International Journal of Energy and Environmental Science
2016; 1(1): 19-28
http://www.sciencepublishinggroup.com/j/ijees
doi: 10.11648/j.ijees.20160101.14

Landfills: Investigating Its Operational Practices in Ghana

Ernest Kusi[1, *], Ampaw Kofi Nyarko[2], Linda Appiah Boamah[1], Clement Nyamekye[3]

[1]Department of Environmental Management and Technology, Koforidua Technical University, Koforidua, Ghana

[2]Department of Energy Systems Engineering, Koforidua Technical University, Koforidua, Ghana

[3]Department of Civil Engineering, Koforidua Technical University, Koforidua, Ghana

Email address:

kusi_ernest@yahoo.com (E. Kusi), n.amp84@yahoo.com (A. K. Nyarko), aferilin@yahoo.com (L. A. Boamah), nyamekyeclement@gmail.com (C. Nyamekye)

[*]Corresponding author

To cite this article:

Ernest Kusi, Ampaw Kofi Nyarko, Linda Appiah Boamah, Clement Nyamekye. Landfills: Investigating its Operational Practices in Ghana. *International Journal of Energy and Environmental Science.* Vol. 1, No. 1, 2016, pp. 19-28. doi: 10.11648/j.ijees.20160101.14

Received: November 3, 2016; **Accepted**: November 22, 2016; **Published**: January 3, 2017

Abstract: The purpose of this study is to explore landfill operational activities in Ghana. Very little studies have been conducted on landfill operational practices in Ghana and this study therefore seeks to bridge that gap to help researchers, policy makers, landfill operators and the general public to improve upon existing landfill management. The types, operational practices and the challenges of the landfill management were the main areas touched upon in this study. Information was obtained mainly by primary sources through questionnaires, interviews and site visits. Additional information was however obtained through secondary sources. Three (3) landfill strategies were identified as final disposal sites for collected Municipal Solid Waste. Kpone engineered landfill, Abokobi controlled dump and Nkanfoa open dump sites were the three main landfill sites that were selected. The study showed landfill sites were found very close to residence, water bodies and highways. 65% - 75% of generated municipal solid waste ended up in landfills. Open dumping was the predominant form of landfill types in Ghana as it was found in most of the communities in municipalities and districts. Result obtained from the study revealed that vehicles and equipment cost are the highest contributor to the operating cost in all the three sites; it ranged between 58.4% - 61.9% of the total operating cost. The cost of fuel and lubrication fluids represented about 22% of the total operating cost. Frequent break down of equipment, lack of funds to run a more efficient operation, inaccessible nature of the road during raining seasons and encroachment due to absence of fence, were some of the challenges facing landfill operations in Ghana. Recycling of waste was highly recommended to divert more waste from ending up in landfills, thereby increasing its life span. Metropolitan, Municipalities, District Assemblies and private service providers should be made to follow the basic operational controls and standards in relations to landfills in Ghana as specified in landfill operational guidelines with strict enforcement of the policy by Environmental Protection Agency.

Keywords: Landfill, Solid Waste, Operational Activities, Waste Reception

1. Introduction

The most common way by which municipal solid waste is disposed in Ghana is through landfilling, and this according to the Environmental Protection Agency is due to its low cost and convenience [1]. However, as a result of improper design and poor operational practices of these landfills, it has resulted in environmental problems such as surface and ground water pollution, bad odor and prevalence of disease vectors. This has led to a situation where communities have resorted to Not In My Back Yard (NIMBY) syndrome, preventing further development of landfills as it happened at Kwabenya, Ghana [2]. In Ghana, landfills are usually abandoned quarries and mining excavations and in a bid to reclaim these lands, they end up being filled with waste. Therefore most of the country's landfill sites are essentially dumpsites with little mechanical operational measures in place. Despite efforts to encourage alternative waste disposal options, according to Agamuthu in 2013 [3], landfilling of waste continues to be the predominant waste management option for the foreseeable future. For instance, in the developing countries about 90-95% of municipal solid waste end up at the landfills [4]. With an increase in waste quantities due to population growth, urbanization and economic development, the need for the country to have properly designed and operated landfills cannot be overemphasized. However as [5] stated, the state of the art of landfilling developed in the U. S. A and Europe based on long term experience and profound research are often directly applied to landfills in tropical countries with different waste quality, high temperature and severe rainfalls. In addition, research with the aim to optimize landfilling under these conditions is lacking.

Although the quantity of waste has increased and the quality more diversified, very little information exist on the kind of waste that end up in landfills in the country. Improper design and bad operational practices have given a wrong impression to the public that landfill can be managed with little or no impact on the environment, customers and workers. As a result, most people do not want landfills to be constructed on or near their properties.

Moreover, landfill operators are unable to provide required infrastructures and machinery necessary to meet operational standards due to unsustainable financing for landfill management.

Again very few educational and research institutions offer training in landfill studies, which has resulted in the lack of skilled personnel working in the area of landfill management.

Lastly, compliance to the guidelines that regulates landfills in the country by the Metropolitan, Municipalities, District Assemblies (MMDAs) and private service providers has not been optimum. This is due to the fact that regulators such as Environmental Protection Agency continue to show reluctance in prosecuting operators who are badly managing landfills in Ghana.

The main objective of this study is to assess current development and operational practices of landfills in Ghana. Specifically, the researchers seek to:

1) Describe the types of landfills currently in operation
2) Identify operational practices associated with the landfill types
3) Determine operational cost of landfilling
4) Identify the challenges of landfill operations

2. General Overview of Study

2.1. Types of Landfill Sites

In Ghana, landfills are grouped into four categories; open dumps, improved dumps, High Density Aerobic (HDA) and sanitary landfills. Open dumps are unimproved, inappropriate dump sites, often found in valleys, whiles improved dumps are usually fenced, have site drainage and separation of special or hazardous wastes. For HDA landfills, waste is spread out widely over site, with extra compaction and leachate recirculation, whereas for sanitary landfill, there is daily cover, impermeable liner, leachate treatment and gas management [1]. This classification is however different from that given by International Solid Waste Association (ISWA) for developing countries as open dumps, controlled or engineered landfills and sanitary landfills. Bioreactor, carbon -neutral and rapid stabilization landfills are also advanced forms of landfills, usually found in industrialized countries [6].

There is no standard method for classifying landfills by their capacity. However, the following nomenclature is often observed in literature.

Small size landfills: less than 5 hectare area
Medium size landfills: 5 to 20 hectare area
Large size landfills: greater than 20 hectare area [7].

2.2. Technical Activities at the Landfill Site

According to Bilitewski, Hardtle, Marek, Weissbach and Boeddicker [8], the goals of proper landfill management are to avoid or minimize contaminant emissions during and after the operations and to provide comprehensive documentation of the landfill and its behavior. Proper landfill operational practices are key to successfully completing a landfill final cap and installation of a gas control and collection system. Several operational practices such as waste type management, waste compaction, daily cover, storm water management, leachate control can make an important difference in landfill management [9]. Operations of a sanitary landfill require a series of activities, some of which are normally conducted continuously whiles others are conducted at a fixed frequency. Some of the more important operational procedures that must be considered for all methods of landfilling include:

- Preparation and maintenance of the site (site stockpiling, erection of structures, installation of utilities).
- Environmental control (dust, mud, vectors & pests, odor, noise, litter, fires etc.).
- Hours of operation.
- Procedures during inclement weather [10].

To meet the comprehensive reporting requirements and to be able to repair and limit damage on the landfill, the following operational controls must be followed carefully;

- An operating plan must be developed.
- The landfill must be subdivided into cells.
- A comprehensive inspection of the incoming waste must be undertaken.
- When landfilling the waste, it should be carefully compacted.
- The following under listed equipment must be installed and routinely monitored:
  - A groundwater monitoring system
  - Measuring instruments to detect settling and wrapping inside the landfill and the landfill liners
  - Instruments for collecting meteorological data
  - Instruments to measure state of water necessary to determine the water balance of the site
  - Monitoring instrument to collect data on leachate quality and other liquids
  - Instruments to measure and monitor the temperature at the landfill base
- A landfill performance report must be completed.
- When closing a landfill or any section thereof, the surface must be capped and vegetated.

For continuous oversight of landfills after closing, special long-term care measures and monitoring are required [8]. Calabro, Moraci, Orsi and Gewitilli [11] stated that waste pretreated before landfilled can reduce landfill volume by 30%. Landfill process loss has been estimated to be equal to be about 5% of the total mass of the incoming municipal waste. The reduction in volume of cover material represents 25% of the total used volume.

Landfills should be operated to reach a sustainability goal. Ideally, the end result of operating a sustainable landfill will be a stable, reusable land area which is in equilibrium with the environment within one generation. An example of sustainable landfilling is the current European Union Directive, which achieves this concept by permitting landfill disposal of predominantly inorganic waste only through extensive mechanical and biological treatment [12]. Municipal solid waste disposal practices in Ghana in the past have not been environmentally friendly. Landfills in Ghana are usually located in ecologically or hydrological sensitive areas. They are generally operated below the recommended standards of sanitary practice. Municipal and budgetary allocations for operation and maintenance are inadequate. The result is substandard and unsafe facilities which pose public health and aesthetic burdens to the citizens they are meant to serve. It is estimated that throughout the country only about 10% of solid wastes generated are properly disposed [13]. According to Bliss [14], there are three (3) significant issues that should be considered in modern landfill management:

- The importance of achieving high waste compaction densities.
- The vital role management plays in running a modern landfill best equipment.
- Choosing the best equipment to accomplish the task.

According to Hansjorg and Mutz [15], the following are the minimum standard of operations which should be maintained at a landfill site; control and documentation of incoming waste; division of the dumping area in special sections; dumping the waste in layers, not thicker than 2m and compacting it by means of a bulldozer or a compactor; construction of (intermediate) access roads in the disposal site itself; construction of marginal dams at the exposed (outer) parts of the landfill; the layers of garbage should get a thin soil cover at least once a week; mobile equipment at a modern landfill should be available (at least two (2) bulldozers, at least one(1) wheel loader, two (2) service trucks, a chopper–wheel–compactor, one (1) van, intercom–equipment(walky-talky).

Nokyoo [16], also considers lack of operational procedures and environmental controls as problems of landfill operations.

2.3. Operational Cost of Landfill Activities

Cost is a major driver and often a limitation for most landfill sites. The full cost of the site should be estimated by assessing the costs required for planning, operation, maintenance, administration, decommissioning and after care [17]. Landfill costs can be broken down into two (2) categories; capital costs and operating costs. Capital costs include land acquisition, professional services for design and the procurement of permits, machinery, and equipment purchases, site preparation and construction. Capital costs can range from 25% to 50% of the total lifetime costs of a landfill. Capital costs are usually paid by a public entity.

Operating costs are all costs associated with the day to day operation of the landfill. These range from salaries and wages to equipment maintenance and repairs. Ideally these costs should be covered through tipping fees from users of the landfill.

Capital cost is usually fixed cost, since it is set during the course of landfill operations. Operation cost on the other hand is a variable cost because it is a function of rate and magnitude of waste requiring disposal. [10].

Macline, Del, Caselani, Sandroni and Macline [18] estimated total cost of a sanitary landfill using the five (5) life phases of a sanitary landfill as follows:

- 1^{st} phase: feasibility studies, which includes economic study, land search, land purchase, legal documentation, taxes and licenses.
- 2^{nd} phase: development, construction infrastructure, detailed construction plans, areas enclosures, access roads, internal roads, water and sewage installations, electricity, power and telephone facilities.
- 3^{rd} phase: operation (disposal cells, impermeability system, waste disposal, drainage, flare system, green areas plantation, environmental monitoring, labor, management and taxes).
- 4^{th} phase: closure (covering works with special clay).
- 5^{th} phase: remediation and land recovery (leachate transportation and treatment in a sewage treatment plant, green areas maintenance, environmental monitoring and labor).

For sanitary landfills in developing countries, capital costs range from 40–70%, labor costs range from 20-30%. Economies of scale for sanitary landfill is based on the need to fully utilize heavy landfill equipment that has compaction ability based on its weight, as well as ability to push, spread, grade and cover waste. Typically, a landfill should handle at least 300t/day (from up to 600,000 people/daily shift), [19]. Landfill costs in developing countries are not very different from those in high income countries, as they are not labor intensive. Cost of disposal per ton for a sanitary landfill has been estimated to be in the USD 5-20 range [19]. Small modern landfills of 125 tons of waste daily capacity has an estimated disposal cost per ton of USD 33.06. The cost per ton of waste disposed of at a sanitary landfill in Brazil for large and medium landfills is estimated to be US22.93 and USD 26.43 respectively; and for small one a prohibitive USD 49.44 [18].

Factors which may influence landfill costs includes;

- Waste quantity; affects economies of scale
- Gently sloping base; reduces base and drainage costs
- Valley within hills; affects depth potential
- Weather; affects leachate potential
- Soil availability; affects cost of daily cover

- Receiving water; affects leachate treatment
- Length of new access road; a major investment [19].

Reference [20] also stated that the costs of waste disposal options depends on the following;

- General landfill strategy (necessary landfill equipment and technology for emission treatment).
- Geological and climatic characteristics of the location.
- Gross domestic product (GDP).
- Capacity of the disposal sites.

3. Methodology

3.1. Profile of Study Areas

The landfill sites serving three Metropolitan areas were used for this study. The Greater Accra Metropolitan Area (GAMA) with a total land area of 200 square km was the first metropolitan selected. With a population of four million, it is the second largest conglomeration in Ghana and the eleventh largest metropolitan area in Africa. Within the metropolitan is Accra, the capital city of Ghana. According to the Ministry of Local Government and Rural Development (MLGRD), refuse generated in the city has increased three-fold over the last two decades primarily due to population growth, increased urbanization and improved lifestyles. Approximately 2000 metric tons of waste are generated daily in the city, however only 1200 to 1300 tons are properly collected and disposed.

The Tema Metropolitan area, which is east of GAMA is the second metropolitan selected. Tema, the biggest city in the metropolis, houses a lot of industries and factories, as well as a port being used as a hub for exports and imports. It had a population of 537,000 as of 2012 with an annual growth rate of 2.6%. Due to the existence of large numbers of industries, the municipal solid waste generation rate is about 376 tons per day with a generation rate of 0.7%. The total waste collected is 70% of the total generated waste in the metropolis. The third metropolitan area, Cape Coast Metropolis has a population of 169,894. It covers an area of 122 square kilometers and it is the smallest metropolis in Ghana. Waste generation per day is about 250 tons with 138.6 tons collected and disposed.

3.2. Data Collection

Two kinds of data were collected for the study, although primary data was the main type used. The primary data were collected with the use of oral interviews, questionnaire, and site visits. An initial talk was held with Directors of Waste Management and Environmental Health Officers in Metropolitan and District/Municipality respectively within the sampled MMDAs where information on companies managing the landfills in their respective areas was obtained and researchers introduced to them. Data on method of waste disposal and the major landfills in the country were obtained from Ministry of Local Government and Rural Development.

The researchers also contacted the Director of Waste Management and Municipal Environmental Health Officers within the project study areas to obtain information on the types of landfills currently in operation, waste generation rate and companies operating the landfills.

A questionnaire, targeting landfill managing companies, was designed to gather information on landfill management and operation. Information such as area and population serviced, opening and expected closure date, the size and annual waste intake, number of workers and their qualifications, machines employed, leachate and fire, vector control management, environmental monitoring, compaction density and ratio of cover material to waste, distance of landfills from town centers, number and type of complaints and accidents were obtained from Zoomlion Ghana Limited and J. Stanley Owusu companies who manage all the landfills in Ghana. Information on the quantity of waste generated, costs of landfills, including capital and operating costs, licenses issued to landfill operators, contract arrangement and challenges of landfilling were obtained from landfill operators. Directors of Waste Management and Environmental Health Officers in Metropolitan, Municipal and District Assemblies were interviewed to acquire the list of companies managing landfills in their respective areas. Operational practices associated with the landfill types were obtained through site visits. Other information gathered which has direct or indirect impact on landfill management and operation included compaction density and ratio of cover material to waste. In addition, secondary data regarding policies and landfill operational guidelines in Ghana were collected from written books and journal articles. The entire data collection exercise lasted throughout 2013.

3.3. Study Sample Selection

Stratified random sampling technique was used to select landfills from the three metropolitan areas. The following characteristics were utilized for the sampling. Firstly, the landfills were chosen from three main types namely; engineered landfill, improved dump and open dump. After that, landfills were filtered out with diverse waste sources and different socio-economic groups utilizing it. Based on these criteria, three landfills were selected for the study. They were the Kpone engineered landfill, Abokobi improved dump and Nkanfoa open dump. The Kpone landfill had all the necessary features of an engineered landfill. There were little challenges selecting the Abokobi dumpsite as an improved dump since it is the only one in operation in the country. The sampling revealed the open dump as the most common type of landfill in Ghana but the Nkanfoa open dump was selected due to its easy accessibility and proximity to the researchers.

3.4. Data Analysis

Text, tables and graphs were used to describe the types of landfills and their operational practices and challenges of landfilling.

4. Results and Discussion

4.1. Types of Equipment Used at the Site

Table 1 shows equipment and vehicles used in landfill operations for different landfill types. Kpone landfill had the highest number seven (7) whiles Abokobi dumpsites had four (4) landfill equipment on site. Nkanfoa dumpsites had no permanent machine on site. Landfill equipment and vehicles available for operations includes bulldozer, excavator, landfill compactor, pick-ups and tipper trucks (Figure 1). Bulldozers were used for pushing and leveling of waste. Excavating of cover materials and subsequent transporting to working face were done by excavator and tipper trucks. The Pick Ups serve as operational vehicle. The high number of equipment and vehicles at Kpone landfill could be attributed to the large quantity of refuse it receives daily (1,300tons) when compared to Abokobi and Nkanfoa dumpsites which receives 400tons and 138.6tons respectively. Reference [21] recommends 1 caterpillar tractor, 1 wheel loader, 2 compactors, 1 vehicle (all terrain), 1 small bus and 1 sweeper with a water tank. Kpone landfill and Abokobi dumpsite are justified to have the available equipment on site as their machinery level falls within the recommended level of landfilled waste (>= 400tons per day) that are required machinery for economic reasons, put forward by [19]. However, the total number of landfill equipment for Abokobi dumpsite when compared to the quantity of refuse it receives daily(400 tons) points to the fact that the equipment are underutilized.

Figure 1. A truck on a weighing scale at Kpone Landfill © 2013.

Table 1. Number and type of landfill equipment and vehicles on landfill types.

	Landfill type		
Type of landfill equipment	*Kpone*	*Abokobi*	*Nkanfoa*
Bulldozer	2	2	-
Excavator	1	1	-
Landfill compactor	1	1	-
Tipper trucks	1	0	-
Pick up	2	0	0
Total	7	4	0

Source: survey data, 2013

4.2. Waste Reception

Kpone landfill site was found to be controlled by a fenced gate. The gate opens between 7am to 5pm for daily operations. It is closed for an hour to enable landfill officers prepare for the night shift (7pm–6am). During this break, landfill equipment are fuelled and change over between staff takes place. The gate is also assisted by five (5) security personnel; two (2) people for day operations and 3 people for night operations. Although Abokobi and Nkanfoa dumpsites had no proper gated entrance, there was a presence of two (2) security officers at Abokobi dumpsites. Whiles Abokobi dumpsite was operating an 8hr service (8am -5pm), Nkanfoa dumpsite had no time restriction to dumping of refuse. None of the three (3) landfill strategies had a signage at the entrance indicating the name of the landfill, type of waste received at the landfill, operating hours and tipping fees charged. According to [22], the first step in controlling the way waste is brought to the landfill and the type of waste disposed, is to control the access to the site. Site entrance should be staffed for the whole day.

There is scale house at Kpone landfill manned by four (4) data clerks for recording details of each load, thus, type of waste, its source (location) and the quantity of waste. The refuse truck with a load is weighed when entering. The empty truck after discharging it load is weighed again when leaving landfill site. The difference in weight is estimated to be weight of the waste. There was no scale or weighbridge at both Abokobi and Nkanfoa dumpsites. However, at Abokobi dumpsites, details of each waste load are recorded by supervisors manually. For instance, quantity of waste is estimated using the truck load.

Waste segregation before dumping was absent for all the landfill types. With the exception of Kpone landfill, all the landfill types had no directional signs such as speed limits to control traffic.

The mass of incoming waste represent essential information for landfill operators for determining the necessary daily cover material, ensuring that waste layers do not exceed the planned height. It is also important to local authorities as it provides data about the waste quantities generated and landfilled [23]. Primary and secondary access roads found at Kpone landfill were found to be graveled providing good traction to the waste trucks. Trunk roads were found at both Abokobi and Nkanfoa dumpsites which become difficult to access during the raining season. According to [6], maintaining continuous access to the tipping face reduces reliance on emergency tipping areas. All landfill roads need to be well graded. The use of a graded running course on main site roads is usually essential to ensure all weather access. The roads at Kpone landfill were two (2) way whiles that found at Nkanfoa and Abokobi dumpsites were all one way.

4.3. Waste Deposition

Drivers follow directional signs from the entrance at Kpone landfill to the working face. There are two (2) working faces large enough to contain more than one truck unloading at the bottom of the working face. Each working face had one landfill equipment (i.e. bulldozer and compactor) alternating. Unloading at the working face by the refuse trucks is done through the instruction of spotters shown in Figure 2. The refuse collection trucks reverse up to the base of the working face to discharge its load. However, waste placement at the dumpsites were found be done any how as there are no working faces or cells and spotters.

After unloading, waste is leveled and compacted with the use of bulldozer and landfill compactor respectively as found at Kpone and Abokobi dumpsites. Reference [17] stated that effective placement of waste is affected by experience and training of operators. It was observed that compactor was making 4-5 passes on the leveled refuse. However, compaction density could not be ascertained. At the Kpone dumpsites, waste placement was done on a flat surface area.

Figure 2. *A spotter at the working face of Kpone landfill directing unloading trucks © 2013.*

However, at Abokobi dumpsite, refuse was discharged at the base of a heaped refuse. Nkanfoa dumpsites had no permanent landfill equipment on site. However, pushing and leveling takes place when the site is full.

Reference [23] states that waste compaction is essential at every landfill due to its positive effect regarding the saving of landfill space. In addition, compacted waste has a range of other benefits such as better mechanical stability, less odor release, higher gas generation rates and reduced risk of landfill fires.

A daily operational activities end with the covering of the waste with cover materials (i.e. sand) which was 15cm thick as observed at Kpone landfill. There was no covering of waste at both Abokobi and Nkanfoa dumpsites. A stock pile of covering materials was found to be 100m away from the working face of Kpone Landfill. However, it came to light that waste covering is not done regularly due to absent of permanent tipper truck on site. Some of the cover materials are used to construct earth bunds at the periphery of the working face to protect the general public from unsightly seen of refuse at the working face.

4.4. General Site Management and Control

4.4.1. Litter Control

There was high littering onsite and on the road leading to the dumpsite at both Abokobi and Nkanfoa dumpsites, as compared to Kpone landfill site. Nkanfoa had the highest littering. The less amount of littering at Kpone landfill could be attributed to the presence of soil bunds, fence, janitors and scavengers who ensured that litter blown from the working face to other areas of the landfill and surrounding roads were picked and controlled on site every day. However, waste is dumped anyhow at Abokobi and Nkanfoa dumpsites especially during the raining season as trucks find it difficult to access the roads leading to the working face. According to [22], a landfill is not well managed if paper (litter) or other lightweight material is blowing around the site. The use of portable litter screens around the working face of the landfill is an effective way to control much of the wind-blown litter.

4.4.2. Dust Control

There was high amount of dust at both Nkanfoa and Abokobi dumpsites compared to that of Kpone landfill. The nature of road, that is, graveled coupled with once a week watering of the roads with the use of water tanker accounted for low level of dust at Kpone landfill. On the other hand, the graded road and absence of a water tanker for watering the road justified the high level of dust around the dumpsites at Abokobi and Nkanfoa dumpsites.

4.4.3. Surface Water and Leachate Management

Figure 3. *Anaerobic pond for leachate treatment at Kpone dumpsites © 2013.*

There was an underground pipe drainage system connected to drain chambers at the base of the cells and a pumping machine at Kpone landfill. Abokobi also had a drain on site but was full of litter. There was no drainage system at Nkanfoa dumpsites. The absence of better drainage system at both Abokobi and Nkanfoa dumpsites could contribute to the flooding of the sites during the raining season preventing refuse trucks from dumping, due to its inability to access the road. Figure 3 illustrates how leachate was controlled at Kpone landfill through the use of facultative and anaerobic ponds.

The absence of better drainage system at both Abokobi and Nkanfoa could contribute to pollution of ground water and leachate entering the home of residence living close to the dumpsites. Reference [23] states that sufficient water drainage capacity at the landfill bottom is crucial at Tropical climates as precipitation rates and thus leachate generation rates are high, especially during the wet season. Insufficient drainage would cause water saturated zones at the landfill bottom, which reduces the mechanical stability and thereby endangers the landfill of mechanical failure.

4.4.4. Landfill Gas Management

There was a facility to extract gas generated within the degraded refuse at Kpone landfill. The facility consists of High Density Polyethylene (HDPE) pipes inserted in Gibeon cages. The Gibeon cages are then filled with stone boulders as shown in Figure 4. The pipes are vertically installed at a depth of 2m inside the refuse. However, the extracted gas was not utilized but discharged into the atmosphere through venting. Abokobi and Nkanfoa dumpsites had no gas extracting facility. Odor emanating from the dumpsites was high compared to that of Kpone landfill. The high amount of odor at the dumpsites could be attributed to the fact that decomposition of waste was taking place in the presence of air (Aerobic). On the other hand, decomposition of waste at Kpone waste was anaerobic (i.e. in the absence of air) thus less amount of odor emanating from the landfill. Management of landfill gas in particular methane, is of importance due to its explosion risk and its high greenhouse gas potential. Landfill gas represents a major source of greenhouse gas emission up to 5% of total greenhouse gas emission in developing countries [23].

Figure 4. *Gas extracting structure at Kpone landfill © 2013.*

4.4.5. Landfill Fires

Landfill fires were common to both Abokobi and Nkanfoa dumpsites. However, no fire was observed at Kpone landfill. The rampant fire outbreak was partly due to uncontrolled scavengers who set fire to the waste when trying to obtain precious metals from E- waste and also from burning refuse in disposing trucks. The absence of fire hydrant on site at the dumpsites to fight fire when it occurs aggravates the situation. However, the presence of fire hydrant, cover materials and better waste handling techniques employed at Kpone landfill accounted for its low fire incidence. Fires are common at dumpsites. It can cause serious damage to the infrastructure of the landfill and can be a major hazard for site staff. Additionally, landfill fires can create significant problem (in terms of health, air quality and social acceptance) with the surrounding neighborhood (Figure 5).

Figure 5. *Occurrence of fire at Abokobi dumpsite © 2013.*

4.4.6. Scavenging Activities

Scavenging activities were found in all the landfill types. At Kpone landfill, however, scavenging activities were controlled. Scavengers were registered and wore appropriate clothing (e.g. hand gloves and reflectors). They were allowed to undertake scavenging between 8am–3pm daily. There was a scavenging yard to contain materials recovered from the waste. There is also a shed which serve as a changing and resting room for scavengers. They were found to assist in litter control and weeding around the landfill site. An average of about twenty five (25) scavengers was found to visit the landfill daily. At both Abokobi and Nkanfoa dumpsites, scavengers were not controlled and were found wearing inappropriate clothing. They had unlimited access to the dumpsites and was identified as a source of landfill fires on the dump sites. About fifteen (15) and Ten (10) scavengers was identified in visiting the Abokobi and Nkanfoa respectively. Figure 6 demonstrates activities of scavengers upon the arrival of a truck.

Figure 6. *Unloading truck surrounded by scavengers at Abokobi dumpsites © 2013.*

According to [22], scavenging on landfill sites should be actively discouraged, since it is disruptive to safe and well managed landfill operations. However, where it cannot be prevented, operational decisions have to be made about its control. The key is to the problem is to restrict their activities to areas and times which suit the operators of the landfill.

4.4.7. Environmental Monitoring

Groundwater was monitored once every year at Kpone landfill to examine the functionality of the base liner and extent of pollution from leachate. This monitoring is done by sampling a ground water monitoring wells (upstream and downstream) located at the base of the landfill, illustrated in Figure 7. There was no monitoring for pollution at both Abokobi and Nkanfoa dumpsites. The monitoring period identified was adequate as recommended by [23] which states that at least once a year monitoring of upstream and downstream groundwater wells is sufficient. According to [8], the disposal of waste materials has effects on air, water, soil and landscape.

Figure 7. *Sampling of ground water wells for analysis © 2013.*

4.4.8. Recordkeeping

Information on the landfill was available and properly filed at the administrative building of Kpone landfill. However, at Abokobi dumpsite, documents were found to be scattered inside a 40 feet container which serve as administrative office. Whiles Kpone landfill had an operating plan in place, none of the two (2) dumpsites had any plan for operation. Operation was therefore based on try and error. Nkanfoa had no proper office to house operational information. Reference [24] states that in order to determine the chronological progression of the landfill behavior and as proof of compliance with the allowable emissions for regular collection, the relevant operational data is required. He recommended that meteorological data, emission data, data on the landfill and groundwater data should be collected

4.5. Operational Cost

The monthly operational cost per ton of the three landfill sites selected for the study is shown in Figure 8. It can be seen that Abokobi dumpsite has the highest operational cost per ton. Nonetheless, Kpone landfill has the highest ranking in operational cost (Table 2). Nkanfoa dumpsite ranked 3rd in both monthly operating cost and operating cost per ton.

A remarkable result obtained from the study is the fact that vehicles and equipment cost is the highest contributor to the operating cost in all the three sites. It could be as high as 58.4% and 61.9% of the total operating cost in the case of Abokobi dumpsite and Kpone landfill respectively. The cost of fuel and lubrication fluids represented about 22% of the total operating cost. This figure is in line with the range quoted by [19].

Kpone landfill operating cost represent 79.4% of total disposal cost. This figure is outside the 50-75% bracket obtained by UNEP in 2005. However, it fell between the 30-86% range proposed by [25]. Moreover, its USD 3.85 operating cost per ton is within the USD 3-10 estimation of UNEP. Nkanfoa dumpsite has the lowest operating cost per ton because operations does not involve the use of heavy machinery and environmental standards are not adhered to. Nonetheless, the operating cost is slightly higher than the 0.8USD recommended by [26].

Table 2. *Monthly operational cost for Kpone Landfill, Abokobi dumpsite and Nkanfoa dumpsite.*

S/N	Description	Kpone Landfill		Abokobi dumpsite		Nkanfoa dumpsite	
		USD	USD/Ton	USD	USD/Ton	USD	USD/Ton
1	Vehicles, Plant & Equipment	93085.95	2.386656	58231.85	4.852796	3825.45	0.918108
2	Fuel and Lubricants Cost	32233.2417	0.826297	26900.5644	2.241714	644.9709	0.153018
3	Environmental Management & Site Maintenance	12283.945	0.314962	8926.05	0.743838	42.505	0.010201
4	Sub-total expenses (1+2+3)	137603.137	3.52834	94058.4644	7.838347	4512.926	1.081327
5	Direct Staff Cost	12045.917	0.309011	5406.636	0.450553	389.0058	0.093511
6	Sub-total direct Cost (4+5)	149649.054	3.837351	99465.1004	8.2889	4901.932	1.174838
7	Administrative Overheads	579.130625	0.014877	270.3318	0.022528	18.7022	0.004251
8	Post Closure Cost	0	0	0	0	0	0
9	Total Cost (per month)	150228.184	3.851803	99735.4322	8.311428	4920.634	1.179089
	Estimated Solid Waste Delivered per month	16576.95		5100.6		1772.459	
	Cost per ton for O&M	3.8518031		8.3114277		1.179089	

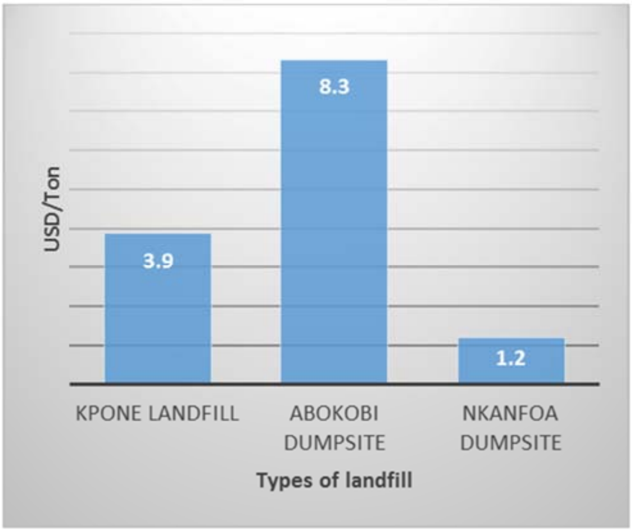

Figure 8. *Monthly operational cost per ton for the study areas.*

4.6. Challenges

The data obtained from landfill managers using questionnaires and interviews revealed several challenges at landfill sites. Table 3 and Table 4 shows the challenges at engineered landfills and controlled/open dump sites respectively. Each of the challenges has a financial connotation attached to it. According to managers of the engineered landfills, because low quality heavy equipment machinery are procured, they breakdown frequently. In addition, maintenance schedules are not followed thereby reducing the lifespan of the equipment. The study also revealed that the Government subsidizes the tipping fee for disposal of refuse at the landfill sites. However, there are delays in the disbursement of these funds leading to lack of funds to cover operational cost. The staff at these engineered landfills have insufficient technical know-how to operate the machinery. It was observed in one interview that some operators did not have any formal education so find it challenging to fill log sheets at the station. The situation is direr when the equipment breakdown with repair works mostly based on the trial and error approach.

Table 3. *Challenges faced by operators of engineered landfills.*

Frequent breakdown of equipment
Lack of funds to run a more efficient operations
Inability of government to pay contractors
Daily covering of refuse
Lack of technically skilled landfill workers

Table 4. *Challenges faced by operators of controlled and open dumps.*

Frequent breakdown of equipment
Inaccessible roads in wet seasons
Smoke from burning waste at the site
Encroachment due to absence of fence
Lack of lighting system to aid in night operations
Uncontrolled leachate flow
Dumping of liquid waste at the site

5. Conclusion

This study provides insight on operational practices of landfills in Ghana. The study identified open dumps, improved dumps and engineered landfills as the three landfill types in operation in Ghana. The following conclusions were drawn from the study:

1) Most communities in municipalities and districts resort to open dumps for disposing their Municipal Solid Waste. It is predominant because it is convenient and less expensive to operate. Engineered landfills are operated only in Metropolitan areas.

2) The location of landfill sites is a major concern. The study revealed that the landfills are sited close to water bodies, highways and schools.

3) Operation and maintenance procedures were strongly adhered to in engineered landfills sites albeit the same cannot be said for open and improved dumps.

4) Among the three landfill types, engineered landfills has the highest operational cost.

5) Lack of funds to pay contractors and repair broken down vehicles, impassable roads and encroachment due to absence of fence are some of the challenges facing landfill operations in Ghana.

Based on the findings of this study, the following recommendations are made;

1) The development of new landfills should be sited not too close to natural features, residential areas and institutions in order to have minimal negative impact on them.

2) Waste streams must be sorted to encourage recycling and recovery of materials before being sent to the landfills as this practice would increase the life span of landfills.

3) Public private partnerships schemes such as BOT etc. should be adopted to increase private sector involvement in the acquisition and developments of landfills as government alone cannot shoulder all the cost of building new landfills.

4) The Environmental Protection Agency (EPA) should enforce the landfill operational guidelines to the latter by prosecuting MMDAs who have been flaunting the policy with impunity.

5) Monitoring of landfills by MMDAs should be intensified to check private companies operating the landfills.

6) Government should pay promptly management fees due private landfill contractors in order to adhere to basic operational controls and standards.

7) Operators and mechanics of landfills should be trained to be abreast with modern trends of machine usage and repair and maintenance issues in order to reduce landfill operational cost.

8) Compliant from the public on the operations of landfills should be taken seriously by the regulators in order to reduce "NIMBY syndrome" with regards to acquisition and development of new landfills.

References

[1] Environmetal Protection Agency, (2002). Ghana Landfill Guidelines. Accra: Academic Publishers.

[2] Ivor, J. S and Gordon, C. (2012). Impact of Land Use on River Systems in Ghana. West African Journal of Applied Ecology, 20(3), 83-95.

[3] Agamuthu, P. (2013). Landfilling in developing countries. Journal of Waste Management & Research, 31(1), 1-2.

[4] Schneider, D. R., & Ragossnig, M. (2013). Biofuels from waste. Journal of Waste management & Research, 31 (4) 339-340.

[5] Stedman, R., Hoyer, K. U., & Cosset, R. (2005). Leachate treatment. Proceedings of Tenth International Waste Management and Landfill Symposium.

[6] International Solid Waste Association (2010). International Guidelines for Landfill Evaluation. Industriemagazine Verlag, Austria.

[7] Zhu, D., Sanai, P. U., Zurbrugg, C., Mani, S. (2008). Improving Municipal solid waste management in India. A source book for policy makers and practitioners, The World Bank.

[8] Bilitewski, B. Hardtle, G, Marek, K., Weissbach, A., and Boeddicker, H. (1997). Waste Management. First edition, Springer-Verlag Berlin Heidelberg, Germany.

[9] Riat, A. P. E (2010). Landfill operations to improve installation of cap and gas collection. Methane to markets partnership Expo, New Delhi, India.

[10] UNEP (United Nations Environment Program) (2005). Landfills in Africa. Regional overviews and information sources. International Environmental Technology Centre Newsletters. Global Environment Centre Foundation, Japan.

[11] Calabro, P. S., Moraci, N., Orsi, s and Gewitilli, E. (2007). The effect of mechanical-biological. Pretreatment of municipal waste on a landfill management proceeding Sardinia, Italy.

[12] Reinhart, D. R., Amini, H., Bolyard, S. C. (2012). The role of landfills in US sustainable waste management. Environment engineer: Applied research and practice Vol.15. American Academy of Environmental Engineers, Annapolis, USA.

[13] Kwetey, S., Cobbina, S. J., Asare, Wilhemina, A., Mensah, A., Duwiejuah, A. B. (2014). Household Demand and Willingness to Pay for solid waste management service in Tuobodom in North Techiman- North District, Ghana. American Journal of Environmental Protection, 2(4). 74-78.

[14] Bliss. R. A. (2016). A compact guide to landfill operations: Machinery, management and misconception. Waste management world. Pennwell Publishing, USA.

[15] Hansjorg, O. and Mutz, D. (1994). Guidelines for an appropriate management of domestic sanitary landfill sites. (GTZ) GmbH. Munich, Germany.

[16] Nokyoo, C. (2012). Status and policy on municipal solid waste management for Thailand. Asia pacific workshop on global partnership on waste management. Institute of Global environmental strategies, Japan.

[17] Roberts, A., Horlyck, A., NG, C. and Dever, S. (2013). The importance and value of good landfill planning. Proceedings of Fourteenth International Waste management and Landfill Symposium. Sardinia, Italy.

[18] Macline, C., Del Bel, D., Caselani, C., Sandroni, P., and Macline, V. (2011). Economics of sanitary landfills in Brazil. International Waste Working Group. Sardinia 2011 Proceedings, Italy.

[19] Cointreau, S. (2010). Solid waste management conceptual issues on cost recovery, financial incentives and inter-governmental transfers. Accessed from http://worldbank.org/solidwaste. (10th April, 2013)

[20] Fellner, J., and Brunner, P. H., (2007). Setting priorities for waste management strategies in developing countries. Journal Waste Management and Research, 25, 234-240.

[21] Widman, R. Fixed and movable technics in landfill technology and operations. Lecture notes for Msc. Environmental engineering and management programme, KNOTEN WENMAR, Germany.

[22] Rushbrook, P., and Pugh, M. (1999). Solid waste landfills in Middle and Lower Income countries: a technical guide to planning, design and operation. World Bank technical paper; no. WTP 426 Washington, D. C: The World Bank.

[23] Munawar, E. and Fellner, J. (2013). Guidelines for design and operation of municipal solid waste landfills in Tropical climates. ISWA Working Group on Landfill Report. Industriemagazine Verlag, Austria.

[24] Kraft, E. (2010): Landfill Technology and operations. Lecture notes for Msc. Environmental engineering and management programme, KNOTEN WENMAR.

[25] Couth, R. J and Davies, J. N. (2003). Landfill financing and contracts. Sardinia 2003 Conference Proceedings. IWWG Publication.

[26] Fellner, J. (2005): Landfill strategies as a function of Economic Conditions. Landfill Management Workshop in Syria, Agricultural University of Damascus.