci/Lij)R and (Ci/Lij)M).
4. Calculate the pollutant index (IP) value using the formula:

$$\text{IP} = \sqrt{\frac{\left(\frac{\text{Ci}}{\text{Lij}}\right)\text{M}^2 + \left(\frac{\text{Ci}}{\text{Lij}}\right)\text{R}^2}{2}} \quad \text{................................ equation 3}$$

Information :

IP	: Pollution Index
Ci	: Concentration of parameter test results
Lij	: Concentration of parameters according to water quality standards
$(\text{Ci/Lij})_M$	: Maximum Ci/Lij value
$(\text{Ci/Lij})_R$	: Average Ci/Lij value

Table 1. Evaluation of Pollution Index (IP) Value

IP interval	Information
0 IP 1.0	meet quality standards (good condition)
1.0 < IP 5.0	lightly polluted
5.0 < IP 10	moderately polluted
IP 10	heavily polluted

(Source : Decree of the State Minister of Environment Number : 115 Year 2003)

In this study, spatial analysis of the distribution of groundwater quality was also carried out with the inverse distance weighted (IDW) procedure using ArcGIS 10.3 software. The IDW scheme is one of the popular methods used by hydrologists and earth scientists because of its ease of implementation and interpretation. The main characteristic of this method is that all points on the earth's surface are considered to be interdependent based on distance. Therefore, the height of the calculation result depends on the height of the surrounding data points. (Achilleos, GA 2011). The data used to create a map of the distribution of groundwater quality is obtained from Table 2.

3. RESULT DISCUSSION

3.1 Taking Sample

The data used in this study is secondary data from the research of Tangahu and Sambodho (2021). Leachate sampling was carried out at the Jabon TPA, while groundwater sampling was carried out at 12 wells in the surrounding area at the Jabon TPA. The sampling location can be seen in Figure 4.1. The coordinates of the sampling point, the distance from the landfill along with the concentration of each groundwater quality parameter can be seen in Table 2. Guidelines for groundwater quality standards can be seen in Table 3.

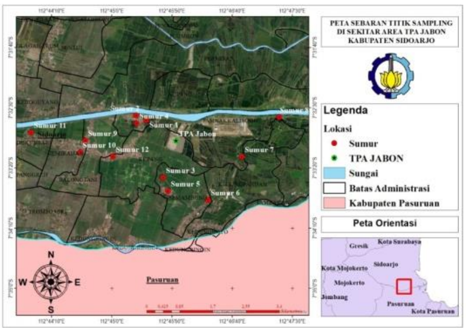

Figure 1. Sampling Point

Table 2. Coordinates of Sampling Point, Distance from Landfill, and Concentration of Groundwater

Well Name	Coordinate	Distance from Landfill (m)	Concentration				
			EC (µs/cm)	DO (ppm)	COD (mg/L)	TDS (ppm)	Cd (mg/L)
Jabon Landfill	7°32'57" South Latitude 112°45'48" E	0	10420	4.39	1208.9	5212	0.516
Well 1	7°32'42.00"S 112°45'38.00"E	550.24	2328	3.58	20.8	1164	0.1217
Well 2	7°32'37.01"S 112°45'26.37"E	779.46	1289	1.64	20.8	729	0.1163
Well 3	7°33'28.09"S 112°45'42.87"E	862.29	1850	5.36	41.6	958	0.1146
Well 4	7°32'46.01"S 112°45'20.99"E	977.8	1387	2.15	166.4	693	0.1145
Well 5	7°33'39.15"S 112°45'50.74"E	1230.77	1484	1.05	41.6	742	0.1146
Well 6	7°33'42.50"S 112°46'19.30"E	1469.55	2191	2.68	20.8	1096	0.1127
Well 7	7°33'11.04"S 112°46'46.60"E	1497.15	6500	2.56	62.4	3520	0.1138
Well 8	7°32'37.72"S 112°47'13.74"E	2491.42	6260	3.28	41.6	2981	0.1134
Well 9	7°32'58.77"S 112°44'41.55"E	2189.2	1147	1.46	145.6	573	0.1150
Well 10	7°33'9.50"S 112°44'42.40"E	2249.4	998	1.20	83.2	499	0.1102
Well 11	7°32'50.20"S 112°43'52.38"E	3691	527	1.38	41.6	263	0.1154
Well 12	7°33'10.90"S 112°45'5.72"E	1543.2	869	2.62	20.8	434	0.1144

(Source : Tangahu & Sambodo, 2021)

Table 3. Quality Standards of Groundwater Parameters

No.	Parameter	Unit	Quality Standard
1.	DO	ppm	6
2.	COD	mg/L	10
3.	EC	s/cm	3265
4.	TDS	mg/L	1000
5.	CD	mg/L	0.01

(Source: PP RI No. 22 Year 2021)

3.2 Determining Water Quality Status by Pollution Index Method

The relationship of distance to groundwater quality parameters is modeled by the exponential number of terms graph 1. Selected model *exponential* graph selected because in this case the decrease does not match using a linear graph, and a linear graph can have a negative value, whereas almost all parameters in this study will not be negative, or have a value of zero, for example groundwater usually contains Cd of 1 g/L. Soil that is not contaminated with pollution has a Cd content of 0.36 mg/kg, but the value varies according to the type of soil (Kubir *et al.,* 2021). Water that has undergone a distillation process (distilled water) still has an EC concentration of up to 0.5 S/cm (Bari and Rajon, 2016)

Based on this formulation, it can then be used to calculate the groundwater pollution index in the area around the landfill. In this study using the trial error calculation method, where the distance variable number(x) from the TPA taken randomly. Variable distance(x) taken only one meter from the landfill. The first step before determining the pollutant index is to calculate the concentration value of each groundwater quality parameter (EC, TDS, COD, Cd, and DO). The relationship data, formulation and concentration of groundwater quality parameters obtained can be seen in Table 5.

Table 5. Relations, Formulation and Concentration of Groundwater Quality Parameters

No.	Relationship between Distance with Groundwater Quality Parameters	Formulation	Concentration
1.	Distance relationship to EC	$f(x) = ae^{bx}$ with coefficient : a = 10118.4 b = -0.00189473	$f(x)$ =10118.4 * e $^{(-0.00189473*1)}$ $f(x)$ =10099,246 is 10099.246 s/cm.
2.	Distance relationship to TDS	$f(x) = ae^{bx}$ with coefficient : a = 5079.18 b = -0.00202122	$f(x)$ = 5079.18*e $^{(-0.00202122*1)}$ $f(x)$ = 5068,924 So the concentration of TDS at a distance of 1 m from the TPA is 5068.924 mg/L.
3.	Distance relationship to COD	$f(x) = ae^{bx}$ with coefficient : a = 1208.76 b = -0.00646675	$f(x)$ = 1208.76 * e $^{(-0.00646675*1)}$ $f(x)$ = 1200,968 So the COD concentration at a distance of 1 m from the TPA is 1200,968 ppm.
4.	Distance relationship to Cd	$f(x) = ae^{bx}$ with coefficient : a = 0.446093 b = -0.001175	$f(x)$ = 0.446093 * e $^{(-0.001175*1)}$ $f(x)$ = 0.445 So the concentration of Cd at a distance of 1 m from the landfill is 0.445 mg/L.
5.	Distance relationship to DO	$f(x) = ae^{bx}$ with coefficient : a = 4.05381 b = -0.00037974	$f(x)$ = 4.05381 * e $^{(-0.00037974*1)}$ $f(x)$ = 4.0524 So the DO concentration at a distance of 1 m from the Jabon TPA is 4.052 ppm.

The next step is to calculate the pollutant index value using equations 1 to 3. In this study, the value of Ci is the concentration of each groundwater quality parameter from the formulation obtained from the analysis of curve fitting minitab 17. Lij is the concentration of parameters according to the quality standard of water designation. , the quality standard used using PP RI No. 22 Year 2021 . The recap of the New Ci/Lij value to calculate the pollutant index from a distance of one meter from the Jabon TPA can be seen in Table 6.

Table 6. Recap Calculation of Pollutant Index Value

No.	Parameter	New Ci/Lij
1.	EC	3.129
2.	TDS	3.322
3.	COD	**11,398**
4.	CD	9,242
5.	DO	0.491
$(Ci/Lij)_R$ =		**5.516**

Note : **11,398 = (Ci/Lij) $_M$**

Based on Table 6. above, the pollutant index can be calculated according to equation 3. Based on this calculation, it is known that the pollutant index value is 9.0495. Based on Table 1. the pollutant index is classified as moderate pollution, because the pollutant index value is in the 5.0-10.0 interval.

3.3 Analysis of Dispersion of Groundwater Quality

Based on Figure 2. shows that, most of the area around the Jabon TPA is predicted to have groundwater EC values in the range of 1001 – 2000 s /cm. Some of the villages of Semambung, Tambakkalisogo, Kedungpandan and Jemirahan are predicted to have groundwater EC values in the range of 5001 – 6000 s/cm. The area around the Jabon TPA is predicted to have an EC value of groundwater in the range of 6001 – 10,000 s /cm. Based on Figure 3. shows that, most of the area around the Jabon TPA is predicted to have a TDS value of groundwater in the range of 1001 – 1500 mg/L. Some villages in Semambung, Jemirahan, Tambakkalisogo, and Kedungpandan villages, have a TDS value of ground water in the range of 2501 – 3000 mg/L. The area around the Jabon TPA is predicted to have a TDS value of ground water in the range of 3501 – 5000 mg/L. In this study, the parameter quality standard TDS 1000 mg/L. So that most of the TDS values for groundwater in the area around TPA Jabon are below the quality standard. Based on Figure 4. shows that, there are 6 villages that are predicted to have COD values 150 mg /L. The villages include Kupang, Jemirahan, Tambakkalisogo, Permisan, Plumbon and Penatarsewu villages. In this study, the COD parameter quality standard was 10 mg/L. So that this greatly exceeds the value of the COD quality standard. This high COD value can also be caused by the penetration of landfill leachate that has polluted the residents' wells, besides that the pond waters can also be a source of organic matter, where this source can come from inside or outside the pond waters, and this can affect COD quality of groundwater (Tamyiz, 2015). In Figure 4, ponds and ponds are marked with a green round symbol . As shown in Figure 4, the location of wells 3, wells 4, and wells 5 are adjacent to the pond, the COD value of groundwater is 166.4 mg/L, 41.6 mg/L and 41.6 mg/L (can be seen in Table 2). Well 3 is the well with the highest COD value of groundwater, and at this location is surrounded by 4 ponds. Excessive COD content can reduce DO content and pH (Supriyantini *et al.,* 2017).

Based on Figure 5. shows that, all groundwater Cd concentrations in the area around the Jabon TPA are above the environmental quality standard, and most of the groundwater Cd values in the area around the Jabon TPA are predicted to be above 0.1241 mg/L. In this study, the quality standard of Cd 0.01 mg/L. This shows that all groundwater around the TPA has been contaminated with heavy metal Cd. According to Novianti (2018), the toxicity of Cd can be affected by pH, where the solubility of Cd will decrease when the pH increases. Based on research conducted by Tangahu and Sambodo (2021), it is known that almost all groundwater in the area around the TPA has a pH range of 5 to 6.5. A pH value lower than 7 is considered acidic, and a pH value greater than 7 is considered alkaline. So that the condition of groundwater in the area around the landfill that is acidic can trigger the spread of Cd concentrations in groundwater, because the heavy metal content of Cd can be easily dissolved or increased when the pH is low. Cadmium (Cd; atomic number 48, atomic weight 112.41) belongs to group XII of the periodic table of chemical elements. This silvery-white soft metal is physically and chemically similar to zinc and mercury (Genchi *et al.,* 2020). Cd is a metal that is highly toxic to humans when the element accumulates in the body. Cd has been shown to cause severe damage to various organs, namely the lungs, liver and kidneys, testes, brain, and even the placenta. Oral exposure to Cd can cause kidney damage, osteoporosis, prostate, and kidney cancer. Chronic exposure to low levels of cadmium can also cause negative effects on the kidneys and bones (Dokmeci *et al.* , 2009). Based on Figure 6. shows that, most of the areas around the Jabon TPA have many areas that have DO values in the range of 2 – 2.9. There are 3 villages that have a DO value in the range of 1 – 1.9, namely Semambung, Jemirahan and Tambakkalisogo Villages. There are 3 villages that have DO values ranging from 3 to 3.9, namely Jemirahan, Kupang and Tambakkalisogo Villages. In this study, the quality standard parameter DO 6 mg /L. So it is predicted that in all areas around the Jabon TPA, the DO value of groundwater is below the quality standard. The distribution map of groundwater quality parameters (EC, TDS, COD, Cd, and DO) in the area around the Jabon TPA can be seen in Figures 2 to 6.

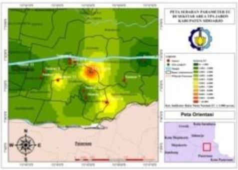

Figure 2. EC . Parameter Distribution Map

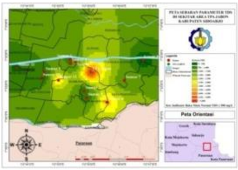

Figure 3 . TDS Parameter Distribution Map

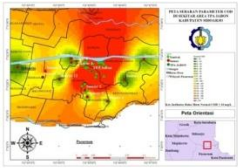

Figure 4. COD Parameter Distribution Map

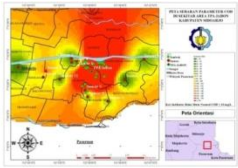

Figure 5. Cd . Parameter Distribution Map

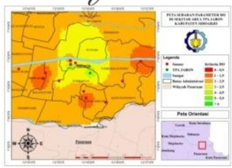

Figure 6. DO . Parameter Distribution Map

4. CONCLUSION

The dispersion of leachate penetration to groundwater in the area around the Jabon TPA up to a radius of 3691 meters is classified as index moderate pollution, with a pollution index value of 9.0495. The concentration of COD, Cd and DO in groundwater in the area around the Jabon TPA is up to a radius of 3691 meters from the TPA, measured above the quality standard, this can be influenced by the penetration of leachate by the TPA. Based on this problem, it is necessary to increase the leachate treatment at the landfill immediately, so that the leachate does not contaminate the groundwater of the area around the landfill which can have a negative impact on human health, and so that residents can use groundwater safely.

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