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Environmental Risk Assessment of Sarimukti Landfill Postfire in Indonesia

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Abstract

Indonesia aims to ensure that 100% of urban waste is properly managed focusing 80% on waste collection and 20% on reduction, while transitioning toward a processing-based waste management system. Despite various solutions, achieving substantial progress remains difficult. Waste pollution, including unsightly waste, foul odors, and hazardous leachate, negatively impacts the environment. The fire at Sarimukti landfill was caused by careless disposal of cigarette butts during the dry season. Exacerbated the situation and affected more than 15 hectares. Therefore, an environmental quality evaluation using an Integrated Risk-Based Approach (IRBA) is required. According to Ministry of Public Works Regulation Number 03 of 2013, this evaluation is crucial before deciding whether to rehabilitate or close the landfill. This study characterizes waste during a fire disaster, assesses leachate quality in Sarimukti landfill treatment facility, and conducts a rapid environmental assessment using the IRBA method to determine landfill feasibility. The burned waste had an average moisture content of 10.41%, volatile matter of 49.04%, ash content of 50.95%, fixed carbon of 31.05%, and a calorific value of 3,391.19 cal/g. The leachate quality exceeded standards for BOD, COD, and total nitrogen, while pH, TSS, mercury, and cadmium remained within acceptable limits. The final Environmental Risk Index assessment yielded a very high hazard evaluation of 622.24, indicating that the landfill should be closed due to its significant environmental and social impacts.

1. Introduction

The incidence of fires is one of the most serious of these landfill failures. According to statistical data of landfill events in various nations, fires are the most persistent and chronic worldwide problem associated with all types of landfills occurring regularly over the decades in both developing and industrialized countries. From 2023 to 2024, many landfills in Indonesia experienced significant fires. Various factors are suspected to have caused these fires, including the accumulation of methane gas produced from the decomposition of organic waste, which is highly flammable when exposed to sparks. Additionally, high temperatures due to climate change and prolonged dry seasons exacerbated the situation, increasing the risk of landfill fires. Other contributing factors include suboptimal waste management, illegal waste burning, and the use of unsafe equipment.

Sarimukti Landfill which has been in operation since 2011, had its use extended until 2024. On Saturday, August 19, 2023, a fire broke out at the landfill, reportedly caused by human error. The fire affected an area of 16.5 hectares, leaving the landfill's surface charred and shrouded in thick smoke from firefighting efforts. Due to the persistent nature of fire, Sarimukti Landfill was declared a disaster emergency. This prompted the West Java Provincial Government to act swiftly to manage the situation. Efforts included not only extinguishing the fire but also preparing emergency sites to accommodate new waste. Accelerating fire suppression was critical to restoring the landfill's operations to normal. However, extinguishing the fire alone was insufficient proper cooling of the land was necessary to stabilize the waste piles [1]. The fire resulted not only burned waste but also air pollution caused by the thick smoke, disrupting the landfill's waste management operations and creating a waste emergency. Beyond the fire incident, the Sarimukti Landfill already faced several issues, including overcapacity in all zones, leachate problems, open dumping practices, and other environmental management challenges.

In addition to the fire incident, which caused Sarimukti Landfill operations to be less than optimal, the facility was already facing other challenges. Sarimukti Landfill actually has several problems ranging from landfills in all zones that are overloaded, leachate problems, open dumping, and other environmental management problems. Thus, before making a decision to rehabilitate the landfill or permanently close the landfill, it is necessary to evaluate environmental quality through an environmental risk index assessment using Integrated Risk Based Approach (IRBA) method.

2. Methodology

The method used is the data collection method. Starting with a literature review, field observation, secondary data collection, and primary data collection. Then discussing and analyzing the obtained data. The collected data is integrated with an environmental assessment decision tool using the IRBA (Integrated Risk-Based Approach) method. Secondary data collection is an initial preliminary stage by literature study and data collection obtained from previous research in the form of hardcopy or softcopy of archival documents, journals, literature, textbooks, important notes, internet websites, and related agencies as a basis for the basis of the study to support research data. Primary data was obtained from direct testing of landfill waste piles at Sarimukti Landfill. Primary data collection was carried out by taking waste samples, leachate water, and methane gas measurements at Sarimukti Landfill after the fire disaster. A survey was conducted to see the existing conditions of the Sarimukti Landfill. Waste sample results will be analyzed through laboratory testing by parameters needed for environmental assessment.

2.1 Environmental Assessment IRBA Method

The Integrated Risk Based Approach (IRBA) is regulated in Appendix V of Regulation of Minister of Public Works Number 03 of 2013 concerning the Implementation of Waste Facilities and Infrastructure in Handling Household Waste and Waste Similar to Household Waste. This method serves as a decision-making tool for determining whether to close or rehabilitate open landfills based on environmental risk assessment. The risk index for landfills is calculated by summing values that are considered to contribute to environmental pollution [2]. The risk index includes both the attribute weight index and sensitivity, as presented in Table 1. The risk index for each landfill is calculated by multiplying the attribute weight by the sensitivity index, which is derived from observations and interviews. Conclusions regarding hazard levels and recommended actions are determined using a hazard evaluation table based on the risk index, as shown in Table 2.

Table 1 *IRBA's tool [2]*

S/ N	Attribute	Attribute Weightage	Sensitivity Index			
			0.00-0.25	0.25-0.50	0.50-0.75	0.75-1.00
I-Site specific criteria						
1.	Distance from nearest water supply source (m)	69	>5000	2500-5000	1000-2500	<10000
2.	Depth of waste pile (m)	64	<3	3-10	10-20	>20
3.	Area of landfill (Ha)	61	<5	5-10	10-20	>20
4.	Groundwater depth (m)	54	<20	10-20	3-10	<3
5.	Permbeability of soil (1 x 10^{-4} cm/s)	54	<0,1	1-0,1	1-10	>10
6.	Groundwater quality	50	Not a concern	Potable	Potable if no Alternative	Non-potable
7.	Distance to habitat (protected forest etc.) (km)	46	>25	10-25	5-10	<5
8.	Distance to nearest airport (km)	46	>20	10-20	5-10	<5
9.	Distance from surface water body (m)	41	>8	1,5-8	0,5-1,5	<0,5

S/ N	Attribute	Attribute Weightage	Sensitivity Index			
			0.00-0.25	0.25-0.50	0.50-0.75	0.75-1.00
10.	Soil type (% clay)	41	>50	30-50	15-30	0-15
11.	Life of the site for future use (years)	36	<5	5-10	10-20	>20
12.	Type of waste (MSH/HW)	30	100% MSW	75% MSW+ 25% HW	50% MSW + 50% HW	>50% HW
13.	Total quantity of waste at site (tons)	30	<104	104-105	105-106	>106
14.	Quantity of wastes disposed (tons/day)	24	<250	250-500	500-1000	>1000
15.	Distance to the nearest village in the predominant wind (m)	21	>1,0	0,6-1,0	0,3-0,6	<0,3
16.	Flood period (annual)	16	>100	30-100	10-30	10
17.	Annual rainfall at site (cm/year)	11	<25	25-100	125-250	>250
18.	Distance from the city (km)	7	>20	10-20	5-10	<5
19.	Public acceptance	7	No public concerns	Accepts dump rehabilita ti-on	Accepts dump Closure	Accepts dump closure and remediat ion
20.	Ambient air quality – CH4 (%)	3	<0,1	0,05-0,01	0,05-0,1	>0,1
			II – Related to characteristics of waste at the landfill			
21.	Hazardous contents in waste (%)	71	<10	10-20	20-30	>30
22.	Biodegradable fraction of waste at site (%)	66	<10	10-30	30-50	60-100
23.	Age of filling (years)	58	>30	20-30	10-20	<10
24.	Moisture of waste at site (%)	26	<10	10-20	20-40	>40
					III – Related to leacheate quality	
25.	BOD of leachate (mg/l)	36	<30	30-60	60-100	>100
26.	COD of leachate (mg/l)	19	<250	250-350	350-500	>500
27	TDS of leachate (mg/l)	13	<2100	2100-3000	3000-4000	>4000

Table 2 *Hazard evaluation criteria based on the risk index [2]*

S/N	Overall score	Hazard Evaluation	Recommended action
1	601-1000	Very High	The landfill must be closed immediately because it pollutes environment or social problems
2	300-600	Moderate	Landfill continued and rehabilitated to controlled landfill in phases
3	<300	Low	The landfill was continued and rehabilitated into a controlled landfill. This site has the potential to be developed into a long term landfill.

3. Existing Conditions

3.1 Study Area

In 2006, Sarimukti Landfill began operations as a final waste disposal site and composting facility, receiving waste from the cities of Bandung, Cimahi, the regency of West Bandung, and part of the regency of Bandung. Initially, the Sarimukti Landfill was operated until 2011, but its usage was extended until 2023, with a focus on maximizing waste processing through composting and semi-sanitary landfill methods. However, currently, there is no composting processing, and waste is managed through open dumping, which is overseen by the West Java Regional Waste Management Office, and implemented by the Regional Waste Management Technical Implementation Unit (UPTD PSTR) of West Java [3]. The Sarimukti Landfill is located in the Gedig Block, Sarimukti Village, Cipatat District, West Bandung Regency. The total land area of Sarimukti Landfill is 25.2 ha (21.2 ha belongs to Perhutani, 4 Ha belongs to Bandung City and Cimahi). The expansion land with the national road boundary is 18 ha so total area of Sarimukti landfill is 39.2 ha [4]. According to data from the West Java Provincial Environmental Agency, it is known that the waste generated and sent to the Sarimukti Landfill amounts to 60.000 tons per month or 2.000 tons per day.

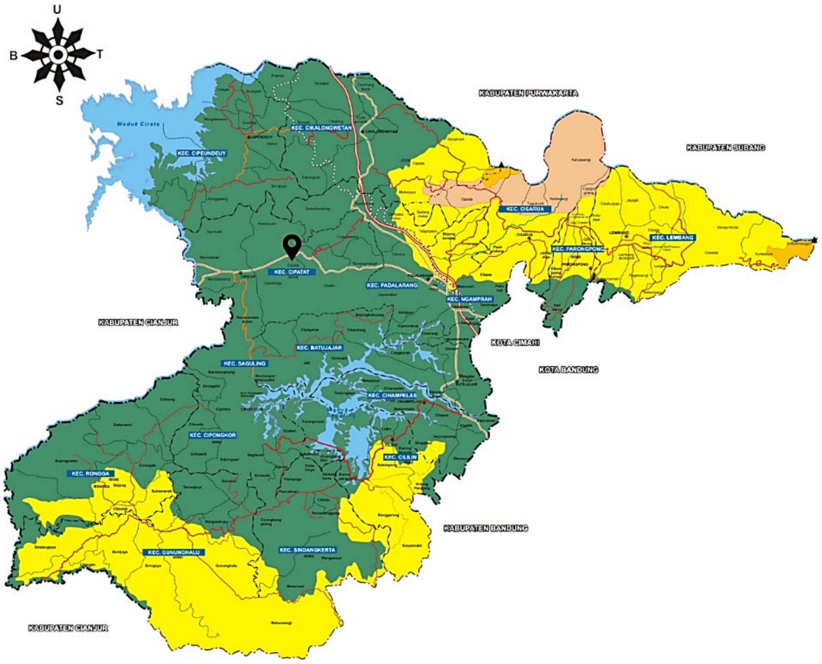

Fig. 1 *Study area of Sarimukti landfill [15]*

3.2 Sarimukti Landfill Fire

Landfill fires release dense clouds of toxic smoke, dispersing hazardous pollutants over vast distances and posing serious environmental risks [23]. Yet in Indonesia, comprehensive data on these fires—frequency, types, causes, or impacts—remains scarce. This lack of documentation makes it challenging to study landfill fires scientifically. To bridge this gap, researchers turned to online news reports for insights. Between 2004 and 2019, 37 landfill fires were recorded across 25 Indonesian landfills. In 2023, 14 incidents occurred, including the Sarimukti landfill fire. These figures, while alarming, likely underestimate the true scale of the problem, as many smaller fires go unreported.

Fig. 2 *Condition of Sarimukti landfill fire*

On Saturday, August 19, 2023, at 8:00 PM WIB, a massive fire erupted at Sarimukti Landfill in Indonesia, engulfing all zones and burning 16.5 hectares of waste. Authorities suspect human error triggered the disaster [5]. Land fires involve uncontrolled burning of vegetation or organic material forests, peatlands, grasslands, or farmland that can spiral out of control, destroying ecosystems, natural resources, and endangering lives. These fires stem from natural factors like prolonged dry spells or lightning, or human activities such as reckless land clearing, agricultural expansion, or careless waste burning. Large landfill fires pose severe threats to safety, health, and ecosystems. Environmentally, they release toxic gases containing carcinogens like dioxins and furans, polluting air, water, soil, and even crops in surrounding areas. Research confirms traces of contamination from landfill fires linger in affected regions. From a safety perspective, underground fires can create unstable pockets of charred waste, weakening landfill stability and increasing risks of slope collapses or sudden surface cave-ins [24]. In rural communities near landfills, prolonged subsurface fires may destabilize waste piles, leading to dangerous slides or collapses. A tragic example is the 2005 Leuwigajah dumpsite disaster in Bandung, Indonesia, where heavy rainfall and a long burning underground fire caused structural failure, triggering a landslide that killed 141 people [23].

Landfill fires release smoke and greenhouse gases, degrading air quality, harming human health, and accelerating global climate change [18]. Like wildfires whether sparked by human activity or natural causes these fires begin with combustion [6]. Among waste combustion methods, open burning of solid waste is especially harmful, releasing extreme levels of pollutants into the air, soil, and water [7]. Scientifically, fire is a chemical reaction that produces energy as heat and light. It relies on three key elements: heat, fuel, and oxygen a concept often shown in the fire triangle. In landfills, "fuel" includes flammable materials like plastics, paper, wood, and rubber. Oxygen comes from air or wind, while heat can originate from natural heat-generating processes within the waste, sunlight, sparks, lightning, electrical faults, or nearby flames. When these three elements meet, fire ignites. Remove just one, and combustion stops.

In landfills, a subsurface oxidation reaction that causes a temperature rise without open flames is known as a hot spot, heating incident, or ROSE (Rapid Oxidation Subsurface Events) [8]. These reactions typically occur deep within the landfill mound. In contrast, when oxidation happens at the surface, it often leads to open fires due to the abundance of oxygen. Landfills are essentially massive piles of mixed waste, much of which is highly flammable think plastic packaging, paper, cardboard, rubber, wood, branches, and similar materials. These mounds can range from 5 to 30 meters in height and span anywhere from 3 hectares to hundreds of hectares. Exposed to weather like rain, heat, and wind, landfills also naturally produce methane, a flammable gas. These conditions create fire risks with unique characteristics compared to fires in buildings or other structures. Landfill fires can occur in two forms: surface fires and subsurface fires. Surface fires, common in Indonesian landfills, burn within the top 1 to 4 feet (0.3–1.2 meters) of the waste layer. This zone allows aerobic decomposition, which generates heat and can ignite materials like paper or plastics. These fires often worsen as methane gas from deeper layers fuels the flames, producing thick black smoke and temperatures between 80°C and 230°C (176°F to 446°F). Subsurface fires, on the other hand, are harder to detect. No visible flames appear—only smoke and heat seeping from the mound. These hidden burning areas, called hot spots, reach far higher temperatures (309–406°C or 588–763°F) due to intense, oxygen-limited combustion [16].

Area of the landfill that is burning differs from the surface area. The burning occurs in areas where the waste decomposition process has already shifted to anaerobic conditions, producing flammable methane gas. Fires within the landfill are common in the United States and Europe, where landfills use the dry tomb system. This system is drier compared to the conditions of landfills in Indonesia, where the interior is typically wet and submerged in leachate. The emergence of hot spots is generally triggered by natural heat (self-heating) from aerobic decomposition by bacteria. Aerobic conditions should not occur in the interior because there is no air or oxygen. However, aerobic conditions arise due to increased oxygen concentration in the interior of the landfill, entering through the surface. Air can enter the interior of the landfill because the waste is loose (not compacted) or due to excessive methane gas extraction. The natural heating process causes temperatures to rise to 80-90°C, which can ignite the methane gas. Hot spots inside the landfill are generally more difficult to extinguish than surface fires. Fires within the landfill result in the formation of empty spaces, which can cause the surface of the waste to collapse. These fires also produce flammable and toxic gases, such as carbon monoxide. In addition, internal fires damage the gas piping and leachate piping systems, as well as the landfill's base liner. Given the current challenges in waste management in many regencies and cities, the risk of fire continues to threaten, especially during the dry season. With these conditions, what can be done is to prevent anything that could trigger a spark in the dry waste piles at the top of the landfill. Preventing fires is better than having to fight the blaze later [9]. Hence, landfill fires pose a major hazard that needs to be considered in both the planning and operational management of landfills.

The subsurface burning area within landfills differs from surface fires, typically occurring in zones where waste decomposition has transitioned to anaerobic conditions, producing methane gas. Such internal fires are prevalent in U.S. and European landfills, which often employ a dry tomb design a system far drier than Indonesian landfills, where interiors are frequently saturated with leachate. Subsurface fires (hot spots) are primarily triggered by self-heating from aerobic bacterial decomposition. While anaerobic conditions (lacking oxygen) should dominate landfill interiors, aerobic activity arises when oxygen infiltrates through loose, uncompacted waste layers or due to excessive methane extraction. This process elevates temperatures to 80–90°C, igniting trapped methane. Subsurface fires are notoriously difficult to extinguish compared to surface fires. They create voids within waste layers, leading to surface collapse and releasing toxic gases like carbon monoxide. Additionally, these fires compromise critical infrastructure, damaging gas and leachate piping systems as well as landfill liners. Given Indonesia's waste management challenges—particularly during dry seasons—proactive prevention is paramount. Key measures include eliminating ignition sources (e.g., sparks) in dry surface waste layers. Addressing root causes, such as improving waste compaction and regulating methane extraction can reduce oxygen intrusion and self-heating risks. As landfill fires pose significant operational and environmental hazards, fire prevention must be prioritized in landfill design and management protocols [9].

4. Result and Discussion

4.1 Waste composition

Waste dumped in landfills varies based on the source of its generation. As the final disposal site, a landfill collects waste from different sources within its service area. The characteristics and composition of the waste at each landfill are shaped by the specific traits of the local population. Figure 3 illustrates the composition of waste in the Sarimukti landfill (% percent wet weight of waste).

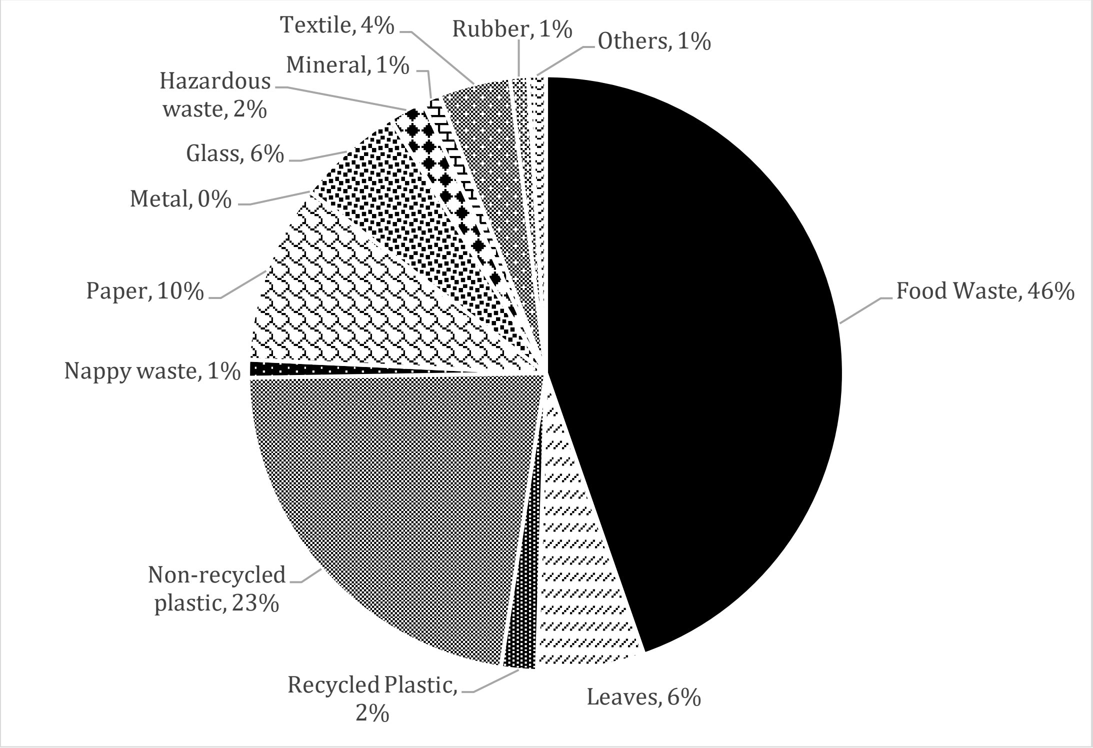

Fig. 3 *Waste composition of Sarimukti landfill*

The waste composition of Sarimukti landfill is dominated by organic waste, such as food waste or kitchen waste, followed by non-recyclable waste, including packaging waste, sheet waste, plastic, and other materials. Additionally, paper waste is the third most dominant type, consisting of cardboard, paper, newspapers, magazines, and other similar items.

4.2 Leachate Quality

Leachate forms when water filters through waste, absorbing bacteria, heavy metals, and toxic chemicals. If landfills lack proper lining or management, this contaminated liquid can seep into nearby groundwater a critical source of drinking water posing serious health risks. Strong odors from landfills or waste incineration facilities also raise public health concerns [20]. Leachate composition depends on factors like climate shifts, temperature fluctuations, rainfall patterns, waste types, and moisture levels in buried materials [17]. Data from Sarimukti Landfill's leachate (Table 3) shows BOD, COD, and N-Total levels exceeding regulatory limits, while pH, TSS, mercury, and cadmium remain within acceptable standards.

Table 3 *Results of monitoring the quality of burnt waste leachate*

No	Parameters	Unit	Quality Standard	Value	
				Outlet	References Method
1	pH	-	6-9	7.59	SNI 6989 11-2019
2	BOD5	mg/L	150	*181.26	SNI 6989.72.2009
3	COD	mg/L	300	*560.62	SNI 6989.2.2019
4	TSS	mg/L	100	89	SNI 6989.3.2019
5	N Total	mg/L	60	*137.82	SK GUB KDH Tk I Jabar No,6 Tahun 1999
6	Mercury (hg)	mg/L	0.005	<0,0015	SNI 6989.78.2011
7	Cadmium (Cd)	mg/L	0.0	0.005	SNI 6989.16.2008

At 18 years old, Sarimukti Landfill now classified as aging infrastructure. Over time, its leachate has grown less biodegradable yet retains high pollutant levels. Elevated BOD and COD readings reflect intense organic content from decomposing waste—a common trait in Indonesian landfills, where organic waste dominates [10]. This explains why leachate treatment here prioritizes biological processes to break down organic matter [11]. However, Sarimukti's anaerobic and aerobic treatments show minimal impact on BOD/COD levels. To improve efficiency, chemical pre-treatment could optimize the BOD/COD ratio before biological processing. Advanced Oxidation Processes (AOP) may also help treat this stubborn leachate. N-Total levels in effluent still far exceed standards. Foam formation disrupts oxygen levels in aerobic ponds, stalling nitrification. Adding ammonia stripping units could address this. Post-fire leachate becomes dark, foul-smelling, and contains complex compounds. Studies note firefighting efforts can spike concentrations of specific pollutants, worsening contamination risks.

4.3 Characteristics Waste

Laboratory testing provides essential insights into burned waste composition and properties, such as moisture content, ash levels, volatile matter, fixed carbon, and calorific value. These metrics are critical for evaluating how burned waste behaves in landfills, its flammability risks, and its broader environmental and sustainability impacts. Table 4 summarizes key characteristics identified through lab analysis.

Table 4 *Characteristics burned waste*

S/N	Type of characteristic burned waste	Score
1	Water content	10.41 %
2	Ash content	50.95%
3	Volatile matter	49.04%
4	Fixed carbon	31.05%
5	Higher heating value	2890.8 kcal/kg
6	Lower heating value	2496.1 kcal/kg

With an average moisture content of 10%, burned waste is relatively dry, improving combustion efficiency by minimizing energy required to evaporate water. During combustion, moisture evaporates entirely, leaving little to no trace post-burn. Ash content averages 50.95%, indicating significant inorganic residue. High ash levels necessitate careful residue management, such as soil covering, to mitigate risks. While ash itself is non-combustible, residual organic material within ash layers can reignite fires if exposed to heat or oxygen. Fixed carbon levels (31.05%) reflect slow-burning material that generates sustained heat. Post-combustion, most fixed carbon converts to ash and gas, but unburned remnants may fuel reignition. Volatile matter (49.04%) releases energy rapidly during combustion, yet incomplete burning due to low temperatures, short residence times, or insufficient oxygen leaves residual volatiles. These remnants retain flammability, posing reignition risks. High heating values (HHV) suggest strong energy potential, while minimal differences between HHV and lower heating value (LHV) indicate efficient energy release. However, residual fixed carbon and volatiles, combined with low moisture and ash containing organic traces, create conditions conducive to reignition.

Despite combustible materials diminishing during the 1-month fire, residual components retain reignition potential. Proactive supervision, residue management, and preventive measures such as monitoring oxygen exposure and ensuring complete combustion are critical to safeguarding landfill stability.

4.4 Methane Gas Measurements

Landfills emit gases such as carbon dioxide, methane, and volatile organic compounds (VOCs) during anaerobic decomposition of waste [21]. This study focused on methane due to its outsized global warming potential approximately 25 times greater than carbon dioxide over a 100-year period making it a critical environmental concern [22]. Methane levels were measured using a Portable Gas Detector, a device designed to quantify gas concentrations released from landfill sites. To capture emissions, researchers positioned the detector near excavated sampling areas created for waste collection. Excavation inherently releases trapped gases, enabling direct measurement of methane volumes as they escape.

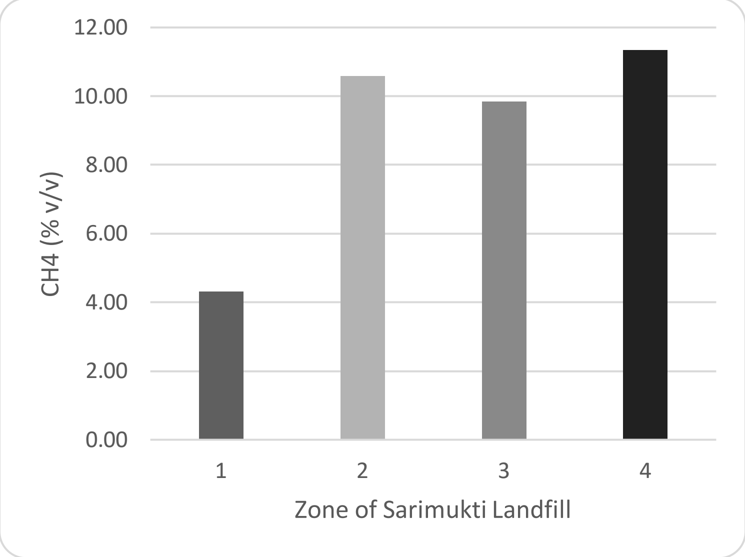

Fig. 4 *Methane gas measurement*

Gas measurements at Sarimukti Landfill reveal methane levels vary significantly between zones, with some areas showing alarmingly high concentrations. Such conditions create flammable hazards if exposed to ignition sources, demanding meticulous management to mitigate risks. While trace amounts of CO_2, CO, H_2S, and SO_2 were detected, their concentrations remain below hazardous thresholds. Methane production correlates strongly with organic waste content, as anaerobic decomposition intensifies with higher organic matter. Accurate emission forecasting requires accounting for landfill age, as methane generation rates decline as decomposition stabilizes over time.

4.5 IRBA Assessment of Sarimukti Landfill

Table 5 *IRBA assessment of Sarimukti landfill*

S/N	Attribute	Result Data	Weight	Sensitivity Index	Risk Index
1.	Distance from nearest water supply source (m)	2000	69	0.667	46.000
2.	Depth of waste pile (m)	60	64	0.875	56.000
3.	Area of landfill (Ha)	43.44	61	1.336	81.496
4.	Groundwater depth (m)	0	54	0.750	40.500
5.	Permbeability of soil (1 x 10^{-4} cm/s)	0	54	0.000	0.010
6.	Groundwater quality	Not drinkable	50	0.875	43.750
7.	Distance to habitat (protected forest etc.) (km)	0.14	46	0.757	34.822
8.	Distance to nearest airport (km)	34	46	0.117	5.367

S/N	Attribute	Result Data	Weight	Sensitivity Index	Risk Index
9.	Distance from surface water body (m)	483.29	41	0.992	40.657
10.	Soil type (% clay)	72	41	0.110	4.510
11.	Life of the site for future use (years)	2	36	0.100	3.600
12.	Type of waste (MSH/HW)	50% municipal waste, 50% household waste	30	0.625	18.750
13.	Total quantity of waste at site (tons)	8801273	30	0.970	29.092
14.	Quantity of wastes disposed (tons/day)	1.863	24	0.722	17.335
15.	Distance to the nearest village in the predominant wind (m)	360	21	0.550	11.550
16.	Flood period (annual)	2	16	0.800	12.800
17.	Annual rainfall at site (cm/year)	185.4	11	0.621	6.829
18.	Distance from the city (km)	21	7	0.025	0.175
19.	Public acceptance	Accepts dump closure and remediation	7	0.875	6.125
20.	Ambient air quality – CH4 (%)	9.8	3	0.995	2.985
21.	Hazardous contents in waste (%)	2	71	0.050	3.550
22.	Biodegradable fraction of waste at site (%)	40.6%	66	0.633	41.745
23.	Age of filling (years)	18	58	0.700	40.600
24.	Moisture of waste at site (%)	17.31	26	0.433	11.252
25.	BOD of leachate (mg/l)	181.26	36	0.953	34.313
26.	COD of leachate (mg/l)	560.20	19	0.853	16.209
27	TDS of leachate (mg/l)	7160	13	0.882	11.462
	Total Risk Index			622.24	

Based on the assessment, a value of 622.24 was obtained, which indicates a very high hazard evaluation. The recommended action for a very high hazard evaluation is that the landfill must be closed immediately due to environmental pollution or social problems. The preferred actions include closing the open landfill operation, not reusing it as a landfill, and taking corrective actions to reduce its impact. The risk index analysis using the IRBA Method before the fire resulted in a score of 758.02. The evaluation showed that the landfill posed a very high hazard and needed to be closed immediately due to environmental contamination or social issues. This indicates that the risk index value decreased after the fire. The reduction was due to changes in several parameters: the fraction of biodegradable waste, moisture content in the waste pile, BOD values in the leachate, COD values in the leachate, and TDS levels in leachate.

Surface fires burned away significant biodegradable organic matter, converting much of it to ash and gas. This reduced biodegradable fractions in upper waste layers, though deeper layers retained organic content. Intense heat also vaporized moisture, drastically lowering overall water content in affected zones. Leachate quality shifted post-fire with BOD and COD levels dropping due to diminished organic matter available for microbial breakdown or oxidation. TDS values decreased as organic solids burned off, though residual inorganic components kept concentrations elevated. Despite these reductions, the landfill's overall risk remains severe. Immediate closure, cessation of operations, and remediation efforts are essential to address persistent threats. These include unstable waste layers prone to collapse, residual organic matter capable of reignition, and compromised leachate systems that risk groundwater contamination. While the fire temporarily mitigated certain hazards, long-term solutions must prioritize sustainable waste management practices to prevent future crises.

4.6 Sarimukti Landfill Rehabilitation

Based on IRBA assessment, Sarimukti landfill should be closed. However, this has not been possible due to the unpreparedness of transferring waste management services to another landfill. For now, it is necessary to rehabilitate the landfill towards better waste management. The waste disposal operations at the Sarimukti landfill site planned to implement the sanitary landfill method, using local cover soil [12].

Waste regulations at landfills govern types of waste allowed, including household, market, commercial, office, educational institution waste, and other similar sources. Hazardous and toxic waste is prohibited from entering landfills and must be handled according to regulations. Medical waste and other types of waste cannot be dumped at landfills. The 3R process (Reduce-Reuse-Recycle) must be implemented, allowing only residues for disposal. Settlements must be built at least 500 meters from landfill boundaries, and a buffer area with green plants must surround landfills. Operations of landfills, whether through controlled landfill or sanitary landfill methods, must ensure management of leachate, gas handling, environmental maintenance, and worker safety. Success in landfill management requires good supervision, monitoring, and regular reporting. Landfills must carry out waste sorting, recycling, composting, and residue disposal. Rehabilitation needs to be well planned, including management of leachate and gas, as well as pollution control. After rehabilitation, landfills must not be operated with open dumping, and compost from mining activities should not be used for food crops [13].

Several recommendations for controlling methane gas at the Sarimukti landfill include controlled biogas release and flaring to reduce greenhouse gas emissions. Further investigation is needed to understand the conditions of the waste piles and biogas at deeper depths, considering safety and security aspects. Regular monitoring is also crucial to ensure that methane levels do not reach explosive limits. Methane control can be implemented by installing gas wells and suction pumps, along with interconnected gas collection pipes. The collected gas can be utilized as an energy source or flared. However, gas collection must be regulated to prevent excessive oxygen ingress into the waste pile, which could trigger a fire [14].

5. Conclusion

The Environmental Risk Index assessment for Sarimukti Landfill yields a final score of 622.24, classifying it as *very high hazard*. Immediate closure is the recommended action to mitigate environmental and social risks. However, current limitations in transitioning waste services make closure unfeasible. As an interim solution, rehabilitation efforts must prioritize adopting sanitary landfill practices, including use of locally sourced cover soil, to enhance environmental management and operational safety [12]. Upgrading infrastructure, optimizing waste treatment processes, and minimizing environmental impacts—such as groundwater contamination, air pollution, and odor—are critical steps. These improvements aim to extend the landfill's lifespan while maintaining sustainable waste management until permanent alternatives, like new facilities or advanced processing systems, become viable. Visible environmental conditions directly shape community perceptions of landfill operations, underscoring the need to maintain surrounding areas and foster local acceptance [10]. Waste minimization remains the most effective pollution control measure. Key strategies include incentivizing manufacturers to design durable products, promoting sustainable consumer habits, and supporting community initiatives to reduce single-use items.

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Conflict of Interest

The authors affirm that they have no conflicts of interest related to the publication of this paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *I Made Wahyu Widyarsana,* ***data collection:*** *I Made Wahyu Widyarsana, Nisrina Maulidya;* ***analysis and interpretation of results:*** *I Made Wahyu Widyarsana, Nisrina Maulidya;* ***draft manuscript preparation:*** *I Made Wahyu Widyarsana, Nisrina Maulidya. All authors reviewed the results and approved the final version of the manuscript.*

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