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CAPACITY DEVELOPMENT FOR LANDFILL INFRASTRUCTURE

Ogbeifun, E[1], Agwa-Ejon, J.[2] and Mbohwa, C.[3]

Abstract

Landfill, as a Municipal Solid Waste (MSW) disposal infrastructure, has progressed beyond mere dumping site to infrastructure of high economic importance; it is useful for entrepreneurial development, poverty alleviation scheme, energy generation and reduction in the emission of Green House Gas (GHG) and harvesting biogas for other economic use. The life cycle of a typical landfill structure is over thirty years from design to final closure; it has many components that include design, construction, operation, waste collection, transportation, recycling, maintenance and reuse of landfill site after closure. The whole process requires a steady stream of adequately resourced personnel. Therefore, embracing the concept of continuous capacity building will ensure the provision of suitable manpower at the strategic, tactical and operational levels for the effective and beneficial management of the landfill project throughout its life cycle.

This research is the product of extensive desktop search and examination of a training programme for personnel at the strategic and tactical level of a pilot landfill project, facilitated by the authors. The result showed that the trained personnel were empowered to train others at the various phase of the landfill project, thus ensuring continuous supply of competent manpower to operate the project profitably.

Keywords: Waste disposal, Landfill infrastructure, Dumping site, Operation, Capacity building

1.0 Introduction

Landfill, is the most common method of Municipal Solid Waste (MSW) disposal system the world over. It has progressed beyond mere dumping site to infrastructure of high economic importance; it is useful for entrepreneurial development, poverty alleviation scheme, energy generation, reduction in the emission of Green House Gas (GHG) and harvesting biogas for other economic use (Jaramillo and Matthews, 2005; Bosmans et al, 2013). Significant small and medium scale industries have been developed along the different phase of the MSW management system. The collection and transportation phases have witnessed lots of activities ranging from manual to mechanical processes. Sorting of MSW at source is an emerging trend in developing countries, however, informal sorting system through the activities of scavengers and buy-back is improving the amount waste being recycled, recovered for reuse and reducing the quantity of waste disposed of at the landfill sites (Memon, 2010**;** Usapein and Chavalparit, 2013). The quality and quantity of bio-gas produced from landfill infrastructure depends on the quality content of the solid waste and the methodology of depositing the waste at the landfill Site.

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The content of the bio-degradable waste will influence the quantity of the bio-gas produced. Depending on the size, a single landfill site can be reliable for the production of sufficient bio-gas for energy generation or bio-gas can be harvested from a combination of landfill sites. Further, the bio-gas can be harvested and fed into a grid system as alternative energy source for electricity generation (Jaramillo and Matthews, 2005). Thus the effective management of landfill structure provides economic advantage, clean and healthy environment for the benefiting community.

The life cycle of a typical landfill, depending on the size, span across many years from design, construction, operation, management and final closure. The activities of one phase have positive or negative effects on succeeding phases. Each phase requires best practice so that the entire landfill project will be economically viable and achieves the set objectives. It is imperative, therefore, that the personnel to manage the landfill project, from strategic, to tactical and operational levels should be adequately resourced in both technical and modern management system. Against the backdrop that the majority of the activities around the landfill project involve routine operations within health hazard environment, there is the possibility of high employee mobility. Therefore, continuous capacity building of the relevant cadre of employees is indispensable for the management and operation of functional and viable landfill project.

This research is the product of desktop search and examination of a training programme for personnel at the strategic and tactical level of a pilot landfill project facilitated by the authors. The result showed that the trained personnel were empowered to train others at the various phase of the landfill project, thus ensuring continuous supply of competent manpower to operate the project profitably.

2.0 Theoretical background

The management of MSW has attracted significant research activities in the past and in recent times due to the contribution of the gas emitted from landfill sites to the problem of global warming. The synthesis of literature, in this section, will be limited to key issues surrounding waste collection, separation, recycling, waste to energy and harvesting biogas for economic use as well as capacity building. These efforts are aimed at reinforcing the need for the development of adequately resourced persons for the effective operation of a functional landfill project.

2.1 Collection and separation of MSW

In the majority of communities, both developed and developing countries, the collection and disposal of MSW is the responsibility of the Local council or Municipal council; however, in limited cases, private entities are involved MSW collection and disposal. The most common scenario is where mixed waste are collected from door to door in residential, institutions or industrial areas and transported to the landfill site without sorting (Gallardo et al, 2012). Nevertheless, in order to realize the multiple benefits from landfill project, modern methodologies are required. This will facilitate the development of appropriate economic

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[1,2,3] Department of Quality and Operation Management, Faculty of Engineering and Built Environment, University of Johannesburg, South Africa.

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activities around the collection and separation of waste so that limited quantity as well as quality waste is disposed in the landfill site that can facilitate the production of landfill biogas for other uses. Furthermore, efforts are being made, in developing economies, to embrace the culture of the 3R (Recycle, Reduce and Reuse) (Memon, 2010; Usapein and Chavalparit, 2013). In this regard, separation of waste is being given significant recognition. The separation can be in two levels, either separation at source, which requires extensive interactions with all stakeholders at both residential and corporate organizations or the sorting is done in designated collecting centre.

In developing countries, with high rate of unemployment, labour intensive method for the collection and separation of MSW, operation, including ancillary projects can be a viable avenue for creating meaningful employment and by extension poverty alleviation. To buttress this fact, Ofori-Boateng et al (2013) cited a landfill project in Ghana, that has energy generation component in MSW management system, engaging "510 persons per year" (Ofori-Boateng et al, p.100), in the construction and operation phase only. Researchers have examined the activities of scavengers and observed that if they are properly organized, they can play significant role in MSW collection, sorting and disposal (Agunwamba, 2003; Berkun et al, 2011; and Asim et al, 2012). It requires that this group of people be organized formally, so that the same or separate groups will be involve with the collection or and separation of the waste at the designated centres. The recyclable items are sold while the residue of waste is delivered to the landfill site. Alternatively, if it is not possible to organize the scavengers, the MSW should be transported to the landfill site where appreciable sorting is done by organized scavengers, who can sell their proceeds in the buy-back centre within the landfill site (Gallardo et al, 2012; Johari et al, 2012). In the developed economies MSW are being separated through semi-automated and automated processes (Baskakov, 2014). The non-recyclable waste are then used as feed stock for energy generation (Bosmans et al, 2013) or disposed off at the landfill site where biogas can be harvested in the future (Kumar and Sharma, 2014). It may appear as if managing the collection and separation of MSW before depositing in the landfill site is simple, yet the success of this phase depends on the level and competence of the coordinating personnel.

2.2 Municipal solid waste to energy

The search for alternative source of energy and the reduction in the emission of GHG has compelled many nations to develop economic use of the MSW deposited landfills. It is not necessary to re-invent the wheel in developing economies; instead they can adapt from a wide array of technologies to harness the resources available in landfill for economic advantages. There are two principal approaches for turning MSW to energy: either through the mechanical conversion of the pre-sorted MSW or harvesting the biogas that can be used for energy generation (Bosmans et al, 2013; Tsai and Kuo, 2010 and Ofori-Boateng et al, 2013). Though there are other by products that can be derived from landfill site, few of the possible alternatives should be tested first at the pilot level. The incineration method of converting MSW to energy is not too complicated and serves as a good starting point. It is worthy to note that "the successful implementation of Waste to Energy (WtE) technologies…depends on the WtE process efficiencies which are in their turn dependent on the feed quality" (Bosmans et al, 2013, p.12).

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The size of the incinerator varies depending of the available technology, the volume of regular waste and the use of the generated energy. Developing countries like South Africa, Turkey, Malaysia and Ghana (Couth et al, 2010; Berkun et al, 2011; Johari et al, 2012; Ofori-Boateng et al, 2013) have developed small to medium scale incineration plants for electricity generation to serve rural communities. National and global environmental law requires that an Environmental Impact Assessment (EIA) report must be produced before embarking on an incineration project (Abd Kadir et al, 2013). The MSW fed into the combustion chamber is subjected to high degree of temperature, the decomposed waste in gaseous state is transported to the gas turbine as heat to produce electricity or heat through the boiler for domestic (or industrial) use (Bove and Lunghi, 2006; Couth et al, 2010; Baskakov, 2014). The Internal Combustion Engine (ICE) is the most employed technology for electric energy generation from landfill gas (LFG) (Bove and Lunghi, 2006). The advantages of the ICE include reasonable initial capital investment, compact nature of the infrastructure so that it is easy to transport from one site to another, and the technology governing its operation are not too complicated. However, the major disadvantage of this system is the “high air pollution generated” (Bove and Lunghi, 2006, p. 1395), but this can be reduced by using “measures such as furnace design, air distribution and control engineering” (Bosmans et al, 2013, p.13).

Furthermore, adopting appropriate technology, the trapped bio-gas in an ongoing or closed landfill can be harvested for other economic use, such electricity generation, heating or fed into the national grid or delivered to other private concerns for industrial use.

2.3 Harvesting biogas for economic use

The quality of solid waste deposited in a landfill determines the rate of decomposition and the quantity as well as the quality of biogas produced (Niskanen et al, 2013). Depending on the size of the landfill, the recovered gas can be converted to energy for alternative use in the same landfill site or transported to another site; it can also be fed into the national grid (Jaramillo and Matthews, 2005). If there are no immediate plans designed for the use of the biogas, it can be sold to other interest group(s) for further use. Besides harvesting the bio-gas for alternative energy usage, it reduces the risk associated to the emission of GHG and other environmental pollution that are harmful to human health and vegetation (Niskanen et al, 2013 and Kumar and Sharma, 2014). The technology for harvesting the biogas can be incorporated into the construction of a new landfill or constructed into closed landfill. The setting involves a network of perforated pipes that are installed in a vertical, inclined or horizontal position and connected to gas extraction engine (Couth et al, 2010; Bidart et al, 2013; Kumar and Sharma, 2014). Depending on the size of the landfill, the generation of LFG “starts shortly after a landfill begins receiving waste and can last for up to 30 years after the landfill closes” (Jaramillo and Matthews, 2005, p.7365).

The most suitable extraction engine should be chosen based on the capacity, energy efficiency of the engine type and ready market of experts to operate and maintain the engine. Couth et al, (2010) suggests the use of gas engine because it “offer a greater range in their output from around 50% to full load (e.g. 0.5 – 1MW)” (Couth et al, 2010, p.401). Other engine types are equally suitable depending on the environmental conditions in the site of installation and the level of technical competence of the operators. Common problems associated with these extraction engines include blockage of the suction track (de-coking)

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caused by the solid waste particles extracted along with the gas and oil circulation within the engine (Couth et al, 2010). The extracted gas is stored and screed off of all waste particles and then fed into reciprocating Internal Combustion (IC) engines. “IC engines burn landfill gas in the presence of oxygen to turn the engine; this engine is connected to a crankshaft that turns a generator and produces electricity” (Jaramillo and Matthews, 2005, p. 7366). South Africa, as well as some other developing countries, has experimented with the extraction of bio-gas from landfills to generate electricity for small rural communities. From 2011 till date, 38 gas production and energy operation sites have been registered, in South Africa, for generation of electricity for rural communities (www.thenewage.co.za).

Due to lack of appropriate technical experts, poor maintenance, the equipment installed in many landfill site are either performing bellow installed capacity or have stopped functioning (Couth et al, 2010; Johari et al, 2012; Ofori-Boateng et al, 2013; Bosmans et al, 2013); thus highlighting the need for the development of appropriate human capacity to serve as the lubricant that oils the wheel of landfill project to be able to deliver economic value as well as provide positive environmental impact on the community proximate to the project.

2.4 Capacity building

The term capacity building can be applied to different aspect of the same concept; it suggests the increase in the ability, capability and resource of people as well as institutions to be able to execute a given task. Capacity building can be described as: “…the development of institutional, organizational, managerial, and technological (both soft and hard), and individual abilities, capabilities, skills, and knowledge….” (Farazmand, 2004, p.5). Capacity building can also be seen in the light of: “…individual training, construction of physical facilities, and infrastructure and organizational development (Horton, 2002, p. 3). The developments could be in technical, managerial, financial, legal, etc. capacity; indeed all areas considered necessary for the effective execution and operation of the desired project. Effective capacity building requires selecting the right calibre of persons in the vertical and horizontal (Farazmand, 204) component of the relevant organs that will execute the infrastructure project. In every infrastructure delivery and in particular the landfill project, the technical personnel are the engineers and related professionals while the horizontal components include but not limited to the Human Resource (HR) division, health personnel, logistics, legal, community relation officers and finance department. Successful capacity building exercise should not be seen as a one-off activity, because such attempts hardly produce lasting change in the participants’ behaviour (Horton, 2002). In order to inculcate the culture of continuous capacity building into infrastructure development projects, Potter and Brough (2004) suggests what they refer to as ‘system capacity’ development. Explaining further, they opined that “An organizational *system* is composed of a network of *programmes* of services, *staff, facilities, structures* ... and *process* of supervision, decision-making, information passing, financial flow, and so forth” (Potter and Brough, 2004, p. 339). The words in italics are the component parts of an organization that requires specific capacity developments on continuous basis. The authors developed a framework for capacity development that include nine critical areas thus: Programme capacity, personal capacity, workload capacity, supervisory capacity, facility capacity, support service capacity, systems capacity and role capacity; suggesting that each of these capacity functions be developed based on the hierarchy of needs (Potter and Brough, 2004).

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Though considerable efforts have been devoted to specialized capacity building to manage infrastructure projects in Africa, however, the concept of systemic capacity building has not been given serious consideration. Thus the investments in the development of human capacity, physical facilities, and equipment are not yielding the desired results, until there is a functional system in place. The lack of such system is evident in the "Poor supervision, lack of accountability …slow disbursement of budget, lack of authority, corruption, and lack of attention to support systems, such as maintenance, information systems, destroyed confidence and initiative ((Potter and Brough, 2004), p.339). Another setback is the frequent movement of trained personnel from one office to another, in some cases, outside the area where their capacity was recently developed. In this regard, less resourced persons are saddled with the responsibility of managing the infrastructure project which is beyond their level of competence.

Landfill infrastructure has assumed a strategic component in the effective management of MSW, besides being a mere dumping site, it is an instrument of social transformation, environmental management, mitigation of negative factors of global warming, and active agent in poverty alleviation. In order to achieve these and more benefit from landfill project, it is imperative that the project be managed throughout its life cycle by adequately resourced personnel, by embracing the concept of continuous (systemic) capacity building.

3.0 Research method

Extensive literature search helped to locate the dynamics in the management of landfill project as MSW disposal system, exposing the many dimensions of its positive contribution to local and national economy, enhancing healthy environment and contribution to the mitigation of the emition of GHG. The search brought to fore the multi-dimensional components of landfill project thus justifying the need for adequate human resource to manage the project. Further, the research examines the training programme for vertical and horizontal personnel of an African country embarking of the use of landfill as MSW disposal system. The training involved personnel at the strategic and tactical level of a pilot landfill project. The result showed that the trained personnel were empowered to train others at the various phase of the landfill project, thus ensuring continuous supply of competent manpower to operate the project profitably.

4.0 Findings and discussion

This section briefly report on the training session facilitated by the authors, for the pioneer personnel for the pilot landfill project about to be embarked upon by an African country.

4.1 Course objectives

The course objective was to provide comprehensive information on the planning and efficient operation of landfill as suitable MSW disposal system. This include discussion on site selection, legal, environmental, community, design and construction considerations with the aim of developing an infrastructure that is environmentally friendly and reduce the risk of pollution and contamination of the source of water supply to the community. Furthermore, the course was to explore the modern economic use of landfill and expose the participants to the practical administration of landfill projects by some municipalities in South Africa.

4.2 Course participants

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The course participants were drawn from the core engineering profession (the vertical component) and the indirectly related but relevant professionals (horizontal component) within the same municipal councils were the pilot projects were to be sighted. The participants were officers in the strategic and tactical level of leadership. Though some of the participants were advanced in age and years of service (who may not be in active service when the landfill project will become fully operational), the majority of the personnel from the vertical and horizontal component were young and have longer years of service. The beauty of this arrangement is the strength derivable from the mix where the voice of the older ones will guide the project proposal, providing the needed *force* to make the project attractive to their home government and the younger ones will provide the strength, innovation and enthusiasm to run with the project, allowing continuity of credible leadership for a long time (Potter and Brough, 2004). Furthermore, the composition of the participants from the vertical and horizontal component of the municipal structure facilitates easy comprehension of the concept of the landfill project, its complex details, and involvements. Though all of them may not grasp the technical details, their participation in the training prepares them for objective interactions with the professionals when discussing the implementation plans and can fast track approvals (Potter and Brough, 2004; Couth et al, 2010; Johari et al, 2012; Ofori-Boateng et al, 2013; Bosmans et al, 2013). The contribution of the participants from the horizontal component were sincere and thought provoking, challenging the professionals to provide suitable answers; they represented the voice of the community who will be at the receiving end of the landfill project (Memon, 2010**;** Usapein and Chavalparit, 2013, Ofori-Boateng et al, 2013). Though the management of the MSW provides a potential solution to the issue of unemployment in developing economies, the health personnel in the team were passionate on the safety of the scavengers, other direct and indirect employees in the chain of services and the proximate communities (Agunwamba, 2003; Berkun et al, 2011; and Asim et al, 2012; Gallardo et al, 2012). The mixture of participants, the quality of deliberation and the content of the assignment submitted at the end of the course, provides hope that the participants will execute meaningful landfill projects.

4.3 Course structure

The course structure provided a blend of theoretical foundations of landfill project from concept, site selection, environmental, legal and community considerations. It provided detailed geotechnical and geological consideration, especially as it affects pollution of the source of water for the proximate community (Rowe and Fraser, n.d.). Strong emphasis was laid on the construction phase of the landfill project. Realising that the entire landfill site cannot be constructed in a seamless process, close attention should be paid to the water proofing system and leachate management to reduce the risk of ground water pollution (Fellner et al, 2009; Voronova et al, 2011). The loading of waste material into the landfill should be handle carefully so that the water proofing membrane layers are not destroyed, the leachate collection system are not clogged and the bio-gas harvesting pipe network are not distorted, nor are the monitoring devices dislocated.

Participants were exposed to the economic benefits of landfill project, especially the generation of electricity. Nevertheless, as a pilot project, participants were encourage to experiment with waste to energy through harvesting bio-gas from different landfills and generate electricity from a central point (Jaramillo and Matthews, 2005; Niskanen et al, 2013; Kumar and Sharma, 2014). If any infrastructure, landfill inclusive, is to serve its

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purpose, the operators should imbibe the culture of maintenance management; thus encouraging the concept of continuous capacity building for the down-the-line operators of the landfill project. It is rewarding to note that the formal closure of the operation phase of an active landfill is not the end of the project. The harvesting of the bio-gas continues for a long time. At the end of LFG harvesting, the landfill site can be transformed into other profitable use, such as sports and recreation field, stadium development, shopping complex, low-rise residential houses, and so on (Dalal et al, 2010).

4.4 Course outcome

The participants were divided into six groups (ensuring a proper mix of the vertical and horizontal composition) and given assignments encapsulating the entire course (lecture and field trips), with each group concentrating in an aspect of the landfill project. The objective was that when the whole assignment is compiled into a single volume, each group will have access to complete information to guide them for the effective implementation of a landfill project. The assignment covered policy formulation for the development of landfill project; site selection, design and construction considerations; practical issues in the operation of landfill: biogas harvesting and leachate management; logistics and cost development; capacity building and maintenance management as well as management system, monitoring and evaluation.

5.0 The Japanese experiments

Japan, like many other developed countries, is turning their challenges into opportunities for developments. The shortage of suitable landfill site for the disposal of MSW has driven Japan to embrace the concept of 3Rs and they have recycled anything within their environment, through effective separation of MSW. For example, the segregation pattern employed by Kamikatsu town, which is in a rural community in Tokushima area, includes the separation of:

> Aluminium cans, steel cans, spray cans, metal caps, bin without colour, brown bin, other bin, reuse bin, other glass and ceramics, cell battery, fluorescent lamp, broken fluorescent lamp, mirror and thermometer, electric bulb, expanded polystyrene, used clothes and textiles, tetra pack, cardboard, newspaper, magazine and copy paper, chop stick, PET bottle, cap of PET bottle, lighter, futon and carpet, diaper and sanitary napkin, waste food oil, plastic package and container, combustibles which has no other use, waste battery and tire, bulky garbage, home appliances, organic waste, and PVC for agriculture and bottle for pesticide (Kojima, 2013).

The success being recorded hinges on the fact that the country encourages separation of waste at source. Further, this concept is strengthened by the establishment of cortege industries that concentrate of washing the dirt, from primary use, off plastics articles making it ready material for use by recycling industries. These cleaned plastic products can packaged as they are or reduced into pellets, delivered to local industries or exported to boost oversea trades (Robison, 2013). Another local use the Japanese have done with MSW is the “Plastic – to – oil – Technology”; were they have developed heavy duty fuel suitable for the operation of generators, boilers and construction equipment (Robison, 2013). This option requires a great deal of technology, investment and certification process that it may not be a viable project for developing economies in the elementary stage of integrated MSW management. Nevertheless, the plastic cleaning plant is worth investigating; it will provide reasonable source of income to many people, encourage separation of waste at source, improves environmental hygiene, cleaner gutter and reduction in the menace of flooding due to blocked drainage system from plastic waste.

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6.0 Conclusion and recommendation

The use of landfill as a means of MSW disposal system is a proven and acceptable methodology all over the world. Nevertheless, the system has progressed beyond mere dumping site to infrastructure of economic and environmental concern, requiring highly resourced personnel to manage the venture. The search for alternative source of energy and the reduction in the emission of GHG has compelled many nations to develop economic use of the MSW deposited landfills. It is not necessary to re-invent the wheel in developing economies; instead they can adapt from a wide array of technologies to harness the resources available in landfill for economic advantages. In a pilot project, it may be reasonable to start the 'waste to energy' system from harvesting bio-gas trapped in an ongoing or closed landfill for other economic use, such electricity generation, heating or fed into the national grid or delivered to other private concerns for industrial use.

Effective capacity building requires selecting the right calibre of persons in the vertical and horizontal (Farazmand, 204) component of the relevant organs that will execute the infrastructure project. In every infrastructure delivery and in particular the landfill project, the technical personnel are the engineers and related professionals while the horizontal components include but not limited to the Human Resource (HR) division, health personnel, logistics, legal, community relation officers and finance department. Successful capacity building exercise should not be seen as a one-off activity, because such attempts hardly produce lasting change in the participants' behaviour (Horton, 2002). Though considerable efforts have been devoted to specialized capacity building to manage infrastructure projects in Africa, however, the concept of systemic capacity building has not been given serious consideration. Thus the investments in the development of human capacity, physical facilities, and equipment are not yielding the desired results, until there is a functional system in place.

The selection of participants for the training by the host country was well thought of, they were drawn from the core engineering profession (the vertical component) and the indirectly related but relevant professionals (horizontal component) within the same municipal councils were the pilot projects were to be sighted. The participants were officers in the strategic and tactical level of leadership. Furthermore, the composition of the participants from the vertical and horizontal component of the municipal structure facilitates easy comprehension of the concept of the landfill project, its complex details, and involvements. Though all of them may not grasp the technical details, their participation in the training prepares them for objective interactions with the professionals when discussing the implementation plans and can fast track approvals (Potter and Brough, 2004; Couth et al, 2010; Johari et al, 2012; Ofori-Boateng et al, 2013; Bosmans et al, 2013). The mixture of participants, the quality of deliberation and the content of the assignment submitted at the end of the course, provides hope that the participants will execute meaningful landfill projects.

Furthermore, research endeavours should be channelled towards exploring how to identify the relevant components of the 'system' around any proposed or infrastructure in operation that requires enhanced capacity (Potter and Brough, 2004).

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