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EVALUATION OF LANDFILL MANAGEMENT AT PIYUNGAN LANDFILL YOGYAKARTA BY USING INTEGRATED RISK BASED APPROACH METHOD

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Highlights

- Piyungan landfill have an important role in the solid waste management in Yogyakarta Special Region, especially Yogyakarta City, Sleman and Bantul Regency.
- This research shown that Piyungan landfill has a potential for high hazard, and the landfill must be closed immediately because it pollutes the environment or causes social problems according to IRBA method.
- The factual conditions in the field indicate that technical age and capacity are serious problems faced in terms of waste management.

Abstract. The volume of domestic waste in the Special Region of Yogyakarta (DIY Region) during the last five years has increased significantly by 34%, while the volume of waste handled has only increased by 8%. The average produced waste was 1,008.26 tonnes/day, while the handled waste reached 642.01 tonnes/day. That means 366.25 tonnes of unhandled waste per day, resulting in environmental pollution. This paper aims to evaluate the management of the Piyungan landfill by using the Integrated Risk Based Approach (IRBA). IRBA is a tool of decision-making created in 2005 for landfill rehabilitation, including sites with high health risks, maximum environmental impacts, and sensitive public concerns. A total of 26 parameters were used to evaluate the landfill and waste management in the Piyungan landfill site. The Risk Index (RI) calculated using the IRBA method shows that the final result of the Piyungan landfill was 649.76. The value of RI indicated a potential for high hazard, and the landfill must be closed immediately because it pollutes the environment or causes social problems. The factual conditions in the field indicate that technical age and capacity are serious problems faced with concern with the management of waste for the Yogyakarta, Sleman Regency, and Bantul Regency as Piyungan landfill users.

Keywords: IRBA, management of the landfill, Piyungan landfill, waste, Yogyakarta.

Introduction

Solid waste generation in urban settlements comes from households, food stalls, public buildings, restaurants, tourism areas, and home industries. Increased solid waste and management is an environmental problem that is difficult for local authorities to deal with in some countries, including developing countries (Ojuri et al., 2018). Several factors that contribute to the solid waste generation increase are the growth of population, rapid urbanization, a growing economy, and an increase in living standards (Astono et al., 2016; Fakhurozi et al., 2021; Minghua et al., 2009; Turan et al., 2009). Increasing solid waste is a threat to environmental pollution, impacting human health, so it is necessary to plan appropriate management strategies to overcome these problems. Management of solid waste is a systematic, comprehensive, and sustainable activity, including the reduction and handling of waste. Generally, the currently recognized models and stages of solid waste management include landfilling and selecting waste at the source, collecting waste, transporting waste to temporary disposal sites/final landfills, processing waste, and final processing (Saxena et al., 2021).

The Special Region of Yogyakarta is one of the tourist destinations with an increasing number of visits every year. According to the report of 2020, Yogyakarta city was visited by 40,832 foreign tourists and 1,992,735 domestic tourists (Dinas Pariwisata Yogyakarta, 2020). In

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addition, Yogyakarta, known as the city of education, makes many newcomers study in this city yearly. These conditions encourage increasing waste generation in Yogyakarta (Ariyani et al., 2019; Purnama Putra et al., 2018). The total volume of waste produced during the last five years has increased by 34%, while the volume of waste handled has only increased by 8%. During the last five years, the average volume of waste production reached 1,008.26 tonnes/day, while the volume of handled waste reached 642.01 tonnes/day. Consequently, 366.25 tonnes of daily waste without experience handling contributes to environmental pollution.

The main problem with the increasing volume of waste is the limitation of the Piyungan landfill in accommodating waste. If the waste capacity is exceeded, it will lead to disasters such as explosions and landslides (Rezaeisabzevar et al., 2020; Yin et al., 2016). Waste impacts health and the environment, including contaminants in soil, groundwater, surface water, air quality, and socio-economics (Serdavic, 2009). Therefore, it is urgent to conduct scientific research to determine the feasibility of the Piyungan landfill.

There are several methods to evaluate the landfill, such as the Fuzzy Delphi Method (FDM), Multi-Criteria Decision Making Method (MCDA/MCDM), Analytic Hierarchy Process (AHP), Mixed Integer Linear Programming (MILP), DUPIT Index, and Integrated Risk Based Approach (IRBA) (Eiselt, 2006; Erkut & Moran, 1991; Kharat et al., 2016; Kurian et al., 2005; Mohammed et al., 2018; Simsek et al., 2006). This study considers the IRBA method in determining the rehabilitation or reconstruction potentials of the Piyungan landfill.

Integrated Risk-Based Approach (IRBA) is a tool of decision-making designed in 2005 for landfill rehabilitation which includes the sites with high health risks on maximum environmental and sensitive public impacts (Kharat et al., 2016). Indonesia adopted this decision-making tool through the Regulation of the Ministry of Public Works of the Republic of Indonesia Number 03/PRT/M/2013. Widiarti et al. (2020) used the IRBA method to assess the environmental risk because dumping activities in the dumpsite of Kopi Luhur (Cirebon, Indonesia) described that the dumpsite is facilitated corresponded to the level of moderate hazard with a total score of the risk index of 575.25. Recommendation action for Kopi Luhur dumpsite based on the research is immediate rehabilitation of the dumpsite into a sustainable landfill. Hence, the recent research objective is to evaluate the management of the Piyungan landfill using IRBA.

1. Materials and methods

1.1. Time and location

This study was conducted from June to November 2021, and the material object is the Piyungan landfill (Figure 1). Piyungan landfill is located in Sitimulyo Village, Piyungan Subdistrict, Bantul Regency, Special Region of Yogyakarta, Indonesia. There is an Opak River about ±1 km west of the Piyugan landfill.

1.2. Procedure

This research stand for parameters based on Kurian et al. (2005), the analysis in more detail about other all the risk factors that may affect the environment, e.g., noise, vibration, non-ionizing radiation, disposal techniques, layers techniques, landfill cluster cell closure techniques, water management techniques are not considered in this

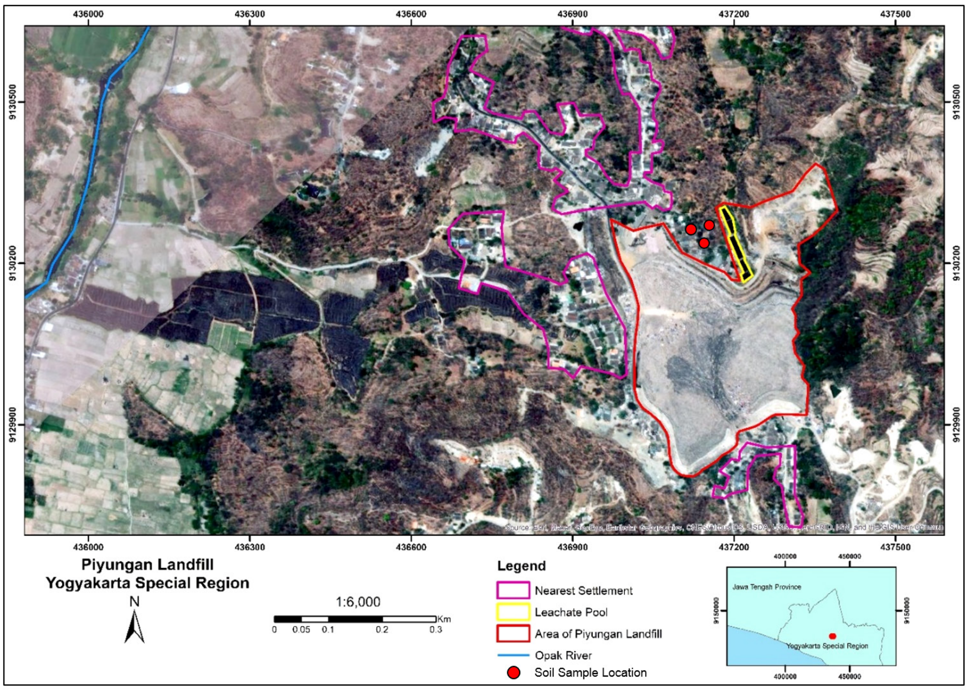

Figure 1. Location of the study area in Special Region of Yogyakarta, Indonesia

research. IRBA is a tool of decision-making designed since 2005 for landfill rehabilitation/reconstruction. The parameters considered in the IRBA analysis are categorized into 3, namely geological characteristics of location (20 parameters), characteristics of waste (4 parameters), and characteristics of leachate (3 parameters) (Table 1). In this research, the data were obtained by observation, interview, measurement, laboratory test, and literature review. The observation is implemented for some attributes, groundwater depth, hazardous contents in waste, and a biodegradable fraction of waste. The interview is applied for the public acceptance attribute. Measurements are applied for attributes related to distance such as nearest distance of water source, distance to critical habitats, nearest distance to the airport, distance from the surface of water body, the nearest distance village in predominant wind direction, and distance from the city. Laboratory tests are applied for the type of underlying soil and moisture of waste at the site attribute. Meanwhile, the other attribute is using literature review to collect research data.

While we stand for the parameters based on Kurian et al. (2005), the analysis in more detail about other all the

Table 1. The IRBA decision-making parameters (source: Kurian et al., 2005)

S/N	Parameter	Weight	Index of sensitivity			
			0.00–0.25	0.25–0.50	0.50–0.75	0.75–1.00
I – The Criteria of Site Specific						
1	Nearest distance from the source of water supply (m)	69	>5000	2500–5000	1000–2500	<1000
2	Filling waste depth (m)	64	3	3–10	10–20	>20
3	Landfill area (Ha)	61	<5	5–10	10–20	>20
4	Depth of groundwater (m)	54	>20	10–20	3–10	<3
5	Soil permeability (1×10^{-6} cm/s)	54	<0.1	1–0.1	1–10	>10
6	Quality of groundwater	50	Not a concern	Potable	Potable if no alternative	Non-potable
7	Distance to critical habitats such as wetlands and reserved forest (km)	46	>25	10–25	5–10	<5
8	Distance to the nearest airport (km)	46	>20	10–20	5–10	<5
9	Distance from the surface of water body (m)	41	>8000	1500–8000	500–1500	<500
10	Underlying soil type (% clay)	41	>50	30–50	15–30	0–15
11	The site life for future use (years)	36	<5	5–10	10–20	>20
12	Waste type (MSW/HW)	30	100% MSW	75% MSW + 25% HW	50% MSW + 50% HW	>50% HW
13	Waste total quantity at the site (tonnes)	30	$<10^4$	10^4–10^5	10^5–10^6	$>10^6$
14	Waste disposed of quantity (tonnes/day)	24	<250	250–500	500–1000	>1000
15	Distance to the nearest village in the direction of the predominant wind (m)	21	>1000	600–1000	300–600	<300
16	The proneness of the flood (flood period in years)	16	>100	30–100	10–30	<10
17	Annual rainfall at the site (cm/year)	11	<25	25–125	125–250	>250
18	Distance from the city (km)	7	>20	10–20	5–10	<5
19	Public of acceptance	7	No public concerns	Accepts landfill rehabilitation	Accept landfill closure	Accept landfill closure and remediation
20	Quality of ambient air – CH_4 (%)	3	<0.01	0.05–0.01	0.05–0.1	>0.1
II – Related to Waste Characteristics at Landfill						
21	Contents of hazardous waste (%)	71	<10	10–20	20–30	>30
22	Waste Biodegradable Fraction at the site (%)	66	<10	10–30	30–60	60–100
23	Filling age (years)	58	>30	20–30	10–20	<10
24	Waste moisture at the site (%)	26	<10	10–20	20–40	>40
III – Related to Leachate Quality						
25	Leachate BOD (mg/L)	36	<30	30–60	60–100	>100
26	Leachate COD (mg/L)	19	<250	250–350	350–500	>500
27	Leachate TDS (mg/L)	13	<2100	2100–3000	3000–4000	>4000

risk factors that may affect the environment, e.g., noise, vibration, non-ionizing radiation, disposal techniques, layers techniques, landfill cluster cell closure techniques, water management techniques are not considered in this research.

Each parameter from Table 1 is given weights and an index of sensitivity to calculate the Risk Index (RI). The value of RI was assessed by using Table 2 to obtain the level of hazard and proposed recommended action. The IRBA tools is furnishing the Government and others implementing guidance of authorities to prioritize actions concerned with landfill rehabilitation or permanently closing (Widyarsana et al., 2019).

1.3. Data analysis

The RI can be utilized to classify landfills as closed or rehabilitated. The higher obtained, the more significant risk is for the health of humans, and actions have to be immediately adopted at the landfill field. The priority further decreases as a value in total. The lowest value indicates the low sensitivity and narrow environmental impact (Widiarti et al., 2020). The criteria for evaluating the hazard level based on the index of risk value for landfills are explained in Table 2. The Sensitivity index (SI) and Risk Index (Risk Index/RI) are formulated below:

$$\frac{HV - LV}{HV - AM} = \frac{MmV - MnV}{MmV - Si};$$

Table 2. Criteria of hazard evaluation of index of risk (source: Kurian et al., 2005)

No	The value of Risk Index (RI)	Hazard evaluation	Recommended action
1	601–1000	High	The landfill must be closed immediately because it pollutes the environment or causes social problems
2	300–600	Moderate	The landfill is continued and rehabilitated to be a controlled landfill in stages
3	<300	Low	The landfill is continued and rehabilitated to be a controlled landfill. This area has the potential to be developed to be landfill

$$RI = \sum_{i=1}^{n} Wi \cdot Si,$$

where: Wi – the $-i$ parameter weight, with a value range of 0–1000; AM – Attribute measurement; Si – The index of sensitivity of the $-i$ parameter, with range of value 0–1; MmV – Maximum Value of Si; RI – Risk Index, with a value range of 0–100; MnV – Minimum Value of Si; HV – Highest Value; LV – Lowest Value.

2. Results and discussions

Piyungan landfill is located in a basin with varying, steep, and horizontal slopes. Formed on land with a deep enough ravine of 40 m. Based on the observations, the Piyungan landfill was using an open dumping system that focused on natural decomposition and the economic value of waste collection by scavengers (Figure 2). The open dumping system is where waste is piled up and compacted in an open space. The open dumping system impacts the environment such as air, water, and soil pollution (Serdavic, 2009).

We performed three main criteria for IRBA decision-making parameters, the criteria of site-specific, leachate quality, and the characteristics of waste at the landfill. The three main criteria have a more detailed parameter to obtain the total Risk Index (RI) score.

2.1. The criteria of site specific

The site-specific criteria, as shown in Table 1, will be assessed through the four grouped parameters, i.e., (1) environmental and social influence, (2) geological and hydrogeological condition, (3) influence on the hydrological and atmospheric condition of the area, and (4) the landfill characteristics its self.

2.1.1. Potential of environmental and social influence

The potential of the environmental and social influence of the landfill is assessed through parameters 1, 7, 8, 18, and 19. The nearest source of water supply is 452 meters away and is derived from groundwater, while the closest critical habitat is 12.13 kilometers away, measured from Wanagama forest to the landfill. The nearest airport is Adi Sucipto

Figure 2. Scavengers in Piyungan landfill

Airport, which is 8.59 kilometers away, and the nearest city is Yogyakarta City, which is about 5 kilometers away. The nearest airport is located within 8.59 km, where Adi Sucipto Airport is located, while the nearest city is Yogyakarta City which is located about 5 km from the landfill.

Parameters of community acceptance of the Piyungan landfill condition were achieved by conducting in-depth interviews with several identified stakeholders. The method of determining the informants is by using the purposive sampling method. Purposive sampling is a technique of sampling the data sources with specific considerations (Intrakamhaeng et al., 2020; Marliani, 2014). Because not all samples have criteria that match the phenomenon being studied, this sampling method is used.

In brief, the interviewed stakeholders include government representatives (village heads), landfill managers, affected communities, and direct beneficiaries of the existence of the Piyungan landfill. The survey results show that community groups are affected in Bawuran II Hamlet, Bawuran Village, due to leachate seeping that pollutes the river. However, the affected community did not believe that the Piyungan landfill should be closed, but rather that physical improvements and management be carried out. The community groups who directly benefit from the existence of the Piyungan landfill strongly disagree that the Piyungan landfill is permanently closed but only needs to be rehabilitated and better managed.

The other things during the field survey around the Piyungan landfill were cow herding and the presence of scavengers (Figure 3). More than 1000 cows and about 480 scavengers live at the Piyungan landfill. The cows feed them self by fresh waste transported by truck. Cows are eating food waste while the scavengers are taking economical solid waste such as bottle plastic. Meanwhile, the scavengers are an affiliate of a community, Mardiko (Makaryo Adi Ngayogyokarto), led by Maryono. This community has an excellent administrative system, such as recording each scavenger's name and origin. It will be helpful to distribute relief from other institutions or communities.

2.1.2. Geological and hydrogeological condition

The geological and hydrogeological conditions of the area are included in parameters 4, 5, 6, and 10. These parameters show the geological and hydrogeological proneness of the area to be influenced by the landfill. Geological condition is represented by parameters 5 and 10, the data is obtained from the Department of Environment and Forestry of Bantul Regency (Bantul, 2020) and laboratory testing. The permeability of the soil around the Piyungan landfill is 341×10^{-6} cm/second (Bantul, 2020). The permeability coefficient of landfill is the crucial index to determine the quantity of leachate, which is closely related to the depth and unit weight of the waste. This index is concerned with waste in terms of depth and weight (Yang et al., 2016). The regulations of technical safeguard are heavily focused on the liners of isolation with low permeability (layer of clay or bentonite) as contamination prevention by migrating downward of leachates through geological formation in underlying (Serdavic, 2009).

The soil test results obtained from the soil samples in the dumpsite can be seen in Table 3. The samples of soil were taken from 3 different locations around the Piyungan landfill. Soil samples were taken with an average weight of 1 kg, with the depth of each sample being 20 cm for annual crop conditions, 38 cm, and 40 cm for annual plant conditions. The laboratory test results indicated that the sample of soil A had a moisture content of 17.44% with a texture of 78.86% sand, 14.94% clay, and 6.20% dust, so it was classified as sandy. Sample B has a moisture content of 15.17% with a texture of sand, clay, and dust, respectively 69.64%, 19.67%, and 10.69%, or classified as loamy sand. Sample C has a moisture content of 15.23% with a texture of 74.24% sand, 17.38% clay, and 8.39% dust, so it is categorized as loamy sand.

The United Soil Classification System explains that the soil sample at Piyungan landfill is included in sandy loam or category A, which is the runoff potential is low, and the infiltration rates are high even if it is wetted. They are constructed of deep, chiefly, well to drain sands or gravels and

Figure 3. Cows herding and scavengers in Piyungan landfill

Table 3. Properties of soil samples (source: Laboratory Test, 2021)

No	Sample code	Moisture (%)	Soil texture			
			Sand (%)	Clay (%)	Lanau (%)	USCS
1	A	17.44	78.86	14.94	6.20	Sand
2	B	15.17	69.64	19.67	10.69	Sandy loam
3	C	15.23	74.24	17.38	8.39	Sandy loam

have water transmission at a high rate. Commonly, soils composed of high clay contain low permeability, limiting flushing solution passage (Feng et al., 2021b).

The hydrogeological condition considered in this research is represented in parameters number 4 and 6, which are groundwater depth and groundwater quality. The groundwater depth of the Piyungan landfill ranges from 5–15 meters, with a layer of soil containing limestone (Nursetiawan et al., 2020). Based on the previous studies, the quality of groundwater in the Piyungan Landfill area shows that the groundwater at a radius of <1 km from the Piyungan landfill has been polluted by leachate. The results of the water quality test around the Piyungan landfill (radius <1 km) also showed that the pollutant content, including chloride (Cl), nitrate (NO^{3-}), total chromium, and total coliform had exceeded their normal limits, polluted groundwater also contained sulfides (S^{2-}) was 0.0043 mg/L and COD (Chemical Oxygen Demand) was 19.4 ml/l. Both values have exceeded the class 1 quality standard (drinking water standard), so groundwater is no longer consumed because it harms health. However, in reality, there are still as many as 35% of the residents who use the groundwater for consumption purposes (Ramadhan et al., 2019).

2.1.3. Hydrological and atmospheric condition of the area

The hydrological and atmospheric condition of the Piyungan Landfill is assessed by parameters 9, 15, 16, 17, and 20. Parameters 9, 16, and 17 show the hydrological condition in the area. From the measurement, the nearest of surface water is within 1,030 meters of the landfill, where the Opak River is located. From the literature review, it is obtained that the flood period in the Piyungan Landfill is 100 years, while from the BMKG data, the annual rainfall in the area is 119.78 cm/year.

Surface water is a source of water found on the ground surfaces level such as rivers, reservoirs, dams which are rainwater reservoirs, and lakes. Surface water has a prominent position in the cycle of global water, environmental processes, and the society of humans, and this is urgently needed regarding the distribution and extent of the surface of the water on Earth (Luo et al., 2021). Based on observations of the location of the surface water closest

Table 4. Properties of surface water (Opak River) (source: Balai Pengelolaan Sampah, 2021)

No	Parameter	Unit	Quality standards	Results			
				Upstream		Downstream	
				March 2021	June 2021	March 2021	June 2021
1	Sample temperature	–	±30 °C from air temperature	28.3	25.5	28.5	23.6
2	TDS	mg/L	1000	224	92.1	198.1	99.3
3	pH	–	6–8.5	9.28	7.91	8.82	7.88
4	Dissolved Oxygen (DO)	mg/L	Minimum 5	8.02	7.07	8.16	7.27
5	TSS	mg/L	50	10	118	12.5	90
6	Total Phosphate	mg/L	0.2	0.472	3,241	0.193	0.822
7	Nitrate (NO_3^-)	mg/L	10	0.122	0.413	0.048	0.376
8	COD	mg/L	25	3,738	29.558	9,711	35,949
9	Chromium Val 6 (Cr^{6+})	mg/L	0.05	<0.003	<0.003	<0.003	<0.003
10	Lead (Pb)	mg/L	0.03	0.0103	0.0256	0.0125	0.0108
11	Copper (Cu)	mg/L	0.02	0.0195	0.0359	0.0186	0.0258
12	Zinc (Zn)	mg/L	0.05	0.0059	0.0256	0.0072	0.0244
13	BOD5	mg/L	3	<0.86	1.24	1.25	3.22
14	Goal. coliform	MPN/100 mL	5000	49×103	110×103	33×103	94×103
15	Goal. Fecal coli	MPN/100 mL	1000	33×103	110×103	23×103	94×103

to the Piyungan TPST is 1.03 km, namely the Opak River watershed. The report on the implementation of the Piyungan landfill (Environmental Management Plan – Environmental Monitoring Plan, Indonesian, namely RKL-RPL) for the January–June 2021 period, river quality monitoring is carried out every three months, namely in March and June 2021 (Balai Pengelolaan Sampah, 2021). The following results are presented in Table 4. The results also align with the previous studies which mentioned that the leachate already polluted the groundwater and also surface water with the indication of high heavy metals and coliform bacteria composition (Nursetiawan et al., 2020; Parhusip et al., 2017; Axmalia et al., 2021).

Parameters 15 and 20 show the atmospheric condition in the Piyungan landfill, which respectively indicate the nearest village from the direction of the predominant wind and the quality of ambient air in the area. From the BMKG data, it is known that the direction of the predominant wind is from southeast-south to northwest-north, so the nearest village is located within 71.28 meters from the landfill. The quality of ambient air in the area is measured in the percentage of CH4, which is obtained from DLHK DIY (2021). The methane gas in the area is within 0.05%, indicating the medium-poor quality of the ambient air in the area.

2.1.4. Landfill characteristics

The parameters 2, 3, 11, 12, 13, and 14 are considered landfill characteristics, representing the potential risk that might occur due to the condition of the landfill itself. The filling waste of the Piyungan landfill is around 128 meters, while the total area is 12.5 Ha and the waste volume capacity is 2.7 million m^3. According to the Piyungan landfill profile book, the total quantity of waste at the site is around 3,371,401 tonnes, and the daily waste disposed of in the landfill is around 693.126 tonnes/day. The site is intended to be operated until 2017, so there is no site life for future use. There is no sufficient information to explain the waste type data, so the waste type data is not considered in this research.

From all of the landfill characteristics data, most of the parameters show moderate to high sensitivity, while the future site life is very low sensitivity because it is assumed that the landfill is overused. The high filling waste depth, broad site area, very high quantity of waste at the site, and overcapacity of daily waste disposed of represent a hazardous characteristic of landfill and could lead to a terrible influence on the surrounding area. The landfill management should determine the future site life to estimate the future condition if these over-activities on the site keep going.

2.2. Leachate quality criteria

The landfill's leachate is in the form of liquid, describing its origin predominantly through water infiltration in the water mass or from the same decomposition of biodegradable waste (Serdavic, 2009). The leachate pollution result from the biological, chemical, and physical processes in the landfill, and the waste composition and the water regime of the landfill are also produced by the progressive waste compaction to the extent of lesser (Postacchini et al., 2018). The results of the analysis of the leachate pool compared with local regulations are presented in Table 5.

Sampling was carried out every month from January to June 2021. Regarding these measurement results, it is known that May is the highest value for Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD), with values of 12,065 647.75 and 8,248.64 mg/L, respectively. Meanwhile, the lowest value for TDS was in February at 6.555 mg/l, the lowest value for BOD was in June at 41.85 mg/l, and for COD, the lowest was in February at 2.560 mg/l.

The calculation of the Risk Index (RI) related to the landfill leachate has weighted 36, 19, and 13 for BOD, COD, and TDS, respectively. The score for the sensitivity index for all leachate criteria is 1, regarding their high potential for landfill pollution and its complexity. These criteria contribute 68 scores for Risk Index analysis. All of the leachate parameters in the Piyungan area from January to June 2021 have exceeded the threshold of local regulations, which stipulate that the maximum values are ruled

Table 5. Properties of leachate sample from January to June 2021 (source: Balai Pengelolaan Sampah, 2021)

No	Parameter	Unit	January	February	March	April	May	June	Acceptable content
1	Temperature	°C	24.2	24.5	24.7	25.4	24.4	22.1	±3 °C air temperature
2	TSS	mg/L	244	200	76	89	355	172	100
3	TDS	mg/L	8,215	6,555	9,500	9,000	12,065	11,430	2,000
4	BOD	mg/L	384.54	472.97	271.44	665.28	647.75	41.85	100
5	COD	mg/L	3,238	2,560	4,204.8	4,135	8,248.64	4,136	300
6	Lead (Pb)	mg/L	0.804	0.4811	0.0787	0.0744	0.0275	0.0867	0.1
7	Copper (Cu)	mg/L	0.372	0.5801	0.0852	0.0507	0.0388	0.0955	0.5
8	Chromium (Cr)	mg/L	1.312	0.6353	0.0245	0.2054	0.0206	0.0667	0.5
9	Ph	–	9.63	9.3	8.62	8.6	5.5	8.92	6–9
10	Iron (Fe)	mg/L	1.98	1.78	1.04	0.79	5.680	0.880	2
11	Zinc (Zn)	mg/L	0.924	0.5303	0.1566	0.6821	0.0448	0.1153	5

by the Indonesian Ministry of Environment and Forestry (see Table 5.)

Recently, many studies have shown that leachate is a significant source of poly-fluoroalkyl substances (PFAS) in the environment. PFAS are contaminants group that has attracted worldwide attention due to their widespread distribution, the persistence of the environment, and impacts on the adverse ecosystem and human health, such as cancer, weakened immune systems, and thyroid hormone disorders (Feng et al., 2021a; Grandjean & Clapp, 2015).

Table 6. Risk Index worksheet

S/N	Parameter	Weight	Sources of data	Piyungan landfill		
				Measurement of attribute	Index of sensitivity	Score
I – Criteria of Specific Site						
1	Distance from the nearest source of water supply (m)	69	Map Measurement	452	0.86	59.34
2	Filling waste depth (m)	64	DLHK Bantul (2020)	128	1	64
3	Landfill Area (Ha)	61	DLHK Bantul (2020)	12.5	0.557	34.02
4	Depth of groundwater (m)	54	Nursetiawan et al. (2020)	5	0.572	30.88
5	Soil permeability (1×10^{-6} cm/s)	54	DLHK Bantul (2020)	341	1	54
6	Quality of groundwater	50	Literature Review	Potable if no alternative	0.75	37.5
7	Distance to critical habitats such as wetlands and reserved forest (km)	46	Map Measurement	12.13	0.28	12.88
8	Distance to the nearest airport (km)	46	Map Measurement	8.59	0.68	31.28
9	Distance from the body of surface water (m)	41	Map Measurement	1030	0.63	25.83
10	Underlying soil type (% clay)	41	Laboratory testing	17.33	0.751	30.79
11	The site life for future use (years)	36	DLHK Bantul (2020)	1	36	0
12	Waste type (MSW/HW)	30	No Data			
13	The total quantity of waste at the site (tonnes)	30	DLHK Bantul (2020)	3371401	1	30
14	Disposed quantity of waste (tonnes/day)	24	DLHK Bantul (2020)	693.126	0.59	14.16
15	Distance to the nearest village in the direction of the predominant wind (m)	21	Map Measurement	71.28	1	21
16	The proneness of the flood (the period of flood in years)	16	Interview	100	0.1	1.6
17	Annual rainfall at the site (cm/year)	11	Wilopo et al. (2021)	231.7	0.49	5.39
18	Distance from the city (km)	7	Map Measurement	<5	1	7
19	Acceptance of public	7	Interview	Accepts landfill rehabilitation	0.5	3.5
20	Quality of ambient air – CH_4 (%)	3	DLHK Bantul (2020)	0.05	0.5	1.5
II – Related to Waste at Landfill Characteristics						
21	Contents of hazardous waste (%)	71	Observation	17.52	0.44	31.24
22	Waste Biodegradable Fraction at the site (%)	66	Observation	35.7	0.54	35.64
23	Filling age (years)	58	DLHK Bantul (2020)	25	0.375	21.75
24	Waste moisture at the site (%)	26	Sihombing and Darmawan (2020)	52.8%	1	26
III – Related to Leachate Quality						
25	Leachate BOD (mg/L)	36	DLHK Bantul (2020)	413.97	1	36
26	Leachate COD (mg/L)	19	DLHK Bantul (2020)	4420.41	1	19
27	Leachate TDS (mg/L)	13	DLHK Bantul (2020)	9460.83	1	13
						649.76

2.3. Waste at landfill characteristics

Four criteria were used to evaluate the relationship between landfill characteristics and waste itself, including hazardous waste content, biodegradable fraction, filling age, and waste moisture. The content of hazardous and biodegradable material is determined by direct observation at the site. The selected sample is used for laboratory testing to measure the moisture content while the filling age of the landfill is conducted using government data. These criteria contribute a 95.65 score from IRBA analysis.

The results of observations in the field, the content of hazardous material in the waste is 17.52%, while the composition of the biodegradable fraction waste is 35.7%. Two types of waste have different indices of sensitivity regarding landfill management, hazardous material has a score of 0.44, and biodegradable waste is 0.54, while the weight of parameter hazardous materials has a higher weight than biodegradable waste. The content of hazardous material has a Risk Index (RI) score of 31.24, and the biodegradable fraction is 35.64.

The humidity of the landfill waste is carried out by taking samples and testing in the laboratory. Regarding the laboratory test results from the measurement of wet weight and dry weight, the humidity of the waste in the Piyungan TPST is 52.8%. Waste moisture is influenced by: Composition of waste, season, humus content, and rainfall. Waste moisture data is helpful in container material planning, collection periodization, and management system design. Referring to the result, the moisture content waste of solid was very high, with a score of Risk Index (RI) is 26.

A high volatile in solid waste refers to compounds of high organic can be converted into another compound, i.e., cell biomasses, energy, and other gasses (Li et al., 2019; Qin et al., 2020). A further waste analysis is utilized to measure the theoretical waste formula and the amount of methane gas obtained from this waste degradation (Warmadewanthi et al., 2021). Methane is one of the gases contributing to an increased (accelerated) global warming which is 28 times more destructive than carbon dioxide (Skytt et al., 2020).

2.4. Results of the decision tool

The attributes of the Piyungan landfill and its corresponding weightage are explained in Table 6. The attribute weighting was multiplied by the sensitivity index, and the total value was the value of landfill RI. According to the total of each criterion, the highest influence is criteria 1 with a total score of 467.134. Criteria 2, with a total of 114.63, is a half of total risk value in waste characteristic where the total value is 221. It shows the high risk of the waste characteristic in terms of hazardous material and composition. The leachate quality, with a maximum total score of 63, is showing a very high risk of the leachate to the environment. From the total of those three criteria, the value of RI at the Piyungan landfill is 649.76. As shown in Table 3, the value of RI indicates a potential high hazard, and the landfill must be closed immediately because it pollutes the environment or causes social problems.

The IRBA method calculations align with the factual conditions, including (1) the use age of the Piyungan landfill has exceeded the technical age (Purnama Putra et al., 2018), and (2) the capacity of the waste in the Piyungan landfill has exceeded the calculation (Ariyani et al., 2019). It is supported by the factual conditions in the field indicating that technical age and capacity are serious problems faced in waste management in Yogyakarta, Sleman Regency, and Bantul Regency as Piyungan landfill users.

Even though the IRBA results show the high risk and recommend closing the place immediately, the survey results show that the community groups strongly disagree that the Piyungan landfill is permanently closed. Two strategic recommendations can be taken to overcome the conditions of the Piyungan landfill, namely by conducting an evaluation study of the Piyungan landfill using other more effective methods to obtain maximum results and improve the management of the Piyungan landfill under the established regulations.

Conclusions

The result of the calculation of the RI Piyungan landfill is 649.76. Based on RI categorized for hazard evaluation (Table 2), the results indicate that the Piyungan landfill management has a potential high hazard, which means that the landfill should be closed immediately due the environment impact or causes social problems. The results of these calculations are consequent with the conditions found. It is confirmed by several factors, namely the age of using the landfill which has exceeded the technical age, and the capacity of the waste that exceeds the processing capacity. Hopefully, conducting a more comprehensive evaluation study and improvement of the management can extend the filling age of the Piyungan landfill and support society and environmental sustainability.

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