ASIAN JOURNAL
ISSN: 0976-3376

Available Online at http://www.journalajst.com

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol. 4, Issue, 12, pp. 042-054, December, 2012

RESEARCH ARTICLE

SOLID WASTE MANAGEMENT APPROACH IN PORT HARCOURT MUNICIPALITY, RIVERS STATE, NIGERIA: THE EFFECTS ON PUBLIC HEALTH AND THE ENVIRONMENT

[1]Tamunobereton-ari, I., [2*]Omubo-Pepple, V. B. and [3]Igbani, G. N.

[1,2]Department of Physics, Rivers State University of Science and Technology, 500001, Port Harcourt, Nigeria
[3]Environmental health unit, Primary health care Department, Ogu/Bolo Local Government Council, Ogu, Rivers State, Nigeria

Received 11th September, 2012; Received in Revised from; 26th October, 2012; Accepted 29th November, 2012; Published online 17th December, 2012

ABSTRACT

This paper x-rayed the holistic impact of solid waste management approach in Port Harcourt municipality on the environment and public health of the people of the area; ranging from waste generation, storage, segregation, collection, treatment and disposal. The study area is densely populated and enormous volumes of solid wastes are generated, which demand proper collection and storage and disposal. Survey method (primary and secondary sources) of investigation was used to obtain the required data. Results show that about 75% of the storage facilities are substandard and insanitary, no colour coded container for different kinds of solid waste, as such all types of waste are lumped together that made sorting and treatment of waste extremely difficult. Results also show that collection of solid waste at open space transfer stations account for about 70%. This exposes the soil to pollution by leachate from the waste and surface water pollution from the runoff during precipitation. It was also observed that there was no compliance to operational standards. Also, aesthetic degradation and pollution of the environment was noted. Specifically, the groundwater bodies around these facilities appear vulnerable. Most importantly, these menaces of poor solid waste management approaches and the consequences cannot be abated, in as much as professionals and sanitarians are isolated from the scheme of things by government and relevant agencies in the area of study.

Key words: Solid waste, Environment, Public Health, Transfer station, Aesthetic Degradation, landfill.

INTRODUCTION

Waste in this context means substances, which have no purpose or usefulness, seen as nuisance that need to be discarded by the generator of the waste. There are two different categories of waste: refuse (solid waste) and sewage, which could be hazardous and non-hazardous. This research is concerned with the solid waste components of waste, which indeed is the headache of all governments and refuse contractors to contain and manage properly especially in cities of developing countries such as the case study of this research (Port Harcourt, Rivers State, Nigeria). However, it is often said that a clean city, is a healthy city, which implies that the health status of a people can be evaluated from their cleanliness that is underpinned by proper management of waste in the environment. Therefore, the essence of proper solid waste management cannot be overemphasized.

Solid waste

This includes all solid waste products which are composed wholly or partly of such materials as garbage, sweepings, cleanings, trash, rubbish, litter, industrial solid wastes or domestic solid wastes including organic wastes or residues of animals, meat, fruit, vegetables, grains or fish; animal excreta or carcasses of animals; rubbish including wood, leaves, vegetation, tree trimmings, dead trees and shrubs, branches, sawdust, shavings, grass, paper products, straw, rags, clothing and all other combustibles; waste matter composed of soil, clay, sand, earth, gravel, fill, stones, bricks, plaster, glass, glassware, crockery, ashes, cinders, shells, metal and other non-combustibles; waste debris resulting from the construction, demolition, repair, or alteration of structures or buildings; accumulated waste materials composed of cans, containers, tires, junk, vehicle parts or other substances which may become a nuisance. Solid waste or refuse management is sequential: storage of generated refuse, collection, transportation, treatment and final disposal of such refuse, which must be done in established standards to minimize the adverse effects of refuse on public health and the environment. Solid wastes management is the human control of the collection, segregation, storage, transportation, treatment, recycling and final disposal of the solid wastes to minimize human exposure to associated danger of solid waste (Ovu, 2008). Table 1 shows sources and types of municipal solid waste (World Bank, 2005).

Environment Regulations

Federal, State and Local Government landfill standards in Nigeria, generally are of two types; the engineering design standards and the performance standards. The engineering standards are essentially building codes which describe the

Corresponding author: omubopepple@yahoo.com

location and how the facility must be built, while the performance standards are concerned with the facility's life, and specify certain level of environmental control to be achieved. In developing landfills, the regulatory standards should be viewed only as minimum requirements which specify a baseline standard of design and performance. There are also established regulations that; all forms of refuse storage and collection facilities should be airtight, leak-proof, be in an isolated confinement, stored refuse be collected regularly to prevent overflow of waste and being nuisance and an eyesore.

The US EPA, under the authority of the Resource Conservation and Recovery Act (RCRA), has regulations regarding: floodplain; disturbance of endangered species; surface water discharges; groundwater contamination; prevention of disease transmission; air pollution control; and safety concerns. Landfill design plans for regulatory compliance are usually submitted to appropriate authorities for investigation, review and approval before commencement of construction. Consequently, the landfill developer(s) may find it a good strategy to build a facility that in some aspects exceeds the regulatory requirement with the design features of an ideal sanitary landfill (leachate controls; surface water controls; gas controls; access roads; special waste handling; fencing; wash racks; monitoring wells; landscaping etc.); some of the features are shown in Figure 1. This may be necessary in order to achieve public acceptance of siting such a facility in a given location (Conrad *et al.*, 1981; US EPA, 1988a).

Area of Study

Port Harcourt is a coastal city located in the Niger Delta region of Nigeria; with coordinates: 4°45′N 7°00′E/4.75°N 7°E, which covered an area of about 2600 km^2 with a population of 1,382 592 (According to the 2006 Nigerian census (Figure 1 shows the study area on the map of Nigeria and the layout of the metropolis (Izeogu, 1989). This figure has been well exceeded as a result of its economic potentials. These potentials resulted to the influx of investors and visitors that had also increased waste generation capacity and the attendant problems of proper refuse management (Alloway and Ayres, 1997; Izeogu, 1989; Williams, 2008; Tamunobereton-ari *et al*, 2010). Geologically, Port Harcourt has a shallow distribution of aquifer (groundwater body); about 20m to 30m depth, which is prone to easy contamination or pollution by contaminants/pollutants that are drained down by percolating water. This calls for utmost concern for proper management of waste in the area.

Solid Waste Storage

It is definite that refuse is generated from natural and human activities, and all such generated refuse on any premise, for the purpose of sanity need to be properly stored in appropriate containers before collection to final treatment or disposal sites. Refuse generated from houses are stored in household storage facilities, which are small in capacity, leak-proof that has cover. Communal storages are used to temporally store refuse generated from a community with high density population due to industrialization and commercialization (Ovu, 2008).

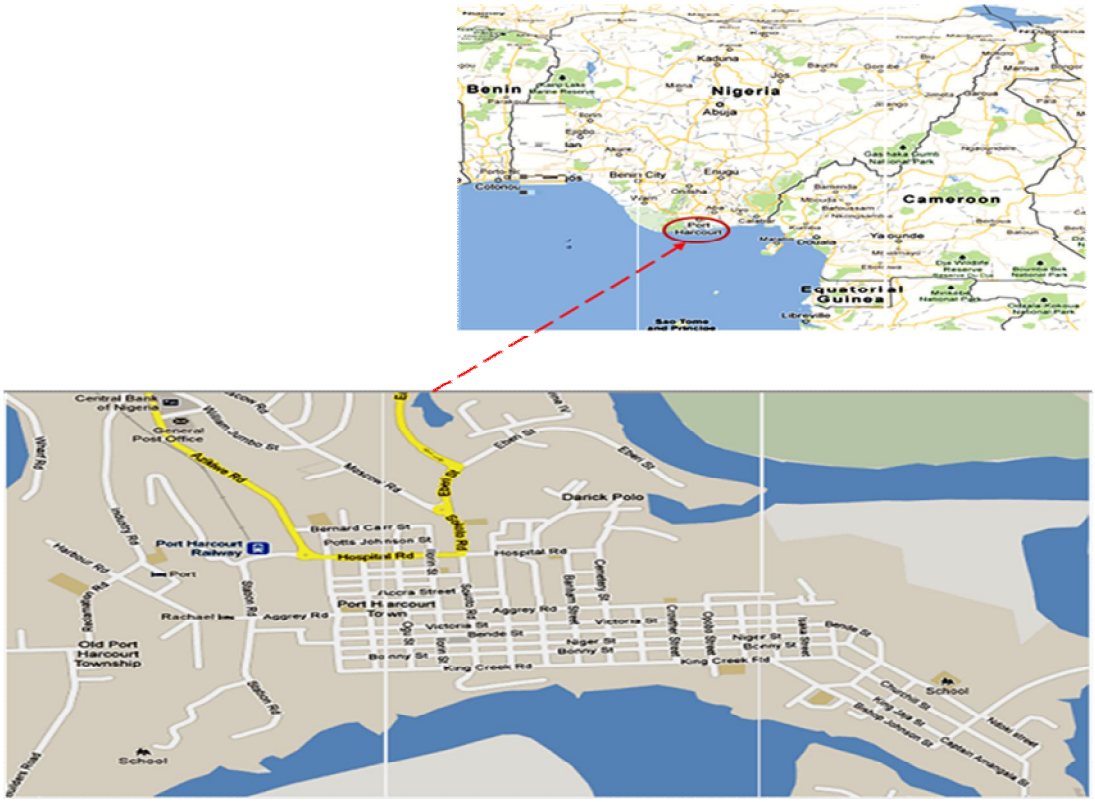

Fig.1: Map of Nigeria and the Layout of the Area of Study-(Port Harcourt Metropolis) [Google Earth, 2012]

Solid Waste Storage Containers

The owner or occupant of any premises where refuse may be present shall provide and keep on such premises sufficient containers for the storage of all refuse accumulating on the premises between collections. Refuse is extremely variable in composition, depending on the income and lifestyle of the generators. Each container shall have a close-fitting top. Containers shall be constructed of flame retardant materials; both the body of the container and the cover. The flame retardant materials make these containers resistant to destruction by flame except flames of very high temperatures. Dumpsters shall be constructed of metal as shown by Figure 2a is indeed a handled container system, which is a less heavy container that serves as a primary refuse collector of households in a premises and a storage container for the premises before final collection for disposal. Containers on residential properties shall not be placed or maintained in such a way as to unreasonably interfere with the use of the adjoining property. Containers on non-residential properties shall be fully screened and kept in such a manner as not to permit entry of or harbourage for animals, insects or other vermin. Containers on residential property shall be stored in such a manner as to be out of view from the street in front of the premises or in a garage located on the premises except so directed by public health officers. Moreover, waste generated by households, offices etc., needed to be properly packaged (i.e. refuse put in black polyethylene or plastic bags) before taken to the central storage container(s) of the premises to prevent littering in case of overflow and facilitate easy transfer of such during collection.

Occupants of single dwelling unit, double dwelling unit and townhouse properties may, but are not required to, place refuse containers adjacent to the street or alley adjoining the dwelling and off the travelled portion of the road but not earlier than 12 hours prior to the day scheduled for collection. Within 12 hours after the scheduled collection, the containers and any material not collected shall be returned by the resident of such dwelling to the same location designated for storage. Storage facilities or storage containers or bins shall have easy to operate design for handling, transfer and transportation of waste. Figure 2b shows different coloured containers designated for different kinds of refuse for segregation of wastes and promote recycling or reuse of segregated materials; containers for storage of bio-degradable wastes (garbage) shall be painted black, those for storage of recyclable wastes shall be painted red, blue and yellow, and those for storage of other non-recyclable wastes shall be painted white or as may be designated by the municipal authorities. Figure 2c is a similar refuse storage container with four wheels (US EPA. 1988a). Moreover, Municipal authorities shall establish and maintain central storage facilities (which will serve as primary collection point for waste from households, offices and commercial premises) in such a manner as they do not create unhygienic and insanitary conditions around it. The following criteria shall be taken into account while establishing and maintaining storage facilities:

i. Storage facilities shall be created and established by taking into account quantities of waste generation in a given area and the population densities. A storage facility shall be so placed that it is accessible to users.

ii. Storage facilities to be set up by municipal authorities or any other agency shall be so designed that wastes stored are not exposed to open atmosphere and shall be aesthetically acceptable and user-friendly.

Fig. 2a: Two wheels solid waste storage/collection container (Akro Mils model) built for Tilt-trucks

Fig. 2b: Different coloured storage/collection containers for different kinds of solid wastes to facilitate easy sorting of refuse for proper treatment, recycling and disposal (Adapted from Romania-insider.com)

Fig. 2c: Four wheels solid waste storage/collection containers built for tilt-trucks

Refuse Collection and Transportation

The causes of littering and clandestine dumping in urban areas occur because of inadequate availability of litter bins along walkways, inadequate public awareness of their responsibilities as urban dwellers, and inadequate refuse collection service. Littering occurs everywhere and often into drains, while clandestine dumping is commonly on vacant plots, public spaces, or along waterways. Accumulated waste may attract disease vectors, contribute to clogging of drainage (this is indeed the main cause of severe flooding in cities of most developing countries such as; Bangladesh, Colombia, Thailand, Philippine, Nigeria, Niger etc., and even in some

developed countries; France, England, Australia etc.), and sewerage networks; make waste readily accessible to neighbourhood animals and birds that may increase the chances of bioaccumulation of pollutants in such animals and pollute waterways (Alloway and Ayres, 1997). There are three basic methods employed in the collection of refuse from both domestic and estate layout: (a). the curb collection approach; this is a strategy where owners or occupiers of residences bring out their waste bins outside their premises at designated points during collection days, especially for residences where the occupier may not be present during collection hours such that the collection or disposal agents on arrival easily carry and empty such refuse containers and leave them at the location they were taken. The owner later takes back the refuse container to its original place. (b). the alley collection approach; this is a system operated in which refuse bins are located on a narrow path between building, which are later emptied by collection agents during collection hours. This approach is operationally suitable in estates and houses enclosed in the same premises. (c). the backyard collection approach; this is the system of collection of refuse from refuse bins or containers located at the back of building or premises; conceived upon the fact that refuse bins or containers with wastes contained therein may create unsightliness and other environmental health nuisances emanating there-from (Alloway and Ayres, 1997; Conrad *et al*, 1981; Ovu, 2008).

Refuse collection is enhanced by different container systems: (a). the handled container systems; they are less heavy refuse storage/collection containers that made emptying of refuse contained therein during collection hours by workmen much easier. These container systems as shown by Figures 2a, 2b and 2c are the preferred and suitable collection containers for residential and commercial premises. (b). The stationary container systems; these are heavily built collection container with either plastic or metal that are mostly centrally located to collect larger volume of refuse before final transfer for disposal, Figure 3 shows good example of stationary container system. These container systems are mechanically operated and are suitable for communal or institutional collection or a densely populated neighbourhood (Conrad *et al*, 1981; Ovu, 2008). The handled container system, the stationary container systems and the transfer stations are all secondary storage/collection facilities. The vehicles used to transfer refuse to the disposal sites are the tertiary and final collection facilities. Vehicles used for transportation of wastes shall be covered. Waste should not be visible to public, nor exposed to open environment preventing their scattering by wind. Municipal refuse transfer and transportation planning for effective execution should be underpinned by:

(a) The population of the area
(b) The types of refuse generated and the generation capacity of the populace
(c) Availability of vehicles and logistics
(d) The distance between the collection point and the final disposal site
(e) Available funding
(f) Recycling and reuse purposes.

The storage facilities set up by municipal authorities shall be daily attended for clearing of wastes. The bins or containers wherever placed shall be cleaned before they start overflowing. Transportation vehicles shall be so designed that multiple handling of wastes prior to final disposal is avoided, and also to be able to access collection points. Therefore, different categories of vehicles are designated for different types of storage containers and collection routes (Ogbonna *et al.*, 2007). The following refuse vehicles are used for collection and final disposal: (a). The compactor truck; this is a tilt truck specially constructed for sanitary standard collection and disposal of refuse. Shown by Figure 4; the truck is covered, fitted with a lifting and a tipping system, sitting provision for the crew and provision for the keeping of other operational equipments used in the collection and proper positioning of refuse. It is mechanically operated to empty refuse in bins and compact same to accommodate more volume of refuse; it is mechanically operated also to tipping refuse at disposal sites. (b). The pulley-system truck; this is a truck specially design to mechanically haul and transfer/transport refuse in stationary collection containers as that shown by Figure 3 to major transfer stations or disposal site; this truck is suitable for short distance to disposal sites. (c). Open trucks: these trucks in different sizes are employed in the collection and transportation of refuse to disposal sites, these trucks are sometimes fitted with mechanical tipping systems but are loaded by sanitary labourers and are covered with tarpaulin or wire nets when they are loaded to capacity to prevent scattering and littering of refuse by wind.

Fig. 3a: Stationary Container System with Spill refuses

Fig. 3b: Stationary Container System

Fig. 4a: Refuse-Compactor Transport Truck

Fig. 4b: Pulley-system Refuse Transfer Truck

Fig. 4c: Self-Tipping Refuse Disposal Open Truck

Refuse Disposal

There are several methods of refuse disposal. They are: burning of refuse, composting, dumping into the sea, hog feeding, incineration, open dumping, pulverisation, pyrolysis and sanitary landfill. Amongst all these methods, the methods in operation in the area of study are: the burning method, open dumping and the sanitary landfill method. The burning of refuse and open dumping of refuse on an unused plot are most practiced in the suburbs of the metropolis. The main refuse disposal method of practice in the area of study is the so-called sanitary landfill method. Landfill is an area of land marked out and carefully designed; where waste materials are isolated from the surrounding, dumped, compacted by waste compactors as shown by Figure 6, and covered in layers of earth either in a valley or excavated area of a low value land with an appropriate leachate and landfill gas (mainly Methane and Carbon dioxide) control. Landfill is like a bathtub in the ground (Figure 5), which is not strictly a disposal method, but one of containment or indefinite waste storage. Many landfills are used for the disposal of both municipal and hazardous wastes. The disposal utilizes the absorptive properties of the bulk municipal waste and the microbial degradation reaction which occur wherever putrescible material is buried (Alloway and Ayres, 1997). When designing a sanitary landfill, the objectives are: to provide long-term environmental protection, ensure regulatory compliance, and achieve cost-effective utilization of manpower, equipment and space. Characteristics of landfill sites (site topography, site soil, and site bedrock and site groundwater) in most selected sites for sanitary landfill are less than ideal. Therefore, to meet design goals, appropriate engineering techniques are employed at the design stage to overcome the site limitations. Traditionally, the land-filling of solid wastes has been accomplished at the least possible cost. Initially, urban areas deposited their solid wastes on nearby low-value lands, frequently wetlands, creating a waste dump. This approach was followed by excavation of an area and depositing the wastes in the excavated area. Often, the wastes in the dump were burned to reduce volume and some other adverse impacts.

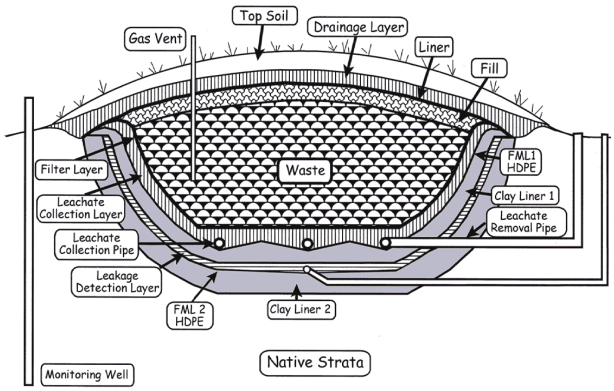

Fig. 5: Double Composite Liner Landfill Containment System (Adapted from US EPA, 1988a)

Fig. 6: Refuse compactor at a Solid Waste disposal site

Eventually, beginning in some areas in the 1950s, it was determined that there was need to cover the daily deposited wastes with a layer of soil to reduce odours and access to wastes by vermin, rodents, flies, birds, pigs etc.; this approach led to the development of the "sanitary" landfill. No regard was given to the potential for the wastes in a sanitary landfill to cause groundwater pollution or for the gas generated in the landfill to be a threat to cause offsite explosions and also to cause public health and environmental problems. While land-filling in the conventional sanitary landfill was recognized in the 1950s as leading to the pollution of groundwater by landfill leachate, it was not until in the 1980s/1990s that there were national regulations that were designed to control groundwater pollution by landfills. The dry tomb landfilling approach, is based on the use of a relatively thin plastic sheeting (high-density polyethylene – HDPE) layer and a compacted soil/clay layer to form what is called a "composite" liner. The evolution of this approach began in the 1970s, when compacted soil/clay liners were proposed for landfills. However, this did not prevent the wastes in the landfill from causing groundwater pollution. Further, the clay liners were found to be subject to a number of problems; the plastic compaction ability of clay and the ability of clay to readily react with chemical compounds from leachate that cause them to dissolve, led to their failure to prevent leachate from passing through them at the design characteristics; (US EPA, 1988a**;** Tamunobereton-ari *et al.*, 2012, ASCE, 1959; Bumb *et al.*, 1988).

Impacts of Poor Performance Standards of Solid Waste Management on the Environment

A solid waste management scheme that fall short of the performance standards of an ideal approach, impacts seriously negatively on the environment: (i) Leachate from faulty storage/collection facilities and transfer stations, and leachate leaked from unlined or leaky lined landfill contaminates/pollutes groundwater, and runoff from the surface of an uncovered landfill and contaminated ground, also contaminates/pollutes surface-water. (ii) The dumping together of municipal and hazardous wastes without proper sorting and treatment of these wastes before their disposal creates high chances of increasing the concentrations of pollutants especially; (heavy metals, volatile organic compounds, PCBs, radioactive elements etc.) in the surrounding soils, water and air (BMA, 1991). (iii) The air quality around the vicinity of a poor storage/transfer station and improperly managed landfill is reduce as a result of air contamination/pollution caused by the diffusion of offensive odour and untapped landfill gases (Methane, Sulphides, Carbondioxide, Nitrogen, Volatile Organic Compounds etc.), emitted into the atmosphere. (iv)The overflow of storage facilities and non-containment of the deposited wastes in the landfill, because of lack of fence, no daily landfill top cover, allows the littering and spread of waste materials outside the vicinity of the facilities and affects the aesthetic beauty of the environment.

Public Health Effects of Improper Solid Waste Management

The effects of poor storage and collection of solid waste, and landfill (disposal site) below ideal design and performance standards on public health are overwhelming because life is dependent on water, soil and air. So if these life-supportive factors are contaminated and/or polluted by poor operation of these solid waste management phases; then one can imagine the magnitude of devastation that it could cause to the ecosystem especially man. Some of the associated public health concerns of poor solid waste management approaches are:

Epidemiological effects

Anosmia is the human health condition where people lose their sense of smell. This effect is an epidemiological aspect of long time constant exposure to offensive odour caused by diffusion into the atmosphere of hydrogen-sulphide and organo-sulphur compounds associated with improper storage of waste and landfill; that is the reason why refuse collectors and landfill employees cannot smell the odours and neighbours can. Another example of Anosmia often occurs with smokers. That is why when you get into a smoker's car, you think it smells awful, but they cannot smell a thing. Lee and Jones-Lee (2007b), well-establish the fact that airborne releases from hazardous chemical sites (including active and inactive landfills) can have a significant adverse impact on the population within the sphere of influence of the site. Hirshfeld *et al.*, (1992), also point out that the non-methane organic compounds in landfill gas contain toxic chemicals that could cause cancer.

According to the Agency for Toxic Substances and Disease Registry (ATSDR, 2006), "Many of the typical landfill gases, notably the alkyl benzenes and the sulphur compounds (both organo-sulphides and acid gases), may present an odour problem that can cause adverse health effects such as mucous membrane irritation, respiratory irritation, nausea, and stress. If an individual has a pre-existing health condition (e.g., allergies, respiratory illness), these additional health impacts can be significant." Elliott *et al*., (2001) reported that children born to mothers living near landfills in England tend to have a higher rate of birth defects than the general population. Kouznetsova, *et al*., (2007**)**, relates residential proximity to hazardous waste sites to hospitalization associated with diabetes. A review of the various studies that have been conducted, however, reveals that the epidemiological approach for discerning health effects associated with populations living near landfills is not sufficiently sensitive to reliably determine whether releases from the landfill are at least in part responsible for the health effects. A complicating factor is that those living near landfills frequently are economically disadvantaged and of a different ethnic mix than the general population.

Physical effects

The physical impacts are related to ground and surface water pollution by leachate migration, atmospheric releases of offensive odours and landfill gas, and fires. Landfill gas is known to cause explosions resulting in loss of life and property, and damage to vegetation.

Social effects

The social impacts of improper solid waste management include:

Aesthetic degradation

Aesthetic degradation of the surrounding by an overflowed storage facility, unconfined transfer station, roadside dumping and litter along transport route and near landfill due to absence of fence and top cover are unsightly, and the emission of offensive odour around these facilities causes an innate human reactions of anxiety, depression and other negative psychological reactions. These reactions are vital to our existence and dictates how we live in harmony with others (Hirshfeld *et al.,* 1992; Omubo-Pepple *et al.,* 2010).

Vermin-Disease Vectors

Vermin include animals such as rats and other rodents, and insects such as flies. In addition to being a nuisance, vermin can be vectors (carriers) of disease organisms and hazardous chemicals that posed danger to man and the ecosystem. Birds (gulls, crows, etc.) attracted by open dumps and landfills can be a significant problem, where large numbers will congregate and circle the sites, defecating on nearby properties, and constitute an uncontrollable nuisance in the vicinity.

Breeding Ground for Disease Carrying Organisms

Poor and unwholesome approach of solid waste management from the point of storage – collection – transportation – final disposal can create favourable conditions for the breeding of vectors or disease carrying agents such as: flies, mosquitoes, cockroaches, worms etc., which is dangerous to the wellbeing of man and the ecosystem.

Human and Vehicular Traffic Jam

Overflow of solid wastes from the storage facilities litters and scatters wastes materials. The indiscriminate roadside dumping of waste and the spread of waste of a landfill onto access roads undoubtedly prevents the free flow of human and vehicular traffic at such locations, thereby unnecessarily waste man hour in a bit to bypass such nuisances.

Flooding Menace

Flooding had become a serious issue of concern of major cities world over, but more in the developing countries; which is seriously attributable to the insensitivity of proper solid waste management. Poor solid waste management had been labelled the major factor to clogging and blocking of existing drainages or water channels (where solid wastes are dumped right into water channels or drainages as shown by Figure 7), which have seriously contributed to severe flooding and associated disasters in the destruction of lives and properties.

Noise Pollution

Hirshfeld *et al*., (1992) discussed landfill noise as part of "Social Effects" of landfills. Noise at landfills can be noticeable in nearby residential areas from truck traffic and bulldozers. It has also been established that excessive noise can have many undesirable effects on those exposed to it. In most cases, however, the noise is simply regarded as an annoyance; that causes hearing loss and stirs up anxiety, depression and also stimulates cardiovascular diseases (Omubo-Pepple *et al.*, 2010; Omubo-Pepple and Tamunobereton-ari, 2011; US EPA (1975). Noise pollution of the areas near a proposed landfill is a justified issue of concern because of the often limited buffer land between where wastes will be deposited and adjacent properties. This means that adjacent property owners can potentially experience noise pollution on their properties by the proposed landfill.

Light Pollution

Another issue of concern to the public is that some landfills operate at night, where nearby Property owners would experience pollution by lights at the landfill. Some landfill operators plan to operate heavy equipment at night, under lights, for compaction of the wastes that had been received that day. This can lead to significant disruption of the interests of the nearby property owners/users, which should be controlled/prohibited.

Other socio-Economic impact costs of landfills

According to Hirschfeld *et al.,* (1992) these are:

- The cumulative decrease of surrounding property values
- Businesses in the vicinity of poorly managed solid waste facilities (storage, collection, transfer station or disposal site) crumble; because customers may not be comfortable to patronise such businesses at such locations.
- The cost associated with land utility effects, also known as an 'opportunity cost' and A 'hastening cost'.

Fig. 7: Solid Wastes Dumped into Water Channels and Drainage that clogged drainages that enhance severe Flooding in the city

Data Acquisition

Port Harcourt municipality, which is the study area, has a population of 1.38 million according to the 2006 National Population Commission figures. This dense population is due to concentration of industrial activities and rural-urban migration for better living. This situation of course had led to unprecedented anthropogenic activities resulting in the generation of enormous amounts of waste of all kinds (municipal, industrial and hazardous) thereby posing great challenges in waste management in the area (Alloway and Ayres, 1997; Tamunobereton-ari *et al.,* 2010). Data for the execution of this work were obtained from both primary and secondary sources. Observation and interview were used to obtain the primary data; while official records from the Rivers State Ministry of Environment and Rivers State Sanitation Authority were obtained as secondary data. The secondary

data were indeed obtained to ascertain minimum requirement established by government upon which operational approvals or permits were issued, confirm operational compliance with regulations and verify regular environmental status evaluations. Based on the geologic information above; the essence of proper solid waste management cannot be overemphasized. Again, during the construction of a sanitary landfill (the disposal sites), excavation is normally made to create enough accommodation space for the deposition of wastes.

This act of excavation causes the Litho-stratigraphic stability of the geologic formation maintained by the pressure of overlying load of materials to be out of equilibrium. Pressure release caused by excavation and removal of materials to create a pit, allows underlying strata to be uplifted by geostatic pressure and expands upwards. This phenomenon results to fracturing of formation strata, which if not properly lined with suitable lining materials can lead to leakage of leachate from deposited waste towards the groundwater body, which may contaminate/pollute the water body and pose serious danger to man. Two landfill or dump sites (Eneka, and Airport road off East-west road), all in Port Harcourt were x-rayed in this work. House-to-house inspection, street tours of the study area were embarked upon to observe and investigate how generated solid wastes are stored and collected for proper disposal (Plummer and McGeary, 1993; Alloway and Ayres, 1997; Tamunobereton-ari *et al*, 2012). For effective analysis and interpretation, the study area was divided into four district: (1) Borokiri and its suburbs; (2). Main town and its suburbs; (3). Diobu and its suburbs and (4). Government reserved areas (Old GRA).

RESULTS AND DISCUSSIONS

The results presented below are findings made by personal observation by house-to-house inspection, street tours and interviews.

Solid Waste Storage Containers

From the findings, the numerical data of Table 2 and the graphical presentation of Figure 8 show that on the average, solid waste storage containers used in the study area are sub-standard except the Old GRA district. Most of the storage containers used in the districts are exemplified by Figure 9.

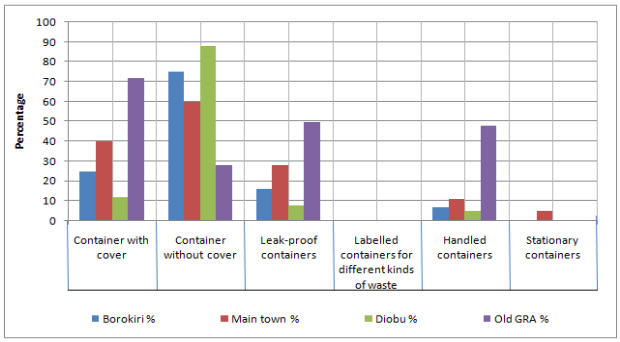

Fig. 8: **Graphical Presentation of types and state of solid waste storage containers in the study area**

Fig. 9: **Solid waste storage containers mostly used in districts of the study area**

Though, Figure 2a types of containers are reasonably provided in the Old GRA district basically due to the fact of the affluence of people living in that area. However, no provision of labelled containers for different kinds of waste in the entire districts to segregate waste at generation and collection points; making sorting, processing, treatment, and recycling of waste difficult. Respondents from the interviews also reveals of their ignorance of an ideal collection and storage; in that any container can be used to gather waste for disposal.

Collection and Transfer of Solid Waste in the Area

The collection of solid waste is indeed a daunting task as such house-to-house collection of waste seemed not feasible except in the Old GRA district where residents make extra payments for such services; as such collection of waste at transfer stations is what was embraced and practiced in most parts of the study area. Both daily and weekly schedule of refuse collection was employed based on the population density and the magnitude of waste generated. Both compactor trucks and open trucks are used to collect and transfer waste; but the issue of concern was the fact that most open trucks after loading of waste are not covered with tarpaulin or any covering through the entire route of transport to prevent windblown litter; as such during transportation, waste are dispersed by wind and litter the streets and roads, constituting more nuisance.

As clearly shown by the data of Table 3 and the graphical presentation of Figure10, there are no confined transfer station facilities, all which were operational are open space transfer stations as shown by Figure 11. Emission of offensive odour of these transfer stations are unbearable and Leachate from waste piles of open transfer stations caused by exposure to precipitation and from residual liquids in the waste itself may contain organic matter, nutrients, metals, salts, pathogens, and hazardous chemicals. If allowed to migrate, leachate can contaminate soil, surface water, and groundwater potentially causing additional impacts such as eutrophication and acidification of surface water and contamination of water supplies. In-fact, based on the climatic conditions and weather pattern of the study area, the potential dangers posed by the contaminants/pollutants from these open transfer stations and dump sites on surface water and groundwater resources are enormous.

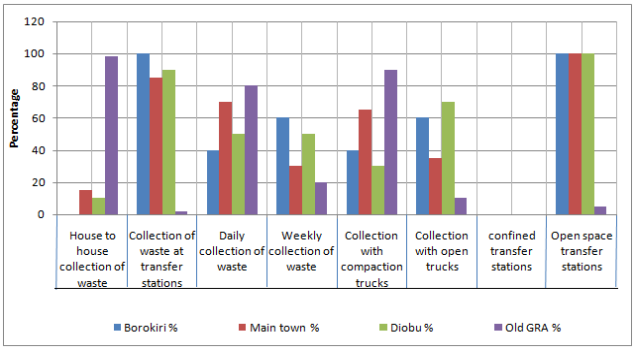

Fig. 10. Graphical presentation of waste collection and transfer machinery

Fig. 11. Photograph of an Open Space Transfer Station where all kinds of solid wastes are discharged upon for final collection and disposal

Solid Waste Disposal Approach in the Study Area

Disposal practices in the area of study are worrisome as they are observed to be insanitary and unacceptable. These insanitary phenomena were visible and observed so, because of majorly the non involvement of trained professional in the executions of the programmes rather; government prefer the used of contractors that engage the services of inexperience labour force to maximize profit to the detriment of the total environment and public health. Dumping of solid waste into drainages is most practiced in Main town and Diobu districts especially during rainy days, where bins are emptied into drainages to relieve residents the stress of taking waste to collection points. The suburbs of Borokiri and Diobu districts are in slums and squatter areas or localities at the water fronts and surrounded by river channels that municipal authorities do not attend to collecting and transfer solid waste for disposal; as such residents in those areas resulted in the dumping of solid wastes into river channels and river banks that in-turn block channels that conduct waters away from cities centres during precipitation; thereby cause the flooding of cities that destroys lives and properties of inhabitants.

Table 4 and Figure 12 show that dumping at vacant plots and public spaces was observed in all the districts of the study area. The practice of reducing or disposal of solid waste by burning was minimal. Also, recycling or reuse of waste was not adopted except sorting and collection of waste by informal sector waste pickers. Generally, the widely adopted method was the collection and transportation of solid waste with trucks at transfer stations for disposal at landfill or designated open dump sites.

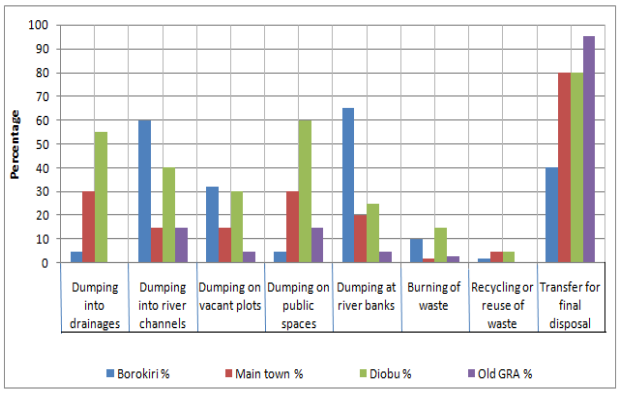

Fig. 12: Graphical presentation of solid waste disposal methods

Based on the technicalities associated with the work and the critical investigations carried out on the facilities operated at the selected sites {Eneka, and Airport road (off East-west road)}, the following discoveries were made and results obtained as shown in Table 5. From the results obtained from site observations and from respondents, and available records, it is evident that operational landfills especially those for this work are not lined; no leachate pipes, no landfill gas pipes and no landfill daily top cover. The area of study, which has very high rate of precipitation (rainfall) and an average temperature of 28^{o}C (favourable climatic conditions) facilitates fast decomposition; resulting to generation of enormous amount of leachate and landfill gases. High moisture as a result of high rainfall causes the leachate to percolate or migrate towards the groundwater body faster in the absence of liner and leachate collection pipes and becomes a potential threat to public health and human life. The landfill gases and the associated odours which are emitted into the atmosphere in the absence of a top cover constitute a nuisance and impact adversely on the population within the spheres of influence of the sites (Tamunobereton-ari *et al.*, 2012)

Results reveal the nearness of residential homes to landfill sites. From Table 5, the site at Eneka was 200m to homes; this distance is very close for comfort of residents and not acceptable. People living in such homes are more exposed to or more impacted upon by landfill odour and sound/light pollutions, which is dangerous to public health (Conrad *et al.*, 1981). The landfill at Airport road (off East-west road) was 800m to home, which is within the acceptable distance from residential homes; but developmental trend indicates encroachment of developers into the buffer zone of the site. Results also show that the absence of landfill supervision warranted the operational non-compliance with standards by operators of these facilities by tipping all kinds of unsorted and untreated wastes by the road side as shown by Figure 13; this constitutes nuisance and environmental concerns to passerby. These wastes are almost always just spread by bulldozer without being properly compacted and top covered with appropriate covering soils. Of course, no wash tracks to wash and disinfect trucks leaving the landfill site to minimize the spread of contaminants/pollutants outside the

location. From Table 5 it is shown that the water quality of the vicinity of the sites are yet to be affected perhaps due to the reasonable distance of the site to residential homes. In addition, there is no evidence of environmental status evaluation of any kind to ascertain the degree of environmental degradation caused by the operations of the landfills (Tamunobereton-ari *et al.*, 2012).

Fig.13: **Landfill or open dump close to an access road**

Table 1 - Sources and Types of Municipal Solid Waste

Source	Typical Waster Generators	Types of Solid Waste
Residential	Single and multifamily dwellings	Food waste, paper, cardboard, plastic, textiles, leather, yard waste, wood, glass, metal, ash, special waste (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires) and household hazardous waste
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping waste, packaging, food waste, construction and demolition materials, hazardous waste, ash, special waste
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastic, wood, food waste, glass, metal, special waste, hazardous waste
Institutional	Schools, hospitals, prisons, government centers	Same as commercial
Construction and Demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal Services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings; landscape and tree trimmings; general waste from parks, beaches and other recreational areas; sludge from water and wastewater treatment plants
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process waste, scrap materials, off-specification products, slag, tailings

Source: World Bank (2005)

Table 2: Types and state of Solid Waste Storage Containers used in Premises

S/N	issues	Borokiri %	Main town %	Diobu %	Old GRA %
1.	Container with cover.	25	40	12	72
2.	Container without cover.	75	60	88	28
3.	Leak-proof containers.	16	28	08	50
4.	Labelled containers for different kinds of waste.	00	00	00	00
5.	Handled containers.	07	11	05	48
6.	Stationary containers.	00	05	00	00

Table 3: Approach of Collection and Transfer of Solid Waste in the Study Area

S/N	issues	Borokiri %	Main town %	Diobu %	Old GRA %
1.	House to house collection of waste.	00	15	10	98
2.	Collection of waste at transfer stations.	100	85	90	02
3.	Daily collection of waste.	40	70	50	80
4.	Weekly collection of waste.	60	30	50	20
5.	Collection and transfer with compaction trucks.	40	65	30	90
6.	Collection and transfer with open trucks.	60	35	70	10
7.	Well designed and constructed confined transfer stations.	00	00	00	00
8.	Open space transfer stations.	100	100	100	05

Table 4: Solid waste disposal patterns in the area of study

S/N	issues	Borokiri %	Main town %	Diobu %	Old GRA %
1	Dumping into drainages	05	30	55	00
2	Dumping into river channels	60	15	40	15
3	Dumping on vacant plots	32	15	30	05
4	Dumping on public spaces	05	30	60	15
5	Dumping at river banks	65	20	25	05
6	Burning of waste	10	02	15	03
7	Recycling or reuse of waste	02	05	05	00
8	Transfer for final disposal	40	80	80	95

Table 5: Findings from two landfill sites

S/N	Issues/Sites	Eneka	Airport road , off East-west road
1.	Landfill liner.	Nil	Nil
2.	Leachate pipe.	Nil	Nil
3.	Landfill gas pipe.	Nil	Nil
4.	Landfill top cover.	No top covering.	No top covering
5.	Waste compaction.	Wastes are just so spread by bulldozers, compactors not used.	Wastes are just so spread by bulldozers, compactors not used.
6.	Fence	No fence.	No fence.
7.	Nearness to major access road.	100m.	10m.
8.	Distance from residential buildings.	200m.	800m.
9.	Odour.	Offensive.	Offensive.
10.	Water quality around the facility.	Not affected.	Not affected.
11.	Treatment and recycling of Waste.	No treatment, no recycling.	No treatment, no recycling.
12.	Landfill supervision	No supervision.	No supervision.
13.	Environmental status evaluation.	Nil	Nil
14.	Operational compliance with standards.	No compliance.	No compliance.
15.	Wash racks	none	none

Conclusions

The findings of the study clearly show the insanitary conditions of solid waste storage facilities used in the study area, in addition, there were no labelled or colour coded containers for different kinds of waste to ease segregation of different kinds of waste; this helps compound the recycling and reuse component of solid waste management. It was also evident that there were no well constructed confined transfer stations, and the open space transfer stations are arbitrarily designated at unused vacant plots or/and most cases at the middle of access roads that cause vehicular and human traffic jam thereby posed undue difficulty to road users. Again, in collection and transfer of solid waste to their final disposal sites, though compactor trucks are also used, most solid waste management contractors use open trucks, which on many occasions are not covered and allow the spread of windblown litters all along the route to the disposal sites and increase the nuisance level in the environment. Due to neglect by solid waste contractors and government agencies to collecting and disposal of waste from slums and squatter areas of the suburbs of the districts of the study area; dumping of solid waste into drainages, river channels, vacant plots, public spaces and river banks was well encouraged and practiced.

Burning of solid waste was minimal, recycling and reuse of solid waste was also minimal except private informal sector waste pickers that sort and collect useable and valuable waste for personal gains. The findings also clearly revealed that the last destination of these solid wastes "landfills" that were investigated did not comply with operational standards either in terms of design or performance, and they have inherent long-term adverse impact potentials on the environment and public health. Therefore, to save the environment and allay public health fears by these shortfalls; government and relevant agencies should intervene and engage in serious monitoring of the activities of the operators to ensure compliance, and also engage in continuous evaluations of the safety levels of landfills while in use, at closure and post-closure periods. The environmental status around the vicinity of existing facilities should be conducted for as long as the wastes in the landfill will be a threat. Government and relevant agencies should also embark on vigorous remediation measures where landfills are already posing serious threats to the environment and human beings. Hither to, all land fills operational in and around Port Harcourt have been mere waste dumps and not sanitary landfills. Consequently, no new landfill facilities should be permitted for construction at any site without thorough and comprehensive investigation by relevant authorities to ascertain compliance to both design and performance standards of a sanitary nature. There are well trained qualified professionals that have the capacity to proper management and containment of these ugly situations. Yet, in the face of these solid waste management challenges, government and relevant agencies are still without recourse to the sanitarians that have the expertise to contain and properly manage solid waste in the area, rather, they engage touts to doing their job that have no proper training to maximize profit at the expense of public health and the environment.

Recommendations

Based on the holistic investigation of the solid waste management regime in the study area, the following recommendations are made to facilitate solid waste management of an acceptable standard:

- Sanitary containers and bags should be used by household and establishment for storage of solid waste and presentation for collection at collection point for easy.
- Collection of waste from slums and squatter areas or localities should be enforced to prevent dumping into river channels, drainages and even at public spaces.
- There should be house-to-house collection of waste to ensure proper coverage.
- There should be regular collection schedule with sufficient frequency to avoid accumulation and overflow of waste.
- Storage facilities shall be created and established by taking into account quantities of waste generation in a given area and the population densities. A storage facility shall be so placed that it is accessible to users;
- Storage facilities to be set up by municipal authorities or any other agency shall be so designed that wastes stored are not exposed to open atmosphere and shall be aesthetically acceptable and user-friendly.
- Storage facilities or bins shall have easy to operate design for handling, transfer and transportation of waste.

- Encourage residents to put out waste at designated times and locations.
- Encourage separation of different kinds of waste materials at the point of generation, so that the collection points do not become sorting points for informal sector waste pickers.
- Use vehicles appropriate for the geographical conditions and wastes types to maximize reliability of collection.
- Transfer stations should be properly designed and constructed to provide confinement and containment of wastes discharged to the stations.
- Cover collection and transfer vehicles along the entire route of transport to avoid windblown litter.
- Clean vehicles used for waste hauling before being used for the transportation of any other good, including compost.
- Landfills should be properly sited, designed, monitored and maintained to the required sanitary standard to meet the operational-performance standard to provide containment of the wastes for as long as the wastes in the landfill will be a threat.
- When Siting waste management facilities; (storage, transfer station, processing and landfill or any dump site), consider the proximity of areas to water supply wells for people and animals, irrigation canals, and surface water bodies that support aquatic life and the ability to prevent contaminated leachate and drainage from entering surface and ground water.
- Finally, adequate and well trained professionals (environmental health officers) should be mandatorily majorly involved in solid waste management schemes for effective execution of programmes.
- There should be regular environmental and health education in these districts to create the necessary awareness of the benefits/adverse effects of good/unwholesome solid waste management practices on the environment and their health.
- From the study, inadequately formulated or poorly implemented environmental policies, or lack of enabling legislatures are also attributable to poor solid waste management. Therefore, Government should establish regulations that will deter citizen and inhabitants from poor and unacceptable solution.

Acknowledgement

The authors are thankful to Mrs. Jane Iyeneomie and IYETAMS Ventures Nig. Ltd; for the proofreading and typesetting of this work. We are also grateful to the Rivers State Ministry of Environment and the Rivers State Sanitation Authority for making available some official records to the actualization of this work.

REFERENCES

Alloway, B.J. and D.C. Ayres, 1997. Chemical Principles of Environmental Pollution, 2nd Ed. *Blackie Academic and Professional, UK*., pp: 190-217.

ASCE, 1959, "Sanitary Landfill" Report by committee on Sanitary Landfill Practice of the Sanitary Engineering Division of the American Society of Civil Engineers, New York.

ATSDR (Agency for Toxic Substances and Disease Registry), 2006. Landfill Gas Primer: An Overview for Environmental Health Professionals, *ATSDR Guidelines for Public Health Action in Response to Landfill Fires.* http://www.atsdr.cdc.gov/HAC/landfill/html/appb.html.

BMA (British Medical Association), 1991. Hazardous Waste and Human Health. *Oxford University Press, Oxford.*

Bumb, A.; McKee, C.; Evans, R. and Eccles, L.1988, "Design of Lysimeter Leak Detector Networks for Surface Impoundments and Landfills," *Groundwater Monitoring Review* 8(2):102-1 14.

Elliott, P.; Briggs, D.; Morris, S.; de Hoogh, C.; Hurt, C.; Jensen, T.; Maitland, I Richardson, S.; Wakefield, J.; Jarup, L., 2001. Risk of Adverse Birth Outcomes in Populations Living near Landfill Sites, *British Medical Journal* 323: 363-368.

http://www.romania-insider.com/only-1-percent-of-trash-recycled-romania-bottom-of-eu-league-again/53958/ (Accessed 7th August, 2012)

https://www.google.com.ng/search?q=map%20of%20Port%20Harcourt&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a&source=hp&channel=np (Accessed 27th August, 2012).

Hirschfeld, S.; Vesilind, P. A. and Pas, E.I., 1992. Assessing the True Cost of Landfill, Waste Management & Res. 10: 471-484.

Izeogu, C. V. 1989. Urban Development and Environment in Port Harcourt, *Environment and Urbanization*, 1(1): 59-65.

Kouznetsova, M.; Huang, X.; Ma, J.; Lessner, L. and Carpenter, D., 2007. "Increased Rate of Hospitalization for Diabetes and Residential Proximity of Hazardous Waste Sites," *Environmental Health Perspectives* 115(1):75-79.

Lee, G. F. and Jones-Lee, A.; 2007b. "Comments on the CIWMB Staff Efforts to Gain Assured Postclosure Funding for Landfills for as Long as the Wastes in the Landfill are a Threat to Public Health and the Environment," El Macero, CA,

http://www.gfredlee.com/Landfills/CIWMBPostCloseFund.pdf

Ogbonna, D. N. , Amangabara, G. T., and Ekere, T. O. 2007. Urban Solid Waste Generation in Port Harcourt Metropolis and its Implication for Waste Management. *Management of Environmental Quality: An International Journal*, 18(1): 71-88.

Omubo-Pepple, V. B., Briggs-Kamara, M. A., and Tamunobereton-ari, I.; 2010. Noise Pollution in Port Harcourt Metropolis: Sources, Effects, and Control. *Pacific Journal of Science and Technology*, 11(2): 592-600.

Omubo-Pepple, V. B., and Tamunobereton-ari, I.; (2011). Noise Induced Hearing Loss within the Rivers State University of Science and Technology, Port Harcourt, Nigeria; *Journal of Basic and Applied Scientific Research*, 1(8): 868-874.

Ovu, S.I., 2008, Introduction to Environmental Health, 2nd Ed., God Giveth Printing and Publishing Company, Nigeria.

Plummer, C. C; and McGeary, D; 1993. "Physical Geology", 6th Ed. Wm.C. *Brown Publishers, England.*

Tamunobereton-ari, I; Uko, E. D., and Omubo-Pepple, V. B. 2010. Anthropogenic Activities Implications for Ground Water Resource in Okrika, Rivers State, Nigeria, *Research Journal of Applied Sciences*, 5(3): 204 – 211.

Tamunobereton-ari, I; Omubo-Pepple, V. B. and Briggs-Kamara, M. A; 2012. The Impact of Municupal Solid Waste Landfill on the Environment and Public Health in Port Harcourt and Its Environs, Rivers State, Nigeria. *Trends in Advanced Science and Engineering*, 3(1): 49-57.

US EPA, 1975. "Measuring External Effects of Solid Waste Management," R. Schmalensee, R. Ramanathan, W. Ramm and D. Smallwood (eds.), NTIS, PB-243407, U.S. Environmental Protection Agency, Washington, D. C.

US EPA. 1988a, "Solid Waste Disposal Facility Criteria; Proposed Rule," Federal Register 53(168):33314-33422, 40 CFR Parts 257 and 258, US Environmental Protection Agency,Washington, D. C.

Williams, L., 2008. Nigeria: The Bradt Travel guide, 2nd Ed. Bradt Travel Guide Ltd, England, 196-203. ISBN. 1-84162239-7.

World Bank. 2005. Waste Management in China: Issues and Recommendations. Urban Development Working Papers, East Asia Infrastructure Department. World Bank Working Paper No.9 Washington DC.

****