Evaluation Of Landfill Management At Gunung Kupang Landfill, Banjarbaru City

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Abstract.

Banjarbaru City is the capital city of South Kalimantan Province with waste generation in 2023 of 67,854,410 kg/year. Based on the Banjarbaru City Waste Masterplan for 2021-2025 supported by Banjarbaru City Regulation No. 5 of 2023, one strategy to reduce the amount of waste dumped in landfills is the optimization and development of waste infrastructure including landfills. Waste management at the Gunung Kupang Landfill has not been optimal when viewed from the capacity of waste management. One strategy in the policy of 'Increasing Service Coverage and Quality of Management Systems' in the Masterplan is the rehabilitation of landfills that pollute the environment. Before the landfill was decided to be rehabilitated, an evaluation was carried out using the ARRPET (Asian Regional Research Program on Environmental Technology) method. An overall evaluation of the existing conditions at the Gunung Kupang Landfill has never been carried out so it needs to be carried out using the ARRPET method. The results of the environmental evaluation of the existing conditions of the Gunung Kupang Landfill with ARRPET produced a risk index score of 529.24. This value is included in the risk index with a moderate category so that the recommended follow-up is to rehabilitate the landfill into a sustainable landfill as soon as possible. Therefore, it is planned to build a methane gas installation and landfill mining in landfill zone 2 as a rehabilitation method so that the potential for environmental pollution can be minimized and the life of the landfill can be extended. Based on the evaluation results, the rehabilitation method is feasible to be carried out where the NPV of both rehabilitation methods is positive and the BCR is more than 1.

Keywords: *ARRPET, Environment, Evaluation, Gunung Kupang Landfill and Rehabilitation.*

I. INTRODUCTION

Banjarbaru City is one of the cities located in South Kalimantan Province. Based on the Banjarbaru City Masterplan data for 2021-2025, it is stated that the Banjarbaru City waste management system plan is based on Banjarbaru City Mayor Regulation No. 31 of 2018, namely the reduction and handling of household waste and household-like waste at the Banjarbaru City level. One of the programs in national waste management is the optimization and development of waste infrastructure including landfill. Optimization and development of landfill can be done by rehabilitating landfill. Before deciding on the follow-up action for a landfill and whether or not rehabilitation is needed, an assessment of the environmental conditions at the landfill must first be carried out.Gunung Kupang Landfill located in Cempaka District is a landfill with a service area of Banjarbaru City. The landfill, which was established in 2004, has 4 landfills with three inactive landfill cells and an existing landfill covering an area of 2,5 Ha since the end of 2023 until now. Research in the form of comprehensive evaluation at Gunung Kupang Landfill has never been carried out since year the landfill was established in 2004. Landfill evaluation is very necessary to categorize the potential risks arising from the existing landfill conditions and focusing follow-up on parameters with higher urgency. In addition, research [1] resulted in soil resistivity potentially contaminated with leachate in the Gunung Kupang Landfill area in the range of 0,22 – 6,44 Ωm with a depth of 5 m to 15,25 m.

One of the objectives of the landfill evaluation is to determine the follow-up that needs to be taken for the landfill. Research [2] produced a risk index value of 480,16 on ARRPET and categorized Supit Urang landfill as having moderate risk, so that sustainable landfill rehabilitation efforts are needed. Research [3] showed that Bakung Landfill had a risk index of 476,96, so that sustainable landfill rehabilitation is needed.One of the waste management strategies in Banjarbaru City is development in the technical-technological field of waste. The policy of 'Increasing Service Coverage and Quality of Management Systems' is implemented in the Banjarbaru City Masterplan in 2021, one of which is the rehabilitation of landfills that pollute the environment. One method to determine the actions needed to handle a landfill is the ARRPET (Asian Regional Research Program on Environmental Technology) method by analyzing aspects such as location-specific criteria, characteristics of the waste being dumped and leachate quality [2, 3]. This method not only evaluates the waste management system at a landfill, but also evaluates the landfill from various aspects. Another method to determine the follow-up plan for the existing landfill in [4] is the Integrated Risk Based Approach or commonly referred to as IRBA (Attachment V of PU Regulation Number 03 of 2013). The ARRPET method uses 27 parameters as assessment criteria in determining actions at the existing landfill [3].

According to [2], the ARRPET method is more comprehensive in discussing suggestions for follow-up to a landfill compared to IRBA. One of the advantages of ARRPET lies in its aim to implement the method comprehensively so that the resulting recommendations can be used by industry, companies and even stakeholders related to environmental issues.The recommended follow-up to the landfill is adjusted to the results of the risk index assessment using the ARRPET method. If the risk index of the Gunung Kupang Landfill has a risk index score below 600, then the landfill can still be continued. The need for rehabilitation or not is also adjusted to the results of the assessment using ARRPET. If the rehabilitation method needs to be applied to the Gunung Kupang Landfill, this method needs to be reviewed from a financial aspect such as NPV and BCR. The cost value such as investment, operational and maintenance costs and the benefit value of the rehabilitation method need to be calculated to determine the NPV and BCR. The greater the NPV value and BCR value, the more feasible the rehabilitation method is to be applied [5]. The application of the rehabilitation method must also consider the remaining land area of the Gunung Kupang Landfill of 3,03 hectares from the inactive zone which is used as a Green Open Space (RTH).

II. LITERATURE REVIEW

Indonesia defines waste as the remains of daily human activities in solid or semi-solid or organic and inorganic form which are produced from natural processes and are considered no longer useful so they are thrown into the environment. [6] defines waste as waste with solid properties and consisting of organic or inorganic materials and is considered to have no use value and must be managed to prevent environmental pollution.Waste is categorized based on the chemical components of the waste, the level of biodegradability, and the source of the waste [7]. Based on the chemical components of the waste, waste is divided into organic waste that contains carbon and is usually bound to and inorganic waste that does not contain carbon [8]. Waste is divided into biodegradable and non-biodegradable waste based on the difficulty and length of the decomposition process [9]. The sources of waste are Municipal Solid Waste (MSW) from housing and other facilities, process waste from the mining industry, agricultural waste from livestock, and medical waste from hospitals and clinics [7].According to [10], Final Processing Site (landfill) is defined as a place where waste is processed and returned to the environment following procedures to be safe for humans and the environment. Unmanaged landfill will cause environmental pollution such as becoming a vector of disease, a source of odor and disturbing aesthetics [11]. Other problems such as methane gas produced by landfill have the potential to cause fires if not managed properly [12].The Gunung Kupang Landfill is located in Cempaka District, Banjarbaru City, South Kalimantan Province. This landfill serves five sub-districts in Banjarbaru City, namely Cempaka District, Landasan Ulin District, Liang Anggang District, North Banjarbaru District and landfill Banjarbaru District.

Based on the data, the total area of the Gunung Kupang Landfill land is 16.93 hectares (169,264 m^2) with 3,03 hectares of empty land used as green open space, landfills in both active and non-active zones covering 13.63 hectares, and built-up land area of 0,27 hectares.Gunung Kupang Landfill has a total of 4 landfills with three landfills that are no longer active and one controlled landfill that is still operating from the end of 2023 until now as a waste disposal method used. The area of controlled landfill at Gunung Kupang Landfill is still operating is 2,5 Ha. Gunung Kupang Landfill has several facilities such as an entrance road for access to the landfill, operational roads and connecting roads. In addition, there are other infrastructure such as the landfill office, IPL, IPLT, drainage, heavy equipment, greening zones including parks and green open spaces, weighbridges, guard posts, hangars for sorting waste and Waste Processing

Unit (UPS) warehouses. Gunung Kupang Landfill also has supporting facilities in the form of a prayer room and toilets.Evaluation of potential risks arising from landfills can be done to determine the types and amounts of pollutants that contaminate the environment around the landfill, the impact of these pollutants on public health, the characteristics of the location and waste in the landfill, and the amount of waste that enters and is processed and disposed of in the landfill [13].

One method for evaluating the existing condition of landfills is the Asian Regional Research Programme on Environmental Technology (ARRPET) [14]. Evaluation in ARRPET includes leachate characteristics from leachate processing installations, waste characteristics in the landfill and landfill location criteria [15].The data needed to support the ARRPET method is waste generation and composition. Based on [16], waste generation is the amount of waste that arises from community activities with units of weight and volume per capita per day, or each building area and road extension. Several methods of measuring waste generation are direct measurement, load count analysis, weight volume analysis and material balance analysis.The composition of waste is divided into physical composition and chemical composition. The physical composition of waste according to [17] is grouped into 11 categories, namely food waste, garden waste, paper and cardboard, wood, cloth/textile, rubber and leather, plastic, metal, glass, nappies and others. The chemical composition of waste such as carbon, hydrogen, nitrogen, sulfur, oxygen and others need to be further analyzed.Each parameter is given a different weight depending on its urgency. The parameter sensitivity index is adjusted to the evaluation results and ARRPET provisions. The result of multiplying the sensitivity index and weight is the risk index for evaluating the existing conditions of the landfill. The scoring criteria and follow-up of the ARRPET risk analysis are described in **Table 1**.

Table 1. ARRPET Risk Analysis Scoring Criteria and Follow-up Action

Risk Index	Potential Dangers	Follow-up Recommendations
<300	Very low	No further action is required against the landfill where the landfill is permitted to continue its activities.
300-499	Low	Landfill needs to be rehabilitated continuously and gradually
450-599	Moderate	The landfill must be rehabilitated into a sustainable landfill as soon as possible.
600-749	High	Landfill activities were stopped and the landfill was closed and remediation was considered as an option for restoring environmental quality.
750-1000	Very high	Landfill activities are closed and LANDFILL is stopped and remediation activities must be carried out

The assessment results in the range of 300 - 599 require landfill rehabilitation in accordance with high-risk parameters. The landfill rehabilitation method is evaluated for its financial feasibility by calculating the cost and benefit values. The Net Present Value (NPV) and Benefit Cost Ratio (BCR) methods are two methods used to assess the financial feasibility of a project. A positive NPV value or more than 0 means that the project is feasible to implement because the benefit value is greater than the cost value [18]. A comparison of BCR values produces a value > 1, meaning that a project is feasible to implement because the benefit value is greater than the cost value [19, 20].

III. METHODS

The research location is Gunung Kupang Landfill in Cempaka District, Banjarbaru City. The research period is September 2024 - December 2024. The research was conducted during the dry season. The data collection technique used the field observation method. The data analysis technique is by interpreting Google Earth images to determine the distance of Gunung Kupang Landfill to facilities and laboratory tests as well as interviews and secondary data.The data in this study are divided into primary data and secondary data. Primary data in this study are waste generation and composition as supporting data and primary data on ARRPET obtained through direct field observation. Measurement of waste generation using the weight volume analysis method, namely calculating the weight of waste entering the landfill from weighbridge data. Composition of waste in each sub-district in Banjarbaru is calculated using the Slovin method with the formula:

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Information:

n = Sample size/number

N = Population size

e = Error rate (*margin of error*) of 20% and confidence of 80%, then e = 0,2

Based on the calculation of the Slovin method, 12 trucks will be sampled with 3 trucks from North Banjarbaru District, 3 trucks from South Banjarbaru District, 1 truck from Cempaka District, 3 trucks from Landasan Ulin District and 2 trucks from Liang Anggang District. The method of sampling the composition of waste follows SNI-19-3964-1994, namely taking 100 kg of waste from each truck for 8 consecutive days. The composition of the waste used follows IPCC (2006) and the B3 composition is added as ARRPET data input. Primary ARRPET data such as distance measurements were collected and analyzed by observation via Google Earth. Groundwater quality data from monitoring wells 1 and 3 of the landfill, soil permeability, soil texture, leachate quality at the inlet and outlet of the landfill leachate treatment installation, ambient air content, and waste water content were collected by field observation and direct sampling in the Gunung Kupang Landfill environment. Data on B3 content in waste and biodegradable waste fractions from waste were obtained by sampling waste in the Gunung Kupang Landfill waste composition measurement section. The laboratories for sample testing are the Banjarbaru Public Health Laboratory Center, the Banjarbaru Industrial Standardization and Service Center Laboratory, and the Lambung Mangkurat University Soil Laboratory.

Secondary data in this study are population data of Banjarbaru City, existing condition data of Gunung Kupang Landfill such as the number of waste collection vehicles and existing infrastructure, secondary data of ARRPET and financial data of Gunung Kupang Landfill. Secondary data of ARRPET, namely the area of landfill, height of waste piles, future age of landfill and age of piles in the landfill were obtained from direct interviews with the Head of Gunung Kupang Landfill which was supplemented with data from the Banjarbaru City Environmental Agency. Community acceptance was obtained from direct interviews with the community around Gunung Kupang Landfill. The amount of waste received and piled up was obtained from weighbridge data. Data on flood periods and rainfall were analyzed by taking BMKG data from 2014-2023. CH_4 emissions at the location and groundwater depth were obtained from literature studies. Financial data that will be used to evaluate the follow-up of the landfill based on the results of ARRPET were obtained from interviews with the landfill and literature studies.Data analysis and discussion begin with the analysis of waste generation based on the average weighbridge data for 8 consecutive days and in 2024. Waste generation is obtained by comparing total waste generation data in SIPSN in 2023 with the percentage data of Gunung Kupang Landfill services to Banjarbaru City based on the Banjarbaru City Masterplan in 2021. The equation for finding waste generation per person per day is as follows:

$$Waste\ Generation \left(\frac{\frac{kg}{person}}{day}\right) = \frac{Waste\ weight\ (\frac{kg}{day})}{Sample\ amount\ (person)} \quad (2)$$

The composition of waste from five sub-districts in Banjarbaru City for 8 consecutive days was averaged from each sub-district so that the composition of each sub-district was known. Furthermore, the composition data for each sub-district was averaged so that the composition of Banjarbaru City waste was obtained for 8 consecutive days. Waste samples are considered representative of the composition of Banjarbaru City waste.Environmental evaluation of Gunung Kupang Landfill using ARRPET begins by calculating the sensitivity index based on existing conditions and weighting according to the research results. The sensitivity index and weighting are then multiplied to obtain the Gunung Kupang Landfill risk index value.

$$RI = \sum_{i=1}^{n} Wi\ x\ Si \quad (3)$$

Information:

RI = Risk index of related parameters with a value range of 0-1000

Wi = Weight with a value range of 0-1000 for the relevant parameter

Si = Sensitivity index with a value range of 0-1 for the related parameter

The risk index results are categorized so that the follow-up actions that need to be carried out at the Gunung Kupang Landfill are obtained. Follow-up actions in the form of rehabilitation methods and closure plans need to be evaluated for their financial feasibility. One method that can be used to evaluate the follow-up plan from a financial aspect is the Net Present Value (NPV) and Benefit Cost Ratio (BCR). The NPV equation according to [18] and BCR according to [21] are as follows:

$$NPV = \sum_{i}^{n} \frac{CF}{(1+i)^n} - Io \quad (4)$$

$$BCR = \frac{(F\frac{1}{(1+i)^2})benefit}{(F\frac{1}{(1+i)^2})\,cost} \quad (5)$$

Information:

NPV = Net Present Value (net cash in the present)

CF = Total income

i = Interest rate or tax

n = Period

Io = Initial investment value (year 0)

BCR = Benefit Cost Ratio (ratio of profit to investment costs)

F = Future money value

IV. RESULT AND DISCUSSION

Waste Generation

Based on observations for 8 consecutive days, the amount of waste entering the Gunung Kupang Landfill was 531,13 tons or equivalent to 66,39 tons/day. This data is different when compared to the data on waste entering the Gunung Kupang Landfill during 2024, which was 82,97 tons/day. This is because the amount of waste entering is fluctuating, influenced by weather, activities and the movement of waste transport equipment.Waste generation, waste generation rate and percentage of service of Gunung Kupang Landfill are calculated based on SIPSN data. It is known that based on the calculation of waste generation in 2023 recorded in SIPSN, the amount of waste generation in Banjarbaru City in 2024 is 67.854 tons or 185,9 tons/day. The amount of waste entering Gunung Kupang Landfill is recorded as 30.285 tons so that the percentage of landfill service to Banjarbaru City is 44,6%. The rate of waste generation per person based on this data is 0,67 kg/person/day. The following is a recapitulation of generation, waste generation rate and percentage of service from 2020 - 2024 referring to SIPSN data.

Table 2. Recapitulation of SIPSN Data in 2020 – 2024

Parameter	2020	2021	2022	2023	2024
Waste generation in Banjarbaru City (tons/year)	53.700	60.120	67.079	67.854	67.854
Amount of waste entering Gunung Kupang Landfill (tons/year)	45.690	53.086	61.494	30.623	30.285
Percentage of Gunung Kupang Landfill service (%)	85	88,31	91,67	45	44,6
Waste generation rate (kg/person/day)	0,58	0,64	0,69	0,68	0,67

Waste generation, waste generation rate and percentage of Gunung Kupang Landfill service are also calculated from the percentage of service data in the 2021 Banjarbaru City Masterplan. The percentage of existing urban waste services in Banjarbaru City in 2020 and 2021 is 96,19% with waste reduction of 14,6%, waste management of 81,59% and unmanaged waste of 3,81%. The 2025 service target of 30% waste reduction and 70% waste management has not yet been achieved with waste management reaching 100%. A recapitulation of the percentage of waste management in Banjarbaru City which is estimated to be the same as the percentage of Gunung Kupang Landfill service can be seen in **Table 3**.

Tabel 3. Recapitulation Waste Services Percentage in Banjarbaru City from 2020 to 2025

Year	Percentage of waste reduction	Percentage of waste handling	Waste reduction and management targets for 2025
2021	14,60%	81,59%	30% reduction and 70% management

Year	Percentage of waste reduction	Percentage of waste handling	Waste reduction and management targets for 2025
2022	18,45%	78,69%	
2023	22,30%	75,80%	
2024	26,15%	72,90%	
2025	30,00%	70,00%	

It is known that based on the calculation of waste generation in 2024, the amount of waste generation in Banjarbaru City in 2024 is 72.068 tons or 197,5 tons/day. It is recorded that the amount of waste entering the Gunung Kupang Landfill is 30.285 tons so that the percentage of landfill service to Banjarbaru City is 42,02%. The rate of waste generation per person based on this data is 0,71 kg/person/day. The following is a recapitulation of generation, rate of generation and percentage of service from 2020 - 2024 referring to SIPSN data.

Tabel 4. Recapitulation of Masterplan Data in 2020 – 2024

Parameter	2020	2021	2022	2023	2024
Waste generation in Banjarbaru City (tons/year)	55.999	65.065	78.145	71.082	72.068
Amount of waste entering Gunung Kupang Landfill (tons/year)	45.690	53.087	61.494	30.623	30.285
Percentage of Gunung Kupang Landfill service (%)	81,59	81,59	78,69	43,08	42,02
Waste generation rate (kg/person/day)	0,61	0,69	0,81	0,71	0,71

Waste Composition

The composition of waste entering the Gunung Kupang Landfill for 8 consecutive days from October 3, 2024 to October 11, 2024 was sampled directly. The average largest waste component in the Gunung Kupang Landfill from each sub-district is food waste with a percentage of 46,98%. The second largest percentage of waste at 16,14% is garden waste. The waste with smallest percentage is B3 waste. Details of waste composition at Gunung Kupang Landfill can be seen in **Figure 1**.

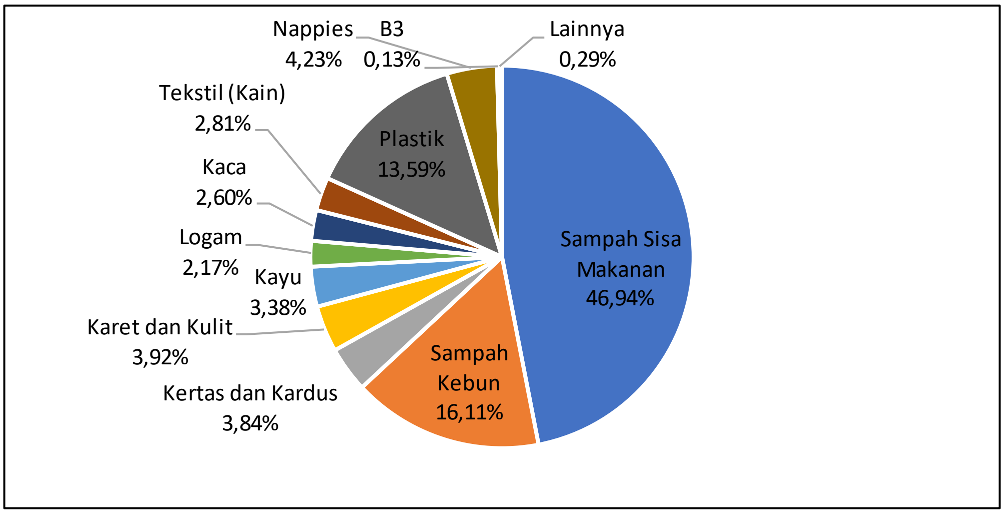

Fig 1. Waste Composition of Banjarbaru City

Environmental Evaluation of Gunung Kupang Landfill with ARRPET

Evaluation of Gunung Kupang Landfill using ARRPET is divided into 27 parameters. The ARRPET method considers 20 parameters related to location criteria, 3 parameters related to leachate characteristics and 4 parameters related to waste characteristics. The calculation results can be seen in **Table 5**.

Tabel 5. Recapitulation of Gunung Kupang Landfill Assessment with ARRPET

No	Parameter	Results	Unit	Weight	Sensitivity Index	Mark
1	Distance to the nearest drinking water source	571	m	69	0,893	**61,6**
2	Depth of the garbage pile	10	m	64	0,5	**32**
3	Land area of landfill	16,9	Ha	61	0,673	**41,02**
4	Groundwater depth	5	m	54	0,589	**36,64**

No	Parameter	Results	Unit	Weight	Sensitivity Index	Mark
5	Soil permeability	5,99 x 10^{-4}	cm/sec	54	1	**54**
6	Groundwater quality	Not a consideration	-	50	0	**0**
7	Distance to habitat	4	km	46	0,8	**36,8**
8	Closest distance to airport	17,5	km	46	0,313	**14,4**
9	Distance to the nearest surface water body	434	m	41	0,783	**32**
10	Soil texture (clay)	1,49	%	41	0,975	**39,98**
11	Future land age	2,19	year	36	0,147	**3,94**
12	Type of waste (waste: B3)	99,70%	rubbish	30	0,002	**0,075**
13	The amount of waste piled up	0,9 x 10^6	ton	30	0,795	**21,75**
14	Daily amount of incoming waste	82,97	tons/day	24	0,08	**1,99**
15	Distance to the nearest settlement	1,16	km	21	0	**0**
16	Annual flood period	100	annual	16	0,25	**4**
17	Annual rainfall	22,04	cm/year	11	0,22	**2,42**
18	Distance to town	10,2	km	7	0,495	**3,47**
19	Public acceptance	Not a concern	-	7	0	**0**
20	CH_4 emissions at site	0,066	%	3	0,58	**1,74**
21	B3 content in waste	0,3	%	71	0,008	**0,53**
22	Biodegradable fraction in waste	70,35	%	66	0,776	**51,21**
23	Age of the pile in the landfill	1	year	58	0,975	**56,55**
24	Water content of waste	65,11	%	26	0,83	**21,68**
25	BOD Value	8,4	mg/L	36	0,07	**2,52**
26	COD Value	264,6	mg/L	19	0,287	**5,45**
27	TDS Value	2.140	mg/L	13	0,261	**3,39**
Total						**529,24**

Table 5 shows that there are three criteria that have a sensitivity index above 0,9, namely soil texture, soil permeability and age of the landfill in the landfill. Soil texture was obtained from taking soil samples around the active landfill of Gunung Kupang Landfill. Soil samples were tested at the Soil Laboratory of Lambung Mangkurat University using the gravimetric method. The test results were a percentage of dust of 50,81%, sand 47,70% and clay only 1,49%. Based on the soil texture triangle, it is known that the type of soil is dusty clay and the smaller the percentage of clay, the greater the potential for environmental pollution. Soil permeability can be interpreted as the ability of the soil to pass water which shows how much water can be absorbed into the soil [22]. The greater the soil permeability in the landfill, the greater the potential for environmental pollution produced. This is in line with [23] which gives the lowest sensitivity index at high permeability. The soil permeability at Gunung Kupang Landfill of 5,99 x 10^{-4} cm/second does not meet the minimum criteria for soil permeability in [23], which is 10^{-6} cm/second. Meanwhile, the age of the embankment at the landfill is known from the length of active landfill service life of Gunung Kupang Landfill, which is 1 year, as evidenced by the operation of the landfill at the end of 2023. The shorter the age of the embankment, the greater the potential for environmental pollution to occur.The distance between the landfill and vital objects is considered important and is regulated in [23] as one of the criteria for assessing the location of the landfill.

The distance of the Gunung Kupang Landfill to the nearest water source, habitat, and the nearest surface water body has a high value and approaches the sensitivity index 1. [23] states that the landfill should be located in an area without any protected areas or nature reserves in the vicinity, but the Gunung Kupang Landfill is approximately 4 km from the Sultan Adam Mandiangin Forest Park which is included in the conservation forest area. The distance to drinking water sources and airports has met the criteria [23], namely it must be more than 100 m for drinking water sources and 3 km for turbo jet flights and 1,5 km for other types of flights.The depth of the waste pile and the area of the landfill are related to the capacity of the waste, where the greater the capacity of the waste, the greater the potential for environmental pollution [24]. The increase in the amount of waste is sometimes not followed by the development of more adequate infrastructure, thus causing environmental pollution. This is caused by environmental conditions that do not match the criteria for the location of the landfill [25]. The sensitivity index of the depth of the waste pile and the area of the landfill are 0,5 and 0,67 respectively, so it can be concluded that it does not have much potential for environmental pollution.The groundwater depth was obtained from research [1], namely in the range of 5 – 7,5 m. Low groundwater levels mean that the distance to the source of pollution is getting closer and will result in greater potential for pollution [26]. The groundwater depth at the Gunung Kupang Landfill has met the criteria in [23], namely a minimum groundwater level of 3 m.

Groundwater quality testing was conducted by considering the physical, chemical and biological parameters of groundwater. Testing on monitoring well 1 and monitoring well 3 resulted in several parameters not meeting quality standards [27] and meaning that the groundwater at the Gunung Kupang Landfill was polluted. Even so, the sensitivity index value was given 0 because the Gunung Kupang Landfill does not use groundwater as a source of raw water, a source of drinking water or for sanitation hygiene needs.The age of the landfill in the future greatly influences the potential for environmental pollution. The longer the service life of a landfill, the greater the potential for environmental pollution in the future. Based on the calculation results, the active landfill age of Gunung Kupang Landfill with a percentage of existing landfill service of 42,02% is 2,19 years. The age of the land is categorized as having low potential for environmental pollution with a sensitivity index of 0,147.Waste type: B3 was obtained from the results of composition sampling for 8 consecutive days at the Gunung Kupang Landfill. The B3 waste component is known to be 0,29% or rounded up to 0,3%. The sensitivity index for this parameter is 0.0025 and is classified as very small because the amount of B3 waste is very low. This means that the type of waste has very little potential for environmental pollution. The B3 content parameter in waste has a sensitivity index value of 0,0075 because the result is the same as the comparison parameter for waste : B3.The amount of waste dumped at the Gunung Kupang Landfill has been accumulated since the landfill was established in 2004 until 2024, which is 0,9 x 10^6 tons. The sensitivity index of 0,73 is included in the high category.

The amount of daily incoming waste of 82,97 tons/day is small compared to the amount of waste entering the Bandengan landfill in Jepara Regency of 152 tons/day [24]. Therefore, the sensitivity index is only 0,08. The distance to the nearest settlement is included in the category of more than 1 km where the Gunung Kupang Landfill is about 1,16 km from the nearest settlement that is exposed to the wind.The calculation of PUH landfill Gunung Kupang was carried out based on the land area data of landfill of 16,9 Ha (0.169 km^2) with a rainfall period of 4 hours (240 minutes). The flow coefficient value is 0.7 because Gunung Kupang Landfill is located in a hilly area. The calculation formula for rainfall discharge used is based on [4] and rainfall intensity refers to the Ishiguro Method. Based on the calculation, PUH Gunung Kupang Landfill is 100 years so that the sensitivity index is 0,25.The rainfall of Banjarbaru City in 2023 based on [28] is 20.41 cm/year. The calculation of rainfall in ARRPET data is based on the rainfall intensity from 2014 - 2023 with an average of 22,04 cm/year. The sensitivity index of 0,22 is included in the low category and does not have the potential to pollute the environment at a high level.CH_4 emissions in landfills were obtained from literature studies and reinforced with ambient air test data at landfills. The average concentration of methane gas in the ambient air of Sumur Batu landfill which uses a controlled landfill system like Gunung Kupang Landfill is 433,434 mg/m^3 [29]. The conversion of this amount produces a result of 660,69 ppm where this value is equal to 0,066% of methane gas in the landfill air. Methane gas in this amount is included in the sensitivity index of 0,5 – 0,75 where the final result of the sensitivity index is 0,58.

Meanwhile, parameters such as SO_2, CO, NO_2, O_3 and noise meet the quality standards [30] and [27].The biodegradable fraction in waste can be interpreted as the ability of a type of waste to be decomposed by microorganisms [31]. Waste components included in this category are food waste and garden waste as well as wood and paper waste. The total percentage of these four waste components is 70,35% and has a sensitivity index of 0,78 which is considered high.The water content of waste at Gunung Kupang Landfill was obtained by taking a 2 kg waste sample by following [6]. The results of the water content of waste at Gunung Kupang Landfill were 65,11% with a sensitivity index of 0,83. High water content of waste will accelerate the process of waste decomposition by microorganisms, causing odor [24].Leachate characteristic testing was conducted at the inlet and outlet of Gunung Kupang Landfill. The characteristics tested consisted of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Dissolved Solid (TDS). The quality standards set for BOD and COD levels are [32], where BOD and COD levels of 8,4 mg/L and 264,6 mg/L respectively meet the maximum threshold of the quality standard. Meanwhile, the quality standard for the TDS parameter is [33] where the maximum TDS level is 2.000 mg/L. TDS at the IPL outlet of Gunung Kupang Landfill still does not meet the maximum threshold of the quality standard.

Rehabilitation Methods

The assessment result of the Gunung Kupang Landfill risk index of 529,24 means that the classification of Gunung Kupang Landfill is included in the range of 450 - 599. Based on the risk index assessment matrix, the potential hazard is included in the moderate category. The recommended follow-up for Gunung Kupang Landfill is to immediately rehabilitate the landfill so that it becomes a sustainable landfill. It is known that the age of the landfill, the amount of waste dumped and the area of the Gunung Kupang Landfill land are included in several parameters that have a high sensitivity index. Therefore, landfill mining is proposed as a method for rehabilitating Gunung Kupang Landfill. Landfill mining is an effort to excavate landfills that have a stockpile age of more than 6 years so that it can reclaim land and reuse waste mined from the landfill. The landfill mining method can reduce the amount of waste dumped and provides one solution to not expanding the landfill area by reusing landfills that have been mined [2]. The landfill mining method is considered effective in reducing environmental pollution [34]. The estimated service life of the landfill if the mined landfill is reused is detailed as follows:

It is known:

Second cell landfill area = 20.000 m^2 = 0,2 km^2

Landfill height = 10 m

Volume of waste excavated = 760,7 m^3/day

So the maximum time for landfill to be reused is:

$$Second\ landfill\ cell\ volume = Landfill\ wide\ x\ landfill\ height$$

$$= 20.000\ m^2\ x\ 10\ m$$

$$= 200.000\ m^3$$

$$Volume\ of\ waste\ mined = (Amount\ x\ volume\ x\ ritation)$$

$$= (10\ unit\ x\ 6\ m^3\ x\ 2\ ritation)$$

$$= 120\ m^3$$

$$landfill\ mining\ time = \frac{Landfill\ volume}{mined\ waste\ volume\ x\ effective\ time}$$

$$= \frac{200.000\ m^3}{120\ m^3\ x\ 330\ days}$$

= 1,667 days or 5 years

Existing landfill land requirements = 1.41 Ha

$$Landfill\ maximum\ time = \frac{Existing\ second\ landfill\ cell\ wide}{Existing\ landfill\ wide\ needed}$$

$$= \frac{2\ Ha}{1,41\ Ha}$$

= 1,42 years or 518 days.

The next step after planning landfill mining as one of the rehabilitation methods of Gunung Kupang Landfill is to calculate the investment, operational and maintenance costs of this method. The cost and benefit analysis is projected for the next 5 years with an estimated 5-year landfill mining work according to the previous calculation results. A recapitulation of the cost and benefit values of landfill mining can be seen in the table below.

Tabel 6. Costs and Benefits Recapitulation of *Landfill Mining* Method

n	Year	Cost and Benefit Value	Cost and Benefit Value + Interest Rate

		Cost Value (Rupiah)	Benefit Value (Rupiah)	Nilai Biaya (Rupiah)	Nilai Manfaat (Rupiah)
1	2025	47.457.966.779	16.960.508.019	44.771.666.772	16.000.479.263
2	2026	8.707.834.643	17.477.803.514	7.749.941.833	15.555.182.906
3	2027	8.794.912.990	18.010.876.521	7.384.378.539	15.122.279.231
4	2028	8.882.862.119	18.560.208.255	7.036.058.796	14.701.423.347
5	2029	8.971.690.741	19.126.294.606	6.704.169.230	14.292.279.961
Total		**82.815.267.271**	**90.135.690.914**	**73.646.215.170**	**75.671.644.709**

The interest rate used is the interest rate referring to Bank Indonesia (BI) in 2024, which is 6%. The value of operational and maintenance costs is assumed to increase by 1% each year [31]. The benefit value is adjusted to the highest inflation rate in 2024 based on BI inflation data, which is 3,05% in March. Based on the recapitulation of costs and benefits in Table 6, the Net Present Value (NPV) and Benefit Cost Ratio (BCR) of the landfill mining method are 2.025,429,539 and 1,03. Based on the calculation results, landfill mining is feasible to be implemented as an alternative to rehabilitating the Gunung Kupang Landfill into a sustainable landfill.Controlling methane gas requires a methane gas installation that is in accordance with the existing conditions of the Gunung Kupang Landfill. The estimated parameters for methane gas emissions at the location are at moderate risk. The controlled landfill system is required to channel methane gas into the open air through the ventilation of the gas capture system to prevent fires or explosions and toxic hazards [31]. It is known that the Gunung Kupang Landfill already has an existing methane gas installation and even utilizes the results of methane gas capture, but this installation has not been used since 2020 due to the COVID-19 pandemic.

In addition, the existing methane gas installation only channels methane gas from the third landfill cell which is no longer active. It is estimated that the methane gas produced cannot be fully accommodated in the methane gas installation even though the potential for methane gas at the Gunung Kupang Landfill is quite large. For these reasons, one of the methods for rehabilitating the Gunung Kupang Landfill is to plan a methane gas installation that is in accordance with the applicable criteria and standards. Methane gas installation is planned to be adjusted to the technical criteria referring to [4].The construction of a methane gas installation has the potential to produce benefits in the form of methane gas distributed to settlements around the landfill to replace LPG gas. The cost and benefit analysis is projected for the next 5 years with an estimate that the existing landfill of Gunung Kupang Landfill will be closed within 5 years. A recapitulation of the costs and benefits of the construction of a methane gas installation can be seen in the table below.

Tabel 7. Costs and Benefits Recapitulation of Methane Gas Installation

n	Year	Cost and Benefit Value		Cost and Benefit Value + Interest Rate	
		Cost Value (Rupiah)	Benefit Value (Rupiah)	Nilai Biaya (Rupiah)	Nilai Manfaat (Rupiah)
1	2025	47.457.966.779	16.960.508.019	44.771.666.772	16.000.479.263
2	2026	8.707.834.643	17.477.803.514	7.749.941.833	15.555.182.906
3	2027	8.794.912.990	18.010.876.521	7.384.378.539	15.122.279.231
4	2028	8.882.862.119	18.560.208.255	7.036.058.796	14.701.423.347
5	2029	8.971.690.741	19.126.294.606	6.704.169.230	14.292.279.961
Total		**82.815.267.271**	**90.135.690.914**	**73.646.215.170**	**75.671.644.709**

The interest rate used is the interest rate referring to Bank Indonesia (BI) in 2024, which is 6%. The value of operational and maintenance costs is assumed to increase by 1% each year [31]. The benefit value is adjusted to the highest inflation rate in 2024 based on BI inflation data, which is 3,05% in March. Based on the recapitulation of costs and benefits in Table 7, the Net Present Value (NPV) and Benefit Cost Ratio (BCR) of the construction of a methane gas installation are 73.903.238.366 and 1,40. Based on the calculation results, the construction of a methane gas installation is feasible to be implemented as an alternative to rehabilitating the Gunung Kupang Landfill into a sustainable landfill.

V. CONCLUSION

Based on the calculation results, the ARRPET risk index value is 529,24. This value is included in the potential hazard with moderate risk and does not require landfill closure. However, Gunung Kupang Landfill needs to be rehabilitated as soon as possible to become a sustainable landfill. The planned rehabilitation method is the construction of a methane gas installation and conducting landfill mining in the second landfill cell that has been inactive for 6-12 years. The rehabilitation method is based on PermenPU No. 03 of 2013.Based on the remaining land area, both rehabilitation methods are feasible to be carried out. The value of the costs and benefits of the construction of a methane gas installation projected for 5 years produces an NPV of 73.903.238.366 and a BCR of 1,4. Meanwhile, the value of the costs and benefits of landfill mining projected for 5 years is 2.025.429.539 and a BCR of 1,03. Based on these results, both rehabilitation methods are feasible and must be carried out at the Gunung Kupang Landfill.

REFERENCES

[1] H. Hardiono, I. Santoso, A. Arifin, *Nilai Resistivitas dengan Variasi Jarak di Tempat Pemrosesan Akhir Sampah Gunung Kupang Banjarbaru*, ***Jurnal Kesehatan Lingkungan***, ***13:2***, 2016, pp. 337-345.

[2] D. N. H. M. Rahawarin, *Kajian Evaluasi Pengelolaan LANDFILL dan Analisis Biaya Manfaat di LANDFILL Supit Urang Kota Malang*, ***Tesis***, 2024, pp. 1-194.

[3] A. Phelia, E. Damanhuri, *Kajian Evaluasi TPA dan Analisis Biaya Manfaat Sistem Pengelolaan Sampah di TPA (Studi Kasus TPA Bakung Kota Bandar Lampung)*, ***Jurnal Teknik Lingkungan, 25:2***, 2019, pp. 85-100.

[4] Peraturan Menteri Pekerjaan Umum Nomor 03 Tahun 2013 tentang: *Penyelenggaraan Prasarana dan Sarana Persampahan dalam Penanganan Sampah Rumah Tangga dan Sampah Sejenis Sampah Rumah Tangga*, Jakarta.

[5] J. Jao, M. Toyokan, E. Vallar, L. Silva, M. C. Galvaz, *Assessment of Municipal Solid Waste Management Scenarios in Metro Manila Using the Long-Range Energy Alternatives Planning-Integrated Benefit Calculator (LEAP-IBC) System*, ***Sustainability, 16***, 2024, pp. 1-20.

[6] Badan Standardisasi Nasional. SNI 19-3964-1994., 1994. *Metode Pengambilan dan Pengukuran Contoh Timbulan dan Komposisi Sampah Perkotaan*. Jakarta (ID).

[7] K. F. Mahyari, Q. Sun, J. J. Klemes, M. Aghbashlo, M. Tabatabei, B. Khoshnevisan, M. Birkved, *To what extent do waste management strategies need adaptation to post-COVID-19*, ***Science of Total Environment, 837***, 2022, pp. 1-13.

[8] F.Suraya,E.A.Safitri,W.R.Maulana,F.A.Pratama,D.Nafisah,*Revitalisasi TPS3R melalui Penyuluhan Pengelolaan Sampah dan Pelatihan Pembuatan Kompos dari Sampah Organik*,***Jurnal Puruhita***,*3*,2021,pp.22-30.

[9] R. Rita, *Management of Biodegradable Waste*, ***Journal of Biotechnology and Biomaterials, 11:6***,2021, pp. 132.

[10] Undang-Undang Nomor 18 Tahun 2008 tentang: *Pengelolaan Sampah*, Jakarta.

[11] N. Ferronato, V. Toretta, *Waste Mismanagement in Developing Countries: A Review of Global Issues*, ***International Journal of Environmental Research and Public Health, 16***, 2019, pp. 1-28.

[12] S. Sunarto, S. Sulistyaningsih, J. Jainuri, S. Salahuddin, *The effect of waste treatment on greenhouse gas reduction and final disposal site (Landfill)*, ***Journal of Physics, 1571***, 2020, pp. 1-6.

[13] A. Phelia, *Kajian Evaluasi TPA dan Analisis Biaya Manfaat Sistem Pengelolaan Sampah di TPA (Studi Kasus TPA Bakung Kota Bandar Lampung)*, ***Tesis***, 2019, pp. 1-167.

[14] C. Visvanathan, K. Joseph, R. Nagendran, K. Thanasekaran, W. Hogland, **Dumpsite Rehabilitation Manual** (first edition), Anna University, India, 2008.

[15] E. Damanhuri, T. P. Damanhuri, **Pengelolaan Sampah Terpadu** (second edition), ITB Press, Bandung, 2019.

[16] Badan Standardisasi Nasional. SNI 19-2454-2002., *Tata Cara Teknik Operasional Pengelolaan Sampah Perkotaan*. Jakarta (ID).

[17] Intergovernmental Panel on Climate Change (2006), *IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 1, IPCC, Japan.

[18] A. S. Sinaga, M. M. Sari, A. A. Hutasuhut, S. T. Zahara, A. Amanda, A. Fitri, M. A. Caesario, *Comparison of capital budgeting methods: NPV, IRR, Payback Period*, ***World Journal of Advanced Research and Reviews, 19:2***, 2023, pp. 1078-1081.

[19] D. Ruminta, *Analisis Perbandingan Perhitungan Kelayakan Finansial Konvensional dan Syariah*, ***Jurnal Ecodemica, 4***, 2020, pp. 92-102.

[20] M. Chaerul,S.A.Rahayu,*Cost Benefit Analysis dalam Pengembangan Fasilitas Pengolahan Sampah: Studi Kasus Kota Pekanbaru*, ***Journal of Natural Resources and Environmental Management, 9:3***, 2019,pp.710-722.

[21] R. A. Ula, I. Haryanto, A. Prasetya, *Analisis Keekonomian Skenario Pengelolaan Sampah di TPA Gunung Panggung Tuban Jawa Timur*, ***Jurnal Rekayasa Proses, 17***, 2023, pp. 1-11.

[22] F. A. Alista, S. Soemarno, *Analisis Permeabilitas Tanah Lapisan Atas dan Bawah di Lahan Kopi Robusta,* ***Jurnal Tanah Dan Sumberdaya Lahan, 8:2***, 2021, pp. 493-504.

[23] Badan Standardisasi Nasional. SNI 03-3241-1994. 1994. *Pemilihan Lokasi Tempat Pembuangan Akhir Sampah*. Jakarta (ID).

[24] F. N. P. Jasmine, A. Aji, *Penilaian Indeks Risiko Lingkungan (IRBA) TPA Sampah Bandengan Kabupaten Jepara*, ***Indonesian Journal of Conservation, 12***, 2023, pp. 108-116.

[25] H. Hamsah, Y. A. Iryawan, N. Nirmawala, *Kesesuaian Tempat Pembuangan Akhir Sampah dengan Lingkungan di Desa Kalitirto Yogyakarta,* ***Plano Madani, 6***, 2017, pp. 1-14.

[26] E. M. Yatim, M. Mukhlis, *Pengaruh Lindi (Leachate) Sampah Terhadap Air Sumur Penduduk Sekitar Tempat Pembuangan Akhir (TPA) Air Dingin,* ***Jurnal Kesehatan Masyarakat, 7:2***, 2013, pp. 54-59.

[27] Peraturan Menteri Kesehatan Nomor 02 Tahun 2023 tentang: Peraturan Pelaksanaan PP No. 6 Tahun 2014 Tentang Kesehatan Lingkungan, Jakarta.

[28] Badan Pusat Statistik Indonesia. 2023. Jakarta.

[29] L. I. Lestari, J. Soemirat, M. Dirgawati, *Penentuan Konsentrasi Gas Metan di Udara Zona 4 LANDFILL Sumur Batu Kota Bekasi*, ***Jurnal Institut Teknologi Nasional, 1***, 2013, pp. 1-11.

[30] Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021 tentang: Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup (Lampiran VII Baku Mutu Udara Ambien).

[31] M. S. Iman, *Evaluasi Pengelolaan TPA Cahaya Kencana Kabupaten Banjar Provinsi Kalimantan Selatan, Tesis*, 2019, pp. 1-341.

[32] Peraturan Menteri Lingkungan Hidup dan Kehutanan RI Nomor P.59/MenLHK/Setjen/Kum. 1/7/2016 tentang: Baku Mutu Lindi bagi Usaha dan/atau Kegiatan Tempat Pemrosesan Akhir Sampah.

[33] Peraturan Menteri Lingkungan Hidup dan Kehutanan RI Nomor. 70 Tahun 2019 tentang: Baku Mutu Limbah Cair Domestik.

[34] M. Hadiwidodo, E. Sutrisno, S. Hartini, M. A. Budihardjo, B. S. Ramadan, A. S. Puspita, F. R. Efriani, *Feasibility Study for Mining Waste Materials as Sustainable Compost Raw Material Toward Enhanced Landfill Mining*, ***Polish Journal of Environmental Studies, 32:3***, 2023, pp. 2323-2335.