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| RESEARCH ARTICLE

Environmental Risk Analysis of Final Processing Sites (TPA) Using the Integrated Risk Based Approach (IRBA) Method: A Case Study of TPA with Landfill Control System

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| ABSTRACT
The place processing end (TPA) Ussu is located in Ussu village, Malili, East Luwu district, South Sulawesi Province. It has been operated since 2015 with a 4 ha land area and serves 5 districts, namely Malili, Angkona, Wasuponda, Towuti, and Noah. In 2019, this landfill was diverted into a system control landfill, but the implementation is still a conventional use system of open dumping. The system has a high risk for the environment, such as water pollution, soil consequence leachate, air pollution that is caused by methane gas, the emergence of disease, and the risk of landfill fire. Risk analysis is required to describe the risk toward the environment from certain activities. The study is conducted to evaluate the risk to the environment from the operational place processing end (TPA) in Ussu. The research method used is the integrated risk-based approach (IRBA) method. The experimental parameters are in the form of 20 TPA criteria parameters, four characteristics of landfill waste, and leachate parameters. Research results show that TPA Ussu scored 477.54 in the category evaluation danger ' medium ' level. The indicator has shown there are risks toward the environment at a medium level. This caused the landfill's age to be still young and hence required rehabilitation based on conditions in the field with repair system operational *landfill control* by gradually reducing or lowering danger risk environment.

| KEYWORDS

Integrated Risk Based Approach, risk environment, landfill.

| ARTICLE INFORMATION

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1. Introduction
Landfill has become a great challenge to infrastructure in various countries, especially developing countries such as Indonesia. According to Larasati (2019), there are a number of disposal methods on land that is open dumping, controlled landfill, sanitary landfill, and improved sanitary landfill.

Ussu landfill is located at 2 °35'10.86" S and 121 °06'11.40" E with a total surface area of about 4 Ha, including office and other supporting facilities. The landfill has been operating since 2015 with a capacity of 14 tons/ day and serves 5 sub-districts in the district East Luwu, namely, Malili, Angkona, Wawondula, Nuha, and Towuti with the farthest distance from 16.8 km. Since early 2019, this landfill has been diverted for the landfill control system. But, as a matter of fact, the implementation is still as the open dumping system that could cause risk, especially deep water pollution soil that causes the forming of leachate (Putri *et al.*, 2018), air pollution caused by methane, the emergence of disease (Rati *et al.*, 2017) as well as fire that come up from lower pile garbage (Ikbal, 2020). Although it is equipped by Leachate Installation Management (IPL), the pool leachate condition is managed poorly and not effectively. Leachate gets no treatment or is unprocessed before being streamed to the environment. Leachate flows directly to the Ussu River. Ussu River flows from south to north of the island and causes massive surface water pollution. The impact of Ussu Landfill pollutes the surrounding environment. The risk cloud is known through the index risk environment.

According to Darwati (2010), the assessment through index risk could be guidelines for landfill conditions and decide whether it can continue to operate or need rehabilitation. The study of environmental risk in TPA Tanggan, Regency Sragen, Central Java by Widayah (2020) stated that the risk index's height score indicates a tremendous risk to the environment and human health, so prevention is required at the location around the landfill. Otherwise, the low index risk indicates a low impact on the environment. One method used in appraisal index risk is the Integrated Risk Based Approach (IRBA). The Integrated Risk Based Approach (IRBA) is a method of making decisions to take some action to landfill through the evaluation index risk environment (Ajimashadi, 2021). Kurian *et al.* (2005) developed IRBA as a tool or device for making a decision in doing rehabilitation. Assessed Aspects called 'parameters' include technical aspects, impact on the environment, and social aspects to society. The parameters are categorized into 3, namely landfill location (20 parameters), waste characteristics in the TPA (4 parameters), and leachate characteristics (3 parameters).

The integrated Risk Based Approach (IRBA) was first used by Joseph et al. (2005) as a tool for making decisions on the location of Kondungaiyur in Chennai City, India, where calculated results scored an index risk of 579. Another study at the Igbatoro landfill, Africa, by Ojuri et al. (2018) calculated a results index of 571.58, categorized as high risk toward health and the environment. In Indonesia, research by Abdillah (2021) on planning Gedangkaret TPA sustainability Regency Jombang with calculated results risk index 538.48 states that the Integrated Risk Based Approach (IRBA) can be used as a device for the state of the environmental status of the landfill and assessed parameters could be customized based on the environmental conditions. The environmental status of the landfill determines the priority of landfill handling. According to Alldilla (2022), in a study of index risk, Simpang landfill environment Gegas, South Sumatra, stated that the IRBA method is the most sensitive method to risk and rated most accurately in determining index risk activity. This study aims to evaluate Ussu TPA operations that implement landfill control systems through evaluation index risk with an integrated risk-based approach (IRBA).

2. Materials and Methods

To meet the risk index parameter, sampling is done at the location of the research or the Ussu TPA, Ussu, Malili, East Luwu, and South Sulawesi Province. The study uses the IRBA (Integrated Risk Based Assessment) method, which became a reference-taking conclusion in accordance with the results end method. The data collection is surveys and interviews, as well as sampling techniques that are purposive sampling and grab sampling (Ivonni, 2017).

Purposive sampling is a sample selection technique based on certain characteristics or categories. The samples are in the form of soil with permeability and texture parameters or % clay. A permeability test has been done on soil type not disturbed with the sampling point at the coordinates of 2 °35'11" S and 121 °06'12" E. The tools used are in the form of tube metal made of hollow iron 5 cm high and a diameter of 7.63 cm, and tube lids are in the form of plastic on both sides (Balittanah. litbag, 2020). For texture test or % clay was performed on the sample soil disturbed with a 30 cm pipe and 6.34 cm in diameter as much as 500 grams (Balai Big Research and Development Source Power Land Agriculture, 2006). Texture parameter sampling points are at the coordinates 2 °35'10" S and 121 °06'10" E. The testing sample uses the ring method sample for permeability parameters of soil and the pipette method for texture or % clay. The test is done at Soil Science Laboratory at Hasanuddin University, Makassar. Grab sampling is a method of taking samples on site, on research that is groundwater samples (well monitor) and leachate in IPL ponds. The method for taking groundwater samples is based on SNI 6989.58:2008 and SNI 6898.59:2008 for the method of taking leachate samples. Groundwater sample with groundwater quality parameters is the test method based on Regulation Governor of South Sulawesi Number 69 of 2010 concerning water quality standards, and test parameters on leachate samples are BOD (SNI 6989.72:2009), COD (SNI 6989.02:2019), and TDS using test method SNI 06-6989.27-2005. Water samples were tested at the Research and Development Agency Industry Laboratory Makassar BBIHP Examiner.

The calculated risk index value is conducted to know the sensitivity score on each parameter (Table 1) so that obtained score end in the form of a score index; later, risk results end the categorized based on results evaluation level hazard (Table 2) for knowing recommended action to subsequent landfill operations (Mandasari, 2017).

Table 1. Device Evaluation Index Risk Environment

No.	Parameter	Weight (Wi)	Index Sensitivity (Si)			
			0.0-0.25	0.25-5.0	5.00-0.75	0.75-1.00
	I. Criteria The place of Final Processing (TPA)					
1	Distance to nearest water source (km)	69	>5	2.5-5	1-2,5	<1
2	Depth charging trash (m)	64	3	3-10	10-20	>20
3	Landfill Area (Ha)	61	<5	5-10	10-20	>20
4	Groundwater depth (m)	54	>20	10-20	3-10	<3
5	Permeability soil (10^{-6} cm/ s)	54	<0.1	1-0.1	1-10	>10
6	Groundwater quality	50	Not Becomes attention	Water can drink	Could drink if no there is alternative	Not could drink
7	Distance to habitat (*wetland/* forest conservation) (km)	46	>25	10-25	5-10	<5
8	Distance to airport closest (km)	46	>20	10-20	5-10	<5
9	Distance to surface water (km)	41	>8	1.5-8	0.5-1.5	<0.5
10	Type layer soil base (% clay)	41	>50	30-50	15-30	0-15
11	Age location for future usage (years)	36	<5	5-10	10-20	>20
12	Type trash (garbage urban/residential)	30	100% trash urban	75% trash urban, 25% waste settlement	50% municipal waste, 50% waste settlement	>50% trash settlement
13	Amount discarded waste (tonnes/year)	30	$<10^4$	10^4-10^5	10^5-10^6	$>10^6$
14	Amount waste disposed of (tons/ day)	24	<250	250-500	500-1000	>1000
15	Distance to settlement close to the direction eye wind dominant (km)	21	>1	0.6-1	0.30-0.6	<0.3
16	Period repeat flood (year)	16	>100	30-100	10-30	<10
17	Rainfall _ yearly (cm^3 / year)	11	>25	25-125	125-250	>250
18	Distance to city (km)	7	>20	10-20	5-10	<5
19	Reception Public	7	Not Becomes attention Public	Accept rehabilitation hoarding rubbish open	Receive closing hoarding rubbish open	Accept closure and remediation rubbish open
20	Quality air ambient CH_4 (%)	3	<0.01	0.05-0.01	0.05-0.1	>0.1
	II. Characteristics Garbage in landfill					
21	B3 content in rubbish	71	<10	10-20	20-30	>30
22	Fraction rubbish *biodegradable* (%)	66	<10	10-30	30-60	60-100
23	Age charging waste (year)	58	>30	20-30	10-20	>10
24	Humidity waste in landfill (%)	26	<10	10-20	20-40	>40
	III. Leachate Water Characteristics					
25	BOD of leachate (mg/L)	36	<30	30-60	60-100	>100
26	COD leachate (mg/L)	19	<250	250-350	350-500	>500
27	TDS leachate (mg/L)	13	<2100	2100-3000	3000-4000	>4000

(Source: Minister of Work Regulation General RI Number 3 of 2013)

Determination of the sensitivity index is conducted by using interpolation as follows.
Then score sensitivity (Si) of each parameter is multiplied by the weight (Wi), result from multiplication add up with use formula:

RI ....(1)

Description:
Wi: Weight from parameter to i - ii, with range value 0–1,000

Si: Index sensitivity parameter to i - ii, with range value 0-1
RI i: Index Risk, with range value 0– 1000

Table 2. Category Hazard Level Evaluation Based on Index Value Risk

No.	Index Value Risk (RI)	Evaluation Danger	Suggested action
1.	<300	Low	TPA is continued and rehabilitated and becomes land urug under control. This location potential for development becomes land urug in a long time.
2.	300-600	Currently	TPA is continued and rehabilitated becomes land urug under control by gradually.
3.	600-1000	Very high	The landfill must quickly be closed because it pollutes the environment or causes the social problem.

(Source: Minister of Work Regulation General RI Number 3 of 2013)

3. Results and Discussion

Assessment results of the environmental risk index are taken from these criteria; landfill location, characteristics of garbage, and characteristics of leachate.

3.1 Site Evaluation Criteria for landfill

Table 3. Evaluation Results Index Risk Landfill Criteria

No.	**Parameter**	**Weight (Wi)**	**Measurement Ussu Landfill**	**Index Sensitivity (Si)**	**Value (RI) (Wiix Si)**
	I. Criteria The place Final Processing				
1	Distance to nearest water source (km)	69	1.25	0.55	37.95
2	Depth charging trash (m)	64	3	0.25	16
3	Landfill Area (Ha)	61	4	0.1	6.1
4	Groundwater depth (m)	54	15	0.45	24.3
5	Permeability soil (1×10^{-6} cm/ second)	54	1.26	0.55	29.7
6	Ground water quality	50	Not Becomes attention	0.25	12.5
7	Distance to habitat (wetland/forest conservation) (km)	46	3	1	46
8	Distance to airport closest (km)	46	57	0.25	11.5
9	Distance to surface water (km)	41	1	0.7	28.7
10	Type layer soil base (% clay)	41	16	0.52	21.32
11	Age location for future usage (years)	36	21	1	36
12	Type trash (garbage urban or settlements)	30	50% trash urban 50% residential	0.75	22.5
13	Amount discarded waste (tonnes/year)	30	5110.65	0.25	7.5
14	Amount waste disposed of (tons/ day)	24	14	0.1	2.4
15	Distance to settlement closest to the direction wind dominant (km)	21	2	0.25	5.25
16	Period repeat flood (year)	16	50	0.3	4.8
17	Rainfall _ yearly (cm/ year)	11	230.25	0.7	7.7
18	Distance to city (km)	7	7.8	0.66	4.62

19	Reception Public	7	Accept rehabilitation hoarding rubbish open	0.5	3.5
20	Quality air ambient CH_4 (%)	3	3.01	1	3

(Source: Primary Data, 2022)

In table 3, there are some parameters that have a sensitivity score close and equal to 1, indicating high danger potency, i.e., on the distance parameter to the habitat (wetland/forest conservation), age location for future use, type waste, and quality air ambient (CH_4). The distance from the landfill location to wetlands/forest conservation is 3 km. This distance is not in accordance with SNI 03-3241-1994, which explains that the minimum distance landfill location against forest conservation is 4 km. Parameters for the use of future landfill sites and types of waste were obtained from the landfill manager. Where it is designed for a period of use > 20 in the future, it is estimated to still operate for up to 20 years. Pollution could possibly occur along with time operation. The research conducted by Ariyani (2018) based on Constitution Number 18 of 2008 concerning state rubbish management that government must do monitoring/evaluation on the place processing end (TPA) every 5 years since the landfill operates to prevent the pollution caused by landfill activities from various aspects. The type of collected garbage is 50% urban areas garbage and 50% settlements waste. Because garbage is collected from the capital city, it varies in type or comes up from various activities like house stairs, markets/supermarkets, offices, and industrial homes up to medium.

Air ambient quality shows that the average methane gas concentration at the Ussu landfill is 3.01%. The calculated result score index of sensitivity of these parameters is 1. The value shows that this parameter has the highest risk. According to Paramita, 2018 simple and hard-buried trash will decay and form methane gas. The gas will damage the ozone layer, which can lead to climate change. And based on the study conducted by Suyasa (2016) stated that the thickness of rubbish piles influences methane emission formation. The thicker the layer, the less oxygen to help the decomposition process, anaerobic (without oxygen) decomposition process will produce methane gas. Generated methane gas in the landfill is impacting not only settlements around the landfill but also the earth's atmosphere, which lead to global warming.

The distance from surface water and bulk rain annually shows a sensitivity score of 0.7. The location of Ussu landfill is 1 km away from surface water that flows directly to the Ussu river. Ussu river is the main river that becomes a water source for the surrounding inhabitants. The bulk rain rate influences the amount and concentration of the resulting leachate. However, the bulk of heavy rain produces leachate in large amounts, but rainwater could dilute the concentration of leachate, so the resulting concentration tends to be lower at the disposal end (Nadia *et al.,* 2021). Because of that, the amount of leachate produced is big, but the concentration is low because it was diluted by rainwater. The distance to the city is as far as 7.8 km; this distance is far enough to minimize the smell and spread of diseases in urban areas that can disturb the citizens.

Besides showing a sensitivity score close to 1, table 3 shows parameters with low sensitivity scores, which means already good Deep charging garbage and landfill area are mutually related to the volume of collected waste. The small volume of waste is accommodated, the less potential for pollution toward the environment (Nadia *et al* . , 2021). The distance of Ussu landfill from Sorowako Airport is as far as 57 km; it has fulfilled criteria based on SNI 03-3241-1994 minimum distance to the closest airport, i.e., 1.5-3 km with type aircraft turbojet. The distance from the Ussu landfill to the settlement is as far as 2 km. This distance is already good for preventing the impact like smell, consequence, gas concentration and methane through direct wind going to settlement residents (Mahyudin, 2017). The climate aspect, like a periodical flood, based on interviews with managers and citizens, has never been repeated flooding in the surrounding area, resulting in waste and leachate being carried downstream/low-lying areas.

3.2 Evaluation Characteristics Rubbish

Table 4. Evaluation Results Index Risk Characteristics Rubbish

No.	Parameter	Weight (Wi)	Measurement Ussu Landfill	Index Sensitivity (Si)	Value (RI) (Wi x Si)
		II.Characteristics Garbage in landfill			
21	B3 content in rubbish	71	5	0.1	7.1
22	Fraction rubbish *biodegradable* (%)	66	27	0.47	31.02
23	Age charging waste (year)	58	7	1	58
24	Humidity waste in landfill (%)	26	60	1	26

(Source: Primary Data, 2022)

There are 4 parameters in the TPA based on risk index characteristics, namely B3 substances in the trash, fraction until biodegradable, age charging trash, and moisture trash. B3 content in rubbish is 5%, and a sensitivity value of 0.1 is rated low, so it has a small risk potential in polluting the environment. Fraction rubbish biodegradable is 27% and shows a sensitivity score far below 1, which means safe for the environment. The smaller the *biodegradable* substances in rubbish, the smaller the pollution impact on the environment(Andhika et al., 2015).

The sensitivity score index (Si) Parameters =1, such as age charging trash and moisture waste in the TPA indicating danger or high level. Based on the table evaluation index risk (table 3), TPA that has been operated >30 has a sensitivity score of 0.25, rated safe enough. According to Damanhuri (2006), age charging, already in progress more than 30 years ago, assumed that landfill conditions in the state are stable if compared with TPA, which is still under 10 years old. The stable condition means the minimum trash avalanche incident; the longer pile of garbage, the more water it has compared with new charging trash. Humidity waste at the Ussu landfill by 60% is categorized as safe (SNI 3242:2008). High humidity causes big gas pressure in stacked trash that can trigger an explosion or fire on the garbage pile (Priatna, i2019).

3.3 Evaluation Leachate Water Characteristics

Table 5. Evaluation Results in Index Risk Leachate Water Characteristics

No.	Parameter	Weight (Wi)	Measurement iUssu landfill	Index Sensitivity (Si)	Value (RI) (Wi x Si)
		III.	**Characteristics iLindi**		
25	BOD ilindi i (mg/L)	36	65.865	0.58	20.88
26	COD ilindi i (mg/L)	19	191.3	0.1	1.9
27	TDS ilindi i (mg/L)	13	324	0.1	1.3

(Source: Data Primer, 2022)

The leachate characteristics consist of 3 parameters, namely BOD, COD, and TDS, with various index sensitivities scores. The BOD content of leachate in the Ussu Landfill is 65.865 mg/L; the value of this raw approach is determined by quality, i.e., 150 mg/L adjusted with Minister of Environment Regulation Life and Forestry Number 59 of 2016 concerning lindi standards quality for business and/or landfill activities. High BOD concentrations show a large number of organic ingredients, so oxygen is needed for the biodegradation process. The higher the BOD concentration, the lower the water quality (Rahmi, 201). Based on the BOD content study in wastewater by Andika et al. (2020) stated that high BOD concentration influences the rate of oxygen in the water that interferes with photosynthesis with the destination for the deficiency process of oxygen in the water. COD content is 191.3 mg/L; this parameter fulfills the quality that has been determined, i.e., 500 mg/L with a sensitivity score of 0.1. TDS content obtained 324 mg/L, which has also been fulfilled as the raw quality that is 4000 mg/L.

3.4 Risk Index Value toward Environment

The calculated t score of the Risk Index Environment (RI) of the Ussu landfill amounts to 477.54. Referring to the Regulation of the Minister of Work General Republic of Indonesia Number 3 of 2013, it is entered in the range of 300-600 and entered the category classification level ' moderate ' danger.

Table 6. Categories Hazard Level Evaluation Based on Index Value Risk Environment

No.	iIndex Value Risk (RI)	Evaluation Danger	Suggested action
1.	300-600	Currently	TPA is continued and rehabilitated, Becomes land urug under control by gradually.

(Source: Minister of Work Regulation General RI Number 3 of 2013)

The danger ' medium ' level indicates TPA activities have a high risk toward the environment, so rehabilitation is required based on the condition in the field with repair system operational landfill control by gradually reducing danger risk level toward the environment. According to Nadya (2018), the age of the TPA can be extended by utilizing or optimizing the operational system of the waste bank so that not all waste goes to the TPA. Special attention is needed to parameters with a sensitivity index score approach equal to 1, such as distance to habitat, surface water, age, future use, type of waste, annual rainfall, ambient air quality (CH4), and waste humidity.

4. Conclusion

Risk environment from Ussu landfill operations based on risk index score with Integrated Risk Based Approach (IRBA) method with 3 parameters evaluation criteria like the place processing end, rubbish characteristic in landfill and leachate characteristics worth a score of 477.54 which is at level evaluation "moderate " danger. This indicates that the landfill has accepted an impact risk environment in condition medium-required rehabilitation based on condition in the field with repair system operational landfill control by gradually reducing or lower level danger risk environment.

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