Environmental Consequences of Poor Landfill Management

Iyenoma ThankGod Osazee and Bhaskar Sen Gupta

ABSTRACT

Landfill is a popular method of waste disposal in many countries due to its relatively low of costs of operation. The offensive aspect of the method is improper removal or disposal of the waste, which has resulted in avoidable sicknesses, diseases and preventable deaths. Carbon dioxide and methane are the two main gases emitted from landfill sites; municipal solid waste issue accounts for almost 5% of total greenhouse gas emissions and methane from landfills accounts for 12% of the total quantity of global methane emissions. Landfills can be put to sustainable use by employing it to produce energy from waste whenever is feasible and it has the capacity to generate revenue. Furthermore, many advanced waste treatment technologies have been developed which received commendable attention in developed countries and are evolving in developing countries. Landfill gas-to-energy is viable economically and for control of methane emissions and effective management of time, costs and quality with minimum risks to humans and the environment.

Keywords: GHGs, landfill, leachate, municipal solid waste, sustainability indicators, treatment technologies.

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I. INTRODUCTION

Environment is the pivot in which physical, social, and economic activities takes place. Some analysts mostly describe environment, whose main resource is land, as 'living earth'. This connotes that the earth or land is capable of reacting positively or negatively depending on the human activities. A common negative approach of dealing with 'earth' is dumping of waste into the ground, streets or drainages indiscriminately thereby causing sicknesses, diseases, and avoidable deaths.

TABLE 1: WASTE PRODUCED BY REGION [2]

Region	Waste Generation Per Capita (Kg/capital/day)		Average
	Lower Boundary	Lower Boundary	
Africa (AFR)	0.09	3.0	0.65
East Africa Pacific (EAP)	0.44	4.3	0.95
East and Central Africa (ECA)	0.29	2.1	1.1
Latin America and Caribbean (LAC)	0.11	5.5	1.1
Middle East and North Africa (MENA)	0.16	5.7	1.1
Organisation for Economic Co-operation and Development (OECD)	1.10	3.7	2.2
South Asia (SAR)	0.12	5.1	0.45

A survey of waste disposal methods employed by selected countries was conducted in 2002 [1]. The survey demonstrated that all the countries have landfill sites: with Canada, 96% leading, followed by Finland, 95% and UK, 88%; the least is Switzerland, 20%; but had the highest in

incinerated scheme of 80%. Many landfill sites accommodate waste that can be recycled. This makes it attractive to scavengers, who by this process are exposed to the risk of contracting diseases and possible sicknesses that may lead to premature death.

A. Aim and Objectives of the Study

The research paper is aimed at assessing the sustainability indicators of various landfill sites using a list of parameters, the objectives are to discuss and analyze waste to energy, and profits by various treatment technologies, as this will help to reduce overdependence on landfilling.

B. Research Limitation

All data were found through desk study rather than at real sites. The main information sources were with regulators, online and academic studies. The standards and regulations guiding many countries vary, this would tend to impact on the quality of data. The confidence came from the fact that many of the countries are signatories to many international organizations, regulations and associations. Nevertheless, an issue that the data collection process threw up was the need to consider the stakeholders' opinions being part of a decision-making process. It would have been imperative to know the views of the citizens of many of the countries about current Waste Management techniques. This was dealt with by deep review of relevant journals and literature of many countries, especially the ones where data were collected.

C. Landfill

The unsystematic and unregulated/unscientific choice of landfill sites can pose a danger to the environment, humans,

and possibly, adjacent aquatic bodies, including groundwater [3]. One main criteria for selecting landfill include providing a reasonable distance away from significant water bodies. This is because of the danger of pollution of the water bodies, which may be of adverse effects to the aquatic life [4]. Other factors are climatic conditions, hydrology, local environmental conditions, e.g., nearness to network of roads, and land availability in its construction [5].

II. GHGS EMISSIONS FROM LANDFILLS

GHG emissions from municipal solid waste has been considered as a major issue because it accounts for almost 5% of total greenhouse gas emissions and methane from landfills account for 12% of the total quantity of global methane emissions [6], [7]. The primary composition of landfill gas is methane and carbon dioxide. Methane is regarded as one of the pronounced GHGs because it has a high potent global warming capability, that is, 28times higher than carbon dioxide [8]. The relative high concentrations of methane have the capability of replacing oxygen in the surrounding atmosphere thereby leading to increased human health risks. Municipal solid waste dumped into the landfill undergoes anaerobic decay process because of the action of methanogens and methane is released into the atmosphere [8], [9].

A. Monitoring of Landfill Sites

The purpose of gas monitoring is to ascertain gas production that has given rise to hazard- the potential of agent, in this case gas level, to cause damage or injury. The monitoring of any landfill should commence six months from the time it was opened for operation and monitoring should be undertaken at 15 years after closure of a landfill as landfill sites consists predominantly of inert waste that may have produced landfill gas (Table 2). Leachate migration in landfills is due to water percolation that accumulates within or below the landfills especially in unsealed landfills above aquifer [10]. A leachate is typically characterized by two factors, viz, its composition and the volume generated [11] both varies among landfills and highly influenced by type of waste, volume, age, climatic conditions, mode of operation and landfilling technology [11], [12]. The efficiency or adequacy of a landfill is in the monitoring of leachate and regular control of groundwater migration [13]. [14] posited that the most important factor influencing landfill leachate composition is the age of the landfill. Many methods of disposing leachate have been evolved over time. For example, in Poland, one main municipal landfill leachate disposal technique is the co-treatment with domestic wastewater. The implementation seems to limit the total number of landfills [15].

III. RESEARCH METHODS

A. Advanced Waste Management Technologies

Four core types of advanced waste technologies: gasification, plasma arc gasification, pyrolysis, and steam classification, utilized for municipal wastes was adopted in this work. However, only gasification, plasma arc

gasification and pyrolysis were considered being the only technologies available in the public domain.

B. Selection of Technique(s) through Decision Analysis

The criteria are clearly spelt out in Fig. 1 and the environmental parameters represented in Fig. 2.

Fig. 1. Flowchart illustrating ATSWM technologies set of criteria for sustainability indicators for three environmental options.

Every key sustainability indicator was weighted against environmental options and award points are given to it on a random scale of 1 to 5 (1 is best and 5 is worst). Fig. 4 shows a flowchart of the relationship between the options and the sustainability indicators. The costs range quoted are 2009 prices and in US Dollars (Table 3). However, many variations in labour, materials and equipment have occurred since 2009 in the USA; in addition to the impact of exchange rate of Dollars and other currencies used in other countries. Table 4 was used to develop flowchart in Fig. 2.

TABLE 2: REGULATORY LIMITS OF LEACHATE CONTAMINANTS COMPOSITION IN SOME SELECTED COUNTRIES OF THE WORLD IN SEVEN REGIONS

Region	Parameter Country	COD (Mg ^{L⁻¹})	BOD ₅ (Mg ^{L⁻¹})	TOC(Mg ^{L⁻¹})	NH ₄ -N(Mg ^{L⁻¹})	PO ₄ -P(Mg ^{L⁻¹})	Dissolved Solids (Mg ^{L⁻¹})	SS (Mg ^{L⁻¹})	Total Nitrogen (Mg ^{L⁻¹})	Phenolic Compound (Mg ^{L⁻¹})	Hg (Mg ^{L⁻¹})	As (Mg ^{L⁻¹})	Pb (Mg ^{L⁻¹})	Ref.
SAR	Cameron	320	44										0.07	
	Nigeria	338	111										0.01	[16]
	South Africa	680	117		0.1								4	[17]
EAP	China	100			15	0.5								[18]
	Malaysia	100	50					10						[19]
	Singapore	718	529	375				400			0.05		0.04	[20]
ECA	Macedonia	985	1250						40					[21]
	Tajikistan		4921								0.0014	0.037	0.0383	[22]
	Ukraine		2					0.75						[22]
LAC	Mexico	790	4780	3395										[23]
	Uruguay	0.3	8					0.7	0.15					[24]
	Venezuela	160		7736										[24]
MENA	Egypt	12850	11700											[25]
	Lebanon	50000	350											[26]
	Saudi Arabia				14.1								1	[27]
OECD	Australia		10	15	0.5	0.1		20	5	0.05	0.0001	0.05	0.005	[28]
	Germany	200	20			3			70		0.05		0.5	[29]
	Sweden	33	361	297									0.001	[29]
SAR	Bangladesh	200	50		50		2100	150						[30]
	India		100				2100	200				0.2		[31]
	Pakistan	1701	724						1.78				0.35	[31]

Fig. 2. Flowchart illustrating outcome for three advanced thermal solid waste management technologies options.

TABLE 3: SUMMARY OF ADVANCED SOLID WASTE TECHNOLOGIES [6], [32]-[37]

Type of Waste Mgt	Average Capital Cost (\$ Millions)	Average Annual Operating Cost (\$ Millions)	Average Tipping Fee	Average # FTE	Renewable Energy (MW)	Average Disposal Capacity (Thousand tons/year)	Average Land Space Required (Acres)	Emissions	# of facilities
Landfill									
Gas-to-Energy	5	0.6	\$34	2	3.0	500	172	Low	485
Gasification / Pyrolysis	65	7.1	\$40	30	4.0	350	8	Low	110
Plasma Arc	90	6.6	\$40	50	4.3	200	5	Low	3
Gasification									
Mechanical									
Biological	78	7.9	\$70	30	4.0	225	6	Low	70
Treatment									

TABLE 4: INDICATING ENVIRONMENTAL SET OF CRITERIA ASSESSMENTS FOR THREE OPTIONS

ENVIRONMENT			
Options	Gasification	Pyrolysis	Plasma Arc Gasification
Tipping Fee	3	3	2
Environment Impact	2	2	1
Public Acceptability	4	3	1
Number of Facilities	3	4	2
Total	12	12	6
Rank	2	2	1

C. Data Collection and Analysis

A systematic collection of data from various landfill sites globally was carried out for the 21 countries selected from 7 regions (Table 7). All data collections were done through desk study; sources would be regulators, online and academic studies. This was subjected to the environmental parameters that produced Table 5.

TABLE 5: INDICATING ASSESSMENT OF THE COSTS FOR THREE OPTIONS

TOTAL COSTS			
Options	Gasification	Pyrolysis	Plasma Arc Gasification
Environment	12	12	6
Operation	16	13	10
Costs	14	13	14
Total	42	38	30
Overall Rank	3	2	1

IV. PROCEDURE FOR COMPUTATION

For the feasibility study on the technological aspects of solid waste to energy generation, the following equation was adopted from an earlier work [38]. The essence was to analyze the weights of waste as per the reviewed literature on 'Gasification and Pyrolysis' technologies already discussed.

Let the rank in the selected criterion be represented by $r_{i,j}$, for $i = 1, 2, 3, j = 1 \dots 13$, where i represents the technologies and j represents the criterion.

The value of the inward will determine the relative weights of rank for each criterion.

Let the values awarded for each criterion be represented by a_j , for $j = 1 \dots 13$. Then,

$$W_j = \frac{a_j}{\sum_{j=1}^{13} (a_k)^n} \text{ for } j = 1 \dots 13 \quad (1)$$

Equation (2) demonstrates how the total rank was computed:

$$rT_i = \sum_{j=1}^{13} (r_{ij} w_j), \text{ for all } i \quad (2)$$

The ranking of technologies i will now be determined based on the minimum ($r_T, 1, r_T, 2, r_T, 3$).

Illustration of the calculation process using the equation using tipping fee as an example.

From Table 4 Awarded Points on the three technologies = $3+3+2 = 8$.

Average value of awarded points = $8/3 = 2.67$.

From Table 5 Total Costs based on the three options gives: $42+38+30 = 110$.

Average of Total Costs = $110/3 = 36.67$.

Weight of Criteria = $2.67/36.67 = 0.072$.

All other values in Table 6 were computed using the above procedure as illustrated.

A. Interpretation of Results

The procedure made pairwise comparison of technologies alternatives of the 7 regions of countries selected. Local priorities of alternatives were interpreted in the calculations in this intermediate step which are reflected in Fig. 4. These computed criteria weights for each region where the sum of criteria weights in each region is equal to 1 (Fig. 3).

Fig. 4. The application of the solid waste technologies in each of the seven regions.

TABLE 6: RESULTS OF CALCULATIONS AND ANALYSIS FROM RESEARCH METHODS

S/N	Tipping Fee	Environment Impact	Public Acceptability	Number of Facilities	Revenue	Development Period	Flexibility of Process	Net Conversion Efficiency	Capital Cost	Land Requirement	Ease of Permitting	Marketability	Operation Cost
Aggregate value	2.67	1.67	2.67	3	2.67	4	3.67	3.33	3.33	2.67	3	2	2.67
Weight of Criteria	0.072	0.045	0.072	0.08	0.072	0.107	0.098	0.089	0.089	0.072	0.08	0.054	0.072

(a)

(b)

(c)

(d)

(e)

(f)

(g)

Fig. 3. Criteria weights obtained from ATSWM technologies(a) Latin America and Caribbean, (b) Organisation and Economic Cooperation and Development, (c) sub-Saharan Africa Region, (d) Middle East and North Africa, (e) South Asia Region, (f) Eastern and Central Region, (g) East Asia and Pacific.

TABLE 7: COUNTRY CLASSIFICATION ACCORDING TO REGION [2]

Africa (AFR)	East Asia & Pacific (EAP)	Eastern & Central Asia (ECA)	Latin America & the Caribbean (LAC)	Middle East & North Africa (MENA)	Organisation for Economic Co-operation and Development (OECD)	South Asia (SAR)
Angola	Brunei Darussalam	Albania	Antigua & Barbuda	Algeria	Andorra	Bangladesh
Benin	Cambodia	Armenia	Argentina	Bahrain	Australia	Bhutan
Botswana	China	Belarus	Bahamas, The	Egypt, Arab Rep.	Australia	India
Burkina Faso	Fiji	Bulgaria	Barbados	Iran, Islamic Rep.	Belgium	Maldives
Burundi	Hong Kong	Croatia	Belize	Iraq	Canada	Nepal
Cameroun	Indonesia	Cyprus	Bolivia	Israel	Czech Republic	Pakistan
Cape Verde	Lao PDR	Estonia	Brazil	Jordan	Denmark	Sri Lanka
Central African Rep	Macao, China	Georgia	Chile	Kuwait	Finland	
Chad	Malaysia	Latvia	Colombia	Lebanon	France	
Comoros	Marshall Islands	Lithuania	Costa Rica	Malta	Germany	
Congo, Dem. Rep	Mongolia	Macedonia, FYR	Cuba	Morocco	Greece	
Congo, Rep.	Myanmar	Poland	Dominica	Oman	Hungary	
Cote d'Ivoire	Philippines	Romania	Dominican Republic	Qatar	Iceland	
Eritrea	Singapore	Russia Federation	Ecuador	Saudi Arabia	Ireland	
Ethiopia	Solomon Island	Serbia	El Salvador	Syrian Arab Rep	Italy	
Gabon	Thailand	Slovenia	Grenada	Tunisia	Japan	
Gambia	Tonga	Tajikistan	Guatemala	United Arab Emirates	Korea, South	
Ghana	Vanuatu	Turkey	Guyana	West Bank and Gaza	Luxembourg	
Guinea	Vietnam	Turkmenistan	Haiti		Monaco	
Kenya			Honduras		Netherlands	
Lesotho			Jamaica		New Zealand	
Liberia			Mexico		Norway	
Madagascar			Nicaragua		Portugal	
Malawi			Panama		Slovak Republic	
Mali			Paraguay		Spain	
Mauritania			Peru		Sweden	
Mauritius			St. Kitts and Nevis		Switzerland	
Mozambique			St. Lucia		United Kingdom	
Namibia			St. Vincent and the Grenadines		United States	
Niger			Suriname			
Nigeria			Trinidad and Tabago			
Rwanda			Uruguay			
Sao Tome and Principe			Venezuela, RB			
Senegal						
Seychelles						
Sierra Leone						
South Africa						
Sudan						
Swaziland						
Tanzania						
Togo						
Uganda						
Zambia						
Zimbabwe						

V. CONCLUSION

Sustainable solid waste management is practically difficult; however, finding solutions to the waste situation that is ever increasing is paramount for any country and indeed the rest of the world. In order to progress the process, analytical hierarchical process (AHP), which was first made known by [39] and best practicable environmental option (BPEO) are renowned approaches of resolving complex

decision-making problems by deriving weights to denote the comparative significance of different criteria has been applied.

Many technologies are available as well as many have been reviewed. In all, landfill gas-to-energy seems the most viable economically and for control of methane emissions, in addition to producing dependable source of energy.

These three technologies virtually reduce or eliminate the need for landfills in some instances, in addition to meeting

sustainability measures; however, the economic aspects of plasma arc gasification have not been fully verified because of its high technical requirements.

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