

Shallow Groundwater Pollution Index Around the Location of Griyo Mulyo Landfill (Jabon Landfill) in Jabon District, Sidoarjo Regency, East Java, Indonesia

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ABSTRACT

The leachate coming from the landfill is a serious problem. This is because the leachate water can contaminate the wells of the residents around the landfill. This research was conducted at Jabon Landfill located in Jabon District of Sidoarjo Regency, East Java Province, Indonesia. Jabon Landfill has been operating since 2003 with a controlled landfill system that has triggered environmental risks due to the leachate output. The purpose of this study was to determine the classification of the shallow groundwater quality status based on the pollution index (PI) around Jabon Landfill at a distance of around 250 meters, 500 meters and 1,000 meters from the landfill. The pollution index was determined by analyzing the pollutant concentration consisting of these following parameters: pH, BOD, COD and Fe. The results of the analysis show that the pH parameter had a higher value than the pH at Jabon Landfill of 7.2–7.5. The pH at Jabon Landfill was 6.35. The Fe parameter shows that the value of 1.694 in the groundwater well closest to Jabon Landfill and the wells further away indicates that the Fe concentration was lower for the latter, namely 0.081 at a distance of up to 200 meters. On the basis of the Pollution Index, the highest value was 5.45 at Well 7 is located 196 m from Jabon Landfill. Meanwhile, the well furthest from Jabon Landfill at a distance of 1,000 m showed a lightly polluted status with a Pollution Index of 1.91. The further the location of the well away from Jabon Landfill, the Pollution Index value tended to decrease. This means that the pollution status generally improves. Overall, the pollution status of the 18 wells shows that 2 wells are moderately polluted, 15 wells are lightly polluted and 1 well is in good condition.

Keywords: pollution index, leachate, Jabon Landfill, water quality status

INTRODUCTION

Sidoarjo District, East Java Province, is developing as a large industrial area. According to the data from the Civil Registry Service for 2018, the total population was 2,238,069 people. Such number of people produces a lot of waste. Sidoarjo Regency only has one final waste disposal site (landfill), namely the Griyo Mulyo Landfill (Jabon Landfill) in Jabon District. The amount of

waste that entered Jabon Landfill in April 2020 was 11,433,700 tons.

The amount of waste has continued to increase, which has had an impact on the environment, especially the production of leachate. Leachate is a liquid substance produced in the process of decomposing waste and it has a very strong odor. Leachate occurs due to the entry of water into the garbage pile, which can cause groundwater pollution, especially in the shallow groundwater (dug

wells) of the residents around the landfill. Subsequent contamination of groundwater through leachate discharged is a major environmental problem experienced around landfills (Afolayan and Ogundele, 2012). Replenishing an aquifer with water from the ground is groundwater recharging (Bhattacharya, 2010). Leachate, which is increasing in volume, seeps into the ground, which in turn results in the contamination of the subsurface water, subsequently contaminating the shallow wells used by the residents as a source of drinking water.

One type of rural water supply facility that is widely used by the government as a source of clean water is dug wells. This facility uses shallow groundwater, so its existence is considered to be efficient and effective when it comes to meeting the needs of daily life. Groundwater is used more widely, because it is easier to obtain and relatively safe from pollution compared to surface water. Therefore, understanding the local groundwater sources is very important in sustainable development (Selvam et al., 2016). Shallow groundwater is the primary need for the people who do not have tap water, and it usually takes the form of dug wells or shallow boreholes in people's houses. The use of groundwater through the means of either boreholes or dug wells is also carried out by the residents around Jabon Landfill. Generally, shallow groundwater is found at a depth of around 15 meters. If the well water is polluted by the leachate from Jabon Landfill, there will be a decrease in the quality of the well water and it cannot be used again properly. The water may have an impact on the health of the community and surrounding environment in the area (Vinet and Zhedanov, 2011).

Jabon Landfill has 3 (three) monitoring wells. Some of the parameters still exceed the quality standards set by the Regulation of Ministry of Health no. 492/2010. Jabon Landfill often overloads and the condition of high rainfall due to the climate results in increased leachate production contributing to leachate penetration. This landfill service covers all waste in Sidoarjo Regency, which causes the waste to rot quicker and produce the pollutants that can contaminate the groundwater. The leachate load that is collected is not maximal and this surplus causes seepage. In addition, clean water in Jabon is no longer easy to obtain because the groundwater has been polluted by the liquid waste from the landfill. On the basis of this fact, it is necessary to conduct research in order

to determine the distribution of pollutants due to leachate. This study aimed to determine the concentration of the pollution parameters according to the leachate characteristics at various horizontal distances from the landfill site. This pollutant concentration was used to determine the water quality using the Pollutant Index method for the shallow wells around Jabon Landfill.

LITERATURE REVIEW

Leachate

Leachate is a liquid that arises from the entry of external water into a landfill that rinses any dissolved materials, including the organic matter resulting from the biological decomposition processes. Leachate can cause pollution if it is not treated first before being discharged into the environment. Leachate is generally toxic because it contains high amounts of many microorganisms, in addition to heavy metals which are dangerous if exposed directly to the environment (Juliardi and Wiyanti, 2018). The garbage buried in the landfill (final disposal site) location contains organic substances. If it rains, it will produce leachate with a high mineral and organic content. If the leachate is allowed to flow into the soil surface, it can have a negative effect on the surrounding environment, including humans. In addition, the level of leachate degradation ability in nature is very low. This is indicated by the low value of the BOD/COD ratio. The characteristics of leachate vary greatly depending on the processes that occur in the landfill, which can be physical, chemical and biological. The type of waste, site design, geochemistry, climatological conditions, and hydrogeology affect the leachate migration to groundwater (Lee and Kitanidis, 1993). The leachate produced from materials that often contain toxic substances can be the greatest threat to groundwater pollution, especially if industrial waste is dumped on the land (Longe and Balogun, 2010). There is no significant difference between the dry season and wet season measurements, except for some of the pollutants at several landfill sites. Generally, groundwater contamination appears after five years and peaks several years afterward. Shallow groundwater contamination in the community appears within 1,000 meters of the landfill. It is mostly categorized as a serious groundwater contamination, which occurs within

Table 1. Quality standard of leachates

Parameters	Maximum concentration	
	Value	Unit
pH	6 – 9	-
BOD	150	mg/L
COD	300	mg/L
TSS	100	mg/L
N Total	60	mg/L
Mercury	0.005	mg/L
Cadmium	0.1	mg/L

200 meters of the landfill. This suggests that the contamination of the groundwater near the landfill must be considered, especially in developing countries (Han et al., 2016).

The composition of leachate depends on the composition of the waste. This is according to (1) the type and age of the buried waste, (2) the water balance in the landfill and (3) the microbes that play a role in the decomposition. The process of decomposing waste requires the presence of decomposing microbes, including fungi, yeast, and actinomycetes. These microbes can dissolve in water. This means that if there is a water flow present, then the microbes will be carried away by the water. Leachate generally contains high levels of organic and inorganic compounds (sodium, potassium, calcium, magnesium, chlorine, sulfates, phosphates, phenols, nitrogen and heavy metal compounds). The action of bacteria helps rainwater in the decomposition process to produce leachate. Inorganic macro-components such as chloride, ammonia, Cd, Ni, Cu, Pb, and Fe and xenobiotic organic compounds such as halogenated organic compounds are usually contained in leachate. Chemicals such as pesticides, solvents and heavy metals may also be present (Kostova, 2006). The quality standards for the leachate water produced from the final processing site (landfill) can be found in Appendix I of the Regulation of the Minister of Environment of the Republic of Indonesia No. 59 of 2016 concerning the Quality Standard of Leachate for Business and/or Activities of Waste Final Processing Sites.

The movement of leachate in soil

Leachate can seep into the ground and mix with the groundwater or flow on the ground and infiltrate into the river water. The ability of leachate to contaminate either the surface water or groundwater is influenced by the geological

conditions (soil type and rock type) as well as the hydrological conditions (depth and movement of groundwater, amount of rainfall, and surface flow control) where the landfill is located.

Gravitational potential is the main force that causes the flow of leachate, which generally moves from a high to a low angle. As the distance from the pollution source increases, the contaminant concentration in groundwater decreases (Adeolu et al., 2011; Ling and Zhang, 2017; Mor et al., 2006). Much of the research related to soil-water environmental assessments near landfills and waste management facilities has resulted in the impact of landfills on the groundwater quality (Adamcová et al., 2016; Calvo et al., 2005; Gworek et al., 2016; Koda, 2012; Koda et al., 2017, 2015; Ling and Zhang, 2017; Pande et al., 2015).

The mechanism of the entry of leachate into the groundwater layer, especially shallow groundwater, involves through several stages. Leachate can contaminate groundwater. The mechanism for the entry of leachate into the groundwater layer, especially shallow groundwater (wells), goes through the following process:

1. Leachate is usually found in the areas used to dispose of waste without management, namely in a layer approximately 2 meters below the soil surface.
2. In particular, if the leachate enters the ground through infiltration, then immediately the soil surface is filled with water.
3. Due to such factors as rainwater, the leachate is accelerated into the soil layer, namely the aeration zone. This is at a depth of 10 meters below the soil surface.
4. Due to the large amount of leachate formed, the leachate water enters either the shallow groundwater layer or the saturated groundwater layer.
5. In the saturated soil layer, the collected water is mixed with the leachate water which is used as a drinking water source through shallow wells (Hadi and Irfan, 2016).

Groundwater

Shallow groundwater is the water that is above the first impermeable layer. Shallow groundwater is very vulnerable to contamination. Shallow ground water occurs because of the process of water infiltration through the surface of the soil. Any mud will be retained, as will

some bacteria, so the ground water will be clear but contain more chemicals (dissolved salts) because it passes through the soil layer which has certain chemical elements. This soil layer functions as a filter. However, the risk of impurity is still present, especially at the water level close to ground level. After meeting a dense layer of water, the water will collect as shallow groundwater. This groundwater is used as a clean water source through shallow wells.

Shallow groundwater comes in at a depth of ± 15 meters. As a source of clean water, shallow groundwater is often considered from a rather good quality perspective. In terms of quantity, it is not good and it depends on the season.

RESEARCH METHOD

The Pollution Index method is based on two quality indices. The first is the Average Index (IR). This index shows the average level of pollution using all of the parameters in one observation. The second is the Maximum Index (IM). This index focuses on one type of parameter that predominantly causes a decrease in water quality in one observation.

On the basis of the Decree of the Minister of Environment Number 115 of 2003, the water quality can be determined using the Pollution Index. This is a different concept from the Water Quality Index. The Pollution Index (IP) is determined for a particular designation and then developed for several uses for all parts of a water body or part of a river.

L_{ij} indicates the concentration of the water quality parameters listed in the Water Quality Standard (j) and C_i indicates the concentration of the water quality parameters (i) obtained from the analysis of the water samples at a sampling location from the river channel. PI_j is the Pollution Index for the designation (j) which is a function of C_i/L_{ij} .

$$PI_j = (C_1/L_{1j}, C_2/L_{2j}, \dots, C_i/L_{ij}) \quad (1)$$

Each C_i/L_{ij} value indicates the relative pollution caused by the water quality parameters. This ratio has no units involved. The $C_i/L_{ij} = 1.0$ is a critical value because this value is expected to be met by the Water Allocation Quality Standard. If C_i/L_{ij} is > 1.0 for a parameter, then the concentration of this parameter must be reduced or set aside if a body of water is used for a particular

designation (j). If this parameter is meaningful for the chosen designation, then it is absolutely necessary to treat the water. In the IP model, various water quality parameters are used; it requires an average value of the entire C_i/L_{ij} value as a measure of the pollution. This value will not be meaningful if one of the C_i/L_{ij} values is greater than 1. This index must include the maximum C_i/L_{ij} value.

$$PI_j = \{(C_i/L_{ij})_R, (C_i/L_{ij})_M\} \quad (2)$$

value $(C_i/L_{ij})_R$: average value C_i/L_{ij}
 $(C_i/L_{ij})_M$: maximum value C_i/L_{ij}

The water will be increasingly polluted at a designation (j) if the value of $(C_i/L_{ij})_R$ and/or $(C_i/L_{ij})_M$ is greater than 1.0. If the maximum value of C_i/L_{ij} and/or the average value of C_i/L_{ij} is greater, then the level of pollution of the water body will also increase.

$$PI_j = m \sqrt{\left(\frac{C_i}{L_{ij}}\right)_M^2 + \left(\frac{C_i}{L_{ij}}\right)_R^2} \quad (3)$$

Where m = balancing factor

The critical state is used to calculate the value of m $PI_j = 1.0$ if maximum value $C_i/L_{ij} = 1.0$ and average value $C_i/L_{ij} = 1.0$ so that:

$$1.0 = m\sqrt{(1)^2 + (1)^2} \quad (4)$$

$m = 1/\sqrt{2}$, then the equation becomes:

$$PI_j = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)_M^2 + \left(\frac{C_i}{L_{ij}}\right)_R^2}{2}} \quad (5)$$

This method can directly relate the level of contamination to whether or not the river can be used for certain purposes and the value of certain parameters. The Water Quality Standard (BMA) used in this study was the Class II Water Designation Criteria (PP 82/2001). The use of Class II BMA is due to the absence of a technical study

Table 2. Relationship between the pollution index value and water quality

Pollution index value	Water quality status
0 – 1.0	Good condition
1.1 – 5.0	Light polluted
5.0 – 10.0	Moderate polluted
>10.0	High polluted

on the designation of the water for Lake Ranupani. Under a condition where a technical study of the designation of the water sources has not been carried out, BMA uses the criteria for designating class II water even though the water source is used for various raw water needs (Government Regulation 82/2001 article 5, article 9, article 11, article 12, paragraph 1).

RESULTS AND DISCUSSION

Sidoarjo Regency is included in the medium city category. On the basis of the Jakstrada, the area of waste services in Sidoarjo Regency is 714.24 km² with the percentage of solid waste service coverage being 48%. The amount of waste dumped in the landfill is 575 tons/day and the amount of unmanaged waste is 227 tons/day. The amount of daily waste generated by the capital city in Sidoarjo Regency is 168.00 tons/day while the daily waste generation for the non-capital cities is 1112.00 tons/day. According to Marendra (2019), the leachate discharge generated by Jabon landfill is 3.72 liters/second. On the basis of the calculations by Jakstrada Sidoarjo Regency, Jabon Landfill land has been depleted in 2019 (the land used in 2019 was ± 10.1 Ha) because it has exceeded its capacity of only 8.5 Ha.

The measurement of the waste generation entering Jabon Landfill is based on the primary data from the observations conducted at Jabon Landfill. This is done because Jabon Landfill does not have a weighbridge yet. The waste quantity analysis was therefore calculated from the volume of waste according to the number of waste transport fleets and their capacity every day. The results of the data collection show that the total waste

generation is 1206.65 m³/day or 329198.9 kg/day (Lumban Gaol and Warmadewanthi, 2017).

The composition of the waste at Jabon Landfill was observed. The types of waste entering the landfill from the observations were compostable waste (food scraps/crusts and garden waste) consisting of food scraps totaling 77% and garden waste totaling 26.77%. The following type of waste had the largest percentage at 15.6% plastic (HDPE, LDPE, PET, PS Styrofoam, PP bag, and other plastics), 10.4% diapers (including diapers and pads), 4.8% fabric, 2.66% paper, 1.86% cartons, 0.54% rubber (used sandals, rubber bands and used tires), 0.27% hazardous waste (spent batteries, leftover medicines, used lamps, objects contaminated with hazardous etc), 0.25% glass (glass bottles and other glass shards), 0.16% iron (iron plates and tin) and 1.92% other (waste not included in any of the above group specifications).

The dispersion of contaminants was observed by determined the direction of groundwater flow. Several groundwater points (wells) were selected to measure the elevation of the water level. Measurements are taken from the depth of the water face of the well lip, the height of the well lip from the ground. The groundwater level elevation is then calculated. Dispersion is assumed to be in line with groundwater flow and groundwater flow from the higher water level elevation to the lower elevation. Twelve well points that have been surveyed are then plotted for use in dispersion modeling are shown in Table 4.

The physical characteristics of the waste were also analyzed using proximate analysis, which included the analysis of the moisture content, volatile solids, fixed carbons and ash content. Proximate analysis was carried out in the laboratory to determine the water content in the waste. The Volatile Solids (VSs) were analyzed to determine the organic matter content in the waste and the ash analysis was used to determine the content of the ash produced from burning waste. The analysis of the waste characteristics can be divided into several types, namely biowaste organic waste (food waste and garden waste), non-biowaste organic waste (plastic, paper, cardboard, cloth, rubber and other organics), bio + non-biowaste and mixed waste (combined organic and inorganic). The results of the proximate analysis are presented in Table 5. The chemical characteristics of the waste were also analyzed using ultimate analysis. The results of the analysis are shown in Table 6.

Table 3. Waste generation in Jabon Landfill

Day	Waste generation (m ³ /day)	Mass (kg/day)
1	1,218.0	332,295.4
2	1,214.4	331,313.2
3	1,198.8	327,057.2
4	1,193.6	325,638.5
5	1,228.0	335,023.6
6	1,225.6	334,368.8
7	1,201.2	327,712.0
8	1,173.6	320,182.1
Average	1,206.6	329,198.9

Table 4. Twelve well points

Number	Coordinate	The Depth of Groundwater from the surface Well (cm)	Height surface Well (cm)	Elevation (m)	Ground water level (cm)	Distance from Landfill (km)
Well 1	7°32'42.00"S 112°45'38.00"E	198	70	4	272	0.55
Well 2	7°32'37.01"S 112°45'26.37"E	175.5	29	3	153.5	0.94
Well 3	7°32'46.01"S 112°45'20.99"E	221.5	60	3	138.5	0.91
Well 4	7°33'28.09"S 112°45'42.87"E	149	42	2	93	0.96
Well 5	7°33'39.15"S 112°45'50.74"E	189.5	79	2	89.5	1.31
Well 6	7°33'11.04"S 112°46'46.60"E	149.5	65	3	215.5	1.81
Well 7	7°33'42.50"S 112°46'19.30"E	121	54	3	233	1.68
Well 8	7°32'50.20"S 112°43'52.38"E	160	76.5	3	216.5	3.57
Well 9	7°32'58.77"S 112°44'41.55"E	164	61.5	3	197.5	2.10
Well 10	7°33'9.50"S 112°44'42.40"E	89	0	2	111	2.10
Well 11	7°33'10.90"S 112°45'5.72"E	156	73	2	117	1.39
Well 12	7°32'37.72"S 112°47'13.74"E	170	31	3	161	2.68

The determination of the status of well water quality around the landfill area was carried out using the Pollution Index Method (IP) as stated in the Decree of the Minister of Environment Number 115 of 2003 concerning Guidelines for Determining the Status of Water Quality listed (see Table 4.1). A pollutant index score in the range of 0–1.0 means that the condition is good, while 1.1–1.50 is lightly polluted, 5.0–10.0 is moderately polluted and >10 is heavily polluted.

An example method for calculating the Pollution Index value for Well 1 is as follows:

a) Well 1's pH is 7.5 with a Class I pH quality

standard of 6 – 9. Because the pH parameter quality standard is in the form of a range, the average (Lij) is calculated first:

$$(Lij) \text{ average} = \frac{(Lij)_{max} + (Lij)_{min}}{2}$$

$$(Lij) \text{ average} = \frac{9+6}{2}$$

$$(Lij) \text{ average} = 7.5$$

b) The pH of the measurement results shows the same value as the quality standard, meaning that the C/L value can be obtained using the following calculation:

Table 5. Proximate analysis results

Parameter	Waste characteristic	%
Water content	Organic biowaste	74.08
	Organic non-biowaste	35.39
	Organic biowaste + non-biowaste	54.22
	Mixture (organic + anorganic)	50.71
Volatile Solid	Organic biowaste	7.05
	Organic non-biowaste	9.12
	Organic biowaste + non-biowaste	9.54
	Mixture (organic + anorganic)	9.04
Fixed Carbon	Organic biowaste	3.27
	Organic non-biowaste	10.26
	Organic biowaste + non-biowaste	4.93
	Mixture (organic + anorganic)	2.16
Ash content	Organic biowaste	15.61
	Organic non-biowaste	45.23
	Organic biowaste + non-biowaste	31.31
	Mixture (organic + anorganic)	38.10

Table 6. Ultimate analysis results

Parameter	Waste characteristic	%
Total N	Organic biowaste	0.59
	Organic non-biowaste	1.93
	Organic biowaste + non-biowaste	1.22
	Mixture (organic + anorganic)	1.5
Hydrogen	Organic biowaste	6.51
	Organic non-biowaste	5.88
	Organic biowaste + non-biowaste	5.58
	Mixture (organic + anorganic)	5.98
Carbon	Organic biowaste	54.25
	Organic non-biowaste	49.01
	Organic biowaste + non-biowaste	46.53
	Mixture (organic + anorganic)	49.86
Oxygen	Organic biowaste	38.65
	Organic non-biowaste	43.18
	Organic biowaste + non-biowaste	46.67
	Mixture (organic + anorganic)	42.65



Figure 1. Sampling points around Jabon Landfill (Marendra and Tangahu, 2020)

$$(Ci/Lij) = \frac{Cim-(Lij)average}{(Lij)min-(Lij)average}$$

$$(Ci/Lij) = \frac{7.5-7.5}{9-7.5}$$

$$(Ci/Lij) = 0$$

On the basis of the analysis, it is known that the value (Ci/Lij) <1.0 does not require a new calculation (Ci/Lij). It can therefore be used without calculating the value (Ci/Lij) using the new formula. The calculations (Ci/Lij) were performed for the other parameters, namely COD, BOD and Fe. The results of the analysis regarding the calculated values (Ci/Lij) are shown in Table 7.

On the basis of the results of the calculation (Ci/Lij) for each new parameter, calculating the new value (Ci/Lij) is as follows:

$$(Ci/Lij) average = \frac{\left(\frac{Ci}{Lij}\right)_1 + \left(\frac{Ci}{Lij}\right)_2 + \left(\frac{Ci}{Lij}\right)_3 + \left(\frac{Ci}{Lij}\right)_4 + \dots + \left(\frac{Ci}{Lij}\right)_n}{n}$$

$$(Lij) average = \frac{0.00+7.42+6.85+0.27}{4}$$

$$(Lij) average = 3.638$$

On the basis of the results of the new (Ci/Lij) calculation, we then determined the maximum (Ci/Lij) value of the highest (Ci/Lij) value for

Table 7. Calculation of the C/L value

Parameter	Concentration of Point 1	Standard	C/L	C/L new
pH	7.5	6–9	0.00	0.00
BOD	38.60	2.0	19.30	7.42
COD	148.32	10.0	14.83	6.85
Iron	0.08	0.3	0.27	0.27

the new (Ci/Lij) of all parameters. The maximum value (Ci/Lij) is 7.42.

We then calculated the Pollution Index value according to the following calculations:

$$IP_j = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)_M^2 + \left(\frac{C_i}{L_{ij}}\right)_R^2}{2}}$$

$$IP_j = \sqrt{\frac{3.638^2 + 7.42^2}{2}}$$

$$IP_j = 5.31$$

The IP value of each well monitoring point can be seen in Table 8. The highest pollution status was found in Well 7 with an IP value of 5.45. The lowest IP value was obtained from Well 12 with an IP value of 1.06. This comparison of the pollution status can be seen using the Pollution Index method in Figure 2.

The leachate samples were found to have the largest Pollution Index value of 7.70 with an associated status of moderately polluted for water quality. The first well closest to Jabon Landfill in the east had an IP of 5.31 with a fairly polluted quality status. Wells 2 to 6 wells that are the farthest away from the landfill are lightly polluted. The higher the pollutant index value, the more polluted the well water is.

To the south of Jabon Landfill, Well 7 at a distance of 196 m from the landfill has an IP of 5.45, categorizing it as moderately polluted. Wells 8 to well 12 have a lightly polluted water quality status. To the west of the Jabon Landfill, Wells 13 to 17 have a lightly polluted water quality status. Wells 13 and 14 are 103 and 197 meters apart

Table 8. Groundwater quality status around the landfill (Marendra and Tangahu, 2020)

No.	Sampling point	Distance (m)	Direction	Pollution index	Water quality status
1	Well 1	219	East	5.31	Moderate polluted
2	Well 2	241	East	4.79	Light polluted
3	Well 3	379	East	4.41	Light polluted
4	Well 4	485	East	3.23	Light polluted
5	Well 5	971	East	2.98	Light polluted
6	Well 6	1000	East	1.91	Light polluted
7	Well 7	196	South	5.45	Moderate polluted
8	Well 8	211	South	3.50	Light polluted
9	Well 9	353	South	2.91	Light polluted
10	Well 0	444	South	2.17	Light polluted
11	Well 11	710	South	1.32	Light polluted
12	Well 12	990	South	1.06	Light polluted
13	Well 13	103	West	2.76	Light polluted
14	Well 14	197	West	2.56	Light polluted
15	Well 15	391	West	1.42	Light polluted
16	Well 16	464	West	1.91	Light polluted
17	Well 17	707	West	1.39	Light polluted
18	Well 18	911	West	0.93	Good condition
19	Leachate	0	—	7.70	Moderate polluted

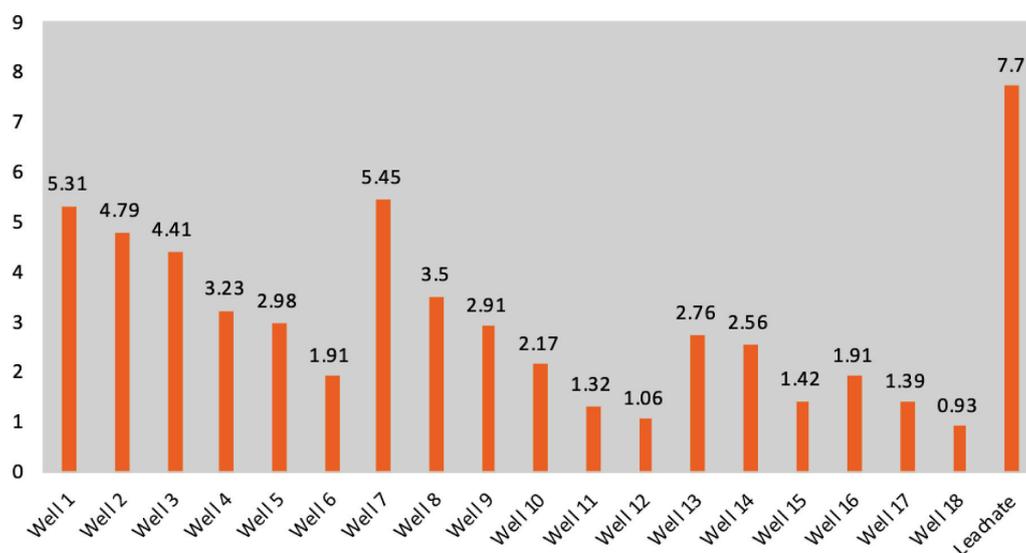


Figure 2. Pollution status based on the pollution index value

from the landfill, respectively. Although they are west of the landfill, there is still leachate seeping into shallow groundwater at that distance. However, Well 16 has a higher Pollutant Index value because the well has an agricultural pen. The cage is less than 11 meters from the well, meaning that pollution can occur.

The variables used in this analysis were the independent variables of Distance (X1) and Groundwater Depth (X2) and the dependent variable of

Water Quality Status (Y). A statistical test was performed using multiple regression methods.

From the SPSS output, it was found that the significance value of the Distance variable (X1) was 0.005 and the significance value of the Groundwater Depth variable (X2) was 0.000. Since the significance values of 0.005 and 0.000 are lower than 0.05, according to the basis for the decision-making in the t test, it can be concluded that Distance (X1) and the Initial Depth of

Table 9. Multiple regression test (Marendra and Tangahu, 2020)

Model		Coefficient ^a				
		Non standardized coefficient		Standardized coefficient		
		B	Std. error	Beta	t	sig
1	(Constant)	8.940	1.344		6.653	0.000
	Distance (X1)	-.003	0.001	-.629	-3.238	0.005
	Groundwater depth (X2)	-.793	0.170	-.758	-4.653	0.000
Dependent variable: Water Quality status (Y)						

the Groundwater (X2) affects Water Quality (Y) (see Table 9).

Distance has an important role in the distribution of contaminants. The distance to the landfill and the associated water quality status tend to be directly proportional. In other words, the closer the dug well is to the pollutant source, the greater the pollution. Dug wells provide water that comes from the groundwater relatively close to the soil surface, making it vulnerable to contamination through seepage from pollutant sources. The distribution of the leachate pollution can be identified up to a depth of 15 meters. The effect of the depth of the groundwater level on the concentration of pollutants is in accordance with the depth of the groundwater level. This will determine the ability to reduce the pollutant content. The shallower the groundwater, the greater the likelihood of pollution is. The groundwater level is used as a reference to determine the effects of pollution.

The analysis of the pH values, COD and BOD concentrations in Jabon Landfill and in the wells around the landfill was also taken from the secondary data based on the research by Mirwan and Saputra, (2018). According to the results of this study, the leachate content of Jabon Landfill is as shown in Table 10.

On the basis of this research, in order to determine leachate contamination in the wells around Jabon Landfill, the samples were taken from the surface of the well water and at a depth of 1 m at a radius of 600 m, 800 m and 1,000 m from Jabon Landfill.

PH analysis results

The samples taken from the surface of the water and at a depth of 1 m at a radius of 600 m, 800 m, and 1,000 m indicate that the highest pH value was found in Wells 1 and 2 (radius 600 m) at 7.5. The lowest pH value was found in Wells 3, 4 and 5 (radius 1,000 m) at 7.2.

COD analysis results

The samples taken from the surface of the water and at a depth of 1 m at a radius of 600 m, 800 m, and 1,000 m showed that the highest COD value was found in Wells 1 and 2 (radius 600 m) at 148.32 mg/L. The lowest COD value was found in Wells 3, 4 and 5 (radius 1,000 m) at 15.68 mg/L.

BOD analysis results

The samples were taken from the surface of the water and at a depth of 1 m in a radius of 600 m, 800 m, and 1,000 m showed that the highest BOD value was found in Wells 1 and 2 (radius 600 m) at 38.06 mg/L. The lowest BOD value was found in Wells 3, 4 and 5 (radius 1,000 m) at 8.01 mg/L. The quality of the water around Jabon Landfill can be seen in Table 11.

The results of the groundwater level measurements in each well at all points in each of the Eastern, Southern and Western regions were shown in Figures 3 to 5.

In the Eastern region, the well with the deepest groundwater level was Well 4 at 1.2 m. The

Table 10. Leachate concentration of Jabon Landfill

Parameter	Unit	Result		Standard
		I	II	
pH		8.4	8.4	6 – 9
COD	mg/L	4,120.0	739.458	10
BOD	mg/L	3,862.5	659.555	2

Table 11. Fe concentration of the well water in Tambak Kalisogo Village, Jabon Sub-District, Sidoarjo District

Distance (m)	Number of wells	Fe average (mg/L)	Standard* (mg/L)
0 – 50	5	1.694	0.3
51 – 100	6	0.797	
101 – 150	4	0.106	
151 – 200	5	0.081	

Table 12. Well water characteristics – frequency distributions based on turbidity criteria in Tambak Kalisogo Village, Jabon Sub-District, Sidoarjo District

Distance (m)	Turbidity criteria				Number of well	Percentage (%)
	Clear (n)	Percent (%)	Turbid (n)	Percent (%)		
0 – 50	-	-	5	100	5	100
51 – 100	6	100	-	-	6	100
101 – 150	4	100	-	-	4	100
151 – 200	5	100	-	-	5	100
Total	15	75	5	25	20	100

Table 13. Well water characteristics – frequency distributions based on the taste criteria in Tambak Kalisogo Village, Jabon Sub-District, Sidoarjo District

Distance (m)	Taste criteria				Number of well	Percentage (%)
	No taste	Percent (%)	Taste	Percent (%)		
0 – 50	3	60	2	40	5	100
51 – 100	2	33.3	4	66.7	6	100
101 – 150	2	50	2	50	4	100
151 – 200	5	100	-	-	5	100
Total	12	60	8	40	20	100

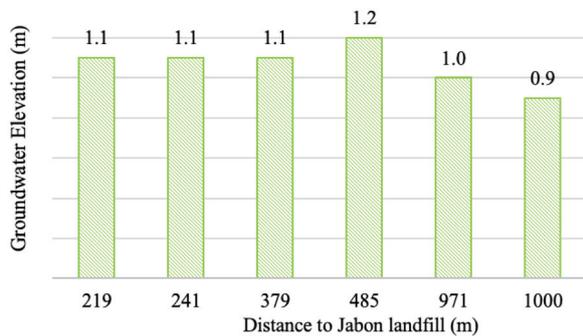


Figure 3. Groundwater elevation in the Eastern Region

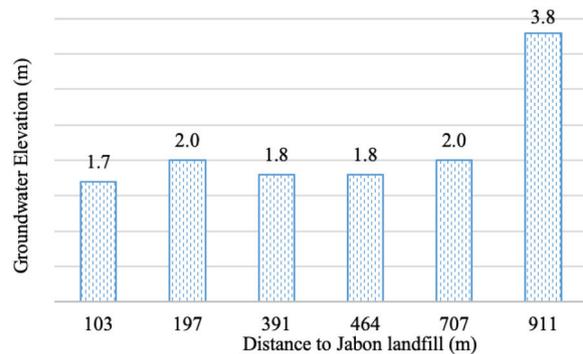


Figure 4. Groundwater elevation in the Southern Region

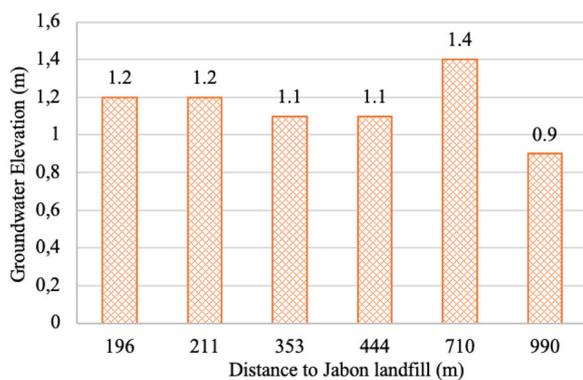


Figure 5. Groundwater elevation in the Western Region

shallowest was Well 6 at an altitude of 0.9 m at a distance of 900 m from Jabon Landfill. In the southern region, the deepest groundwater level was obtained at Well 12 at a distance of 911 m at a depth of 3.8 m. The shallowest groundwater level was at Well 7 at a distance of 103 m from Jabon Landfill obtained at a depth of 1.7 m. A depth of 1.4 m, which is the deepest groundwater level, was obtained at Well 17 at a distance of 710 m in the West Area. A depth of 0.9 m, which is the shallowest groundwater level, was obtained at Well 18 at a distance of 990 m in the same area.

CONCLUSIONS

On the basis of the obtained results and discussion, it can be concluded that:

1. The parameters related to the leachate characteristics in the groundwater around Jabon Landfill such as pH have a higher value compared to the pH in Jabon Landfill at 7.2 to 7.5. The pH value in Jabon Landfill is 6.35. In addition, the Fe parameter has a lower value, namely 1.694 in the groundwater well closest to Jabon Landfill. The further away from Jabon Landfill the well is, the lower the Fe concentration, namely down to 0.081 at a distance of up to 200 meters.
2. The wells closer to Jabon Landfill showed as having a value closer to the leachate characteristics of Jabon Landfill. Details at 0 – 250 m indicates Lightly Polluted to Moderately Polluted, 251 – 500 m indicates Lightly Polluted and 501 – 1,000 m indicates Good to Lightly Polluted.
3. On the basis of the Pollution Index, the highest value was 5.45 at Well 7 located 196 m from Jabon Landfill. Meanwhile, the well furthest from Jabon Landfill at a distance of 1,000 m had a lightly polluted status with a Pollution Index of 1.91. The further the location of the well from Jabon Landfill, the lower the Pollution Index is, showing that the pollution status tends to improve. Overall, the pollution status of the 18 wells examined shows that 2 wells are moderately polluted, 15 wells are lightly polluted and 1 well is in good condition.

Acknowledgement

The authors would like to show gratitude to The Ministry of Research and Technology, Program of Research Technology National Research and Innovation Agency (RISTEKBRIN) for the full financial support. The authors also thank to The Directorate of Research and Community Service (DRPM), Institut Teknologi Sepuluh Nopember for the letter of agreement for the implementation of basic research.

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