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Sustainable Waste Management Systems in Higher Institutions: Overview and Advances in Central University Miotso, Ghana

Edward Kweku Nunoo
Department of Environment and Development Studies, Central University Miotso, Miotso, Ghana
Institute for Oil and Gas Studies, University of Cape Coast, Cape Coast, Ghana

Definitions

Sustainable waste management is defined as waste management systems' evaluation processes that incorporates feedback loops to protect the environment alongside resource and energy consumption from the most favourable to the least favourable actions per the waste hierarchy.

Introduction

It is established that HEIs can teach and demonstrate the theory and practice of sustainability by taking actions that can help to understand and reduce unsustainable practices of their own activities including waste management (Kianoosh 2015). When waste is not properly managed, it becomes a threat to health and a major social and environmental problem. Problems of waste handling have become a development issue, deeply rooted in science and technology and societal readjustment. Defining a system to regulate waste must integrate the moral and cultural reorientation of communities to invoke basic rights and obligations that will produce outcomes necessary for addressing the menace (Hoffman and Ventresca 2002). An efficient waste management system extends beyond technological needs to include social, institutional, legal, and financial aspects. According to Leonard (2005), its sustainability entails organizing and managing adequate finances, infrastructure, and workforce with the involvement of all stakeholders to sustainably deal with the problem. The relevance of this is study, on zero waste management systems in Central University, is well noted by Bailey (2015) that HEIs can play a key role in promoting sustainable development due to inherent expertise among university staff and students as well as their engagements with the wider community.

Defining Key Terms

Key terminologies, as they relate to zero waste management systems, are defined here to enhance in-depth understanding of the system.

Waste

Waste is defined as an unwanted or undesired material or substance (Hoffman and Ventresca 2002). In CUM, it consist of rubbish, trash, junk, and garbage or the unwanted materials, left over from the food plaza, lecture halls and laboratories,

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library facilities, students halls of residents, administrative blocks and lecturers offices, and/or effluents from same CUM community in-house activities. In other words, waste is a man-made substance, which in its actual structure and state is deemed not useful to the owner(s). Lands contaminated from improper disposal practices or chemical spills from laboratory experimentation, junk, or transport yards in HEIs are also considered as brownfields.

Solid Waste

Solid waste (SW) means any other waste material other than liquid waste (LW). SW in CUM include garbage; refuse; sludge from a wastewater treatment systems, water supply treatment systems, or air pollution control systems in facilities; and other discarded solid or semisolid materials coming from CUM communities, or contained gaseous materials, resulting from the transport yard and agricultural operations and/or from community activities.

Waste Management

Waste management (WM), according to Amoah and Kosoe (2014) and Puopiel (2010), is the administration of activities that provides for the collection, transportation, and disposal of garbage, sewage, and other waste products. WM in CUM encompasses management of disposal methods, collection, all processes and resources for proper handling of waste materials, transportation and maintenance of waste transport trucks and disposal facilities, as well as compliance with standards, health codes, and environmental regulations.

Waste Management Systems

Waste management systems (WMS), according to Hagerty et al. (1973), refer to a specific technique (strategy), device, or systems, used to manage waste materials. This may deal with the collection, transportation, recycling, disposal, or processing of waste (Puopiel 2010; Miller 2004; Kreith 1994). WMS varies according to both the kinds of waste material to be treated and the aims of the treatment itself (Tchobanoglous et al. 1993, 1997). Supported by CUM management, the Department of Environment and Development Studies (EDS) has evolved a system whose main goal conforms to best WM practices, to maintain a clean and healthy environment, curb health epidemics and environmental pollution, and recover materials for reuse or recycling (Momoh and Oladebeye 2010; Miller 2004; Shuebeler et al. 1996).

Waste Management Systems

An Overview in CUM

Ghana, with a total population of 29 million (GSS 2010), has over 205 accredited higher educational institutions (HEIs) contributing meaningfully to the teaching, research, and service fraternity in diverse capacities. These institutions are made of public and private tertiary institutions, technical universities, polytechnics, distance learning, colleges of education, and nursing (NAB 2017). CUM is the largest private HEI in Ghana with over 7000 students (NAB 2017). Over the past 2 decades, CUM has responded positively to the high-level manpower training needs by developing diversified academic programs in the social sciences, including law, technology, and applied sciences, including architecture, physician assistantship, pharmacy and nursing, and business management, and, thus, contributes enormously to waste generation in the Greater Accra Region (NAB 2017).

Preintegration of Environmental Concerns

The amount of waste generated by urban centers during and immediately after the colonial era and attainment of independence (*Ghana, then known as the Gold Coast was colonized by the British until She become independent on the sixth of March 1957*) was insignificant due to low population density (GSS 2010; Bremner et al. 2010), low societal levels of exploitation of natural resources, and low levels of technology characterized by simple lifestyles. Common wastes produced during these times were mainly ashes from burning hydrocarbons and human biodegradable waste which were released back into the environment with minimal impact

(Al-Youssfi 2002). Prior to the integration in CUM (Pre-1990s), waste materials generated were environmentally friendly and mainly found in the form of biodegradable food leftovers and packaging materials from leaves and papers. Tools and residues from wood or metal were recycled or passed down through the academic calendars for reuse. When it became necessary for CUM to discard off large waste materials (papers, stencils, and junkyard waste), this was routinely organized and burnt in isolated controlled dumpsites on campuses.

Pro-integration of Environmental Concerns

With the onset of environmental concerns and unsustained growth of urbanization in Ghana (Benneh et al. 1993), buildup of waste, mainly from nondegradable plastics from uncollected dumpsites and opened spaces, began to stir up rapid deterioration in the levels of sanitation and the quality of urban life which eventually drifted into HEIs campuses. Streets, open spaces, and gutters became choked with filth due to inadequate waste clearance regulations, non-compliance, and the creeping in of a complex societal lifestyle. With the onset environmental concerns becoming aspects of decision-making in Ghana (Pro-1994), calls for the establishment of a responsible ministry, agencies, and municipal authorities with waste removal powers became institutionalized (Bailey 2015). Spurred by increasingly floods, partly to be blamed on plastic wastes leading to devastating cholera outbreak and public health-related issues in the urban centers, especially in the city of Accra, major legislations were promulgated after the 1972 Stockholm conference, to better manage waste; the 1992 environmental policy, EPA Act 1994 (Act 490) and the 1999 Legislative Instrument 1652 (LI 1652), which sought to manage waste using best practices (Boamah 2010; Bailey 2015).

WM in Ghana, today, is the responsibility of the Ministry of Local Government and Rural Development, which oversees the activities of Metropolitan, Municipal and District Assemblies (MMDAs). Regulatory powers are, however, vested in the Environmental Protection Agency (EPA) under the auspices of the Ministry of Environment and Science. The MMDAs are responsible for the collection and final disposal of municipal waste through their Waste Management Departments (WMDs) and their Environmental Health and Sanitation Departments. Due to the high volumes of waste generated daily in the cities, it has become necessary to involve private waste management entities. Subscribing to best management practices, CUM has adopted a system that handles four main types, food, rubbish, special, and hazardous waste, summarily defined in this paper under section "Types and Sources of Waste."

Types and Sources of Waste

Food Waste

Food waste is any food substance, raw or cooked, which is discarded or intended or required to be discarded from the food plaza, halls of residents, and university communities. These organic residues are generated by the handling, storage, sale, and preparation, cooking, and serving of food (Miezah et al. 2015). It includes uneaten portions of meals and trimmings from food preparation activities in kitchens, restaurants, and canteens from the food plaza (Miller 2004) and the university community.

Rubbish

Includes both combustible and noncombustible solid wastes from the university community excluding food wastes or other highly putrescible materials. These fall within a category defined by Tchobanoglous et al. (1993) and EGSSAA (2009) to include all forms of paper, cardboard, plastics, textiles, rubber, leather, wood, furniture, and garden trimmings. Noncombustible rubbish consists of glass, tin cans, aluminum cans, ferrous and other nonferrous metals, and dirt.

Special Waste

Special waste is defined as any waste material which, because of its physical characteristics, chemical make-up, or biological nature, requires either special handling procedures or permitting or poses an unusual threat to human health, equipment, property, or the environment (Miller 2004). These include general hospital/clinic, laboratory

and agricultural wastes, pathological waste, pharmaceutical waste, radioactive waste, infectious waste, chemicals waste, sharp objects, lithium batteries, and pressurized containers. These are segregated at source and specially disposed of in CUM.

Hazardous Waste

Hazardous waste is waste with properties that make it potentially dangerous or harmful to human health or the environment. These may exhibit any one or a number of the following characteristics: toxic, ignitable, reactive, and corrosive. They could assume the form of liquids, solids, or gases (Al-Youssfi 2002).

Municipal Waste (MW)

MW includes all type of waste generated by households and commercial establishments and managed, especially, by local government bodies. The contents of what is called municipal waste may vary from country to country and even from one municipality to the other. Waste generated in HEIs exhibits all characteristics of municipal waste. In a well-developed country with good recycling systems, municipal waste will mainly include items that cannot be recycled (Kumar et al. 2016). Those that are not able to be recycled are disposed of in landfills. In most developing economies and for that matter, Ghana, landfills are not engineered.

Advances in CUM Waste Management Systems

Waste generated in CUM consists of many different materials. Detailed understanding of the composition of solid waste is deemed necessary to inform management (Denison and Ruston 1990; Miezah et al. 2015) on how to best deal with it. The system in CUM starts with control of waste generation from the various sections of the university campus (administration, lecture halls and offices, halls of resident, food plaza, etc.), storage (maximum of 3 days), collection, transfer and transport of waste (by a cleaning company and a private waste management company called Zoomlion), processing, and disposal (by Zoomlion), in accordance with best practices and principles of public health, economics, engineering, aesthetics, and other environmental considerations responsive to public attitudes. Wastes generated are first stored either in dustbins in offices, laboratories, or in dustbins or skip containers placed at vantage points on campus. Sometimes it becomes necessary to transfer the waste from small collection equipments (dustbins) to bigger tractors, tricycles, or skip containers when the volume of waste becomes surmountable and finally to bigger trucks for disposal. There is a research project by the Department of Environment and Development Studies (EDS) on material recovery for reuse and recycling where students segregate plastics, papers, and food leftovers for further processing. This project is expected to be extended to surrounding communities after the pilot exercise.

Key Components of the System

Waste Generation

Thousands of tons of solid waste are generated daily in our cities with most of them ending up in open spaces, including gutters, dumps, and wetlands. It contaminates surface and groundwaters and poses major health hazards. Waste generation rates in urban cities vary approximately between 0.5 and 0.8 kilograms per person daily (Miezah et al. 2015). Large amounts of waste are generated beyond management capability of existing infrastructure and finances to efficiently manage them. Over 65% of urban cities do not have home collection services (Boadi and Kuitunem 2005). In HEIs however, an average of 70% across the country are served with institutional collection services. Separation at source is not a priority making sustainable WM problematic.

Waste Handling

Waste handling comprise all activities associated with managing wastes until they are placed in storage containers before collection or returned to recycling centers (Tchobanoglous et al. 1993). In CUM handling is done by the company responsible for providing cleaning services to the

university. Specific activities associated with handling wastes material at the source vary depending on the types of materials that are recovered for reuse and the extent to which these materials are separated from the waste stream. Handling is also required to move the loaded waste from the collection centers to the final disposal sites depending on the type of collection services available. These services are provided by Zoomlion in CUM.

Waste Separation (Segregation)

This involves the recovery of separated materials, processing of solid wastes components, and the transformation of the solid wastes that occur, primarily, in locations away from the source of generation. Known methods used for recovery of waste materials separated at source include curbside collection, drop-off, and buyback centers. Currently there are no buyback services in CUM. The separation occurs onsite and processing of these wastes usually occurs at recovery centers, transfer stations, combustion facilities, and disposal sites. Waste components are separated by manual separation of the waste components and size reduction by shredding, separation of ferrous metals using magnets, volume reduction by compaction, and combustion (Tchobanoglous et al. 1993).

Waste Storage

This refers to all places where generated waste is stored until collected. Storage may be affected by factors such as climate, type of container, container location, and contamination of waste components. These factors have a greater bearing on the storage of perishable materials, which decompose rapidly. These are collected quickly. Those that delay in collection are stored in skip or dustbins and not thrown away indiscriminately because of health, environment, and aesthetic consideration.

Waste Collection

Collection of wastes involves gathering of the wastes materials and haulage by vehicles after collection to locations where the collection vehicles are emptied (Miezah et al. 2015; Bartone 1991). Collection are provided and supervised under various management arrangements, ranging from municipal services to franchised private service providers. Collection methods include communal collection points, curbside collection and drop-offs, setout-setback, and backyard carry.

Waste Transfer and Transport

Transfer and transportation of waste involves two steps: (1) the transfer of wastes from smaller collection bins, skips containers, and tricycles to larger transport equipments (provided by Zoomlion) and (2) the subsequent transport of the wastes, usually over long distances to the final disposal site (Baabereyir 2009). The transfer usually takes place at stations approved by Zoomlion. Although motor vehicle transport is most common, transport by rail and barges are also possible. In Ghana tricycles are used to transfer the wastes to storage containers, where they are subsequently transported to the disposal sites by skip container and tractor-trailer trucks.

Waste Dumping

Best management practices demand that waste collected need to be dumped at engineered sites (Amoah and Kosoe 2014). This is not the case in Ghana. Landfills are not engineered posing high risk of infections through runoffs during rains and pollution of underground water. These sites are of great concern due to their threat to human health and pollution of underground water through leaching.

Zero Waste Management System

A key goal of zero waste management, according to Flintoff (1984), Shuebeler et al. (1996), Miezah et al. (2015), and Kianoosh (2015), is to protect the health of the population, promote environmental quality and sustainability, support economic productivity, and generate employment and income. To achieve the above goals, it is necessary to establish sustainable systems of waste management that meet needs of the entire population. In CUM, the system is absorbed and carried out by the university, employing and developing capacities of all stakeholders, including students and its local communities with advice

from government agencies at the local regional level.

The Systems Approach

CUM approaches sustainable waste management from the perspectives of the entire cycle of material use from production, distribution, and consumption as well as waste collection and disposal. Immediate priority is given to effective collection and disposal. Waste reduction at source and recycling are relatively young novelty but equally pursued as important longer-term objectives. The systems' principles of sustainable WM strategies, in order of preference, are prevention and minimization of waste generation, maximization of waste recycling, and reuse and ensure safe and environmentally sound disposal of waste. This environmentally friendly and socially acceptable method adheres to the WM hierarchy depicted by Fig. 1.

Source Reduction (Reuse)

Source reduction (prevention) is the application of best strategies and practices aimed at reducing waste at source. It takes many different forms, including reusing or donating items, buying in bulk, reducing packaging, redesigning products, and reducing toxicity. Purchasing products that incorporate these features supports source reduction. Source reduction can save natural resources, conserve energy, reduce pollution, reduce the toxicity of our waste, and save money for consumers and businesses alike.

Recycling

Recycling is a method of reducing the amount of wastes that enter disposal sites (Puopiel 2010). It converts material which will otherwise remain useless into valuable resources, capable of generating employment and bringing in economic returns. Recycling prevents the emission of many greenhouse gases and water pollutants, saves energy, supplies valuable raw materials to industry, creates jobs, stimulates the development of greener technologies, conserves resources for our children's future, and reduces the need for new landfills and combustors (Bradshaw et al. 1992; Miezah et al. 2015).

Composting

Composting is the process of turning organic household waste into fertilizer through aerobic fermentation. It is a minimally used form of waste disposal in most cities and does not contribute to the danger of food pollution. Of about 1250 tons of garbage collected per day, between 10% and 15% is composted (Bradshaw et al. 1992).

Energy Recovery

Energy recovery from waste is the conversion of nonrecyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion, and landfill gas (LFG) recovery. Currently CUM is practicing anaerobic digestion during gasification and landfill gas in trial stages. This process is often called waste-to-energy (WTE).

Treatment and Disposal

Landfills are the most common form of waste disposal and are an important component of an integrated waste management system. They are primarily regulated by government agencies and meet stringent design, operation, and closure requirements in order to stay open. Methane gas, an end product of waste, can be collected and used as fuel to generate electricity. After a landfill is capped, the land may be used for recreation sites such as parks, golf courses, and ski slopes.

Incineration

Incineration is a controlled combustion process for burning combustible waste to gases and reducing it to a residue of noncombustible ingredients (CED 2003). During incineration, moisture in the solid waste gets vaporized and the combustible portion gets oxidized and vaporized. Carbon dioxide ($C0_2$), water vapor, ash, and noncombustible residue are the end products of incineration. Incinerators have the capacity to reduce the volume of waste drastically, up to ninefold than any other method (Kwawe 1995).

Sanitary Landfill

Sanitary land filling includes confining the waste, compacting, and covering it with soil. It not only

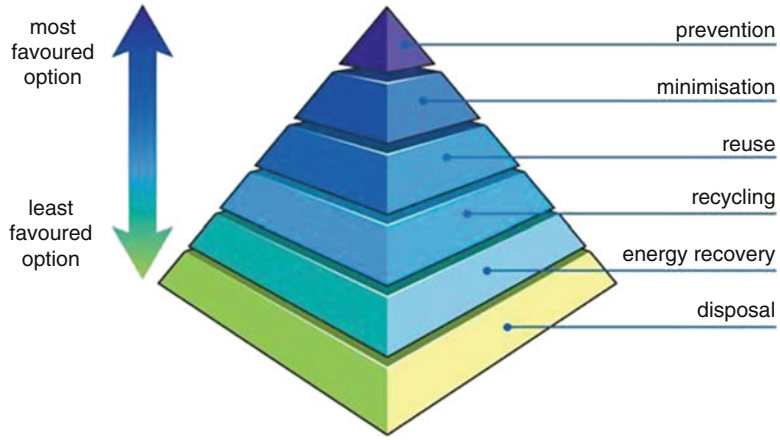

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Fig. 1 Zero waste management hierarchy based on US EPA 2008

prevents burning of garbage but also helps in reclamation of land for valuable use. The placement of solid waste in landfills is the oldest and definitely the most prevalent form of ultimate waste disposal (Chandra and Linthoingambi 2009).

Challenges and the Way Forward

In spite of these advances in WMS, a number of challenges have been identified militating against sustainable waste management in CUM. HEIs are faced with acute financial challenges resulting in inadequate service coverage and operational inefficiencies of services. This sometimes leaves wastes at dumpsites uncollected for number of days resulting in untidy environment around installations and buildings, very bad odor, and numerous flies. The system is also challenged with limited utilization of recycling activities for waste recovery for reuse, improper landfill disposal, and inadequate management of hazardous and health-related wastes due to limited knowledge on its implications on the parts of some university staff and students as well as local communities. These go a long way to compound existing public health facilities battling with municipal environmental health problems. Effective management of solid waste must therefore go beyond developing viable self-financing schemes to raising awareness of local communities on sanitation and proper hygiene, forging cooperation with local government agencies, private waste management agencies, and other higher educational institutions which may have an edge in handling such situations.

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