Proceedings of the 9ICEG
9th International Congress on Environmental Geotechnics
25-28 June, 2023 | Chania, Greece
© Authors: All rights reserved, 2023
https://doi.org/10.53243/ICEG2023-335

Development and application of a rapid risk assessment tool (RRAT) for rehabilitation of disposal sites: Case study of Province of Aklan, Philippines

M. D. Diola[1], P. S. Castro[1], J. Q. Raca[1], and M. N. Tanchuling[1]

[1]*Institute of Civil Engineering, University of the Philippines Diliman, Quezon City, Philippines, email: mddiola@up.edu.ph*

ABSTRACT

Open dumpsite is the most common type of disposal site for municipal solid wastes (MSW) in lower-middle and low-income countries because of its low cost and maintenance characteristics. However, this option causes severe environmental issues. As of 2021, all the open dumpsites in the Philippines were closed following the provisions of the Ecological Solid Waste Management Act of 2000 (RA 9003). This study aims to develop and apply a rapid risk assessment tool (RRAT) for rehabilitation of dumpsites and landfills in the Philippines. The risk attributes included in the tool were selected based on literature, policies, and consultation with experts. The attributes were categorized into main criteria: accessibility, socio-economic, environmental, characteristic of waste at the disposal site, and hydrogeological and geological conditions. Using the pairwise comparison method, the 28 attributes were ranked to determine their corresponding weightages. Each attribute was measured in terms of their corresponding sensitivity index to compute the total dumpsite Risk Index (RI), which ranges from 0 to 1000. The RRAT developed aims to classify a disposal site, and determine its risk index (RI) and hazard potential. The highest attribute that was ranked by the experts was proximity to perennial surface water; while the lowest attribute was artificial depth of filling. The tool was initially applied in two disposal sites in Aklan Province – Banga Controlled Dumpsite and Malay Sanitary landfill. They obtained risk indices of 370 (low) and 199 (very low), respectively. The results of the assessment were used to validate the tool and determine the recommended actions for the disposal sites investigated.

Keywords: dumpsite rehabilitation, rapid risk assessment tool, landfills, municipal solid waste

1 INTRODUCTION

In lower-middle and low-income countries, such as the Philippines, open dumpsites are considered one of the standard ways of disposing wastes. The Senate Economic Planning Office (SEPO) states in their 2017 report that open dumping remains the common waste disposal practice in the country due to the limited number of controlled dumpsites and sanitary landfills. In addition, the report states there were 403 open dumpsites — far greater in number compared to the 108 controlled disposal facilities and 118 sanitary landfills in the country. More than three hundred open dumpsites were reported to be closed in 2021 to complete the closure of all open dumpsites in the country in compliance with the provisions of RA 9003 – Ecological Solid Waste Management Act of 2000, highlighting the inadequacy of the existing waste disposal infrastructure.

Despite its harmful effects, open dumping was considered as the most used and accepted MSW treatment and disposal method because of the low-cost and low-technical requirement of removing waste from the environment (Vaverkova, 2019). However, the waste disposal practice come with a lot of disadvantages and risks due to the lack of proper planning and control mechanisms. For example, the lack of proper treatment of decomposing biodegradable wastes in the dumpsites would result in leachates and harmful gas production (Kurian et al., 2003) which could possibly endanger human life and the environment. Moreover, open dumpsites are susceptible to open burning, and groundwater pollution, and are exposed to scavengers and disease vectors.

It is essential to perform evaluative studies for the development and implementation of sustainable landfills, solid waste management, and rehabilitation of existing open dumpsites (Vevarkova, 2019). The problem regarding the lack of adequate solid waste disposal sites in many countries calls for the need

for sustainable solutions that would minimize the risk potential and cost of landfill establishment. One of which is through the rehabilitation of open dumpsites. Currently, resources for upgrading dumpsites are limited (Kurian et al, 2003). In the Philippines, guidelines on dumpsite rehabilitation are available in DENR Administrative Order 09-2006 (DAO 09) General Guidelines in the Closure and Rehabilitation of Open Dumpsites and Controlled Dump facilities. DAO 50-1998 provides a set of criteria to help assist government units and decision makers identify and determine the potential sites for developing solid waste disposal facilities. Although there are available dumpsite assessment tools used in other countries, there is still a need to develop such tools that would be best suitable in the Philippines given that not all risk attributes or criteria are applicable in the country.

This paper aims to develop a quick decision-making tool that will assess the risk of existing dumpsites and sanitary landfills using analytic hierarchy process survey and review of related tools and studies. The rapid risk assessment tool (RRAT) will provide a consistent approach and methodology for conducting risk assessments. This research also aims to apply the tool and to recommend a remediation action for selected existing dumpsites and sanitary landfills in the Philippines — particularly in Banga Controlled Dumpsite, Kalibo Controlled Dumpsite, and Malay Sanitary Landfill in the Province of Aklan.

2 METHODOLOGY

2.1 Study area

The province of Aklan is located in Region 6, Western Visayas, Philippines, and is categorized as a first class province. Aklan is composed of seventeen (17) municipalities, in which Kalibo is considered the capital town. It has a land area of 1,821 km^2 and a population of 615,475 in 2020 (PSA). The province has one sanitary landfill located in Malay municipality, while all the open dumpsites were closed or converted into a controlled dumpsite. According to their 10-year Solid Waste Management Plan approved in 2018, Aklan generates 194,714.02 kg/day of waste, with a waste generation rate of 0.31 kg/cap-day. The waste of Aklan is composed of 46.25% biodegradable wastes, while 27.66%, 22.37%, and 3.18% are recyclable, residual, and special wastes, respectively.

Banga is a 3rd class municipality with 30 barangays and land area of 84.53 km^2. The controlled dumpsite of Banga is located in Brgy. San Isidro, wherein the population was 320 in 2015 then decreased to 266 in 2020, according to PhilAtlas.com. The Municipality of Malay is categorized as a coastal town. It is a 1st class municipality with 6,601 ha of land area, in which two-thirds of Malay's land area is Boracay Island, separated from Panay Island. Tourist waste is the major source of waste in Malay, Aklan.

2.2 Selection and categorization of risk attributes

The risk attributes were selected based on literature and existing guidelines in the Philippines which includes DAO 09 and DAO 50. Some of the attributes determined and included in the risk assessment tools developed by Kurian et al. (2005) and Pandiyan et al. (2010) and their corresponding sensitivity index were adopted. The site sensitivity qualities were chosen based on literature, evidence collected through observation of activities, investigations in and around a few dumpsites, and expert consultation on the attributes' contribution to pollution, health hazards, and social consequences.

The risk attributes were narrowed down based on the following factors:

a. Applicability in the study location. The risk attributes should be appropriate in terms of geographic, climatological, hydrological, geological and other various conditions of the country.
b. Uniformity of the attributes. Attributes in which their parameters are similar in all locations in the country (e.g., seismic zones, precipitation index, etc.) will no longer be included given that it would provide the same value for all dumpsites.
c. Similarity. Attributes that are closely related or similar to one another in terms of their specified conditions and descriptions are merged to avoid redundancy.
d. Consultation with experts. Experts regarding the field were asked to check and validate the risk attributes to be considered for the RRAT.

The attributes were evaluated based on how they are considered to affect the risk of an existing dumpsite or landfill. The attributes were categorized into five categories: (1) accessibility, (2) socio-economic, (3) environmental, (4) characteristic of waste at the dumpsite, and (5) hydrogeological and

geological conditions. The first category pertains to the attributes that describe how the landfill operates since accessibility of landfill can lower the risk of contamination, save money due to lowered transportation cost, and lessen the chances of mess and littering. The second category focuses on the public's perception regarding the existing landfill which includes public health risk and how it affects the worth of the land adjacent to the landfill (Buso, 2015*)*. The third category identifies the impacts of dumpsites in soil, air, water, and other ecological sensitive areas. The fourth category are parameters that include the characteristics and properties of waste stream such as type, physical and chemical composition. Lastly, the fifth category includes the hydrogeological and geological conditions of the dumpsite area such as topography, seismic conditions, how the water flows on a subsurface, and interaction of groundwater to its surrounding soils and land.

2.3 Application of analytic hierarchy process (AHP) survey

After compiling and categorizing the risk attributes to be considered for the RRAT, the expert panels were identified and asked to rank the attributes using an Excel-based AHP survey. Analytic hierarchy process (AHP) survey is a multi-decision-making approach that uses pairwise comparison to scale the importance of attributes. According to Andalib and Soleimani (2017), AHP method samples can be determined with 10-20 people. Saaty's AHP method must result in a 10% consistency ratio to consider it an acceptable result. (Schimdt, et. al 2015; Muralidharan, et al. 2003). Experts consist of sociology and sanitary/environmental engineering academic personnel, municipal officers, and consultants based in the Philippines. The experts were asked to compare two attributes at a time and to input the corresponding intensity of importance from 1 to 9, with 1 denoting equal importance while 9 denotes absolute importance over the other. The attributes were ranked per category to reduce the survey length and to lessen the complexity in obtaining the required consistency ratio of less than 0.10. In addition, the categories were also ranked so that the combined weightages of the attributes will be equivalent to 1000. The experts' survey inputs were used to determine the comparison matrix (Equation 1) (Saaty, 1980) denoted by matrix A.

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \vdots & \dots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix} \quad (1)$$

where a_{ij} denotes the relative importance of criteria i comparing with j, and the relative importance of criteria j compared to i is just the reciprocal $a_{ji} = 1/a_{ij}$, $a_{ij} > 0, i, j = 1, 2, \dots, n$

Once the comparison matrix was obtained, the weighting coefficients of each attribute and category were determined by first calculating the maximal eigenvector ($W_{max} = (w_1, w_2, \cdots, w_n)^T$) and maximal eigenvalue λ_{max} of the comparison matrix (Liang et al., 2017), as shown in Equations 2 and 3.

$$[W_{max}, \lambda_{max}] = eig(A) \quad (2)$$

$$\begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \vdots & \dots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \lambda_{max} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (3)$$

The weighting coefficient vector, *W*, also known as the priority matrix, was calculated through normalization of the maximal eigenvector, as shown in Equation 4.

$$W = \left(\frac{w_1}{\sum_{i=1}^{n} w_i}, \frac{w_n}{\sum_{i=1}^{n} w_i}, \dots, \frac{w_n}{\sum_{i=1}^{n} w_i}, \right)^T \quad (4)$$

Once the corresponding weights of each attribute and category were obtained, the consistency ratio was determined to judge whether the comparison matrix was consistent or not (Saaty, 1980) using Equation 5.

$$CR = \frac{CI}{RI} \quad (5)$$

where CR is the consistency ratio, CI is the consistency index, and RI is the average random index. The consistency index was obtained using Equation 6. The random index, RI, was obtained using the table provided by Saaty (1980).

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (6)$$

The consistency matrix is considered acceptable if the CR is less than 0.1. If it is not acceptable, the experts were asked to recheck their answer until the condition is satisfied. The experts' survey answers were combined by obtaining the geometric mean of all the comparison matrices. The weightages were then recomputed. The assigned weightage of the of the attributes was computed using Equation 7.

$$Assigned\ Weightage = Main_{weightage} \times Sub_{weightage} \times 1000 \quad (7)$$

wherein the $Main_{weightage}$ refers to the weightage of the category and $Sub_{weightage}$ refers to the weightage of the attribute.

2.4 Determination of sensitivity index values

The sensitivity index (SI) pertains to the measurement of the attribute's potential hazard. It is measured on a scale of 0 to 1 wherein "0" indicates no or very less potential hazard and "1" indicates the highest potential hazard. The sensitivity index is important for the computation of the Risk Index (*Saxena and Bhardwaj, 2003 & Kurian et al., 2005*). The sensitivity index per attribute varies depending on their corresponding recommended parameters or measurements. For the study, the SI were based on existing ordinances, studies, and recommendations from experts.

2.5 Calculation of risk index

The risk index is the overall risk potential of the dumpsite or landfill under investigation. Sites with higher index scores indicate higher risk to environmental and human health. It is an important factor in determining the necessary actions recommended for the disposal sites. The RI of the study sites was calculated using Equation 8.

$$RI = \sum_{i=1}^{n} AW_i \times S_i \quad (8)$$

where AW_i = Assigned Weightage of criteria of the i^{th} variable ranging from 0-1000, S_i = Sensitivity Index i^{th} variable ranging from 0-1, and *RI* = Risk Index variable from 0-1000

2.6 Application of the RRAT in the study sites

Upon obtaining the risk index of the dumpsite, its environmental impact and corresponding recommended action are determined using the criteria for hazard evaluation presented by Kurian et. al. (2005). The criteria show that a high-risk index corresponds to a greater risk; therefore, warrants immediate remedial measures. Meanwhile, the sites that resulted in a low-risk index score indicate insignificant environmental and health risks in the area; thus, warrants less priority and immediate actions to lessen its potential risk (Table 1). The RRAT was applied to determine the risk indices of the Banga controlled landfill and the Malay controlled landfill in Aklan. The resulting risk indices were compared to the risk indices obtained from an existing RRAT tool developed by Kurian et. al. (2005).

Table 1. *Basis for the evaluation of the risk index and recommended action (from Kurian et al., 2005)*

Risk Index	Environmental Risk Impact	Recommended Action
Less than 300	Very Low	The site is a potential option for future landfill
300 – 449	Low	Rehabilitate the dumpsite into Sanitary Landfill in a phased manner.
450 – 599	Moderate	Immediate Rehabilitation of the dumpsite into Sanitary Landfill
600 – 749	High	Close the dump with no more land filling in the area. Remediation is optional.

749 – 1000	Very High	Close the dumpsite with no more land filling in the area. Take remedial action to mitigate impacts.

3 ATTRIBUTES FOR THE RAPID RISK ASSESSMENT TOOL (RRAT)

3.1 Accessibility

- Distance to the nearest airport - This reduces the bird-strike hazard to aircraft, a potential risk to aviation safety. This also ensures that the landfill's proposed final elevation will not exceed the maximum allowable top elevation (DAO 50, 1998).
- Distance from gas pipelines, oil pipelines, and power lines (hazard-related) - Landfills should not be located on gas and oil pipeline routes. In the event of damage, pipeline explosions may be carried to methane generated at the dump from the decomposition of garbage (Jahic´ 1980).
- Waste transportation haul distance and time – Disposal sites must be far enough from roads to avoid any aesthetic impacts. However, the economic factor of the distance of the road must also be important since the farther its distance is, the higher cost of transportation (Rezaeisabzevar, 2020). The hauling distance from the waste generation center should be around 15 to 20 km or 30 minutes travel time (DAO 50, 1998). The higher sensitivity index will be applied for the category.
- Proximity to building/construction materials - Availability of construction materials for liners, daily covers, and final cover is important since the proximity distance results in cost reduction. Proper cover reduces leachate generation by preventing surface water from infiltrating the landfill (Djokanovic, 2016; Rezaeisabzevar, 2020).

3.2 Socio-economic

- Distance from sensitive land users (e.g., urban development areas and areas with archeological, cultural and historical importance) - Many monuments, buildings, and historical areas are under protection. According to DAO 50, landfills should not be located in existing or proposed residential, commercial, or urban development areas or areas with cultural or historical importance. Landfills must be 250 m away from residential areas and 1 km from industrial developments.
- Land use or potential use (e.g. potentially used as a tourist destination, major transportation route, or valuable energy or mineral resource) - Waste disposal area should be far from sources of valuable mineral, and energy sources, tourist destinations or major transportation roads. It must also avoid areas near agricultural land and major infrastructure. The large area allotted for landfills can result in a land scarcity for the development of the human society and ecosystem. The land in the Philippines can be classified as agricultural land, forest or timber, mineral, and national parks; and a sensitivity index of 1 is assigned. According to the Philippine Statistics Authority, wastelands are land use not included in the preceding land use classification. Wastelands are not considered for any productive purposes since it includes barren rocky land, and sloping areas.
- Public Acceptability - Dumpsites and landfills must be far from settlement areas but not far enough considering transportation costs. Important factors that must be considered for this attribute are noise, reduction of property value, odor, negative aesthetic impacts, Not in my back yard (NIMBY) syndrome, environmental hazards, and future urban expansion (Rezaeisabzevar, 2020). The attribute was classified as a) no public concerns – lowest values, b) Accepts dump rehabilitation, c) accepts dump closure, and d) accepts dump closure and remediation – highest value (Kurian, 2005).
- Health risks brought by site – Disposal sites can cause public health concerns because of the exposure to landfill gas, and contamination of leachate to the ground and surface water.

3.3 Environmental

- Proximity to Perennial Surface Waters (e.g., river or stream) - Sites must avoid areas near rivers, lakes, swamps, or wetlands since they are seen as potential threats because they generate leachate and other gaseous pollutants. The site should not be located within 300 m of any surface water used for drinking purposes (Rezaeisabzevar, 2020, DAO 50, 1998).
- Soil Quality - The soil polluted by chemicals can cause infertility to the soil which is unable to support crops and flora. The biodiversity of the site can be altered since the local vegetation may stop

growing, in severe soil contamination cases the disruption of vegetation is permanent (Newton, 2018).

- Ambient Air Quality - Ambient air quality is the general amount of pollution or quality of air present in the environment (RA 8749). In this study, the focus will be the percentage (%) of methane or $CH4_4$ present in the existing dumpsite or landfill.
- Distance from ecologically sensitive areas (e.g., parks and reserves) - According to DAO 50, sites should not be located within ecologically sensitive areas proclaimed by law as national parks, conservation parks, recreation parks, forest reserves, or wetlands. The site should be 500 m away from any ecologically sensitive areas proclaimed by the law.

3.4 Characteristics of waste at the disposal site

- Biodegradable fraction of waste at the site - Biodegradable waste is commonly found in municipal solid waste such as green waste, food and kitchen waste, papers, and biodegradable plastic. Proper management of biodegradable waste will avoid the emissions of greenhouse gasses, from waste decomposition, and result in good quality compost, bio-gas, and soil quality.
- Artificial depth of filling of waste - Waste disposed in the site must be regularly covered with soil and compacted, forming cells or layers of waste. The loose layer of waste shall not exceed 0.60 m before the compaction. The depth of filling waste is the measurement of the depth perpendicular to the soil surface or working slope. The recommended depth of filling is 3m.
- Moisture of waste at the site - Determining the moisture evaluates the degradation of solid waste and estimates the rate of leaching and generation of methane gas; thus, the amount of moisture content present in the landfill will determine the best waste management practice and disposal for the MSW (Kurian, et al., 2005; Ozcan, 2016).
- Quantity of wastes disposed/day - The local government units (LGUs) are required to submit a 10-year solid waste management plan under Section 16 of the RA 9003, which includes having a Waste Analysis and Characterization Study (WACS).
- Total quantity of waste dumped at the site - The attribute refers to the total amount of waste that is disposed by the municipality. The higher the amount of total waste disposed, the higher the sensitivity index assigned to the site. This amount is estimated based on the records of the National Solid Waste Management Commission.
- Hazardous/Special contents in waste - Hazardous waste contains chemicals and physical, radiological or biological properties harmful to humans and the environment.
- Age of filling - Landfill leachate composition varies on the age of filling of the landfill. The age of filling depends on how old the wastes have been disposed at the site. Older age of filling corresponds to higher a sensitivity index value for the attribute.
- Leachate quality - Any liquid that is percolating in the deposited waste and sometimes emitted or controlled in the disposal site is considered as leachate. The leachate characteristics highly depend on the composition of waste, precipitation rate, site hydrology, compaction, cover design, waste age, sampling procedures, and interaction of leachate to the environment. and landfill design and operation. The biochemical oxygen demand (BOD) represents the amount of oxygen consumed by bacteria and other microorganisms in wastewater. BOD is used as an index of degree of organic pollution in water. An effective leachate collection and removal from the system is an important practice since it is a potential threat to environment and human health (Danthurebandara, 2012; USGS, 2018).

3.5 Hydrogeological and geological conditions

- Groundwater Table Depth - Leachate is considered a long-term threat to groundwater resources. The depth of the groundwater table is crucial since it minimizes the risk of contamination (Djokanovic et al., 2016; Rezaeisabzevar, 2020). The level of groundwater should be more than 1 m below the bearing surface of the landfill (Sengupta, 2007). The site should not be located in or up gradient of shallow unconfined aquifers for drinking water supply. Areas that are considered as 10-year recharge areas must be avoided.
- Groundwater quality - The assessment of groundwater quality will be based on whether it is not a concern within the environment, potable, potable if no alternative, and non-potable. The groundwater quality does not conform to the drinking standards (Kurian, 2005; Sengupta 2007).

- Area of the dumpsite - The waste disposal area target life should not be less than five (5) years. The area of the disposal site must consider the total service population, waste characteristics, and generation rate (DAO 50, 1998).
- Depth to bedrock - Every land surface has underlying bedrock, in some cases it is covered by soil, rock fragments, organic debris, unconsolidated sediment and in other places have no cover where bedrock is exposed (Miller, 1972). The landfill with higher depth to bedrock is better and avoids a surface with soil cover that exposes bare rock. It is preferable that there is a dense rock below to prevent vertical movement of leachate into the groundwater system.
- Distance from fault lines, cavers, sinkholes, solution channels, and areas with porous rock formations - Landfill sites must avoid areas with an average return period of 50 to 100 years for an earthquake of magnitude six and above to avoid risk of groundwater contamination. The data will be obtained from the Philippine Seismic Map from the Philippine Institute of Volcanology and Seismology (DAO 50, 1998). Landfill damage and pollution leakage can also happen after an earthquake and earth movement (Rezaeisabzevar, 2020).
- Soil stability - Having a stable site for landfill is required for preventing failure of landfill liners, and protecting surface and groundwater contamination (Djokanovic et al., 2016). The three classes of soils that are being considered for the soil stability are; a) Unstable soils such as loess are graded with the lowest value (0), b) sandy clay diluvial are considered moderately stable soils and often gets average value, c) sand, sandy clay, silty sand and loessic are graded as the highest value (Rezaeisabzevar, 2020).
- Flood proneness - Floods can transport pollutants if water reaches the dumpsite or landfill. Floods can also scatter waste across the environment downstream; salt lakes, swamplands, and low-lying coastal areas, therefore, must be avoided. Locations that are prone to flooding are unsuitable for landfilling (Rezaeisabzevar, 2020; DAO 50, 1998).
- Slope stability - Critical aspect of a dumpsite or landfill closure plan is the stabilization of an unstable slope. In the Philippines' law, the exposed waste should be compacted and the top slopes ranging from 2% to 4% to prevent ponding and avoid natural drainage (DAO 09, 2006).

4 RESULTS AND DISCUSSION

4.1 Assigned weightage for the risk attributes

The values were obtained from the combined ranking of the (12) expert panel participants consisting of the following: 4 Sanitary/Environmental Engineering Professors, 1 Sociologist Professor, 3 D/MENR Officials (3), 1 Sanitary Engineering Inspector, 1 personnel of the Department of the Interior and Local Government, 1 Planning Engineer, and 1 Forester. Based on the AHP survey, the environmental related category was considered the highest risk factor when assessing the existing landfill, meanwhile, the lowest factor was accessibility related factors, 0.28 and 0.08, respectively. The impacts of dumpsites in soil, air, water, and other ecologically sensitive areas were highly prioritized by experts. Based on the combined weightages obtained, the final weightage of each attribute was obtained. Comparing the resulting individual attribute weightages, "proximity to perennial surface waters" ranked the highest among all the risk attributes; in contrast, "artificial depth of filling waste" was ranked the lowest by the expert panel, wherein their weights are 93 and 11, respectively. It suggests that it is important that no disposal sites should be located near surface waters since they can be potential threats due to the leachate and other gaseous chemicals they can generate.

4.2 Rapid Risk Assessment Tool (RRAT)

Combining the risk attributes and their corresponding weightages and sensitivity indices, the rapid risk assessment tool was developed (Table 2).

Table 2. *Rapid Risk Assessment Tool for Dumpsites and Landfills in the Philippines*

Risk Attributes	**Assigned Weight**	**Sensitivity Index**			
		0-0.25	**0.25-0.5**	**0.5-0.75**	**0.75-1.0**
Accessibility					
Distance to the nearest airport [km]	15	> 20	10 - 20	10 - 5	< 5
Distance from (hazard related):	27	*** Choose the higher sensitivity index **			
Gas pipelines [m]		> 300	200 - 300	100 - 200	0 -100

Oil pipelines [m]		> 75	50 - 75	25 - 50	<50
Powerlines [m]		> 30	20 - 30	10 - 20	0 - 10
Waste transportation	23	***Choose the higher sensitivity index ***			
Haul distance [km]		0 - 5	5 - 10	10 - 15	> 15
Haul time [mins]		0 - 10	10 - 20	20 - 30	> 30
Proximity to building/construction materials [km]	20	< 5	5 - 10	10 - 15	> 15
Socio-Economic					
Distance from sensitive land users (e.g., urban development areas, and areas with archeological cultural and historical importance) [m]	30	750 - 1000	750 - 500	500 - 250	< 250
Land use or potential use (e.g. tourist destination, major transportation route, or valuable energy or mineral resource)	30	Wasteland/ Unused Land	-	-	Agricultural Land, Forest or Timber, Mineral, and National Parks
Public Acceptability	43	No public concerns	Accepts Dump Rehabilitation	Accepts Dump Closure	Accepts Dump Closure and Remediation
Health risks brought by the site	81	No concerns	Low risk	Medium Risk	High Risk
Environmental					
Proximity to Perennial Surface Waters (e.g., river or stream) [m]	93	> 8000	1500 - 8000	500 - 1500	< 500
Soil Quality	42	very low contamination	low contamination	medium contamination	high contamination
Ambient Air Quality (CH4%)	61	< 0.01	0.05 - 0.01	0.05 - 0.1	> 0.1
Distance from ecologically sensitive areas (e.g., parks and reserves)	88	> 2000	1000 - 1500	500 - 1000	< 500
Characteristics of Waste at the Dumpsite					
Biodegradable fraction of waste at the site [%]	18	< 10	10 - 30	30 - 60	60 - 100
Artificial depth of filling of waste [m]	11	< 3	-	-	> 3
Moisture of waste at the site [%]	19	< 10	10 - 20	20 - 40	> 40
Quantity of waste disposed per day [tons/day]	20	< 250	250 - 500	500 - 1000	> 1000
Total quantity of waste dumped at the site [T]	24	< 10^4	10^4 - 10^5	10^5 - 10^6	> 10^6
Hazardous Waste [%]	34	0	0 - 25%	25 - 50%	> 50%
Age of filling [years]	15	> 30	20 - 30	10 -20	< 10
Leachate quality [BOD]	36	< 30	30 - 60	60 - 100	> 100
Hydrogeological & Geological Conditions					
Groundwater table depth [m]	31	> 20	10 - 20	3 - 10	< 3
Groundwater quality	42	Not a concern	Potable	Potable if no alternative	Non-potable
Area of the dumpsite [ha]	18	< 5	5 - 10	10 - 20	> 20
Depth to bedrock [m]	25	> 15	10 - 15	5 - 10	< 5
Distance from fault lines, caverns, sinkholes, solution channels, and areas with porous rock [m]	44	> 1000	750 - 1000	500 - 750	< 500
Soil Stability [type of soil]	36	> 50	30 - 50	15 - 30	0 - 15
Flood Proneness	37	safe zone	low hazard area	medium hazard area	high hazard area
Slope Stability [%]	37	< 1.5	1.5 - 2.5	2.5 - 7.0	7.0 - 15
TOTAL	**1000**				

4.3 Application and validation of the RRAT

The RRAT developed in this study was used to determine the risk index of the Banga controlled dumpsite and Malay Sanitary Landfill. Banga-controlled dumpsite was converted from an open dumpsite and operates as a temporary waste disposal site while waiting for the budget for the construction of the municipality's sanitary landfill to comply with the provisions stated in RA 9003. Malay Sanitary Landfill is the only operating landfill in Aklan, accommodating the solid wastes from Boracay Island. The RRAT determined the potential risk index of the dumpsites which will be used to validate the recommended or necessary actions.

The potential risks obtained for the Banga controlled dumpsite (BCD) and Malay Sanitary Landfill (MSL) were 370.42 and 199.01, respectively. Both sites obtained the highest risk weight from proximity to perennial surface water, 93 and 27.85. The tool can easily distinguish and assess the potential risk depending on the value of the risk index; low values of RI clearly indicate that the site is safe and needs rehabilitation; meanwhile, high values of RI clearly indicate that there is a high risk of environmental hazard.

The risk index obtained from the developed RRAT was compared to the resulting risk index obtained from the RRAT developed by Kurian et al. (2005) for the existing dumpsites in India. The classification for the said tool was primarily based on the criteria recommended by the Ministry of Environment and Forest, Government of India. Using the method and tool developed by Kurian et al. resulted in a risk index of 309.69 and 204.04 for BCD and MSL, respectively. The result shows some difference between the risk index obtained from the two tools. This may be possible due the fact that the criteria for the selection of attributes, law and ordinances followed differ from each other. Moreover, there is a noticeable difference on the weightages assigned for each attribute possibly due to the difference in ranking obtained from the AHP survey conducted – which may vary according to the expert panel included in the study.

The results show that although the risk index obtained from the two rapid risk assessment tools differs, the proposed or recommended action for the dumpsites assessed are still the same based on Table 1 – the BCD needs to be rehabilitated into a sanitary landfill in a phased manner; the MSL has low risk index because of its engineered sanitary landfill characteristic.

5 CONCLUSIONS

This research paper successfully developed a rapid risk assessment tool (RRAT) that would serve as a quick decision-making tool for disposal site rehabilitation in the Philippines. The overall risk posed by the dumpsites investigated was relatively easy to calculate, given that the necessary data were available from the LGUs and national government agencies. Moreover, the risk index calculation was straightforward based on the equations used. Experts ranked environmental-related categories as the main factor when assessing the hazard of an existing dumpsite, followed by hydrological and geological conditions, socio-economic, fourth is characteristic of waste in site, and lastly, accessibility – obtaining a weightage of 0.283, 0.270, 0.185, 0.178, and 0.084, respectively.

Determining the potential risk of an existing landfill will lessen the country's financial burden to establish a new sanitary landfill when the dumpsite can still be rehabilitated gradually from open dumping to sanitary landfill in a phased manner depending on the risk observed in the site. It is recommended to apply the tool to more dumpsites and landfills from all over the country for further validation.

6 ACKNOWLEDGEMENTS

This research was partially supported by the WebFocus Solutions Thesis Support Grant of the UP Engineering Research and Development Foundation, Inc. (UP ERDFI). The authors would like to acknowledge the University of the Philippines, the Department of Science and Technology (DOST) Science Education Institute (SEI) Engineering Research and Development for Technology (ERDT) and the PCIEERD Human Resources Development Program (HRDP) for the travel grants to present and publish the research study.

REFERENCES

Buso, S., Nakin, M., Abraham, A., Musampa, C. (2015). Environmental and Community Impacts of Waste Disposal in OR Tambo District Municipality (South Africa). *WIT Transactions on Ecology and the Environment.* 193(509-520). DOI: 10.2495/SDP150441

CPCB. (2003). Guidelines for the selection of site for landfilling. Central Pollution Control Board, New Delhi, India.

CPCB. (2005). Environmental Impact Assessment for site selection for common hazardous waste management facilities.

Danthurebandara, M., Passel, S., et al. (2012). Environmental and Socio-economic Impacts of Landfills. Linnaeus Eco-Tech. Reference: https://www.researchgate.net/publication/278738702

DENR Administrative Order No. 09 series of 2006: General Guidelines in the Closure and Rehabilitation of Open Dumpsites and Controlled Dump Facilities

DENR Administrative Order No. 50 series of 1998: Adopting the Landfill Site Identification and Screening Criteria for Municipal Solid Waste Disposal Facilities

DOST. DOST Nationwide Operational Assessment of Hazards. http://noah.dost.gov.ph/

Djokanovic, S.,Abolmasov, B., and Jevremović, D. (2016). GIS application for landfill site selection: a case study in Pančevo, Serbia. Bulletin of Engineering Geology and the Environment. 75. DOI:10.1007/s10064-016-0888-0

EMB, DENR (2018). National Solid Waste Management Status Report.

Kurian, J., Esakku, S., Nagendran R., & Visvanathan, C. (2005). A decision-making tool for dumpsite rehabilitation in developing countries. In: Proceedings of Sardinia 2005, Tenth International Waste Management and Landfill Symposium, 3–7 October, Cagliari, Italy.

MoEF (1989) "Guidelines for management and handling of hazardous wastes", Ministry of Environment and Forests, Government of India, New delhi.

National Solid Waste Management Commission. https://nswmc.emb.gov.ph/

National Solid Waste Management Commission - NSWMC. (2010). Guidebook for Safe Closure of Disposal Sites (2010), 2nd Ed. National Solid Waste Management Commission - NSWMC and Japan International Cooperation Agency (JICA), Philippines.

Newton, J. (2018). Effects of Landfills in the Environment. *Leaf Group Ltd.* Reference: https://sciencing.com/cambodias-environmental-problems-7327797.html

Njoku, P., Edokpayi, J., and Odiyo, J. (2019). *Health and Environmental Risk of Residents Living Close to a Landfill: A Case Study of Thoyoyandou Landfill, Limpopo Province, South Africa*. International Journal of Environment Research and Public Health. DOI:10.3390/ijerph16122125

Ozcan H., Guvenc S., Guvenc L., Demir G. (2016). Municipal Solid Waste Characterization according to Different Income Levels: A Case Study. *Sustainability*. 8, (1044). DOI:10.3390/su8101044

Pandiya, A., Murugesan, A., Vidyadevi, T, Dineshkirupha S. (2011). A Decision Making Tool for Hazardous Waste Landfill Site Location.

Republic Act No. 9003. (2001). Ecological Solid Waste Management Act.

Rezaeisabzevar, Y., Bazargan, A., Zohourian, B. (2020). Landfiil Site Selection Using Multi Criteria Decision Making: Influential Factors for Comparing Locations. *Journal of Environmental Sciences.* 93, (170-184).

Saaty, T.L. (1980) The Analytic Hierarchy Process. McGraw-Hill, New York.

Saxena, A.K. and Bhardwaj, K.D. (2003) Environmental Assessment and up-gradation plan for existing municipal waste disposal site – A case study. Proc. Workshop on Sustainable Landfill Management, Chennai, India, pp. 287–301.

Sengupta, D. (2007). Guidelines For Conducting Environmental Impact Assessment: Site Selection For Common Hazardous Waste Management Facility. *Central Pollution Control Board Ministry of Environment & Forest: India.*

Senate Economic Planning Office (SEPO) (2017). Philippine Solid Wastes at a Glance.

USGS (2018). Biological Oxygen Demand (BOD) and Water. *USGS Science for Changing World.* https://www.usgs.gov/special-topics/water-science-school/science/biological-oxygen-demand-bod-and-water#overview

Vaverkova, M. (2019). Landfill Impacts on the Environment -Review. Geoscience 9, pg 431.

Wiersma and Goossens, L. (2001). Assessment of Landfill Technology Failure. From: https://www.researchgate.net/publication/312054096