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Assessment of solid Waste Management system in Khartoum locality

A thesis submitted for partial fulfillment of the requirement for the degree of Master of Science in chemical Engineering

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JANUARY 2oo9

Dedication

To my parents

To my husband

To my children (Sama & Mohamed)

Tahani 2009

Acknowledgement

I would like to express my sincere thanks to my supervisor, Dr. Bashir Mohamed El-Hassan for his technical support, guidance and assistance.

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Abstract

The objective of this study is to assess the solid waste management system in Khartoum locality Bearing in mind that Solid waste , especially municipal solid waste is a growing problem in Khartoum locality due to the rapid increase in the City population and the inadequate waste management system.

Different stages of the municipal solid waste system that are currently practiced by the authorities were analyzed and focus was made on the protective measures that are currently applied at both of the Old and the New landfill sites in West Omdurman. No environmental protection measures were found in the Old landfill site, while the new site is properly designed especially with regards to landfill gas extraction and combustion. However the New site does not take into consideration any protective measures against leachate pollution.

The study recommended numbers of actions to be taken in order to improve the performance of the solid waste management system in Khartoum locality: Establishment of environmental strategies and policies and enhancement of private sector participation to increase the overall system efficiency and an immediate actions of fencing of the Old site.

المستخلص

هذه الدراسة تهدف الي تقييم نظام ادارة النفايات الصلبة في محلية الخرطوم. مع الاخذ في الاعتبار ان النفايات الصلبة تعتبر مشكلة متفاقمة نتيجة للزيادة الكبيرة في اعداد السكان وعجز نظام ادارة النفايات الصلبة في التعامل الامثل مع هذه المشكلة.

تم تحليل المراحل المختلفة لنظام ادارة النفايات المتبع حالياً من قبل المحلية مع التركيز على سبل حماية البيئة المتبعة في كل من المطمرين القديم والجديد بغرب ام درمان. حيث انعدمت وسائل حماية البيئة في المطمر القديم بينما وجد ان تصميم المطمر الجديد يتوافق مع المتطلبات البيئية حيث يحتوي المطمر الجديد على نظام جيد لجمع وحرق الغاز مستقبلاً، الا انه لم يتخذ وسائل لحماية البيئة من الملوثات السائلة بالنفايات.

توصلت الدراسة للعديد من التوصيات من اجل اصلاح وتطوير نظام ادارة النفايات الصلبة بمحلية الخرطوم.تتمثل في تفعيل الاستراتجيات والسياسات المتخذة مع تفعيل دور القطاع الخاص لتحسين كفاءة عمل النظام ، مع إتخاذ إجراءات فورية بتسوير المطمر القديم

Abbreviations

CBS	:	Central Bureau of Statistics
EPR	:	Extended Polluter Responsibility
ISWM	:	Integrated Solid Waste Management
KSCP	:	Khartoum State Cleaning Project
LFG	:	Landfill Gas
MSW	:	Municipal Solid Waste
NGO	:	Non Government Organization
PPP	:	Polluter Pays Principle
PVC	:	Polyvinylchloride
SWM	:	Solid Waste Management
SWMS	:	Solid Waste Management System
UNEP	:	United Nations Environment Programme
WHO	:	World Health Organization

1. INTRODUCTION

1.1Background Information

Solid waste, especially Municipal Solid Waste (MSW), is a growing problem in Khartoum City and this problem is aggravated due to inefficient solid waste management systems currently practiced in the City. At present in many instances solid waste are collected in mixed state and being dumped with very little environment protection measures causing negative environmental impacts such as ground and surface water pollution and air pollution. Further, the open dumps of solid waste are ideal places for breeding of disease vectors like mosquitoes.

The rate of generation of solid waste in the society is increasing with the increase of population, technological development, and the changes of the life style of the people.

The number of Khartoum State population, according to 1993 census was 2,918,000 inhabitants distributed in Khartoum, Omdurman and Khartoum North as following: 947,000 in Khartoum, 1,271,000 in Omdurman and 700,000 in Khartoum North. According to the Central Bureau of Statistics the estimated population of Khartoum State in 2008 is around 6 million inhabitants, while other NGO's estimate 8 million inhabitants in 2008.

According to the World Bank Technical Paper No. 30 (1987), the waste generation rate for low income countries is 0.4 – 0.6 kg/cap/day. In this respect, the amount of household waste produced in Khartoum State every day is about 3,600 tons.

Regardless of other types of waste produced in Khartoum State, the amount of household waste causes problems for the concerned officials in the municipality. It is worth mentioning that Khartoum State launched in 2002 a Project responsible for collection, transport and disposal of solid wastes.

Waste is an unwanted or undesired material or substance. It is also referred to as rubbish, trash, garbage, or junk depending upon the type of material and the regional terminology. In living organisms, waste relates to unwanted substances or toxins that are expelled from them.

Waste in the Basel Convention of 1997 defined as "substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provision of national law".

Solid waste can be defined as material that no longer has any value to the person who is responsible for it, and is not intended to be discharged through a pipe. It does not normally include human excreta. It is generated by domestic, commercial, industrial, healthcare, agricultural and mineral extraction activities and accumulates in streets and public places. The words “garbage”, "trash", "refuse" and "rubbish" are used to refer to some forms of solid waste.

The term municipal solid waste is used for all waste collected and disposed of by or on behalf of a local authority and typically consists mainly of household waste and commercial waste. It may also include street sweepings, gully empting waste, and construction and demolition waste from local authority sources.

It is critical to adopt a broad approach in developing a working framework for solid waste management (SWM). This covers the social, economic, technology, political and administrative dimensions. For example the social dimension of SWM involves waste minimization; the economic dimension of SWM involves waste recycling; the technology dimension of SWM involves waste disposal; and the political and administrative dimensions cuts across all the three issues of minimization, recycling and disposal.

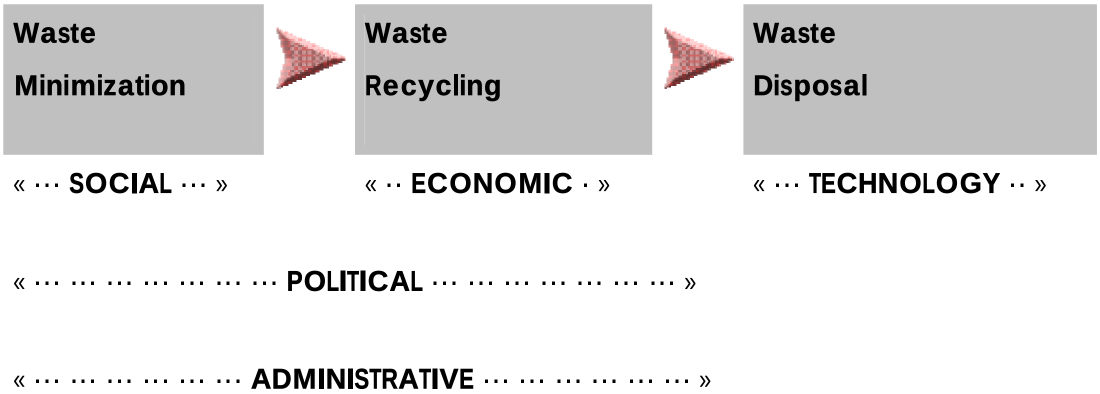


Figure 1.1: Framework for Solid Waste Management

Most local governments and urban agencies have, time and again, identified solid waste as a major problem that has reached proportions requiring drastic measures. We can observe three key trends with respect to solid waste - increase in shear *volume* of waste generated by urban residents; change in the *quality* or make-up of waste generated; and the *disposal* method of waste collected, by land-fill, incineration etc.

Objectives

General objective:

To assess solid waste management in Khartoum locality.

Specific objectives:

1. To identify solids waste treatment practices.
2. To assess preventive measures in the old and the new landfill sites in west of Omdurman in relation to gas and leachate management.

2. LITERATURE REVIEW

2.1 Definitions

Waste management:

Waste management is the collection, transport, processing, recycling or disposal of waste materials. The term usually relates to materials produced by human activity, and is generally undertaken to reduce their effect on health, aesthetics or amenity. Waste management is also carried out to reduce the materials' effect on the environment and to recover resources from them. Waste management can involve solid, liquid or gaseous substances, with different methods and [illegible] h.

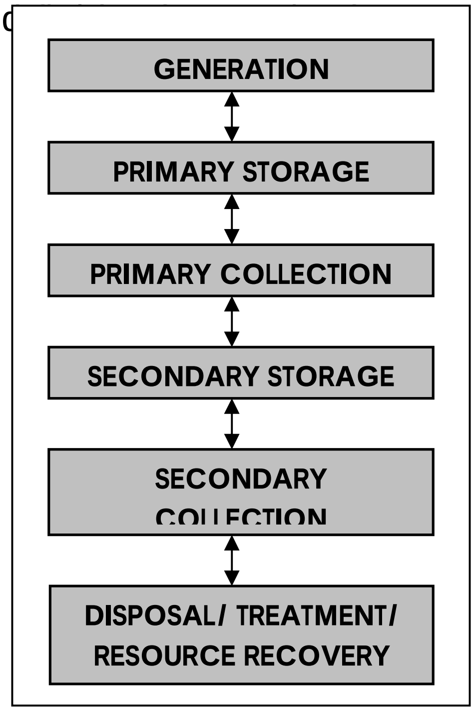


Figure 2.1: Stages of Solid Waste Management

Integrated solid waste management:

Integrated Solid Waste Management (ISWM) is a frame for designing and implementing new waste management systems and for analyzing and optimizing existing systems. It is based on the idea that all aspects of the waste management system should be analyzed together as they are in fact interrelated and they affect each other.

Integrated Solid Waste Management (ISWM) is a comprehensive waste prevention, recycling, composting, and disposal program. An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions. The major ISWM activities are waste prevention, recycling and composting, and combustion and disposal in properly designed, constructed, and managed landfills. Each of these activities requires careful planning, financing, collection, and transport.

Hazardous waste:

Hazardous waste is waste or a combination of wastes that pose a substantial present or potential hazard to humans or other living organisms because such wastes are non degradable or persistent in nature, they can be biologically magnified, they can be lethal, or they may cause detrimental cumulative effects.

2.2 Nature of Municipal Solid Waste

The nature of municipal solid waste varies from region to region. The nature and abundance of the solid waste in a region is not only a function of the living standard and lifestyle of its inhabitants, but also of the abundance and type of the region's resources and degree of industrialization. Commonly the following types of waste can be identified within an urban context:

- Domestic refuse (household waste)
- Trade and office refuse (commercial waste)
- Hospital waste
- Industrial waste
- Hazardous waste
- Garden and park waste
- Street sweepings
- Building and demolition waste

2.3 Risks and problems associated with solid wastes

If solid wastes are not managed properly, there are many negative impacts that may result. Some of the most important are mentioned in the following list. The relative importance of each depends very much on local conditions.

- Uncollected wastes often end up in drains, causing blockages which result in flooding and insanitary conditions.

- Flies breed in some constituents of solid wastes, and flies are very effective vectors that spread disease.
- Mosquitoes breed in blocked drains and in rainwater that is retained in discarded cans, tires and other objects. Mosquitoes spread disease, including malaria and dengue.
- Rats find shelter and food in waste dumps. Rats consume and spoil food, spread disease, damage electrical cables and other materials and inflict unpleasant bites.
- The open burning of waste causes air pollution; the products of combustion include dioxins which are particularly hazardous.
- Aerosols and dusts can spread fungi and pathogens from uncollected and decomposing wastes.
- Uncollected waste degrades the urban environment, discouraging efforts to keep streets and open spaces in a clean and attractive condition. Solid waste management is a clear indicator of the effectiveness of a municipal administration - if the provision of this service is inadequate large numbers of citizens (voters) are aware of it. Plastic bags are a particular aesthetic nuisance and they cause the death of grazing animals which eat them.
- Waste collection workers face particular occupational hazards, including strains from lifting, injuries from sharp objects and traffic accidents.
- Dumps of waste and abandoned vehicles block streets and other access ways.

- Dangerous items (such as broken glass, razor blades, hypodermic needles and other healthcare wastes, aerosol cans and potentially explosive containers and chemicals from industries) may pose risks of injury or poisoning, particularly to children and people who sort through the waste.
- Heavy refuse collection trucks can cause significant damage to the surfaces of roads that were not designed for such weights.
- Waste items that are recycled without being cleaned effectively or sterilized can transmit infection to later users. (Examples are bottles and medical supplies.)
- Polluted water (leachate) flowing from waste dumps and disposal sites can cause serious pollution of water supplies. Chemical wastes (especially persistent organics) may be fatal or have serious effects if ingested, inhaled or touched and can cause widespread pollution of water supplies.
- Large quantities of waste that have not been placed according to good engineering practice can slip and collapse, burying and killing people.
- Waste that is treated or disposed of in unsatisfactory ways can cause a severe aesthetic nuisance in terms of smell and appearance.
- Liquids and fumes, escaping from deposits of chemical wastes (perhaps formed as a result of chemical reactions between

components in the wastes), can have fatal or other serious effects.

- Landfill gas (which is produced by the decomposition of wastes) can be explosive if it is allowed to accumulate in confined spaces (such as the cellars of buildings).
- Methane (one of the main components of landfill gas) is much more effective than carbon dioxide as a greenhouse gas, leading to climate change.
- Fires on disposal sites can cause major air pollution, causing illness and reducing visibility, making disposal sites dangerously unstable, causing explosions of cans, and possibly spreading to adjacent property.
- Former disposal sites provide very poor foundation support for large buildings, so buildings constructed on former sites are prone to collapse.

2.4 Waste Management Concepts

There are a number of concepts about waste management which vary in their usage between countries or regions. Some of the most general, widely-used concepts include:

- **Waste hierarchy** - the waste hierarchy refers to the "3 Rs" reduce, reuse and recycle, which classify waste management strategies according to their desirability in terms of waste minimization. The waste hierarchy remains the cornerstone of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

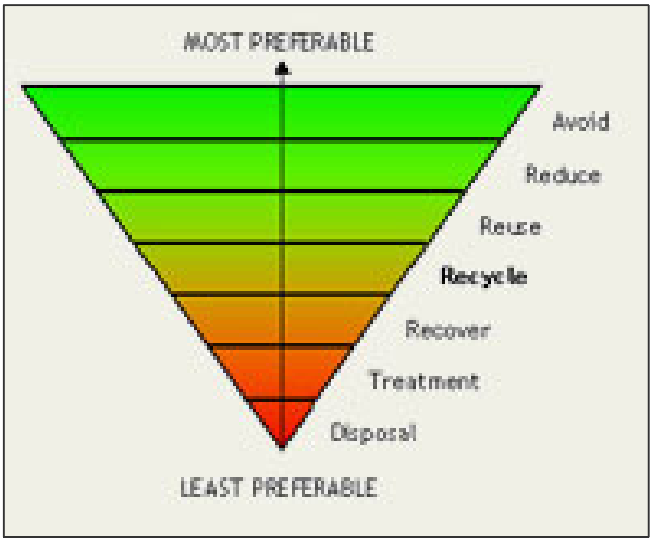


Figure 2.2: Waste Management Hierarchy

- **Extended producer responsibility** - Extended Producer Responsibility (EPR) is a strategy designed to promote the integration of all costs associated with products throughout their life cycle (including end-of-life disposal costs) into the market price of the product. Extended producer responsibility is meant to impose accountability over the entire lifecycle of products and packaging introduced to the market. This means that firms which manufacture, import and/or sell products are required to be responsible for the products after their useful life as well as during manufacture.

- **Polluter pays principle** - the Polluter Pays Principle is a principle where the polluting party pays for the impact caused to the environment. With respect to waste management, this generally refers to the requirement for a waste generator to pay for appropriate disposal of the waste.

2.5 Solid Waste Storage, Collection, Transportation and Transfer

2.5.1 General

Storage, collection, transfer and transportation of solid waste are the main elements of any solid waste management system. Proper storage of waste close to the place where it is generated prevents offending aesthetics, attraction of vectors, and reduces odour formation. Storage devices should be convenient for the user and facilitates safe and efficient collection, processing and disposal. On-site or (primary storage) can be classified into:

- Private containers: this refers to all kinds of bags, bins, buckets, etc. that are primarily used to collect and store the solid waste on the household level.
- Communal containers: these may be stationary or portable. Stationary container sites are more labour intensive to clean, whereas the portable container system allows for rapid and efficient solid waste collection per time unit, provided that people co-operate and dump their waste in the container.

Figure 2.3: Typical Examples of Communal Containers

2.5.2 Primary and Secondary Collection

Primary collection is the picking up of solid wastes from all locations where waste is generated and transportation to central places where either portable containers or permanent structures allow for central storage. Commonly this is realized by either municipal, private, or community based organizations. In industrialized countries primary collection is abandoned because of the high cost involved. Efforts are made to ensure public participation in this phase so that municipal services can directly be initiated at secondary collection level.

Secondary collection is the regular (commonly municipal) service to empty communal containers or remove waste from central storage locations, and bring it either to a transfer station or to the final disposal site. It typically involves larger type of vehicles. The efficiency of this secondary collection is largely decided by the effectiveness of primary collection system being involved.

2.5.3 Types of collection:

Communal Collection:

Householders discharge their wastes at pre-fixed communal locations, where storage facilities are available. These communal facilities are collected/ empted at regular time interval.

Block Collection:

A primary collection vehicles travel a pre-determined route at prescribed time intervals and stops at selected well-known locations. The people can be made alert to bring their waste directly into the collection vehicle by ringing a bell.

Kerbside Collection:

The collection crew collects bins, bags and other containers, which are deposited at the kerbside at fixed time intervals, usually on specific days of the week.

Door-to-Door Collection:

The collection crew enters each individual premises, take out the container and return it after emptying.

2.5.4 Frequency of Collection:

The main factors that have direct bearing on the optimal frequency of collection are:

- Characteristics of the waste.
- Climate.

- System of storage.
- Type of containers provided.
- Unit collection cost.

2.5.5 Collection Equipment and Vehicles:

A wide variety of systems and equipment have been developed for use in the solid waste collection. These systems may be classified based on the mode of operation, the driving force used (manual, animal, or fuel powered), the kind of interaction with storage facilities (fixed or portable containers), and to what degree mechanized vehicle compaction is applied.

2.5.6 Transfer Stations:

A transfer station is a place where local refuse collection vehicles discharge their waste without having to travel unnecessary distances to disposal site, thus saving on unproductive crew time, and cutting down from mileage of the individual vehicles. In general transfer takes place from relatively small vehicles (used in primary collection) to large ones, more designed to transport huge quantities over long distances. Transfer and transport operations provide excellent opportunity for material recovery: recoverable materials return to commercial markets or waste-to-energy facilities, while residual materials ultimately enter the disposal site. In general transfer and transport operations are important when haul distances to available processing centres or disposal sites reduce the economically feasibility of small transport vehicles.

Transfer stations may be classified into three types:

Direct loaded transfer stations:

At this type, the wastes from primary collection vehicles are empted directly either into the vehicle used to transport it to the final disposal site, or into facilities to compact the wastes prior to transportation to the disposal site. In some cases the waste may be empted onto an unloading platform where recyclable products are separated, while remaining waste is loaded in the transfer vehicles.

Storage-load transfer stations:

In this type, wastes are emptied directly into storage pit from which they are loaded into transport vehicles by auxiliary equipment.

Combined direct-load and storage-load:

Location of transfer station:

Whenever possible, transfer stations should be located:

1. As close as possible to the weighed

2. Within easy access of major arterial highway routes as well as near secondary roads.

3. Where there will bee marginal public and environmental objection to transfer waste.

4. Where construction and operation is most economical, and

5. Where basic requirement for waste processing operations can be met without difficulty.

2.6 Collection and Recovery

Most commonly solid waste is collected either on a regular house to house basis, or via communal containers. The city layout, population densities, and waste generation rates per specified area, commonly decide on the most cost-effective system of solid waste collection.

Separate collection of valuable recyclable wastes has high collection cost, but it has the following advantages:

- Help to rise awareness among the public at large,
- Enhance resources recovery,
- Improves the quality of the final product after processing.

Items that are commonly worth separating from domestic waste flows are:

- Glass and porcelains
- Rubber and leather items
- Papers and paper
- Bones

products

- Plastic products
- Metals
- textiles
- Wood
- Organic waste
- Construction debris

2.7 Treatment

A wide range of methods exist to process domestic solid waste. Main objective is to minimize its ultimate volume and, where possible, prevent or recover valuable resources.

Aerobic composting:

By exposing organic solid waste for a prolonged period of time to oxygen the aerobic conversion process will rise the temperature of the waste to over 50 – 60 °C, thereby effectively contribute to pathogen destruction, water evaporation and organic matter conversion into a final stable compost fraction. Approximately 30 kWh electricity per ton of waste is required for aeration and periodic mixing/turning (IEA Bioenergy, 1994). Commonly aerobic composting is able to produce 0.4 – 0.6 kg of compost per 1 kg of waste.

Anaerobic digestion:

By exposing the organic solid waste fraction to anaerobic environment for a substantial period of time at elevated temperature and at a high moisture content, the organic slurry can be converted into energy rich biogas. Approximately 100 – 150 kWh electricity can be produced per ton of organic waste input (IEA Bioenergy, 1994).

Aerobic incineration:

By entering domestic solid waste into a furnace with a temperature of at least 1000 °C, and excess oxygen available, the combustible waste is fully incinerated thereby producing heat (can be converted into steam to drive turbines), fly ashes, and inert slag residues. To economize an incinerator plant a minimum throughput of at least 20 – 25 ton per hour is required. Moreover, the caloric value of municipal solid waste should be 10 – 15 MJ/kg to run the incinerator without additional supply of fuel.

Gasification:

Organic matter is under limited oxygen supply at extremely high temperature converted into a mixture of combustible gases. These gases can be purified and be easily distributed to places of high-energy demand where they can be incinerated in gas turbines. The process is extremely difficult to operate and the advantages are not yet offset against conventional incineration.

Pyrolysis:

A rather novel technology in which organic matter is transferred into combustible gases and residues of oil and tear after exposure to 500 – 1000 °C in the absence of oxygen. Finally the gases are incinerated thereby producing electricity. Drawbacks: high cost, low energy conversion efficiency, and existing technical problems.

Immobilization:

Highly contaminated waste fractions with radioactive or toxic compounds (such as fly ashes from incinerator plants) can be immobilized by encapsulation in inert material and be disposed of. Alternatively these waste fractions can be heated together with calcium carbonate. They form an inert glass type of structure, which is highly impermeable and which can serve as additive in road construction material.

2.8 Final disposal

Sanitary landfills:

Landfills are simple and cheap for waste disposal. However, the increasing land cost and the degree at which groundwater pollution, air emissions, and other nuisance have to be controlled may increase the cost of disposal. Landfills are grouped into three general categories:

- Open dumps

- Controlled dumps
- Sanitary landfills

Table 2.1 below summarizes the characteristics, advantages and disadvantages of each type.

Table 2.1: Key Characteristics of MSW Landfill

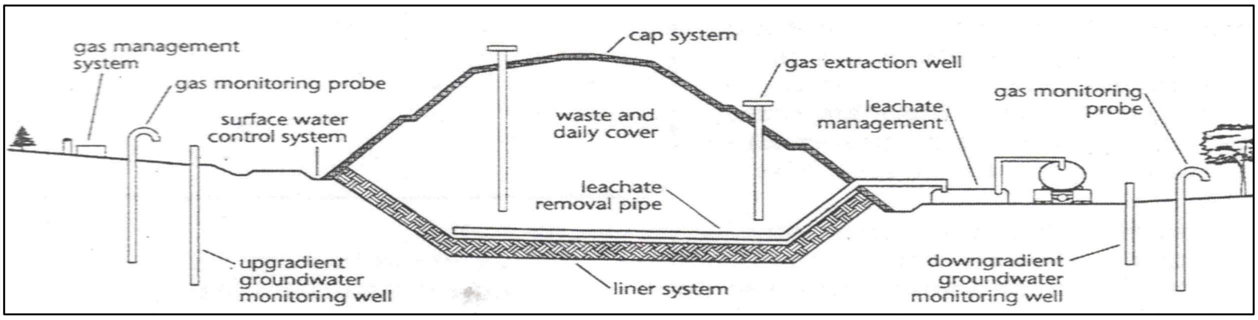
Type	Characteristics	Advantages	Disadvantages
Open dump	◆poorly sited ◆unknown capacity ◆no cell planning ◆little or no site preparation ◆no leachate* management ◆no gas management ◆only occasional cover ◆no compaction of waste ◆no fence ◆no record keeping ◆waste picking and trading	◆easy access ◆"extended" lifetime ◆low initial cost ◆low initial cost ◆low initial cost ◆low initial cost ◆low initial cost, aerobic decomposition ◆low initial cost, aerobic decomposition ◆low cost, access to waste pickers ◆low initial cost ◆materials recovery, income	◆envtl contamination ◆overuse, many noxious sites ◆envtl contamination ◆unsightly, needs remediation ◆gw and sw contamination ◆risk of explosion, GHGs ◆vectors/disease, unsightly ◆shorter lifetime, little ◆indiscriminate use, vermin ◆no record of landfill content ◆least efficient for mat. rec.
Controlled dump	◆sited wrt hydro-geology ◆planned capacity ◆no cell planning ◆grading, drainage in site prep ◆partial leachate mgmt ◆partial or no gas mgmt ◆regular(not usually daily)cover ◆compaction in some cases ◆fence ◆basic record keeping ◆controlled waste picking and trading	◆less risk of envtl contam. ◆permits long-term planning ◆low initial cost ◆easier rainfall runoff, reduced risk ◆moderate cost, reduced risk ◆moderate cost, reduced risk ◆moderate cost, reduced risk ◆extended lifetime ◆controlled access and use ◆valuable information ◆materials recovery, income, lower risk to pickers	◆perhaps less accessible ◆(none) ◆envtl contamination ◆cost ◆cost ◆cost ◆cost, slower decomposition ◆cost ◆cost, maintenance ◆cost ◆harassment, possible displacement of pickers and buyers, loss of recyclable resources
Sanitary landfill	◆site based on EnRA ◆planned capacity ◆designed cell development ◆extensive site preparation ◆full leachate management ◆full gas management ◆daily and final cover ◆compaction ◆fence and gate ◆record volume, type, source ◆no waste picking	◆minimized envtl risk ◆permits long-term planning ◆minimized envtl risk ◆reduced risk at and from site ◆reduced risk from leachate ◆reduced risk from gas ◆vector control, aesthetics ◆extended lifetime ◆secure access, gate records ◆valuable information ◆eliminate risk to pickers	◆access, longer siting process ◆(none) ◆cost ◆cost, preparation time ◆cost ◆cost ◆cost, slower decomposition ◆cost ◆cost, maintenance, staff ◆cost, equipment ◆displacement of pickers and buyers, loss of recyclable resources

* leachate - see Glossary; contam. - contamination; EnRA - environmental risk assessment; envtl - environmental; GHG - greenhouse gas; gw - groundwater; mat. rec. - materials recovery; sw - surface water; wrt - with respect to

Adapted from Tchobanoglous, G., H. Theisen, and R. Eliassen. *Solid Wastes: Engineering Principles and Management Issues*. New York: McGraw-Hill, 1977 and Brunner, D.R. and D.J. Keller. *Sanitary Landfill Design and Operations*. Washington: US EPA, Publication SW-65ts, 1972.

Source: (Coops, O. (1998) Landfill Gas as Energy Source, Grotmij Water and Waste Management, The Netherlands)

Figure 2.5: Typical Schematic of a State-of-the-art Landfill



Source: (Coops, O. (1998) Landfill Gas as Energy Source, Grotmij Water and Waste Management, The Netherlands)

Reuse:

Fly ashes from incinerator plants are commonly used as raw material that can satisfactory be mixed with other construction materials to facilitate road construction, and the establishment of buildings. Compost can serve at the local market as soil conditioner and fertilizer in agriculture if it is not intensively contaminated with in particular heavy metals.

2.9 Selection of Preventive, Processing or Disposal Methods

Selection of the most appropriate methods to deal with MSW, which are cost effective, environmentally sound, and sustainable in the long run, is of continuous concern to municipal authorities. Frequently, the choice is entirely based on the lowest unit disposal cost (U$/ ton. year). However, more and more criteria that has to do with sustainable development such as: prevention of waste generation, cleaner production, maximization of reuse, recovery of valuable materials, and generation of energy in order to save on natural (oil) resources. The city of Michigan (USA) came forward with their innovative solid waste policy management hierarchy. IN their philosophy criteria of sustainable development are to dominate in decision-making, to avoid depletion of scarce resource. Although sanitary landfills might for some time to come remain the most cost – effective disposal method for solid waste.

Some particular factors can be helpful to quickly screen and possibly eliminate methods, which are not suitable or inappropriate for a particular country, region, or location:

1. Waste quantity: solid processing costs are considerably affected by economies of scale. Unless large quantities of solid waste are made available throughout the year incineration is by far too expensive. On the other hand, composting may lend itself particularly suitable to be scaled down to small capacity nits.
2. For landfills: If suitable and cheap landfill sites are not available nearby the city the transport costs will increase substantially. Transfer stations will be required to economize on bulk haulage. Moreover, if suitable cover material is not available on – site to daily cover the solid waste, the additional cost of transporting is over large distances quickly becomes prohibitive.

3. For gasification, pyrolysis and incineration: to economize the installation of an incinerator plant for solid waste a minimum throughput of at least 20 -25 ton/hour (equal to 250.000 ton/ year) is required. Moreover, the caloric value of municipal solid waste should at least be 10 -15 MJ/kg to run the plant without additional fuel. This means that for low – income countries these processes are neither technically, nor economically feasible.
4. For composting: the process is technically feasible if the solid waste contains large fractions of biodegradable material, such as garden, vegetable and fruit wastes (GFT wastes). This typically is the case in low income countries. The economic justification of composting however highly depends on the availability of a local market for its end product : the compost if no financial cost recovery is possible form this compost the process often is economically disfavored over disposal on a sanitary landfill. A major factor deciding on the market value of compost is its degree of contamination.
5. For recycling: in general the economic feasibility depends upon the potential purchasers. Markets must be studied carefully before investing in recovery and recycling. Seeing the typical low percentages of individual waste fractions with potential for separate collection or segregation afterwards it is doubtful whether large scale involvement of municipal corporations is recommendable. It might be better to leave it to the informal sector.

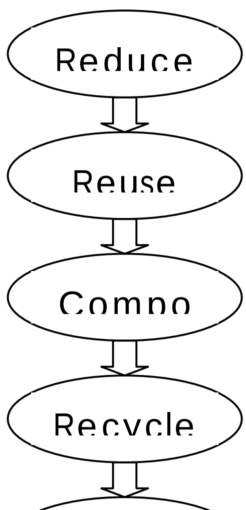


Figure 2.6: Methods to deal with MSW

2.10 Hazardous Waste found in Municipal Solid Waste

Municipal solid waste is largely composed of domestic solid waste and thus seems to be rather harmless. However, this is far from being true. Even domestic wastes contain a substantial chemical or hazardous waste fraction. Many plastic utensils contain heavy metals for colouring purpose (Cd, Hg, Cr or Antimoon). Moreover, many products contain the hazardous PVC (polyvinylchloride).

Properties of waste materials that have been used to assess whether the waste is hazardous are related to safety and health as following:

Safety related properties: Corrosivity, Explosivity, Flammability, Ignitability, and Reactivity.

Health related properties: Carcinogenicity, Infectivity, Irritant (allergic response), Mutagenicity, Toxicity, Radioactivity and Teratogenicity.

3. MATERIALS AND METHODS

3.1 The Study Area

Khartoum locality is a part of capital of Sudan . The city represents the main location for all Government ministries and institution bodies. The best school education is found in Khartoum and the most universities are located in the City. There is no place in the Sudan enjoys better healthcare facilities than Khartoum locality. Most of economic activities and employment opportunities are concentrated also in the locality. As a result of that, the City represents favourable place for permanent residence for the majority of the Sudan's population.

Khartoum locality includes:

- Khartoum sector
- East sector
- West sector
- Middle sector
- Al Shajara sector
- Al Shohada sector

3.1.1 Khartoum State Cleaning Project

In 2002 Khartoum State Cleaning Project (KSCP) was established as a Government Authority responsible for implementation and operation of the waste management system in Khartoum State. Presently, KSCP attained considerable achievements relative to the situation before 2002. However, the drastic increase of population in Khartoum State put extreme pressure on KSCP to operate efficiently. Moreover, lack of strategies, policies, proper planning and treatment methods also affect the efficiency of KSCP's SWMS.

3.1.2 Household Waste Quantities

There are no statistics that show the collected amount from households only. And also there are no statistics that show the all waste generated per day in Khartoum locality.

3.1.3 Household Waste Collection

KSCP collects the Household waste (2 – 3) times per week on the basis of house-to-house collection method. The waste collection vehicles pass in front of each house in the neighborhood, and it is the responsibility of the house resident to catch the vehicle.

3.1.4 Transport of Household Waste

Household waste is transported by vehicles especially designed for this purpose. The waste is transported to collection points within the Municipality. There are two collection points in Khartoum Municipality, they are called Middle Stations or Transfer Stations. The purposes of this Stations is to compact the waste in order to decrease the transport cost to the disposal sites, and to increase the efficiency of the collection vehicles.

3.1.5 Waste Disposal

There is no any treatment method is currently used for the household waste. After waste is being compacted in the Middle Stations, the waste is then transported by special dumpers to the dumping site, which is located in West Omdurman.

3.1.6 New Landfill Site:

In February 2008, a contract has been signed between KSCP and a British company called PECS for the construction and operation of new landfill project located in West Omdurman.

The objectives of the project are as following:

- Safe disposal of municipal solid waste
- Extraction of methane gas
- Utilization of the gas for electricity generation
- Separation and recycling of plastic

3.2 Methodology

To achieve the objectives of this study, the following methodology were applied. Various methods of data collection, quantitative and qualitative analyses through observation, reports, books, articles, interviews and internet were used in this study.

3.2.1 Observation

Data on the various aspects of the solid waste management system were collected in order to analyze the system performance. Such data and information cover all phases of the system; storage, collection, transportation and disposal.

3.2.2 Interviews

Formal and informal interviews were conducted with officials involved in the system. Interviews were made with KSCP officials, Khartoum Locality officials and Transfer Station operators.

3.2.3 Questionnaires

The types of questionnaires applied in the research are conducted with the middle station manager and with the new landfill site operator manager.

4. RESULTS AND DISCUSSION

4.1 Results

4.1.1 Questionnaire (1)

1. The applied system for waste collection from houses is the house to house.
2. The frequency of waste collection form the houses are (2-3) times per week.
3. Days and times of waste collection are not fixed.
4.

(I) the frequency of cleaning and waste collection form large main market are three times per day.

(II) The frequency of cleaning and waste collection from small market is a once per day.

5. The frequency of cleaning and waste collection from main roads is a once per day.
6. The frequency of cleaning and waste collection from large main roads are three times per day.
7. The role of the transfer station in Qoazz is separation and pressing waste.
8. No any separation for any waste component.
9. ……………………………………………………………………

10.The applied type of waste treatment and final disposal method currently being used is the land fill.

4.1.2 Questionnaire (2)

1. The old land fill site

1. The waste will be placed in cells in waste layers which separated by soil layers
2. Waste layer thickness is 3 m
3. Soil layer thickness is (25 - 30) cm
4. The land fill site specification are:

a) The site based on environmental risk assessment [ ]
b) Extensive site preparation [ ]
c) Planned capacity [ ]
d) Designed cell [ ]
e) Daily and final cover [✓]
f) Waste picking [✓]
g) Compaction [ ]
h) Fence and gate [ ]

5. The project features:
   Area = 2 km^2
   Life time = not planned
   Capacity = not planned
6. The project objective is disposal of solid waste
7. There is no any estimate for quantities of gas produced
8. There is no gas collection system.
9. The final emission to the atmosphere is unknown.
10. There is no utilization unit for gases

11. No full leachate management
12. There is no plan about the future uses

2. New land fill site

1. Waste will be placed in the cell in waste layers which separated by soil layers.
2. Waste layer thickness (1.75 - 2) m
3. Siol layer thickness (25 - 30) cm
4. The new land fill site specification
   a. The site based on environmental risk assessment [✓]
   b. Extensive site preparation [✓]
   c. Planned capacity [✓]
   d. Designed cell [✓]
   e. Daily and final cover [✓]
   f. Waste picking [ ]
   g. Compaction [✓]
   h. Fence and gate [✓]

5. The project features are:

Area = 5.14 km^2

Life time = 38 years

Capacity = (2300 - 2500) tones per day.

6. the project objectives are:

(i) safe disposal of locality solid waste.

(ii) extraction of methan gas.

(iii) utilization of the gas for electricity generation

(iv) separation and recycling of plastic.

7. there is no estimation for quantity of gas produced

8. yes

9. the gas will be treat in the flare equipment by combust the extracted and collected gas.

10. the final emission to the atmosphere is un known.

11. there is no any utilization unit for gases.

12. there is no full leachate management .

13. the site will be open yards to all people.

4.2 Waste Quantities and Types:

Estimation of collection waste quantity :-

Waste density = 0.36 ton /m^3 (according to KSCP)

Generated waste = 0.7 kg/ day/ cap

Weight = density x volume

Estimation of collected waste:

Table 4.1 : Amount of collected waste per month (September 2008)

Sector	Volume (m^3)	Weight (ton)
Collected quantity from all sectors	110514	39469.3

Average of collected waste per day = 1315.6 ton

Table 4.2 : Amount of collected waste per month (October 2008):

Sector	Volume (m^3)	Weight (ton)
Collected quantity from all sectors	110689	39531

Average of collected waste per day = $\frac{39531}{31} = 1275.19 ton/day$

The total average of collected waste per day:

$$\frac{1315.6 + 1275.2}{2} = \frac{2590.8}{2} = 1295.4 ton/day$$

There is no any estimation for the all generated waste per day in Khartoum locality.

In a recent study conducted by KSCP, the composition of Khartoum Municipality waste is as shown in table 4.3 below.

Table 4.3: Components of Municipal Waste in Khartoum City

Component	Percentage
Paper	34.40
Plastic	15.30
Organic Matter	32.60
Sand	7.40
Textiles	2.60
Metal	1.70
Glass	3.50
Aluminum	0.05
Khaish	0.15
Wood	0.40
Leather	0.30
Rubber	1.60
Total	**100.00**

Source : KSCP

As shown in table 4.3 above, paper constitute 34.40% of the total amount of waste. This high percentage of paper could be accepted in industrial countries because of the living style in these countries. But for low-income countries such as Sudan the percentage of organic matter should be the highest.

The high percentage of paper in table 4.1 demonstrates that considerable amount of the collected waste in Khartoum City is being collected from streets and markets.

4.3 Waste Collection

The collection dates and times are not known to the residents of the neighborhood. The collection vehicle may come at any date during daytime or during the nighttime. It may also come only once per week, and sometimes may come after one week interval. Therefore the collection from household level is not reliable. Taking into account the unfavorable weather conditions for waste storage at household level, citizens are sometimes forced to dispose their waste in the streets or in the nearest yards to avoid unfavorable odors. This behavior is environmentally risky, where this disposed waste creates breading environment for flies and rats that may seriously affect the public health.

The existing door-to-door collection method is related to the collection frequency. When the collection times are fixed and reliable, this method is efficient. However, this method reduces the productivity of the collection vehicles and hence reduces the efficiency of the whole management system.

Plate 4.1: Improper Waste Disposal Practices in Khartoum locality

4.4 Waste Separation

There is no any waste segregation is being adapted in KSCP management system. However, the waste collection crews informally practice a sort of waste separation. During their collection job, they separate electrical devices, kid's toys, furniture pieces, metal cans, batteries, plastic bottles and other types of waste that may generate additional income for them. They put these wastes in special bags belongs to them, and with prearrangement with the vehicle driver, they stop in certain locations to sell these wastes to what is called waste merchants. The sector of waste merchants is rapidly developing, even some of them have now their private stores to buy and sell these wastes.

4.5 Waste Disposal

Waste generated in Khartoum locality is transported to the old waste dumping site in West Omdurman (40 km from Khartoum). This site is a typical open dump and has the following characteristics:

- Has unknown capacity.
- Has no leachate management.
- Has no gas management.
- There is no compaction of waste.
- There is no record keeping.
- There is no fence, and therefore waste picking and trading is extensively practiced.

Plate 4.2: Waste Pickers at Old dumping site in West Omdurman

The new landfill site, which is located in West Omdurman also, started operations in September 2008. The site has the following features and specifications:

Project features:

- Total area: 5.14 km^2
- Project lifetime: 38 years
- Project capacity: 2300 – 2500 tons per day
- Waste components as per the contract with the British company (PECS) is provided in table 4.4.

Table 4.4: Waste Components for the New Landfill Site

Component	Percentage
Papers	11.80
Plastic	12.70
Organic Matter	49.50
Sand	13.40
Metals	1.70
Glass	3.50
Khaish and cotton	4.60
Wood	0.20
Leather	0.40
Rubber	0.30
Others	1.90
Total	**100.00**

Source : KSCP

Site specifications :

- Cells dimensions 315 × 315 m
- Cell depth 3.2 m below surface

- Total cell height 21 m
- Waste will be placed in the cell in layers. Waste layers shall be compacted and separated by soil layers.
- Waste layer thickness is 1.75 – 2.0 m
- Soil layer thickness is 10 – 20 cm
- No impervious bottom liner underneath the cell
- Cell capacity: one million tons of waste
- Each cell produces gas for ten years
- Distance between vertical gas pipes is 50 m.
- Height of the first pipe is 10 m above ground and is located at 50 m from the beginning of the cell.
- Pipe diameter is 1.0 m.

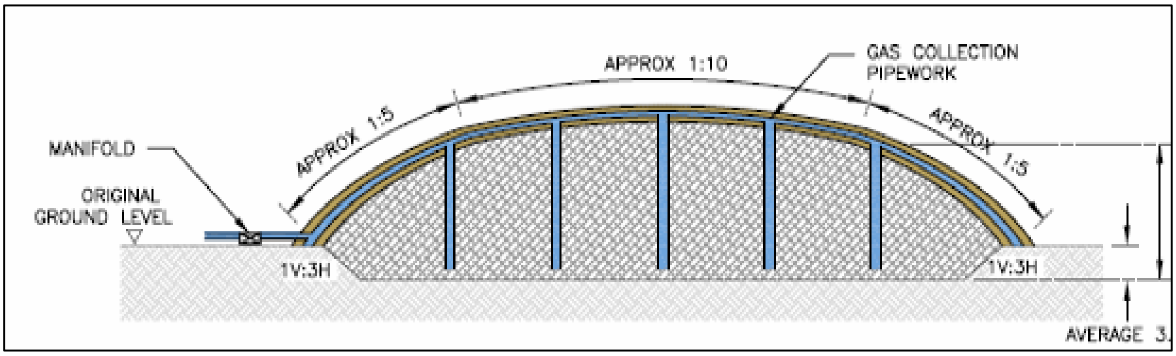


Figure 4.1: Typical Cross Section of the Cell in the New Landfill Site

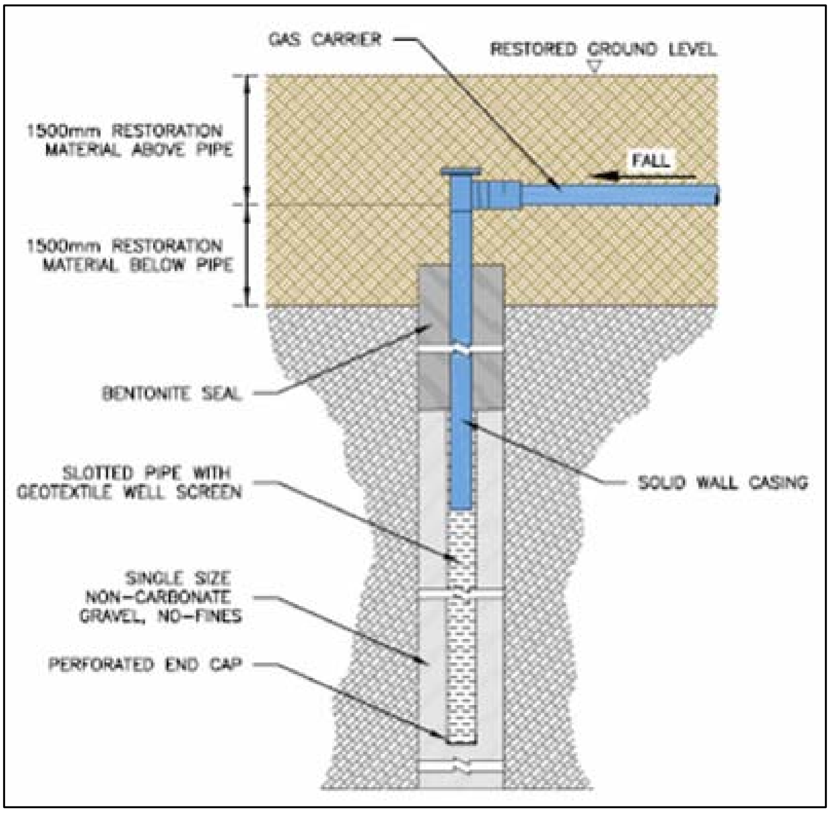


Figure 4.2: Cross section through Gas Well in the New Landfill Site

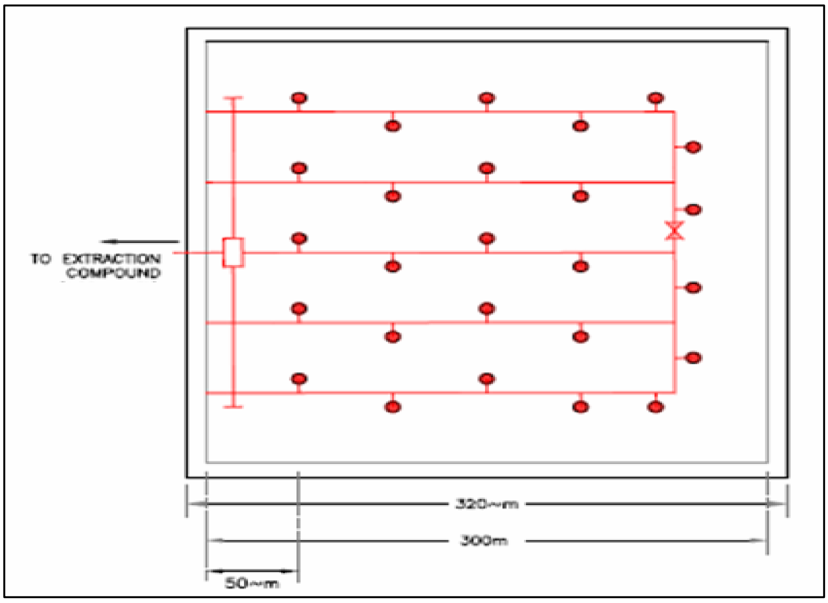


Figure 4.3: Gas Field Layout in the New Landfill Site

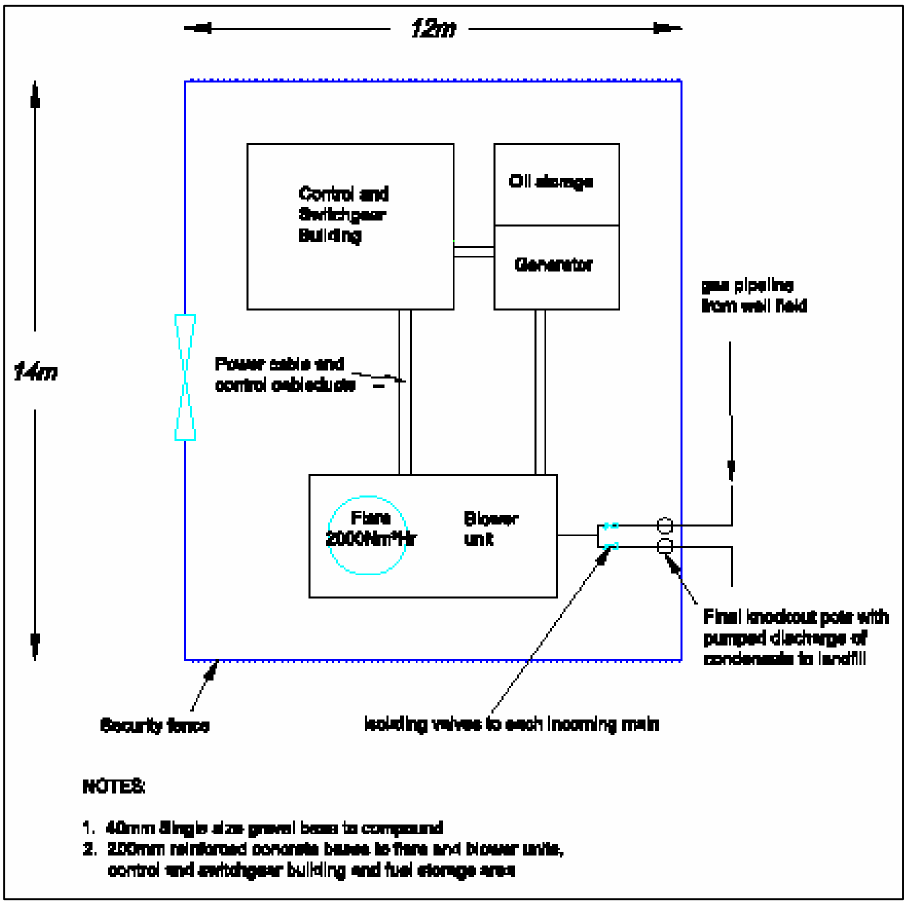


Figure 4.4: Extraction Compound Layout – New Landfill

4.6 Assessment of New Landfill Site

4.6.1 Landfill Gas

Landfilling of organic wastes, such as Municipal Solid Waste, results in anaerobic degradation process in landfill. Gas generated from landfills consists of approximately 60% methane (CH_4) and 40% carbon dioxide (CO_2). 15 – 20% of the landfill material will leave the landfill as gas. The high concentration of methane in landfill gas makes it flammable gas. Without any protection measures, landfill gas may cause several adverse effects to the environment.

The New Landfill Site in West Omdurman includes necessary measures to extract and control the landfill gas. The site was designed to collect and combust the landfill gas. At present, the site does not include utilization unit for energy recovery i.e. production of heat or electricity. The applied gas extraction and combustion system consists of the following components:

- Gas wells in the waste body (figure 4.2)
- Connecting pipework to collect the extracted gas from the wells and to transport the gas to the processing location (figures 4.2 and 4.3).
- Flare equipment to combust the extracted gas (figure 4.4).

The site is therefore being designed properly to extract and combust the landfill gas. However, no information available in regards to the characteristics of the flare equipment, and thus, the final emission to the atmosphere is unknown.

4.6.2 Leachate Control

Leachate management is a key factor in safe landfill design and operation. The natural decomposition of Municipal Solid Waste, in combination with rain infiltration into the site, causes potentially toxic contaminants to flow towards the bottom of the landfill. The wetter the climate, the greater the potential risks of ground and surface water contamination from landfill. The geology of the site can increase or reduce the amount of leachate that enters the environment.

A variety of wastes can contribute contaminants to landfill leachate. Household hazardous waste (eg. Paint products, batteries, garden pesticides, automotive products) and hazardous waste from commercial and industrial generators can release organic chemical contaminants.

The landfill site is therefore should contain engineering features to prevent the release of hazardous substances to the environment. Natural or synthetic materials are often used to line the bottom and sides of landfills to prevent the migration of leachate into near by groundwater and surface water. Many landfills use liners constructed from about one meter of compacted clay. Other liners consist of thin sheets of plastic made from a variety of synthetic materials.

The design of the New Landfill site in West Omdurman does not include any liners (see figure 4.1). KSCP argues that the geology of the area is good enough to prevent leakage of hazardous substances to groundwater. However, if impervious layer does not exist underneath the site, contaminants may pollute surrounding soils in the future.

Plate 4.3: Cells Construction in the New Landfill Site

Plate 4.4: Observation Well constructed at one corner of the New Landfill site

4.6.3 Access to the site

Fencing should be designed to restrict unauthorized access to the landfill and to keep out vermin and stray animals. The fence should be erected along the perimeter of the site. A staffed gate should be the point of entry to the facility for vehicles. Ideally, the gate should be equipped with scales for the weighing of vehicles as they enter the facility/site.

The New Landfill site in West Omdurman is surrounded by a fence to control entry into the site (plate 4.5). The entrance is equipped with scale for weighing quantities of waste entering the site. Such systems provide proper control of the site and also provide necessary information for operational management of the site.

Plate 4.5: Fence of the New Landfill site

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- The amount of generated household waste in Khartoum City is estimated in this study to be more than 1,200 tons per day. KSCP collects 1,000 tons per day from houses, streets and markets. Therefore, KSCP collects maximum 85% of the generated household waste. The remaining amount is being dumped by the citizens into the open environment or being burned in the open environment also.
- Applied system of house-to-house waste collection is not reliable one, as the collection dates and times are often varies from week to another. Citizens are therefore sometimes disposing their waste in the streets or in the nearest yards.
- The establishment of two transfer stations in Khartoum, to compact the waste before transporting to the dumping site, is an advantageous measure in the waste management system

as it decreases the transport cost and increases the efficiency of the collection vehicles.

- Waste generated in Khartoum City is being dumped in either of two dump sites located in West Omdurman. The old site is a typical open dump site with no environment protection measures. The site has no fence and therefore, waste picking and trading is extensively practiced.
- The New Landfill site, which is located in West Omdurman also, is properly designed except the absence of leachate management in the system. The site is fenced and includes weighing scale for vehicles. The site also is equipped with gas collection and combustion equipment, which might facilitate the future utilization of landfill gas.

5.2 Recommendations

The research recommended that is to:

- Establishment of Solid Waste strategies and policies.
- Encouragement of private sector participation in waste recycling. This may require waste separation at household level.
- Enhancement of private sector participation in the waste management system besides enforcement of relevant laws would increase the efficiency of the waste collection, transport and disposal.
- Hospitals waste and hazardous industrial wastes should not be dumped with household waste. They should be treated in special facilities like incinerators.
- One or two observation wells in the New Landfill site are not sufficient to monitor leachate pollution. Additional wells around each cell may be required.

- The old dump site should be fenced immediately to avoid waste picking. The site should be closed as it does not contain any gas or leachate control measures.
- Public awareness is an essential element in the successful of the waste management system.

Questionnaire (1)

1. What is the applied system for waste collection from the houses?

   I. House to house collection[ ]
   II. Block collection[ ]
   III. Communal collection[ ]
   IV. others[ ]

2. What is the frequency of waste collection from the house

   I. (1-2)times /week[ ]
   II. (2-3)times /week[ ]
   III. (3-4)times /week[ ]

3. Are days and time of waste collection fixed?

   I. Yes[ ]
   II. No[ ]

4. What is frequency of cleaning and waste collection from the market?

   I. The frequency from large markets[ ]
   II. The frequency from small markets[ ]

5. What is frequency of cleaning and waste collection from the main roads?

I. The frequency from large roads[ ]
II. The frequency from small roads[ ]

6. What is frequency of cleaning and waste collection from the large main roads?

I. The frequency from large main roads[ ]
II. The frequency from small main roads[ ]

7. What is the role of the transfer station in (Guaz)?

I. Processing of waste[ ]
II. Separation and processing of waste[ ]

8. Is there any separation for some waste component?

I. Yes[ ]
II. No[ ]

9. If the answer for question (8) is yes what is the component that separated?

……
…..

10. What is the applied type of waste treatment and final disposal method currently being used?

I. Land fill[ ]
II. Recycling[ ]
III. Incineration[ ]
IV. Others[ ]

Questionnaire (2)

1. What is the applied method for waste barring?

……………………………………………………………………………..

2. What is the thickness of the waste layer?

……………………………………………………………………………..

3. What is thickness of the soil layer?

…………………………………………………………………………..

4. What is the landfill site separation?

I. The site on environmental risk assessment[ ]
II. Extensive site preparation[ ]
III. Planned capacity[ ]
IV. Designed cell[ ]
V. Daily and final cover[ ]
VI. Waste picking[ ]
VII. Compaction[ ]
VIII. Fence and gate[ ]

5. What are the project features?

I. Area[ ]
II. Life time[ ]
III. Capacity[ ]

6. What are the project objectives?

I. ………………..
II. ………………..
III. ………………..

7. Is there any estimate for quantities of gas produced?

……………………………………………………………………

8. Is there any gas collection system?

I. Yes[ ]
II. No[ ]

9. If the answer for question (8) is yes what is the applied treatment method for collected gases?

…………………………………………………………………………………

10. What is the final emission to the atmosphere?

…………………………………………………………………………………

11. Is there utilization unit for gases in the site?

…………………………………………………………………………….

12. Is there any full leachate management in the site?

…………………………………………………………………………………

13. After closer, what is the future plan?

…………………………………………………………………….

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