Landfill in a Sustainable Waste Disposal

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ABSTRACT

Landfill is as old as mankind, and it is the most common and popular waste disposal globally; it is very likely to be the mostly used method for some time to come despite efforts to recycle and re-use waste materials. However, in many respects landfilling has been highly criticised by stakeholders and regarded as the opposite of sustainability because of the health hazard and environmental burden it constitutes. The efficiency of landfilling rests on technical, economic, and legal framework which seems to be inadequate in many countries. The essence of sustainable landfill is to ensure that the environmental parameters e.g., methane, leachate, etc. are reduced to acceptable risk level (inert waste) in order to prevent damage to humans and the environment. Many European countries in compliance with 2008/98/EC along with 94/62/EC Directive have been able to reduce heavy reliance on the landfill; however, this has raised the use of other waste management methods e.g., Sweden share of landfill disposal is 1% (Table I) this increases dependent on other methods of waste disposal e.g., incineration, 49%, waste treated biologically, 14% in 2011. Nevertheless, landfilling will still be required to dispose of waste which cannot be recycled or treated in other ways.

Keywords: acceptable risk, landfills, sustainability, waste disposal.

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I. INTRODUCTION

Landfill can be denoted as the physical facilities or places where (solid waste and waste residuals) are dumped, usually in controlled and studied way [1]. Landfill is as old as mankind and landfilling seems to be the most common and popular waste management choice. It is the conventional or traditional waste disposal which take the centre stage in waste management in many developed countries (Table I) and still popular in developing countries. This may be due to its relative ease of operation with less technicalities. In many respects, landfilling has been highly criticised and is being regarded as the opposite of sustainability apparently because of the health hazard and environmental burden it constitutes [2], [3]. Many researchers, stakeholders, regulators have advocated that landfill should be eliminated. There is waste biodegradation in landfills which create a greenhouse gas termed landfill gas [4]. This result to global warming and intensive climate change due to disturbance of the ozone atmosphere.

A. Background Information to the Study

It has been discussed severally that traditional or conventional landfills creates some severe environmental consequences in addition to occupation of large expanse of land. Solid waste management problems in every country cannot be overemphasised. The notion of entirely eradicating waste is unthinkable; rather, seeking the appropriate and scientific technique to handle wastes in a justifiable manner, which will ensure the protection of lives and properties, as

well as conserve the environment. Conventional or traditional landfills fall short of three steps of the hierarchy of a new waste concept, which tends to drive sustainable landfills [5]; [6] sums it up thus: *"The safe disposal of waste within a landfill, and its subsequent degradation to the inert state in the shortest possible time span, by the most financially efficient method available, and with minimal damage to the environment"*. The aim of the study was to look at the issues of landfilling as a viable waste management and that despite the perceived shortcoming, the approach may not easily be eased off in many countries. The focus of any sustainable landfill is to alleviate the environmental effects and consequences by reduction of toxic waste and contamination, prevention of leachate where practicable and closing inadequately managed landfill. The primary cause of the harmful nature of landfills is the accumulated quantity of waste which generate methane, high volume of leachate, indiscriminate dumping of waste among others. In the study conducted by [7] from 21 countries in 7 regions of the world, it showed varied regulatory limits of leachate contaminants composition in landfills. Depicted in Fig.1 are leachate volume in 6 countries (Table V) and carbon dioxide equivalent ranges that from 15.9 to 129.7Mt (CO₂-eq [8]. These environmental parameters tend to determine the efficiency of the landfill and its ability to function without causing damage to humans and the environment.

The European Union (EU) have developed many directives aimed at reducing the number of landfills and quantity of waste generated. In 1999, EU Landfill Directive(1999/31/EC) was passed in order to encourage

member countries to work towards a gradual reduction of Municipal Solid Wastes (MSW) to 75% of the 1995 disposal level by 2010 and 35% reduction by 2020 [9]. The outcome was the adoption of various methods for managing waste. This Legislative Act urges Member States to “take adequate measures to reduce the prevention and possible reduction of waste production with its attendant harmful effects”. Feasibility study of 27 European countries was conducted in order to ascertain their share of landfill disposal in percentage. All countries surveyed make use of landfills at varying degree with the highest being Malta, 92% and the least: Sweden, Netherlands, Germany; 1%each (Table I).

TABLE I: MSW PRODUCED IN 1995 AND 2016(KG/CAPITA) ADOPTED FROM [10] AND SHARE OF LANDFILL DISPOSAL (%) ADOPTED FROM [11]

Country	1995	2016	2017	Waste treatment – landfill, 2016 (share of landfill disposal)
Austria	480	552	570	3%
Belgium	446	414	409	1%
Bulgaria	831	404	416	64%
Cyprus	593	592a	637	81%
Czech Republic	312	339	344	50%
Denmark	521	777	781	1%
Estonia	370	327	390	12%
Finland	437	504	510	3%
France	476	510	513	22%
Germany	621	625	633	1%
Greece	331	498	-	52%
Hungary	377	380	385	51%
Ireland*	430	615	-	22%
Italy	468	436	489	28%
Latvia	184	367	438	72%
Lithuania	542	422	455	31%
Luxemburg	587	614	607	17%
Malta	387	584	604	92%
Netherlands	509	518	513	1%
Poland	284	307	315	37%
Portugal*	351	483	487	49%
Romania	254	228	272	80%
Slovakia	294	344	378	66%
Slovenia**	469	434	471	24%
Spain	365	443	462	57%
Sweden	386	442	452	1%
United Kingdom*	501	476	-	28%

*Data from 2014; **Data from 2015.

II. THE LANDFILL SITE

Landfill sites are major habitation of methane, “45% of UK methane emanate are from landfill sites” [12]. Fig. 1 conveys information of 2010 records of ten top countries in the world that emits methane with USA topping the list with 129.7 mmtCO₂-eq [8].

The water that flows into the landfill creates leachate which has the possibility of polluting the surroundings and the environment. Other problems related to leachate include groundwater pollution and oxygen reduction and ecotoxicity (potential adverse effects of biological, chemical, or physical agent on the ecosystems) in surface waters [13], [14]. These issues from the landfilling have raised a red flag among stakeholders and regulators as to whether this method of waste disposal should continue to be entertained. The fact is that every country practice landfilling at different levels as discussed in Table I. Some countries have put regulations in place to contain the menace from the landfills. Sweden have even taken the initiative of converting the landfill gas mainly

carbon dioxide and methane to source of energy. The world population is currently about 8 billion people [15] and this has tremendous impacts on the volume of waste generated. The big picture of waste generated globally is depicted in Fig. 2 projected to 854 million by 2050.

Fig. 1. Methane Emissions from Landfills in ten countries [8].

Fig. 2. Waste generated by various regions of the world [15].

A. Laws, Regulations and Policies

The term Environment Impact Assessment (EIA) as well as referred to as Impact Statement (European Council Directive 85/337/EEC of June 27, 1985) defined it as a “process of description and assessment of the direct and indirect effects of a project on humans, fauna and flora, soil, water, air, climate and the landscape, the interaction of these factors on material assets and the cultural heritage” [16]. The focus on EIA report is to help policy and decision makers consider the environmental impacts of any (landfill) project concluding on whether to continue with the new developments or not. This gave birth to concerted effort to strengthen the procedure so that it could respond to new challenges posed by escalating global environmental problems and degradation. These comprise global warming from greenhouse gases (GHGs) and climate change, ozone layer depletion, biodiversity loss, marine water degradation, pollution, and poverty, all of which are reflections of unsustainable practices in resource management and development.

In order to assess the adverse possible effects of any landfill on the environment and surrounding, including the communities where the proposed project will be cited, a

detailed analysis of geotechnical, environmental and geophysical examinations, etc. are required. The EIA report attempts to determine the effects and hazards of the proposed landfill on the existing relationship between the surroundings and its inhabitants will help determine its appraisal and feasibility. “Council Directive 85/33/EC” discussed the need to conduct an Environmental Impact Assessment in respect of finding the undesirable impacts for some types of projects in the public and the private sectors within the environment”.

B. European Union Directive (1999/13/EC) on Waste Disposal Landfill

This Directive centred on waste disposal in landfill and is popularly referred to as “Council Directive” of April 26, 1999. It was transmitted by the EU to Member States for adoption and domesticated locally on July 1, 2001. The Directive has its main objective, thus: “Prevent or reduce to the barest minimum adverse effects or consequences being faced by the physical environment, with due attention to pollutions for the source of water, underground aquifers, soil structures, air quality, the effect of greenhouse gases (GHGs) and any other dangers that have affected the wellbeing of persons as a result of disposal of waste on landfills, within the lifespan of any landfills.”

EU Commission raised a legislative idea directed at meeting targets within the landfill operation. These targets, which includes recycling and other related aspects, were clearly spelt out in 2008/98/EC Directive alongside 94/62/EC Directive which centres on packaging wastes. The main contents of the proposal are aimed at the gradual phasing out landfilling of waste and due to be completed by the year 2025 for waste that can be recycled. These consists of all forms of plastic, metal, paper, bio-wastes, and glass. While non-hazardous waste landfilling sites, this is expected to tally with 25% maximum limit of landfilling sites. Proposals and actions are aimed at making the landfills more efficient and environmentally friendly.

In order to enforce the Legislative Directive (1999/13/EC), the EU spelt out the approach in which permit shall be granted to operate the landfill site to include: full details of the applicant(s), description of the types, forms and total quantity of the wastes to be dumped, total design capacity of proposed site(s), details of the location of the proposed site for ease of access, planned method of preventing and reduction of pollution and proposal put in place to enhance monitoring and reduction of pollution.

III. THE CONCEPT OF SUSTAINABLE DEVELOPMENT

The term sustainable development can actually mean different thing to so many people; as a result, it is difficult to pin down. Conceptually, it is centred on meeting the needs of the present generation without precluding subsequent generations (Brundtland’s Commission) [17]. This means everyone understands or appreciate the need for growth and to grow the economy. However, it is not everyone that seems to look at the negative influences on development and wellbeing. The 17 Millennium Development Goals (MDGs) drive the scheme termed sustainable development. It is about the big picture as the goals helps to create innovative technologies without causing damage to the surrounding. At

the core of its procedure is the technique that takes earth’s resources into due consideration.

Brundtland’s Commission Concepts and WCED’s opinion [17] tried to demonstrate the challenges and the need for policy guidelines to reduce harm and negative influence on the environment and surrounding. The process of acquiring site for landfill to actual construction has brought a lot of issues to the environment e.g., clearing the place of trees and other natural habitats in the land; the ecosystem is altered. The physical existence of landfill sites tantamount to emission of offensive odours and leachate gases. This has made arguments by environmental analysts strong, as they contend that landfills are not sustainable. However, control of the gases emitted may have long effect of reducing any possible outbreak of diseases in the area. Nevertheless, protection and preservation of the environment from wastes indiscriminately disposed of did not become a major issue of great concern until the 1970s. It was after then that the technical standards improved, laying emphasis mainly on the control of gases and leachates from landfills. This was what led U.S Environmental Protection Agency to establish the Resource Conservation and Recovery Act, which reinforced the procedures on landfills and better environmental protection [18].

The development of high quality and viable waste management practices are significant in the protection and promotion of the health of future generations. The stand point of *sustainable development is that, it is practically possible to have development that attain the demands of the present world population for food, water, energy and shelter without causing harms on health and on the environment, and, not damaging or depleting the global resource base, and not precluding the capability of subsequent generations to meet their own needs* [19]. Bad or poor solid waste management could have high level underground water contamination, which may cause infectious diseases and eventual deaths. EIA report can be used to assess the net contribution of a project or programme to sustainable development [20]. This was done by reiterating that the limitation of project-level impact restricts its scope to the project’s capability to promote or impair sustainable development. This notwithstanding, also observed that some projects clearly promote sustainability through, for example, restoring the soil or reducing damage to the natural resource base arising from economic activity. What needed to be explored at this point, was finding a means of applying sustainability criteria in a project-level EIA. Such method faces two major problems. The first has to do with the nature of sustainable development, which is a “process encompassing the entire economy (or the global economy) in its relationship to the natural order”. This suggests, by implication, that sustainable development cannot be realised by project valuation and selection. The second is that since conventional project-level EIA is limited to the treatment of the potential environmental damage of a project, a full assessment of the entire process will be required. According to [21]: one way of achieving full environmental and resource accounting (that is, the sustainability criterion) is:

- to appraise the impact of the project on the natural resource base and to take account of the adverse effects in the social costs and the positive effect in the societal benefits. All

unabated environmental effects, such as pollution of the atmosphere, the oceans, the waterways, and the land would be internalised so that they become part of the social costs of the project. All natural resource depletion, such as the extraction of minerals, deforestation and ocean fishing, would be indicated as social costs, while any rise in renewable natural resources would be added up to the societal benefits.

A. Landfill Lifespan

Leachates from both industrial and non-hazardous wastes are toxic in contents; however, the waste from industrial sources are more toxic and the quantity of leachate produced hinges on the size of the landfills, the weather, that is, meteorological and hydrological parameters and efficiency of the capping. This explains why the quantity of leachate produced may be high in humid regions or high runoff and shallow water table [22], [23]. The geology and hydrogeology of any prospective landfill site has a lot to do with the level of natural protection of groundwater from pollution by landfill as this will have a healthy influence on the effectiveness and operation of the landfill. Available literature reveals that landfill leachate has high level of Biochemical oxygen demand, Chemical oxygen demand, Ammonia, Chloride, Sodium, Potassium and Boron. According to [24] the condition within a landfill can vary with respect to time and age; hence, there is likelihood of aerobic to anaerobic, which creates room for different chemical reactions to occur.

B. Indicators of Sustainable Development in a Country

Sustaining the environment and surrounding means respect for ecology reliability, carrying capability and preservation of natural resources, including plants and animals' habitats (biodiversity) [25]. Sustainability is a character or element of organisations that sustain themselves over a period; it is not static or an immovable endpoint that can be distinct. According to [26], it is much a broader occurrence than sustainable development, accepting ethical standards relating to the existence of living matter, to the rights of future and subsequent generations and to organisations accountable for ensuring that such rights are entrenched in policies and actions. The appropriate manner to discuss and assess sustainability from environmental perspective is to lay emphasis on natural resource reduction and to know whether the present rates of resource use can be continued in the near future [27].

Some indicators that can be used to evaluate the environmental sustainability of a country [28] are:

- a country whose environmental systems are preserved at healthy levels, and it is seen as improving rather than declining;
- if the levels of anthropogenic (majorly environmental pollution and pollutants emanating in human activity (e.g., emissions of sulphur dioxide) stress are low or adequate to stimulate no noticeable damage to its environmental systems;
- to the magnitude that people and social systems are not prone to environmental disturbance that affect human wellbeing; becoming less susceptible is a sign that a society is on track to more sustainability;
- to the level that institutions are in place that will help to monitor social dimensions of skills, attitudes and

networks that encourage efficient reactions to environmental issues and problems;

- if it works cooperatively with other countries in the management of identified environmental problems and help in reducing adverse transboundary, environmental effects on other countries to the degree that cause no appreciable harm.

TABLE II: TECHNICAL REQUIREMENTS RELATING TO FORMATION AND MANAGEMENT OF LANDFILL LEACHATE ACCORDING TO ANNEX 1 OF THE EU LANDFILL DIRECTIVE (1999/31/EC).
K=PERMEABILITY ADAPTED FROM [4]

	Landfill for inert waste	Landfill for non-hazardous waste	Landfill for hazardous waste
Measures to prevent infiltration	Not required	Required	Required
Leachate collection and treatment	Not required	Required	Required
Geological barrier	$K \leq 1.0 \times 10^{-7} \text{ m.s}^{-1}$ Thickness $\geq 1 \text{ m}$	$K \leq 1.0 \times 10^{-9} \text{ m.s}^{-1}$ Thickness $\geq 1 \text{ m}$	$K \leq 1.0 \times 10^{-9} \text{ m.s}^{-1}$ Thickness $\geq 5 \text{ m}$
Artificial sealing layer	Not required	Required	Required
Drainage Layer	Not required	Required	Required

IV. LANDFILLS LEACHATES

According to EU Directive, landfill has three categories: landfill for inert waste, for non-hazardous waste and for hazardous waste. This classification also depicts (The Council Decision (2003/33/EC)) the type of waste they accept. The technical requirements relating to leachate formation and management are tabulated in Table II. The practice in Sweden is that landfills for non-hazardous and hazardous waste must be supplied with top cover as soon as possible after the completion of landfilling. This has helped to reduce the overdependence on landfill tremendously: [29] posited that 1% of MSW was landfilled in 2010, while 49% was incinerated, 36% recycled, 14% treated biologically and 1% was hazardous waste in Sweden. This was done in order to reduce the amount of leachate formed and contaminant mobilised [30] and reduce over dependent on landfills. This is in line with international and national determination towards enhancing a climate-friendly waste management which should comply with the waste management hierarchy; it gives priorities to waste prevention, reuse, recycling (including composting) and energy recovery from waste before landfilling.

All domestic waste and to a large extent waste raised from the industry will generate leachate. However, domestic waste regular composition usually produce leachate; while in the case of industrial setting, it is highly variable. Table III depicts the composition of leachate and their classification according to age. pH of leachate tends to increase with age; whereas reverse is the case for COD as it correspondingly decreases with age while the concentration of NH_3 increases [31]. However, the chemical composition is highly dependent on the phase of the sample collection. If sample was collected during the acid phase of decomposition, the pH value will be low and concentration of the BOD, COD, nutrients and heavy metals will be high; whereas the pH will be high and BOD, COD and nutrients value lower in the fermentation phase[12]. The primary GHGs such as CO_2 , CH_4 and N_2O occurs

naturally, however, [32] indicated in their work that their concentrations are highly influenced and dictated by human activities such as dumping of waste in the landfill. In the past two centuries, human activities, remarkably the combustion of fossil fuels and changes in land use, have brought about more concentrations of GHGs in the atmosphere, causing a measurable warming of the atmosphere.

TABLE III: TYPICAL COMPOSITION OF LEACHATE IN RECENT, INTERMEDIATE AND OLD LANDFILLS [33]

Parameter	Recent landfill	Intermediate landfill	Old landfill
Age (years)	<5	5–10	>10
pH	6.5	6.5–7.5	>7.5
COD(mg/l)	>10000	4000–10000	<4000
BOD/COD	>0.3	0.1–0.3	<0.1
Organic compounds	80% volatile fatty acids (VFA)	5–30% of VFA+ humic and fulvic acids	Humic and fulvic acids
Heavy metals	Low-medium	Low-medium	Low
Biodegradability	High	Medium	Low

Method of gas collection in landfill has short term effect with a potential long-term effect depending on the leachate

TABLE IV: POTENTIAL EFFECTS OF LEACHATE ON WATER RECEPTOR (MINISTRY OF ENVIRONMENT: A GUIDE FOR THE MANAGEMENT OF CLOSING AND CLOSED LANDFILLS IN NEW ZEALAND AT [34])

Leachate parameter	Short-term effect	Potential long-term effect
Dissolved toxic compounds	High concentration directly toxic to human, stock or aquatic life	Bioaccumulation or biomagnification leading to toxic effect
High dissolve solids	Increased salinity altering ecology and reducing value of surface water for abstraction	Groundwater contamination
High suspended solids	Reduction of light inhibiting macrophyte growth; sedimentation causing smothering of aquatic life; organic particles increasing deoxygenation through microbial breakdown	Habitat alteration: absorbed contaminants increase toxicity
Immiscible organic chemicals (e.g. oils and solvents)	Direct toxicity to humans, stock, and aquatic life; reduction in reoxygenation rates through water surface; visible surface films	Possible carcinogenic and mutagenic effects on aquatic life; deoxygenation
High oxygen demand	Deoxygenation of surface water	Deoxygenation; ecosystem changes
Organic matter	Reduced oxygen levels	Deoxygenation; ecosystem changes
Nutrients (e.g. nitrate)	Plant/algal blooms	Eutrophication

TABLE V: LEACHATE VOLUMES IN SOME EUROPE COUNTRIES [36]

Country	Leachate volumes	Reference
Sweden	Average for Sweden 250–300 mm/a. 10–40mm/a from a clay-capped test cell containing wastes below field capacity.	[37]
Denmark	1. 350mm/a during operation 2. (cf.R~714 mm/a) 75mm/a after capping.	[38]
	3. 320–400mm/a during operation 4. (R~633 mm/a). 56–89mm/a after capping	[39]
Germany	Data 21 operational sites: R~510–1160 mm/a). Leachate ~25–340 mm/a(4–35%R). Low values were from young landfills High values were from older landfills where absorptive capacity was used up.	[40]
Spain	7 mm/a during 2-year period (R~400mm/a). Site near Madrid	[41]
Italy	82 mm/a. Site near Pavia.	[42]
Greece	11–15 mm/a collected but some also lost to groundwater. Total estimated at 40–60mm/a (R 387mm/a, ER 60–100mm/a). Site near Athens.	[43]

V. IMPACTS OF CLIMATE CHANGE ON WASTE MANAGEMENT

Climate change is the direct or indirect contribution of human activities e.g. dumping of waste in landfill, bush burning, etc. which alters the global atmospheric composition

parameters e.g. in dissolved toxic compounds: short-effect are high concentration of direct toxic to humans and aquatic life; while potential long-term effect exhibit high bioaccumulation or bio-magnification leading to toxic effect (Table IV). However, the volume of leachate varies from country to country. For instance, Sweden generates an average of 250–300 mm of leachate annually which reduces to 10–40 mm annually on clay-capped layer wastes below field capacity; whereas Denmark generates 350 mm leachates annually during operation but reduces to 75 mm annually after capping [37]–[39].

In landfill emissions, the Intergovernmental Panel on Climate Change (IPCC) has set an international convention to not report CO₂ discharged as a result of landfill decomposition. This is because biogenic carbon is considered and discussed under the ‘land use/land use change and forestry’. This clearly explains while methane emissions are reported in landfills; it is usually denoted as tonnes of CO₂ corresponding (that is 1 tonne of methane is denoted as 25 tonnes of CO₂-eq) [35]. However, in practice, methane emissions from landfills are seldom determined or measured, instead estimated for reporting.

and this tend to align with the natural climatic variability measured over a comparable period of time [44]. The climate change is considered by friends of the environment as one of the mostly deadly environmental challenges mankind are being exposed to. The climate change causes the sea level to rise, increased occurrence of cyclones plus irregular circulation of rainfall, whose consequences are negative impacts on agriculture production (low yields), plants and animals’ habitats (biodiversity) and natural cycles. These natural instabilities are ascribed to the global warming sensation due to global emission of GHGs such as carbon dioxide (CO₂), methane (CH₄) and nitrogen (N₂O) from anthropogenic activities [45]. According to [46], they attributed the Global Warming Potential of CH₄ as 21 times, N₂O as 310 times more than CO₂ over a period of 100 years.

Waste production and composition differs between countries and within countries. The reasons for this, though not exhaustive, includes differences in population, urbanisation, and lifestyle. A typical controlled landfill involves the process of waste burial and coverage of deposits with, usually a low permeability material which help generates an interior environment that aids methane producing bacteria. The conditions, which help to create greater production of landfill gases due to improved

biochemical activity that is similar to any ecological system are optimal conditions of temperature, moisture and nutrient source. The impacts of the variables, viz: temperature, humidity, precipitation etc. and their possible impacts on waste management have been analysed in Table VI e.g., temperature can cause a decline in air quality which could be detrimental to people having prevailing disease conditions. There are concerns among interests' groups of the build-up of

Carbon 11 oxides as well as some of the GHGs within the atmosphere. The indices of environmental warming are rise in sea level which result in severe flooding of the coastal communities, sporadic outbreak of diseases and increase in death rate, low yield from agricultural activities, negative effects on the ecosystems and possibility of losing the biodiversity [47].

TABLE VI: CLIMATE VARIABLES AND THEIR IMPACTS ON WASTE MANAGEMENT [48]

Climate Variable	Possible Climate Change	Possible Impacts on Waste Management Process
Temperature (°C)	<ul style="list-style-type: none"> • Annual warmth between 1 °C to 5 °C in the year 2080s • More hotter days prevail usually during dry season • Eventually cold weather days reduce usually in wet season • Persistent anticyclone static summer days 	<ul style="list-style-type: none"> • More water requirement on site processes and workers alike • Declined air quality & detrimental heat impact on vulnerable people • Affects biological systems like composting anaerobically digestions • More risk increase with varying distributions of pets and insects
Precipitation	<ul style="list-style-type: none"> • Southern zone of Nigeria experiences more wet days • Increasingly on precipitation intensities in wet season 	<ul style="list-style-type: none"> • Higher changes of flooding's from tidal, sea surface, ground, and surface water bodies • Stability of slopes on waste could be affected due to increasing intensity of precipitations • Affects biological systems like composting anaerobically digestions
Cloud covers	Level of cloud covers reduces	<ul style="list-style-type: none"> • Exposure to sunlight intensity affect workers skins in the event of outdoor working process
Humidity	Certain humidity will increase usually during wet weather	Has implication on outdoors biological activities within the environment
Sea Levels	Average sea levels can increase its volume to about 86cm beyond its present levels as a result of thermal increase as well as land movement by the year 2080s	Inundations to waste management facility and with increase to erosions within the coastal environment

VI. LANDFILL MANAGEMENT STRATEGIES

The overall target of landfill strategies and application of regulations is sustainability. Landfill sustainability can be discussed under the concept of acceptable risk. This connote a proper way of achieving final storage quality of final stability: "(...) when the waste mass, post-closure, does not pose a threat to human and the environment (...) and the landfill no longer require elaborate management or monitoring [49], [50]. However, in many countries, the actual final storage quality has not been clearly defined [51]; instead, the acceptance criteria for inert waste could be used as the leaching limit. The acceptance criteria for inert waste on leaching limit values [52] are typically based on compliance with drinking water standards in the groundwater [36]. This seems to agree with the European Commission that has indirectly defined emissions as a landfill that meets the acceptance criteria for inert waste [53]. Effective landfilling has at its root in planning at the design stage. Aside from the many geotechnical aspects in landfill designs; the selection of optimal location; consideration should be given to environmental, geotechnical, and physical appraisals [54]. At the forefront of landfill designs are effective monitoring system, good leachate management and waste settlement investigation [55]. Landfill should only be constructed where there are buffer zones between the site and the population with acceptable distance as may be dictated by relevant regulations, between a landfill site and where people reside [56]. The efficiency of the landfill operations rest on technical, economic, and legal framework which seems inadequate in many countries. Commitment and resilience on

the part of stakeholders will improve the present situation. In addition, public and private institutions should be encouraged to undertake research in the field of environmental protection and management.

The advantages of bioreactor landfills have generated a shift from the conventional approach to utilisation of landfill gas generation and deployment of bioreactors [57]. One technique employed in many countries for the pre-treatment of MSW is mechanical and biological treatment (MBT). MBT has many aims, viz: to reduce landfill space, recover useful materials and stabilise biodegradable waste before landfilling. This helps to improve quality and lessen the possible risk of settlement, landfill gas production and the need for aftercare [58]-[60]. Monitoring of any landfill site should be taken as a priority. The period for commencement of monitoring of landfill and the duration after the closure of landfill was extensively reported in the work of [7] including the fact that landfill sites after closure consist of inert waste that may generate landfill gas. This account for why all landfill sites should be monitored irrespective of the types of waste for gas formation and migration. The records and findings and measurements taken will help in ascertaining the depth of possible changes that may have taken place over the period as this will provide the basis for detail information of greenhouse gases emission. This is due to increasing concern about climate change and the effects of global warming. GHG emissions have also emerged as hot topic in research on source identification and management [61], [62].

VII. CONCLUSION

The population of the world is on the increase and this tends to pose more challenges for the various stakeholders in the field of waste management. Sustainable landfilling requires the combination of legal, economic, and technical framework in order to meet the challenging volume of waste generated due to population increase. Application of Bioreactor technique for biodegradable wastes should be implemented in the landfill as it aims at accelerating the biodegradation processes. This helps to curtail contamination from the landfill which can be a major source of the spread of sicknesses and diseases to the population. This has brought about increased concern for information of climate change and the effects of global warming.

The development of high quality and viable waste management practices are significant in the protection and promotion of the health of future generations. A healthy environment is imperative to the effective execution of environmental strategies. This is paramount for the countries to attain the goals of global initiatives, especially the Millennium Development Goals. A clean and environmentally friendly habitat should be the desire of every country. It beholds on everybody to work assiduously to reduce environment degradation and its impacts. The legal and technical principles of many countries in respect of waste management should be strengthened as this will help raise the economic venture of the project e.g., by practicing waste to energy programmes.

It is obvious that many countries are making frantic efforts in increasing recycle and re-use of materials, landfilling will still be required to dispose of waste which cannot be recycled or treated in other ways. It is imperative that efforts should be made towards enhancing a climate-friendly waste management in compliance with the waste management hierarchy of waste prevention, reuse, recycling (including composting) and energy recovery from waste before landfilling. Nevertheless, many developing countries who are still lacking in developing other efficient methods of waste disposal will definitely consider landfilling due to its ease of operation.

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