Journal of Natural Resources and Environmental Management
11(4): 578-586. http://dx.doi.org/10.29244/jpsl.11.4.578-586
E-ISSN: 2460-5824
http://journal.ipb.ac.id/index.php/jpsl

Water quality in areas around Galuga Landfill, Bogor Regency, West Java

Yayat Hidayat[a], Wahyu Purwakusuma[a], Sri Malahayati Yusuf[a], Latief Mahir Rachman[a], Enni Dwi Wahjunie[a], Dwi Putro Tejo Baskoro[a], Aditia Sapto Utomo[b], Elianah[b]

[a] Lecturer of the Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University, Dramaga, Bogor, 16680, Indonesia [+62 251-629360]
[b] Alumni of the Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University, Dramaga, Bogor, 16680, Indonesia [+62 251-629360]

Article Info:
Received: 27 - 10 - 2021
Accepted: 14 - 12 - 2021

Keywords:
Galuga landfills, leachate, water quality

Corresponding Author:
Yayat Hidayat
Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University;
Tel. +62-251-629360,
Email: yahida@apps.ipb.ac.id

Abstract*. The research is aimed to analyze leachate, surface water, and groundwater characteristics around Galuga landfill site, Bogor District. Water samples were taken in the dry season of 2014 and the end of the rainy season of 2015 from several sites in areas around Galuga landfills, including leachate water, surface water, and groundwater. Leachate, surface water, and groundwater had temperature and pH in normal ranges; whereas nitrate and Pb contents were high to very high levels, especially in site adjacent to waste piles. The concentrations decreased in line with increasing distance from waste piles. Higher content of nitrate in leachate occurred in dry season, but in well water, it was found in the rainy season. Meanwhile, Pb content in well water were high, both in dry and rainy seasons. Concentrations of nitrate and Pb were higher in leachate water than wastewater quality standard, so that the leachate water was unsafe to be discharged directly to natural waters. The high content of nitrate and Pb caused the well water unsuitable to be consumed without prior water treatment processing.*

How to cite (CSE Style 8th Edition):
Hidayat Y, Purwakusuma W, Yusuf SM, Rachman LM, Wahjunie ED, Baskoro DPJ, Utomo AS, Elianah. 2021. Water quality in areas around Galuga Landfill, Bogor Regency, West Java. JPSL **11**(4): 578-586. http://dx.doi.org/10.29244/jpsl.11.4.578-586.

INTRODUCTION

A landfill is a garbage collection site that accommodates waste from various places, which is then managed so as not to cause pollution in the surrounding areas. The wastes collected in the landfill usually consist of organic wastes (originated from domestic wastes such as food and drink wastes, vegetables, crop wastes, and animal wastes) and inorganic wastes originated from industry and household activities like plastic/glass bottles, fabric waste, household appliance waste, and battery. Naturally, organic waste is quite easy to be decomposed, whereas inorganic waste, especially plastic waste, is very difficult to decompose naturally and needs a long period of time. Besides causing an unpleasant odor (Raghab *et al.*, 2013; Kamaruddin *et al*., 2015), the pile of garbage in landfill areas has the potential to become site for germ development, reduce the aesthetic value (creating bad view), and become a pollutant source for the surrounding areas particularly for water resources (Aziz *et al*., 2015; Kiayee, 2013).

The main pollutants in landfill area which are originated from the decomposition of organic matter are methane gas, organic acids (humic and fulvic), metal compounds, and other compounds dissolved and suspended particles in leachates, depending on weather leachate flow increase in rainy season and decrease in dry season (Naveen *et al.*, 2014). Methane gas that evaporates into the air could affect the composition of greenhouse gases in the atmosphere. Water leachate that percolates into the soil could affect the groundwater quality, while water leachate which is carried by surface flow, would affect the quality of surface water, both in the river and lakes. The risk of groundwater pollution is probably the most severe environmental impact because several landfills were built without the engineered liner and leachate collection systems (Kjeldsen *et al.*, 2002). Leachate in soil surface could create pollution in the surrounding areas, both above and below ground. Surface water which is polluted by leachate with high content of organic substances can undergo a reduction of availability of dissolved oxygen in the water, which will further affect the number, types, and diversity of water biota.

Besides containing organic acids and other phenolic compounds, leachate also contains metal and heavy metal elements originating from organic and inorganic waste that accumulates in landfill. The amount of leachate produced from the landfill depends on rainfall that infiltrates into the waste piles, surface slope, and application of ground cover/land cover crops.

Galuga landfill, located in Galuga village, Cibungbulang Sub District, Bogor Regency, was operated since 1986 as a site to collect garbage waste from Bogor City and Bogor Regency. Galuga landfill is equipped with several supporting facilities such as heavy equipments for compacting the waste, wastewater treatment installation, and compost factory. The wastewater treatment facilities have not functioned properly since 2011, and therefore the leachate water is flowed to the nearest swamp and then being flowed to the Cimanggir sewer, which afterward flows toward the Cianten River. The leachate originated from galuga landfill mixed with swamp water and potentially causes pollution in the surrounding areas, comprising surface water, soil body, and groundwater. One of the biggest problems in landfills is leachate discharge (Raghab *et al.*, 2013). This research aimed to analyze the quality of leachate water, surface water, and well water in areas around Galuga Landfill to describe environmental quality around Galuga Landfill areas, Bogor Regency.

METHOD

Research Location and Time

Field research was conducted in Galuga Landfill, Galuga village, Cibungbulang Sub District, Bogor Regency from July-August 2014 (dry season) and March-May 2015 (the end of rainy season). Water quality analysis was done in the Laboratory of Soil Science and Land Resource Department and PROLINK Laboratory, IPB.

Data Collecting Method

Water samples were taken from several sites near the Galuga Landfill, where the leachate began to flow until it mixes with water in Cianten river (Figure 1). In the dry season, water samples were collected at 6 sites which comprised 4 samples from sewerage and 2 other samples from people's well water. At the end of rainy season 4 water samples were collected from the ditch where the leachate flowed; two other samples were taken from rice field, and one sample from well water. Sampling of water was done during sunny days, assuming that the leachate concentration was at high level, with three replications. In the end of rainy season, soil samples were also collected from the water sample site using, Belgian soil auger at 0-20 cm, 20-40 cm, and 40-60 cm depths. Coordinate points of the sample in Figure 1 are presented in Table 1.

Equipments being used in this research were Hg thermometers, 1.5 litter, and 300 ml polyethylene plastic bottles, cooler box, soil auger, GPS (Global Positioning System), pH-meter, AAS (Atomic Absorbtion Spectrophotometer), spectrophotometer, vacuum pump, 0.45 µm millipore paper, measuring cups, cup glass, kjeldahl tubes, incubation bottles, pippetes, and other tools used in laboratory analysis.

Data Analysis Method

The data resulting from the laboratory were analyzed using quantitative approaches. Descriptive analysis was done to describe the collected data through their values. Afterward, the data were compared from one sample site to those of other locations and compared with the government standard, namely Government regulation No 82-year 2001 (KLHK, 2001), Health Ministry regulation No 492-year 2010 (Permenkes, 2010), and standard of US Environmental Protection Agency 2005 (USEPA, 2005).

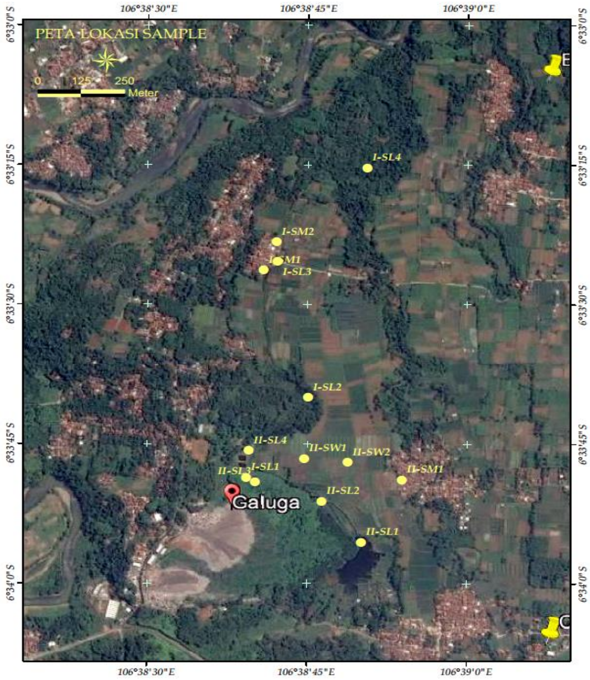

Figure 1 Water and soil sample locations

Table 1 Sampling location coordinates

Location	Geographic Coordinate	Field Condition
I-SL1	106°38'39.2" E 06°33'48.6" S	Leachate water drainage before wastewater treatment facilities
I-SL2	106°38'45.0" E 06°33'40.0" S	Leachate water drainage after wastewater treatment facilities
I-SL3	106°38'42.1" E 06°33'25.4" S	Leachate water drainage around the settlement area
I-SL4	106°38'50.5" E 06°33'15.3" S	Meeting point of leachate drainage and Cimanggir drainage
I-SM1	106°38'40.8" E 06°33'26.3" S	People's well
I-SM2	106°38'42.0" E 06°33'23.3" S	People's well
II-SL1	106^{0}38' 50.0"E 06^{0}33' 55.5"S	Leachate reservoir swamp (hyacinth)
II-SL2	106^{0}38' 46.3"E 06^{0}33' 51.1"S	100 m leachate water drainage after reservoir
II-SL3	106^{0}38' 40.1"E 06^{0} 33' 49.1"S	Leachate water drainage before reservoir
II-SL4	106^{0}38' 39.5"E 06^{0}33' 45.7" S	Leachate water drainage near the wastewater treatment facilities
II-SW1	106^{0}38' 44.7"E 06^{0}33' 46.6" S	Irrigation water of rice field
II-SW2	106^{0}38' 48.7"E 06^{0}33' 47.0"S	Irrigation water of rice feld
II-SM1	106^{0}38' 53.8"E 06^{0}33' 48.8"S	People’s well

RESULTS AND DISCUSSION

Galuga landfill, located in Galuga village, Cibungbulang Sub District, Bogor Regency has been operating since 1986 as a site to collect garbage waste from Bogor City and Bogor Regency. In the beginning of the operation, Galuga Landfill covers an area of 17.0 ha, but currently the total area of Galuga landfill reaches about 27.8 ha which consist of garbage disposal area, garbage piles area, composting area, road facilities and drainage channels, sewerage and wastewater treatment plant, office building and supervisory posts, and health service post. Galuga landfill is found in relatively undulating area and directly adjacent to agricultural and settlement areas with high rainfall intensity (2 500-3 000 mm/year).

Galuga Landfill accommodates various types of waste which are then stacked on soil surface. The landfill was categorized as open dumping system so that it had potential to cause environmental pollution such as air pollution (dust, smell, and greenhouse gases), and water and soil pollution, due to leachate produced from waste piles. The leachate could spread on the soil surface so that it could contaminate surface water and groundwater (including well water around the landfill areas). The composition of pollutant in the leachate was strongly influenced by the waste characteristics (organic-inorganic), ages of waste piles, ease of decomposition (soluble-insoluble), waste pile characteristics (temperature, pH, humidity), water source characteristics (water quantity and quality as influenced by climate and hydrogeology), ground cover composition, nutrient availability, microbes, and the presence of inhibitor. The resulting chemical composition of the leachate and the concentration of pollutant materials varied for each landfill site (Naveen *et al.,* 2014).

Temperature

Water temperature is strongly influenced by environmental factors, especially the amount of solar radiation received by the water body. The high temperature of the water causes an increase in a chemical reaction in water (such as increase in photosynthesis rate) and declining amount of dissolved oxygen. There was no clear difference in pattern of temperatures between leachate water, surface water, and well water. Leachate water had temperatures between 27-31˚C (dry season) and 26-31˚C (the end of rainy season), those of rice field water ranged between 29-33˚C, and well water between 27-28˚C (dry season) and 26-31˚C (the end of rainy season). The difference more influenced the difference in water temperature in the amount of solar radiation received by the water bodies due to water sampling time, which was done between 8-11 AM. Air temperature around the well water site was relatively lower than air temperature in other locations, causing lower temperature of the well water.

Degree of Acidity (pH)

Value of pH is acidity degree used to express the level of acidity or alkalinity of solution. A low pH value indicates the dominant hydrogen ions (H^+) content, and a higher pH value shows more content of hydroxyl ions (OH^-). The pH value is an important parameter of water quality because of its effect on biological and chemical processes in water.

The pH of leachate water was classified as quite alkaline. Leaching process by lower amount of rainwater in the dry season caused leachate water to have a high enough organic acid content, so the pH of leachate water was lower (pH 7.48-8.40) than pH of leachate water in the end of rainy season (pH 7.98-8.67) (Table 2). Well water was classified as ranging between slightly acid-neutral (6.06-6.97), while rice field water was categorized as ranging between neutral-quite alkaline (7.03-8.21). The pH value is still in the normal range, both for leachate water (Direktorat Penyelidikan Masalah Air, 1981), rice field water and well water (KLHK No 82-year 2001). Similar results were obtained from Priambodo research (2005) in Galuga landfill that showed leachate water pH of 6.44-7.58. These values show the leachate water flow from intermediate waste piles (Bhalla *et al.,* 2012; Zainol *et al.,* 2012). Zakaria and Aziz (2018) show that the pH value of leachate from landfill Southeast Asia countries were 8.13 (Malaysia), 7.42-7.45 (Indonesia), and 8.00 (Thailand).

Nitrate

Nitrate is the main form of nitrogen in water and the main nutrient for plants and algae, resulting from the complete oxidation process of nitrogen compound in water. The high content of nitrate in aquatic environment can cause eutrophication. Nitrate is the main contaminant from landfill that leach to soil and ground water. USEPA (2002) decided that the highest nitrate contaminant in clean water facilities should be no more than 10 mg/liter.

Table 2 pH of leachate water (SL), well water (SM), and rice field water (SW) around Galuga Landfill site

Location	Water pH			
	1	2	3	Average
	Dry Season			
I-SL1	7.93	7.69	8.04	7.89
I-SL2	7.72	7.98	7.91	7.87
I-SL3	7.59	7.87	7.95	7.80
I-SL4	7.48	7.70	7.82	7.67
I-SM1	6.08	6.44	6.33	6.28
I-SM2	6.06	6.16	6.21	6.14
	End of rainy season			
II-SL1	8.08	8.40	8.27	8.25
II-SL2	8.15	8.42	8.29	8.29
II-SL3	8.37	8.67	8.51	8.52
II-SL4	8.17	8.20	7.98	8.12
II-SW1	7.03	8.05	8.21	7.76
II-SW2	7.21	7.81	7.97	7.66
II-SM1	6.63	6.88	6.97	6.83

Nitrate contents were higher in dry season than those at the rainy season's end (Table 3). Besides being affected by the age of the waste pile, the nitrate contents of leachate water were also influenced by the amount of rainwater that seeps into waste piles that wash the compound and dissolve organic acid into leachate water flowing the river stream. The highest nitrate level was obtained from water samples closest to the waste piles (I-SL1 and II-SL3), and the concentration was getting lower the farther the distance from the waste piles (I-SL4). Referring to the wastewater quality standard, nitrate content in leachate water at Galuga landfill exceeded the threshold value and were classified as very bad levels (>50 mg/L). The high nitrate contents (600-1 750 mg/L) were also found in leachate research in Bantar Gebang Landfill, Bekasi, Jawa Barat, done by Widyatmoko and Moerdjoko (2002 in Priambodo, 2005).

The position of rice field which was located at lower elevation than that of landfill site, and the absence of good irrigation/drainage channels, caused surface runoff from Galuga landfill to spread in the rice field (during rainy day) so that the nitrate contents were high (38.4-81.8 mg/L) and it is classified as class IV water (KLHK, 2001). The high nitrate content in rice field water was also derived from nitrogen fertilizer being given to increase the rice crop growth.

Nitrate level in well water varied considerably, ranging between those of dry season (9.3-18.6 mg/L) and those at the end of rainy season (37.9-47.2 mg/L). The high seepage water of leachate from landfill and rice field areas into well water (well water adjacent to the rice field) at the end of rainy season causes the nitrate content of well water to be close to the allowed nitrate threshold value for drinking water of 50 mg/L (Permenkes, 2010). Based on nitrate content, the well water was classified into class IV (KLHK, 2001), which means that this water can only be used for watering crops or other uses that are in conformity with this water quality. Consuming water that has high nitrate content can cause blood circulatory system disorders in infant and disruption of human digestive system (Muller, 1991 in Ompusunggu, 2009).

Nitrate level in water has correlation with N-total and C-organic in the soil. Soil at location II-SL3 with high water nitrate content (104.5 mg/L) had high N-total and C-organic content (Table 4). This shows that Galuga landfill also affects the characteristics of soils, both in landfill area and in soils around the landfill site, as well as the water bodies.

Table 3 Nitrate content in leachate water (SL), well water (SM), and rice field water (SW) around Galuga Landfill site

Location	Nitrate Content (mg/L)			
	1	2	3	Average
	Dry Season			
I-SL1	1039.5[a)]	1200.4[a)]	897.2[a)]	1045.7[a)]
I-SL2	832.2[a)]	711.6[a)]	727.0[a)]	756.9[a)]
I-SL3	594.0[a)]	686.8[a)]	776.5[a)]	685.8[a)]
I-SL4	213.5[a)]	241.3[a)]	253.7[a)]	236.2[a)]
I-SM1	9.3	15.5	-	12.4[a)]
I-SM2	18.6	12.4	18.6	16.5[a)]
	End of Rainy Season			
II-SL1	68.3[a)]	76.0[a)]	93.1[a)]	79.1[a)]
II-SL2	57.2[a)]	64.2[a)]	43.2[a)]	54.9[a)]
II-SL3	79.5[a)]	91.6[a)]	142.4[a)]	104.5[a)]
II-SL4	47.9[a)]	61.3[a)]	71.1[a)]	60.1[a)]
II-SW1	61.7[b)]	59.9[b)]	95.7[b)]	72.4[b)]
II-SW2	51.0[b)]	81.8[b)]	59.4[b)]	64.1[b)]
II-SM1	47.2	37.9	38.4	41.2

Notes: [a)] Does not meet the wastewater quality standard, with reference to DPMA (1981); [b)] Does not meet the water quality standard, with reference to KLHK (2001)

Table 4 Nitrate content in water, N-total and C-organic in the soil

Location	Nitrate in Water (mg/L)	N-total Soil (%)			C-organic Soil (%)		
		0-20 cm	20-40 cm	40-60 cm	0-20 cm	20-40 cm	40-60 cm
II-SL1	79.1	0.33	0.26	0.14	3.06	1.94	0.58
II-SL2	54.9	0.20	0.13	0.09	2.53	1.20	0.83
II-SL3	104.5	0.28	0.28	0.23	3.41	2.80	2.21
II-SL4	60.1	0.15	0.13	0.12	2.09	2.09	1.23
II-SW1	72.4	0.22	0.14	0.08	1.70	0.89	0.27
II-SW2	64.1	0.16	0.13	0.11	2.23	1.32	0.68
II-SM1	41.2	0.13	0.08	0.07	1.94	0.86	0.82

Phosphate

The phosphate content in leachate water was derived from the decomposition process of organic waste (that have been processed aerobically by a microorganism) from domestic disposal and industrial waste that use phosphate-based detergent, namely textile industry, commercial washing services, staining, cosmetic industry, metal industry, and so on. The function of phosphate in detergent is to act as a filler to prevent re-sticking (re-attachment) of impurities to the material being washed. The use of this detergent will eventually accelerate the increase in phosphate concentration in water bodies, triggering algal growth (Paytan and McLaughlin, 2007 in Kusumawardani and Saefumillah, 2013). The abundant algae can form a layer on the water surface that will inhibit the penetration of oxygen and sunlight so that it is less favorable for aquatic ecosystem.

Phosphate content in leachate water had exceeded the threshold value of water quality standard (Table 5) and was categorized into class IV (KLHK, 2001). Phosphate concentration decreased with the increasing distance from the landfill site and the increasing amount of surface water entering into the sewerage/drainage channel. In SL1, phosphate concentration was 4.45 mg/L, and it decreased in SL2 (4.13 mg/L), in SL3 (4.19 mg/L), and in SL4 (1.96 mg/L). Phosphate content in SL3 (4.19 mg/L) was slightly higher than phosphate level in SL2 (4.13 mg/L) because of people activity (bathing, washing, toilet use) that produced detergent waste. The significant decrease in phosphate content in SL4 was caused by phosphate dilution as a result of increasing surface runoff from Cimanggir sewer that merges with the sewer/drainage channel to the Cianten River. Phosphate content in well water (SM1 and SM2) was significantly lower than phosphate level in leachate water and was categorized as class I (raw water for drinking water or other uses that meet the water quality standard). The high phosphate content in leachate water of 88.37 mg/L and 45.35 mg/L was also reported by Arbain *et al*. (2008), who measured the phosphate content in leachate water Suwung Landfill, Pedungan village, Denpasar city, Bali Province. Aziz *et al*. (2015), in their research in Malaysia, show the phosphate level in leachate from several landfills were 8-140.8 mg/L (Kulim Landfill), 10-56.6 mg/L (Pulau Burung Landfill), and 24.4-61.8 mg/L (Kuala Sepetang Landfill).

Table 5 Phosphate content (as P) of leachate water and well water (SM)

Location	P Content (mg/L) in water, day-			
	1	2	3	Average
I-SL1	4.31	4.46	4.57	4.45
I-SL2	3.96	4.08	4.36	4.13
I-SL3	3.99	4.27	4.31	4.19
I-SL4	2.16	2.16	1.57	1.96
I-SM1	0.15	0.19	0.16	0.17
I-SM2	0.13	0.10	0.13	0.12

Lead (Pb)

Lead is one of the heavy metals that is usually found in landfill wastes that are derived from the battery, printing materials, and food wastes. Generally, heavy metal concentration in leachate water of landfill is relatively low (Christensen and Kjeldsen, 2001) but higher concentration is usually found in the beginning period of waste pile accumulation, due to metal solubility, which is high at low pH as a result organic acid production (Kulikowska and Klimiuk, 2008). As a result of increase in pH at the end period of waste piles, metal solubility decrease linearly and causes significant decrease in heavy metal, except Pb (Pb forms a complex compund with humic acid) (Harmsen, 1983). Pb content in leachate water of landfill site ranged between 0.09-1.02 mg/L (Rowe, 1995).

The Pb content in leachate water of Galuga landfill in the dry season (0.012-0.199 mg/L) was not far different from the Pb level in the end of rainy season (<0.005-0.180 mg/L) and were classified into wastewater class I (good) and class II (medium) (Table 6). High levels of Pb in leachate water of 0.3 mg/L was shown by Naveen *et al.* (2014) in their research at Mavallipura Landfill, north Bangalore, India. The high Pb level (0.005-0.140 mg/L) in rice field water did not meet the wastewater quality standard (KLHK, 2001), so that the water was classified into class IV. Well water also contained high Pb level so that this water did not meet the drinking water quality standard, in reference with government regulation (Permenkes No 492, 2010). The source of Pb in well water was allegedly derived from leachate seepage of Galuga landfill that entered into groundwater and accumulated in well water, and from poorly managed household waste around the residential environment.

The highest Pb content being allowed for drinking water is 0.01 mg/L. In human, Pb can result in urinary tract cancer and influence metabolism function of protein. In addition, it can also cause death of fish and other organisms at concentration higher than 0.05 mg/L (Hutagalung, 1984 in Diansyah, 2004).

Table 6 Pb content in leachate water (SL), rice field water (SW), and well water (SM)

Location	Pb Content (mg/L)			
	1	2	3	Average
		Dry Season		
I-SL1	0.098[a]	0.194[a]	0.030[a]	0.107[a]
I-SL2	0.011[a]	0.071[a]	0.199[aa]	0.094[a]
I-SL3	0.108[a]	0.088[a]	0.036[a]	0.077[a]
I-SL4	0.067[a]	0.012[a]	0.092[a]	0.057[a]
I-SM1	0.070[c]	0.098[c]	0.040[c]	0.069[c]
I-SM2	0.043[c]	0.124[c]	0.105[c]	0.091[c]
		End of Rainy Season		
II-SL1	<0.005	0.058[a]	0.058[a]	0.040[a]
II-SL2	<0.005	0.058[a]	0.058[a]	0.040[a]
II-SL3	<0.005	0.140[a]	0.180[aa]	0.108[a]
II-SL4	<0.005	0.140[a]	0.180[aa]	0.108[a]
II-SW1	<0.005	0.058[b]	0.140[b]	0.068[b]
II-SW2	<0.005	0.099[b]	0.099[b]	0.068[b]
II-SM1	<0.005	0.099[c]	0.140[c]	0.081[c]

Notes: [a] Meet the wastewater quality standard class I (good) (DPMA, 1981); [aa] Meet the wastewater quality standard class II (medium) (DPMA, 1981); [b] Does not meet clean water quality standard (KLHK, 2001); [c] Does not meet drinking water quality standard (Permenkes, 2010)

CONCLUSION

Leachate water from galuga landfill is not safe to be discharged into water body because of high level of phosphate and very high nitrate content, although the leachate water has temperature, acidity degree (pH), and lead (Pb) content in normal range. The well water has very high nitrate and lead (Pb) contents so that it did not meet the drinking water quality standard and was not suitable for drinking water without prior treatment.

REFERENCES

[Permenkes] Peraturan Menteri Kesehatan Republik Indonesia. 2010. Peraturan Menteri Kesehatan Republik Indonesia Nomor 492/MENKES/PER/IV /2010 Tentang Persyaratan Kualitas Air Minum. Jakarta (ID): Kementerian Kesehatan RI.

[KLHK] Kementerian Lingkungan Hidup Republik Indonesia. 2001. Peraturan Pemerintah Nomor 82 Tahun 2001 tentang Kualitas Air dan Pengendalian Pencemaran Air. Jakarta (ID): Kementerian Lingkungan Hidup Republik Indonesia.

[USEPA] U.S. Environmental Protection Agency. 2005. *Nonpoint Source Control Branch (4503T) 1200 Pennsylvania Avenue*. Washington DC (US): USEPA.

Arbain, Mardana NK, Sudana IB. 2008. Pengaruh air lindi tempat pembuangan akhir sampah suwung terhadap kualitas air tanah dangkal disekitarnya di Kelurahan Pedungan Kota Denpasar. *Ecotrophic.* 3(2): 55-60.

Aziz SQ, Aziz HA, Bashir MJ. 2015. Assessment of various tropical municipial landfill leachate characteristics and treatment oportunities. *Journal of Global Environmental Engineering*. 17(3): 1-13.
Bhalla B, Saini MS, Jha MK. 2012. Characterization of leachate from municipal solid waste (MSW) landfilling sites of Ludhiana, India: A comparative study. *International Journal of Engineering Research and Applications* (IJERA). 2: 732-745.
Christensen TH, Kjeldsen P. 2001. Biogeochemistry of landfill leachate plumes. *Applied Geochemistry*. 16(7-8): 659-718.
Diansyah G. 2004. Kualitas perairan pantai pulau batam, kepulauan riau berdasarkan karakteristik fisika-kimia dan struktur komunitas plankton [skripsi]. Bogor (ID): Institut Pertanian Bogor.
Direktorat Penyelidikan Masalah Air. 1981. *Kriteria dan Standar Kualitas Air Nasional*. Jakarta (ID): Badan Penelitian dan Pengembangan Departemen Pekerjaan Umum Republik Indonesia.
Harmsen J. 1983. Identification of organic compounds in leachate from a waste tip. *Journal of Water Research*. 17(6): 699-705.
Kamaruddin MA, Yusoff MS, Aziz HA, Hung YT. 2015. Sustainable treatment of landfill leachate. *Applied Water Science*. 5: 113-126. doi: https://doi.org/10.1007/s13201-014-0177-7.
Kiayee SB. 2013. Impact of municipal waste leachate application on soil properties and accumulation of heavy metals in wheat (*Triticum aestivum* L). *International Journal of Scientific Research in Environmental Sciences*. 1: 1-6.
Kjeldsen P, Barlaz MA, Rooker AP, Baun A, Ledin A, Christensen TH. 2002. Present and long-term composition of MSW Landfill Leachate: A review. *Critical Reviews in Environmental Science and Technology*. 32(4): 297-336.
Kulikowska D, Klimiuk E. 2008. The effect of landfill age on municipal leachate composition. *Bioresource Technology*. 99: 5981-5985.
Kusumawardani AD, Saefumillah A. 2013. Studi pembuatan ion inprinted polimer untuk penyerapan sodium tripolifosfat (STTP) secara selektif menggunakan kitosan termodifikasi [Internet]. [Downloaded 2019 Aug 7]. Depok (ID): Universitas Indonesia. Available at: http://lib.ui.ac.id/naskahringkas/2015-08/S45452-Aulia%20Dyah-%20Kusumawardani.
Naveen BP, Sivapullaiah PV, Sitharam TG. 2014. Characteristics of a municipal solid waste landfill leachate. *Proceedings of Indian Geotechnical Conference IGC* [Internet]. [Downloaded 2021 Jul 8]. Available at: https://www.researchgate.net/publication/269819277.
Ompusunggu H. 2009. *Analisa Kandungan Nitrat Air Sumur Gali Masyarakat di Sekitar Tempat Pembuangan Akhir (TPA) Sampah di Desa Namo Bintang Kecamatan Pancur Batu Kabupaten Deli Serdang*. Medan (ID): Universitas Sumatera Utara.
Priambodo K. 2005. Kualitas air lindi pada tempat pembuangan akhir sampah Galuga Kabupaten Bogor [skripsi]. Bogor (ID): Institut Pertanian Bogor.
Raghab SM, Meguid AMAE, Hegazi HA. 2013. Treatment of leachate from municipal solid waste landfill. *Housing and Building Research Center Journal*. 9: 187-192. doi: https://doi.org/10.1016/-j.hbrcj.2013.05.007.
Rowe RK. 1995. *Lechate Characteristics for Municifal Solid Waster Landfills*. Canada (US): The University of Western Ontario.
Zainol NA, Aziz HA, Yusoff MS. 2012. Characterization of leachate from Kuala Sepetang and Kulim landfills: a comparative study. *Energy and Environment Research*. 2(2): 45-52.
Zakaria SNF, Aziz HA. 2018. Characteristic of leachate at Alor Pongsu Landfill Site, Perak, Malaysia: A comparative study. *IOP Conf Series: Earth and Environmental Science*. 140(012013): 1-8.