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An analyses of the status of landfill classification systems in developing countries: Sub Saharan Africa landfill experiences

An analyses of the status of landfill classification systems in developing countries: Sub Saharan Africa landfill experiences

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Abstract

Municipal solid waste (MSW) management remains a challenge in developing countries due to increasing waste generation, high costs associated with waste management and the structure of the containment systems implemented. This study analyses the classification of landfilling systems by using documented cases reported mainly in publications in waste management in relation to non-engineered landfilling systems/approved dumpsites in Sub Saharan African (SSA) countries from 2000 to 2018. The work identifies an existing system for the classification of landfill sites and utilises this system to determine the situation of landfill sites in SSA countries. Each article was categorised according to the main landfilling management practice reported: Uncontrolled dumping, semi controlled facility, medium controlled facility, medium/high-engineered facility or high state-of the-art facility. Findings suggested that 80% of the documented cases of landfill sites assessed in SSA countries were classified as level 0 or 1. The structure of the containment and controlled regime were identified by the focus group discussion participants as important predictors of possible strengths, weaknesses, opportunities and threats for the landfill sites considered. The study represents the first identifiable and comprehensive academic evaluation of landfill site classification based on site operations reported in the available peer reviewed literature. The information provides insight on the status of landfill sites in SSA countries with respect to the landfilling management practice and a baseline for alternative corrective measures.

Keywords: Controlled facility; Landfill classification system; Municipal solid waste; Non-engineered landfilling system; Sub Saharan Africa

1 Introduction

Waste generation in SSA is estimated at approximately 62 million tonnes per year. It is estimated that African cities generate waste at a rate of between 0.3 kg and 1.4 kg per capita per day, in comparison with the average 1.22 kg of waste generated in each developed country per capita per day (Dladla et al., 2016). Landfill remains a common and one of the cheapest methods organised for managing municipal solid wastes in most parts of the world. Unfortunately, non-engineered landfill sites pose serious threats to groundwater from either biological, chemical or physiochemical processes or are associated with volatile gases escaping into the environment. Many landfills in developing countries are non-engineered, which makes it quite difficult to harness the waste resources into valuable products for commercialisation. In addition, the poor systems present a potential threat to ground water resource in the form of pollution. However, the report on guidelines for the design and operation of municipal solid waste in a tropical climates (ISWA, 2012) suggests that in developing countries such as Nigeria, Uganda, Ethiopia, etc., where the budgets for

waste management are limited, the use of clay with low hydraulic conductivity (less than 1 × 10−8 m/s) can suffice as a base liner. The looming question might bedoes the clay type and the hydraulic conductivity conform to the specified guide? In particular, another major setback in the handling of municipal solid wastes is inefficient and inadequate laws (legislation) and guidance for the disposal methods practiced by relevant agencies (Nema, 2004). The landfilling management process and facilities involved in the source, collection and recycling, sorting, transportation, treatment and disposal of wastes vary from one nation and region to another. Cultural awareness and belief, organisational abilities, level of technical knowhow, inadequate finance, limited government waste management policies and containment structure, are some of the many factors contributing to the poor MSW disposal practices identified.

The Landfill Directive on the requirement to prevent groundwater from entering into the landfilled waste based on risk, ensures and monitors landfilling operations in developed countries e.g. Europe (EU, 2006), United States of America (EPA, 2012) and Australia (WCS, 2010). In comparison with many SSA countries, there exists laws and guidelines for the development and management of landfills (UNECA, 2009). The thrust remained on collection and disposal of waste with little attention or considerations for other waste management activities or for prevention of groundwater entering into the landfilled waste based on risk. In the United Kingdom the Landfill Directive 1999/31/EC EC, 2002 stipulates that all landfill sites should be engineered. While the Directive's overall objective is to supplement the requirements of the Waste Framework Directive 2006/12/EC (EU, 2006) and prevent or reduce as far as possible the negative effects of landfilling on the environment as well as any resultant risk to humans. In spite of the increase in waste generation in the developing countries, the amounts of municipal solid waste landfilled are consistently on the low side (Aziale and Asafo-Adjei, 2013; Ogwueleka, 2009). Earlier research in Nigeria found that 68% of the solid waste generated by communities was indiscriminately dumped, 21% disposed of through appropriate landfill sites and 11% burnt (Adeniran et al., 2014; Regassa et al., 2011). Aurah (2013) reported that an approximate 10% of total generated waste ends up on the landfill in Nairobi. Furthermore, two separate studies conducted in Nigeria and Ghana concluded: that less than 20% of solid waste in African countries was disposed of through landfilling (Aziale and Asafo-Adjei, 2013; Ogwueleka, 2009). The consistently low quantities spread across African communities suggests that more awareness and education is required to enlighten the public on waste management responsibility. The literature associates the consistent low quantities of waste disposed of to landfill sites as a function of policy, collaborative government services and public sensitisation on waste management hierarchy (Amasuomo, 2016). Dladla et al. (2016) examined the factors that are associated with the prevalence of indiscriminate dumping of waste in communities and elucidated cause-effects between these factors. The study reported that 60% of waste generated in developing countries is indiscriminately dumped and estimated 38% of waste being landfilled, while open burning and recycling accounted for 1% each respectively.

Different classifications of landfills have been reported (Idris et al., 2004; Kamaruddin et al., 2017; UN, 2018) from various countries based on different parameters such as type of waste deposits, types of liner used, the design/construction of the landfills/dumpsites and the landfilling operations/practice. However, the environmental consequences of poor MSW disposal remains and will progress through poor landfills. Emissions from landfills take different forms from landfill gas and airborne particulates to leachate. It has been established that landfill sites in many African countries have no lining or limited lining (Agamuthu, 2012; Zumar M. A. Bundho, 2018). Cossu and Piovesan (2007) suggested that uncontrolled dumping of municipal waste is the main source of carbon sinks from waste management in developing countries. The absence of environmental monitoring at many sites meant that the impact of the landfill on the surroundings could not be

assessed in advance of problems developing. The high percentages of organic waste component in the waste stream in developing countries reported (Dladla et al., 2016; Guerrero et al., 2013; Imam et al., 2008) could potentially be a possible source of methane gas if captured, thereby reducing greenhouse gas (GHG) emissions (Couth and Trois, 2010). Consequently, a methane gas collection system could be utilised for the production of electricity, which could be transmitted to the national grid (Beylot et al., 2013) in these developing countries. However, the viability and acceptability of the technology working in some African countries could be debated due to the poor maintenance culture (Omwoma et al., 2017) and the existing poor infrastructure. The African Energy Policy Research Network continues to support and promulgate information and research towards electricity generation from urban solid waste for many countries in Africa (AFREPREN, 2017). This paper evaluates the status of 31 landfill sites identified from over 60 peer reviewed journal publications in SSA countries, classifying the documented landfill sites based on the reported landfilling management practice using 'guided phrases' and 'words' based on the United Nations Human Settlements Programme (UN-Habitat) classification systems. In addition, by gathering rich information from cases on landfilling practices and classification, the study employed a focus group discussion (FGD) technique, using the purposive sampling method (Palinkas et al., 2015; Patton, 2002) which enabled the generation of desired data.

2 Landfilling practices and classification system

2.1 Overview of the common landfilling systems practiced in SSA countries

When not properly managed, the landfilling of waste can have significant environmental impacts. The migration of leachate from "dilute- and -disperse" landfills (i.e. landfills designed to permit the rapid dispersion of leachate into the surrounding environment) and the resulting contamination of soil and groundwater are common occurrences in operating landfills. In the last two decades, practices at landfill sites have been overwhelmingly investigated, evaluated and reported, suggesting the need for reform and corrective interventions (Adekola and Eletta, 2007; Agbenyeku et al., 2016; Aleluia and Ferrão, 2016; Ayolabi and Oyelayo, 2005; Chakraborty et al., 2018; Efe, 2005; ElSaid and Aghezzaf, 2018; Ferronato et al., 2016; Ferronato et al., 2017; Guerrero et al., 2013; Imam et al., 2008; Iwegbue et al., 2006; Kamaruddin et al., 2017; Masocha, 2006; Mmereki, 2018; Nansubuga et al., 2016; Ojuri et al., 2018; Toyin, 2009; Ukpebor et al., 2003). Fig. 1 and Table 1 depict possible scenarios of landfilling systems in SSA countries. Scenarios [c] and [b] are more prevalent than scenario [a] in many SSA countries. Consequently, landfills in many developing countries require corrective interventions by isolating the immediate environment from the impact of pollutants or constantly monitoring the environment, especially the groundwater to mitigate or reduce the myriad of environmental effects contaminants could possible pose. The absence, limited lining or barrier failure/degradation overtime makes groundwater pollution possible, whilst no leachate removal or failed attenuation together with low rates of leachate removal at treatment plants can result in seepage to both surface and groundwater.

2.2 Overview of the existing classification system

Sanitary dumpsites are highly engineered containment systems, where wastes are isolated from the environment. This environmentally friendly landfill system involves full or partial hydrogeological isolation, formal engineering preparation, permanent controls and planned waste emplacements and coverings (Agbenyeku et al., 2016; Kamaruddin et al., 2017). An assessment criteria is provided by the United Nations Human Settlements Program as presented in Table 3 (UN, 2018). This aligns with Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable

and Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including paying special attention to air quality, municipal and other waste management. While the Indicator 11.6.1: simply determines the Fig. 1 Represents (a) sanitary landfill with bud and cover soil separating filling into cells (b) controlled tipping with clay lining at the base of the landfill containment (c) open dumpsite (Idowu et al., 2014, Idowu, 2015). proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities. Another classification system is the system reported in Asia (Idris et al., 2004), known as the Ministry of Housing and Local Government, Malaysia classification system based on landfilling practice as depicted in Table 2. Munawar et al. (2018) reported that the dumpsites investigated following the enactment of the Waste acts 18/2008 by the Indonesian government, presented a "controlled dumpsite" rather than an engineered landfill site. Insufficient landfilling operation and management costs together with the presence of scavengers at the disposal site, constituted the main reasons for these deficiencies (Munawar et al., 2018). In South Africa, Blight (2006) described the requirement for anti-pollution measures in accordance with waste type, size and climate classification.

2.3 Uncontrolled dumping

This refers to disposal of waste without any considerations for any of the degree of control parameters mentioned above, lacking most "control" functions. The open dumping of waste could result in uncontrolled burning, leachate infiltration into ground and surface water, greenhouse gas emissions and other environmentally adverse effects (Sharma et al., 2008; UN, 2018).

2.4 Semi controlled facility

This refers to sites with basic "control" functions such as site staff; waste placed in designated area; some site equipment and site operation and management. A semi controlled facility would include vehicular access to the site, traffic management, site security with fenced site; no un-authorized site access and gates locked when the site is closed. Waste reception and record keeping would also be in place. Waste unloading and being directed to a designated area supervised by site staff, along with evidence of control over nuisance and control of fires would also be a consideration (UN, 2018).

2.5 Medium controlled facility

The medium controlled facility refers to sites with "satisfactory control". The medium controlled facility should have a waste compactor and site equipment and at high level of control: hard surfaced access roads of adequate width and load-bearing capacity, kept clean and free of mud; with waste covered (at least irregularly). Emission controls to capture particulates; some leachate containment and treatment, trained staff with experience following set operating procedures; equipment properly maintained and ash properly managed is essential (UN, 2018).

2.6 Medium/high-engineered facility

The medium/high engineered facility refers to sites with "compliance control" and should use daily cover material over waste. Evidence of leachate containment, use of engineering linings, treatment and collection of landfill gas are additional requirements. High levels of engineering and process control over residence time, turbulence and temperature; emission controls to capture acid gases and the capture of dioxins are required along with active management of fly ash (UN, 2018).

2.7 High state-of the-art facility

This refers to fully functional sanitary landfill sites: properly sited and designed; leachate containment (naturally consolidated clay on the site or constructed liner); leachate and gas collection; gas flaring and/or utilisation; final cover; with a post closure plan. These sites must be built to and operate in compliance with international best practice including EU or other similarly stringent stack and Green House Gas (GHG) emission criteria, with fly ash managed as a hazardous waste using best appropriate technology (UN, 2018).

3 Research methodology

The present study follows the methodology employed by Ngai et al. (2011) to analyze and classify the operational techniques applied to municipal solid waste management. In this study, the analysis and classification were based on the examination of selected search engines and the use of descriptors, all related to the specific interests and for the period 2000–2018. Then the selected articles were reviewed and categorised based on the selected criteria presented in Table 5. The resulting list and classification were independently verified by research triangulation; and findings were recorded to identify implications and possible future research. Following the selection criteria and evaluation framework, a web based literature review was conducted in order to identify relevant documents. The choice of “Africa” instead of “Sub-Saharan Africa” in the search was used to expand the search as some articles made reference to “East Africa” “West Africa” “Southern Africa” and North Africa. Hence, the relevant articles were scattered throughout the scholarly journals. Consequently, a set of four search engines were selected to perform the journal browsing. Based on the research interest area, four major databases were consulted; Web of Science (WoS), Scopus, PubMed and Science Direct. The conduct and reporting of this review adhere to the general principles recommended by the Centre for Review and Dissemination The initial search (“Municipal solid waste” AND dumpsites* OR Landfills* AND Africa*NOT ASIA*NOT EUROPE*) on Web of Science resulted into 41 documents and following a review of abstracts it further reduced to 14. The initial search from Scopus resulted in 20 documents and following the review of the abstracts for the relevant information, this reduced to 17. The initial search (“Municipal solid waste dumpsites” OR “Landfills” AND “Africa” NOT “Asia” NOT “America” NOT “Europe” NOT “China” NOT “India”) from Science Direct resulted in 75 documents and further review of the abstracts, reduced the total to to 37. The initial search (“municipal solid waste” AND “dumpsite” OR “landfill sites” AND “Africa” NOT ”Asia“ AND ((“2000/01/01”[PDat]: “2018/12/31”[PDat])) on PubMed resulted in 39 documents and further review of abstracts reduced the number of documents to 18 as depicted in Table 7. The analysis was limited to journal articles published in the English Language. An overview of the criteria and results are shown in Table 6. A total number of 175 literature articles were sorted, summarised and discussed using the information provided in the abstract. Two reviewers independently screened all the titles and abstracts following the inclusion criteria. Full text papers of any title or abstracts considered relevant by either reviewer, were retrieved for detailed evaluation based on the inclusion criteria. The relevance of each article was assessed according to the inclusion criteria stated in Table 5. Studies that did not meet the criteria were excluded and any discrepancies were resolved by consensus following Cherry and Dickson, 2013. Each excluded article was registered in an excluded studies table with an explanation. Subsequently, 86 articles were retrieved while about 60 articles were analyzed due to some articles recurring in either one or two of the search libraries. The standardised inclusion/exclusion criteria were as follows:

Only English articles were included in the study.

Only the article related to municipal solid waste dumpsites and landfill sites in peer reviewed journals were selected irrespective of the location, either cities or rural (both were included).

All North Africa studies for the period 2000–2018 were excluded; the study excluded relevant studies from Egypt, Algeria, Tunisia, Morocco, Libya, South Sudan, Sudan, and the Western Sahara.

Articles describing the application of municipal solid waste management without a specific case study and description of practice were excluded.

Only the articles clearly describing how the municipal solid waste management operations were carried out in relation to the facility were included.

Only articles published between the periods 2000–2018 were considered.

Only Sub-Saharan Africa countries were included, excluding Europe, Asia, North, and South America and Australia.

Results indicated that the top 4 journals of articles published on municipal solid waste and practice are: the journal of Waste Management , the Journal of Cleaner Production, the Journal of African Earth Sciences and the Journal of Environmental Management. Science Direct is a multidisciplinary database that provides the best coverage of journal articles identified. To this end, this study represents the first identifiable and comprehensive academic evaluation of landfill site classification based on site operations reported within the available literature. Research identified and elucidated existing systems for the classification of landfill sites. In determining the landfill sanitary level, this study used the modified landfilling classification system in Table 4.

In addition, a focus group discussion (FGD) method was incorporated in the research methods adopted for this study. The choice of FGD was due to the fact that it employs guided, interactional discussion as a means of generating “the rich details of complex experiences and the reasoning behind [an individual's] actions, beliefs, perceptions and attitudes”(Carey, 1995). Furthermore, Powell and Single (1996) suggested that a focus group is appropriate where existing knowledge of a subject is inadequate and elaboration of pertinent issues is necessary. Information was drawn from three layers, the (i) individual, (ii) group and (iii) group interaction (Willis et al., 2009). The purposive sampling method was selected, engaging ten professionals in the waste management industry as recommended by Patton (2002) that it adds power to focus group research because it selects information rich cases, which can best generate the desired data. Prior to the focus group discussion, information leaflets and invites were disseminated to the selected ten professionals. The group size was guided by the study on FGD carried out by Peek and Fothergill (2009). The description of the participant sampling included four waste managers, four members of academia in the field of waste management and two observers from the public. The rationale for the purposive sampling selection was an understanding that participants had a good comprehension of containment systems and solid waste management practice. The members of academia selected for the FGD were researchers whose research interest was in solid waste resource management and water management. The two observers participated to assess any issue of unfairness in the whole process as described by McLafferty (2004) and Powell and Single (1996). The group discussion lasted for forty-five minutes, which was, video recorded, transcribed and analysed.

4 Results and discussion

The results from the evaluation of the extracted data were presented in Table 8. Table 8 depicts the situation of documented cases of many landfill sites in SSA countries. Using data from previous studies and over 60 publications reported on solid waste management, landfills and dumpsites in Africa, the current study endeavoured to draw inferences and conclusion on the classification of 31 selected landfill sites in 13 countries in SSA. Further to the evaluation process, the study utilised the

FGD on landfilling classification system experiences to agin further insights from the participants. Data suggests that 80% of documented cases of the landfill/dump sites in SSA are classified as level 0, or 1, with a few assessed as medium or high as suggested in Table 8. Many of these documented landfill /dumpsites have no/limited-control i.e. uncontrolled burning, absence of lining systems, absence of leachate collection systems and the absence of gas collection systems (methane gas for energy production). In addition, the analysis of the FGD were also presented in the identified themes; understanding and implementation of the existing classification system for landfilling operations and management (O&M) (ii) grading of landfill/dumpsites using the existing classification system for corrective intervention; (iii) implementation of waste regulations and policies; (iv) public/private participation and engagement Vs Government/Council sole management and (v) reducing the carbon emissions. Sub-Saharan African countries face many problems associated with poor municipal solid waste management systems such as groundwater contamination due to non-engineered systems, inefficient implementation of national waste policy, poor understanding of the hierarchy of waste management processes, insufficient data capture and inadequate private participation initiatives with the public (Dladla et al., 2016; Ngwabie et al., 2018; Zumar M. A. Bundho, 2018). Higher education institutions and other research bodies have little research capacity for designing effective solid waste management processes. The protection of groundwater and surface water is increasingly becoming a major consideration in the design of new waste containment facilities in many countries. Hence, the paradigm shift towards “sanitary landfill sites” or “controlled landfilling operations”. The results from the evaluation and analysis of the FGD presented in this study resonates these problems.

4.1 Understanding and implementation of a classification system for landfilling operations and management (O&M)

There are clear indicators that groundwater is under threat due to the inadequate landfilling systems/practices and this has been previously highlighted (Agamuthu, 2012; Ewemoje et al., 2017; Majolagbe et al., 2016; Salami et al., 2015; Ukpebor et al., 2003; Zumar M. A. Bundho, 2018). Salami et al. (2015) reported values above World Health Organization (WHO)/National Environmental Standards and Regulations Enforcement Agency (NESREA) (Nigeria) specific limits for some contaminants in groundwater resources. The group were in agreement that the level of understanding and implementation of either the existing or modified classification system was inadequate and more support should be solicited. In the discussion, participant #7 elaborated on the groundwater contamination problems on the landfill sites “We often find that the waste generators do not separate waste at all, so some hazardous waste finds its way to municipal landfill sites. Such examples compounds the precarious situation and increase the potential for groundwater contamination. There was strong corroboration for the need to train and sensitise landfill operators on landfilling O&M at all three layers of interactions. In addition, the classification system requires the some level of controlled facility and equipment. It is increasingly becoming common knowledge that a solid waste management facility requires adequate investment, which a government might find challenging. The highlight of the interaction was the need for adequate support in understanding the landfilling O&M whilst government might initiate private/public participation and provide permits but linked with policies on waste regulations.

4.2 Grading of landfill/dumpsites using the a classification system for corrective intervention

Group interaction indicated agreement that the grading of landfilling/dumpsites using a classification system was appropriate and essential for any corrective intervention. In Ghana, Asase et al. (2009) and Ebenezer et al. (2013) reported situations where an existing engineered landfill site in Kumasi is inadequate on leachate monitoring systems. Consequently, such a landfill site is unable

to successfully assess or evaluate the contamination level. In Nigeria, 10 landfill sites were identified from the literature and the Olusosun landfill site was assessed as level 2 while Solous, Mpape and Epe were assessed as level 1. However, the remaining 6 landfill sites/dumpsites were classified as level 0. A major argument during the FGD cantered on lining systems. There were diverse opinions on lining systems for poorly resourced countries, where some participants #1, #2, #6 and #7 supported the natural clay linings for such countries, but emphasised the need for site testing of the clay hydraulic conductivity parameter before use. Participant #6 reiterated, "The clay lining material should be specified in the containment description for the site and information should be verified by the regulating agency." Consequently, participants #3, #4, #5 and #8 suggested that geo-synthetic material was their preference. However, all participants corroborated the need for more studies on clay linings and especially on affordable lining materials using local content and from local suppliers. Participant #3 added "It might be a challenge for the regulating authority to test the clay material for every new landfill site or cell. Indicating the acceptable options such as geo-synthetic material might be less cumbersome." The other highlights were the absence of leachate gas collection systems in many of the landfills/dumpsites studied and issues with current practices within the industry. A consensus was drawn that the uncaptured gas was an untapped resources in SSA countries. Although, there are a few studies (Couth and Trois, 2010; Friedrich and Trois, 2011; Ngwabie et al., 2018) on the feasibility study of energy from waste in Africa, more data should be made available through projects and pilot studies to help in decision making process. In summary, the structure of the containment and controlled regime were identified as important predictors of possible strengths, weaknesses, opportunities and threats of the landfill sites under consideration.

4.3 Implementation of waste regulations and policies

During the FGD Participant #4 iterated that the government should be involved in the corrective intervention. "The situation in many landfill sites in Nigeria requires urgent reparation by the government not necessarily state government alone, but an initiative of the Federal government" South Africa, Botswana and Zimbabwe were identified by Zumar M. A. Bundho (2018) as the only countries with some engineered landfill sites. This study is in agreement with Zumar M. A. Bundho (2018) as depicted in Table 8 where Bellville South and Coastal Park landfill sites were assessed as level 3 due to the presence of liners, leachate collection systems and groundwater monitoring. Participant #3 commented on the countries that were assessed as level 3 " It's welcome progress to note that some SSA countries were on the right track. It would be a good experience for countries that are yet to meet these requirements to visit these identified facilities for a tour at the landfill sites assessed as level 3." Countries such as Cameroon, Guinea Bissau, Gambia, Kenya, Rwanda, Tanzania, Uganda, and Sierra Leone all were evaluated as level 0 or 1 using the classification, suggesting that the groundwater resources are unsafe as a result of the potential contaminants from the leachate. The group emphasised that the governments of each country need to establish directives/legislature that would mitigate the adverse effects of landfill sites that fail on stricter requirements. In implementing the policies through the waste regulations, the relevant agencies responsible for the environment in each country should be active and fully involved in the promulgations and enforcement of these regulations/directives.

4.4 Public/private participation and engagement Vs Government/Council sole management

In many SSA countries, the government is solely responsible for the management of municipal wastes (Agamuthu, 2012; Asase et al., 2009; Gogra et al., 2010; Mmereki, 2018; Zumar M. A. Bundho, 2018). The design of an engineered landfill site is expensive but could essentially produce some revenue if a gas collection system was installed (Friedrich and Trois, 2011; Ngwabie et al., 2018; Regassa et al., 2011). The group commented on the need for landfill sites in SSA countries to

work towards attaining level 4, as this might potentially provide an alternative to energy production in many SSA countries (Ngwabie et al., 2018). Participant #4 explained that "Olusosun generates over 2.1 million tonnes of wastes annually, if the methane gas generated from that waste is collected and channelled into electricity production, I would suppose Lagos state would generate enough energy to meet its electricity/power demand." Data suggested 20–38% waste is landfilled in developing or the least developed countries (Dladla et al., 2016); (Adeniran et al., 2014; Regassa et al., 2011). Over 50% organic waste generated and landfilled in Africa decomposes and produces methane gas (Adeoye et al., 2005; Alo and Idowu, 2014; Asase et al., 2009; Nagabooshnam, 2011). There are other studies that provided insight to the quantification of methane gas from landfill sites in Africa (Couth and Trois, 2010; Ngwabie et al., 2018). These studies were indicators that landfill sites could potentially provide energy/power for many SSA countries that have challenges in energy/power supply. There was strong support across the group on concerns about government/council managing municipal waste. The group suggested private/public partnership (PPP) should be considered not only at the point of collection, as observed in many landfill sites managed by the government, but also at the stage by providing landfill waste management permits for potential individuals or companies that show interest. In South Africa, for example, PPP is encouraged; Energy–G system Joburg (pty) Ltd, Enviroserv (pty) Ltd, Buyisa-e-bag, and Reclamation Group (pty) Ltd are evidence of privately owned landfill sites with landfill permits in place (SAWIC, 2010). Interestingly, South Africa Waste Information Centre has provided an inventory of all landfill sites in South Africa with each landfill site, recycling centre, storage and treatment facility classified. However, from available resources on line, South Africa seemly is the only country in SSA to provide such information. Nonetheless, South Africa still had a site that was classified as level 1 from this study. Understanding, that it is a process, SSA countries are gradually making some strides toward a change. The paradigm shift relates to integrated solid waste management actions, which involve: (1) source collection and recycling, (2) creation of modern sanitary landfill equipped with sorting and recycling plant (Energy recovery facility), (3) construction of suitable transfer station networks, (4) timely closure of uncontrolled dumpsites and rehabilitation projects (5) leachate controls (bottom lining and leachate collection systems, (6) gas controls (landfill gas recovery/capturing, gas collection systems with flares or gas utilisation systems for the production of electricity and steam) as suggested by some researchers (Beylot et al., 2013; Koroneos and Nanaki, 2012; Omwoma et al., 2017).

4.5 Reducing the water contamination, carbon emission and aligning to the SDGs

Improper landfilling systems in Africa has resulted in poor hygiene, lack of access to clean water and sanitation by the municipality. Consequently, most of the countries in SSA might struggle to meet the Sustainable Development Goal of reducing by half the proportion of people without access to safe drinking water and basic sanitation by 2030. A projection of how Africa will fare in terms of reaching the goals in 2030 paints an unclear image. Hence, an analysis suggested a clear division of these targets into three categories; those that required reform, revolution and reversal. This led to SDGs dovetail with Africa's priority as articulated in the common African's position "Agenda 2063" "the Africa we want". Participants concluded that addressing the landfilling system in SSA countries would directly or indirectly align itself to meeting some of the SDGs targets, These include "achieve universal and equitable access to safe and affordable drinking water for all", "substantially reduce waste generation through prevention, reduction, recycling and reuse" and "achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimise their adverse impacts on human health and the environment". The

group reverberated the suggestions by Couth and Trois (2010) that the urban communities in Africa could reduce carbon emissions by separation of waste at collection points, removing dry recyclables by door to door collection, composting of the remaining biogenic carbon waste in windrows, using matured compost as a substitute fertilizer and disposal of the remaining waste in controlled landfills. In addition, a waste to energy (WtE) plant could be constructed to exploit the methane gas captured for energy production. This technology is established in developed countries like the UK, Europe, Asia and North & South America. A major source of the UK's renewable energy production is the modern landfill sites. They will continue to generate energy for many years after landfill closure as decomposing waste continues to produce methane gas.

The group laid emphasis on some directions or pathways in reducing or mitigating such contamination or emissions in many SSA countries. A good beginning might be replicating the South Africa Waste Information Centre initiative by carrying out an inventory of all landfill/dumpsites and classifying them. The process should include data capturing of; the site names, site location, date established, operations and management on site, data of waste disposed on site (characterisation and quantification of waste), site capacity, waste authority (government or PPP responsible for MSW management), policies and waste regulations for each country. Following the collation of these data sets, a site evaluation was initiated. The resultant classification dictates a corrective intervention for each landfill/dumpsite evaluated. Landfills classified as level 0 should be closed and adverse effects to the environment should be mitigated. In addition, landfills classified as levels 1and 2 should be improved by providing detailed corrective intervention measures to be implemented.

5 Conclusion

The current study evaluated the situation of many landfills/dumpsites in SSA countries. Using data from four major databases, over 60 publications reported on solid waste management, landfills and dumpsites in Africa met the inclusion criteria for the study. Data suggests 80% of the documented cases of landfill site evaluated were classified either as levels 0 or 1 with no/limited-“control” i.e. uncontrolled burning, absence of lining systems, absence of leachate collection systems and absence of gas collection systems (methane gas for energy production). The findings based on the evaluation and FGD on the classification of 31 selected landfill sites in 13 countries in SSA countries suggest urgent need for identification and classification of all active dumpsites/landfills/dumpsites in SSA countries. In addition, implementing the existing or modified classification system is a clear step in initiating corrective intervention for the identified landfill/dumpsite. The corrective intervention measures could mitigate or reduce potential threats to the environment and health impacts for a sustainable solid waste management system, while aligning itself to the SDGs and associated targets.

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EMBO (2007), Council (2002), EC (2011).

Acknowledgment

The authors of this paper appreciate all previous work carried out by all researchers referenced in this study and particularly the contributions from the waste authority managers.

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