Sudan University of Science and Technology

College of Graduate Studies

Energy Production from Landfill Technology Context of Improved Solid Waste and Management in Khartoum State – Sudan

تكنولوجيا إنتاج الطاقة من مكبات النفايات الصلبة في إطار تطوير إدارة النفايات الصلبة في ولاية الخرطوم – السودان

A thesis Submitted in Partial Fulfillment for the Requirements of the Degree of M.Sc. in Environmental Engineering

Submitted by:

Sara Ahmed Mustafa Wedaa

Supervisor:

Dr. Abuelnuor .A. A. Abuelnuor

Co - Supervisor:

Dr. Abusabah Elfatieh Elemam Elnor

October 2019

الإستهلال

قال تعالى:

﴿ قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ ﴾

{ البقرة: ٣٢}

Dedication

I dedicate this research to my mother and father for their endless Love. From an early age they instilled in me a desire to learn and made sacrifices so I would have access to a high quality education. Without their support and guidance I wouldn’t be where I am today. Who I proudly carry his name. He always believes in my abilities, encourages me and supports me. Who taught me that the best kind of knowledge to have is that which is learned for its own sake and was my supporter until my research was fully finished. And my beloved mother is the source of tenderness and the smile of my life. Your prayers are the secret of my success. She was encouraged me attentively with her fullest and truest attention to accomplish my work with truthful self-confidence.

For my brothers and sisters who are the pillars of my life, they are the source of strength, energy, hope and unconditional love.

To my second father; to my dear uncle who has a great heart. He has always been a source of strength, inspiration, support and encouragement to me.

To my friends who are alleviate the suffering of life and fill my world with joy and optimism.

Finally, I dedicate this effort to my colleagues and I hope it adds real and tangible benefit.

Acknowledgment

In the name of God the Merciful Praise is to God for giving me the strength and ability to complete this research.

First and foremost, I am grateful to my Supervisor **Dr. A.A.A Abuelnuor** for guidance, encouragement and advice he has provided me throughout research time. And he allowed me to encroach upon his precious time freely right from the very beginning of this research work and responded to all my questions and queries so promptly. His dynamism, vision, loyalty, motivation and encouragement have inspired me to diligence and hard work and his help invaluable by comments, suggestions, guidance and advice which contributed to the success of this study. He also taught me the methodology of conducting research and presenting research work as clearly as possible.

I would also like to thank the Assistant Supervisor **Dr. Abusabah E. Elemam** for his support, cooperation, generosity, dedication and assistance in facilitating the obstacles encountered during the study period. He did his best to support, conduct and complete this research at his best.

I never forgot those who contributed and supported me in one way or another during this period and with them this research work became easier; they are **Eng. Sadah A. T. Muawad** and **Eng. Ammar Mohammed Ali**. They also gave me moral support, encouragement and unconditional assistance. Grateful to them very much and take this opportunity to say thank you for everything

Abstract

Recently, the world has begun to experience depletion in energy resources and this issue has become a major concern. Sudan faces a problem with limited fossil fuel resources and an increase in waste accumulation as population growth and economic development play an important role in increasing solid waste generation in addition to increasing energy demand. Sudan is one of the most densely populated countries in Africa, with an annual growth of **2%.** We find that about **20%** of the population of Sudan is located in its capital (Khartoum) and its population is about **8** million, according to the census of the current year. Waste is a must-have product and can be a valuable concern or resource that can be used through waste to energy technologies. This study aims to develop the engineering waste dump in the Faculty of Engineering, Sudan University of Science and Technology, which was designed in October **2017** in the form of a trapezoid with dimensions **(2 * 1.75 * 1.4)** to provide a suitable technical solution for both the waste and energy sectors by changing the waste layers and collection tubes Gas, organic waste was used only and then began monitoring landfill gases and measuring the methane content that can be produced from the total landfill gases. Periodically moisturizing of the landfill was carried out. Water is considered an auxiliary factor for the bacteria responsible for the production of methane and previous studies prove that. A questionnaire was also conducted to analyze and evaluate waste management in Khartoum and to highlight waste dumps in Khartoum and compare them with the standards of engineering landfills. The study proved that the experimental landfill can be an energy source, as the methane ratio reached **68%;** which is a good flammable percentage, and the pH of the landfill was **7.7**; which is suitable for bacterial growth. The study also showed the weakness of the administrative system for collecting, transporting and treating solid waste in Khartoum State and the extent of the existing dumping sites. The study contains recommendations for improving management and technical development of landfills.

المستخلص

في الآونة الأخيرة ، بدأ العالم يعاني من نضوب في موارد الطاقة وأصبحت هذه القضية مصدر قلق كبير. يواجه السودان مشكلة في محدودية موارد الوقود الأحفوري وزيادة في تراكم النفايات حيث يلعب النمو السكاني والتنمية الاقتصادية دورًا مهمًا في زيادة توليد النفايات الصلبة بالإضافة إلى زيادة الطلب على الطاقة. السودان هو واحد من أكثر الدول كثافة سكانية في إفريقيا بنمو سنوي قدره ٢٪ . نجد أن حوالي ٢٠٪ من سكان السودان يقع في عاصمتها (الخرطوم) ويبلغ عدد سكانها حوالي ٨ ملايين نسمة وفقا لتعداد العام الحالي. النفايات هي منتج لابد منه ويمكن أن تكون مصدر قلق أو موردا قيما يمكن استخدامه من خلال تقنيات تحويل النفايات الى طاقة. تهدف هذه الدراسة إلى تطوير مدفن النفايات الهندسي الموجود بكلية الهندسة جامعة السودان للعلوم والتكنولجيا والذي تم تصميمه في اكتوبر عام ٢٠١٧ على شكل شبه منحرف بأبعاد **(٢ * 1,75 * 1,4)** لتوفير حل تقني مناسب لكلا قطاعي النفايات والطاقة عن طريق تغيير طبقات النفايات و انابيب جمع الغاز، وقد تم استخدام النفايات العضوية فقط. ومن ثم بدأت مراقبة غازات المكب وقياس محتوى الميثان الذي يمكن إنتاجه من إجمالي غازات المكب و قد تم اجراء ترطيب دوري للمكب ؛ فالماء يعتبر عامل مساعد للبكتريا المسؤولة من انتاج الميثان والدراسات السابقة تثبت ذلك. كما تم إجراء استبيان لتحليل وتقييم إدارة النفايات في الخرطوم وتسليط الضوء على مكبات النفايات بالخرطوم ومقارنتها بمعايير المكبات الهندسية. وقد اثبتت الدراسة ان المكب التجريبي الذي تم تطويره يمكن ان يكون مصدر للطاقة حيث بلغت نسبة الميثان ٦٨% وهي نسبة جيدة قابلة للاشتعال وكان الوسط الهيدروجيني للمكب **7,7** و هو مناسب لنمو البكتريا. كذلك أوضحت الدراسة ضعف النظام الإداري لجمع و نقل و معالجة النفايات الصلبة في ولاية الخرطوم ومدى سوء المكبات الموجودة. و أخيرا تحتوي الدراسة على توصيات لتحسين الإدارة والتطوير التقني لمدافن النفايات.

Table of Contents

List of Figures

List of Tables

LIST OF ABBREVIATIONS

MSW: Municipal Solid Waste

MSWM: Municipal Solid Waste Management

ISWM: Integrated Solid waste management

WTE: Waste-To-Energy

LF: Landfill

LFG: Landfill Gas

APER: Air pollution emissions report

LDCRS_S : Leachate detection, Collection and Removal Systems

COD: Chemical oxygen demand

BOD: Biochemical oxygen demand

BOD_5: Five-day carbonaceous or nitrification-inhibited BOD

pH: Power of Hydrogen

FML: Flexible Membrane Liners

BOM: Biodegradable organic matter

CERMS: Continuous emissions rate monitoring system

CAA: Clean Air Act

HDPE: High Density Polyethylene

PVC: Polyvinyl Chloride

CMP: Corrugated Metal *Pipe*

CSPS_S: Concentrated solar power systems

PV: Photovoltaic

AD: Anaerobic digestion

VFA: Volatile fatty acid

$NMOC_S$: Non-methane organic compounds

IPCC: Intergovernmental Panel on Climate Change

3RS: Reuse, Reduction, Recycling

EPA: Environmental Protection Agency

Chapter one

Chapter one

Introduction

1.1 Background:

Energy is essential to human life and must be safely accessed through various energy supplies. We note that the most common is the continuous use of fossil fuels to meet multiple life challenges, resulting in difficulties in supply and depletion of energy resources and the emergence of severe environmental impacts such as ozone depletion, global warming, climate change and other environmental concerns due to greenhouse gas emissions according to Air pollution emissions report (APER) reports. as well as the outbreak of geopolitical and military conflicts and the continuous rise in fuel prices, These problems indicate an unsustainable energy situation (Asif and Muneer, 2007, Pérez-Lombard et al., 2008). The solutions to the environmental problems we face today require sustainable long-term actions for sustainable development. In this regard, renewable energy resources seem to be one of the most effective and effective solutions, and for this reason there is a close relationship between renewable energy and sustainable development (Dincer, 2000). Renewable energy is the answer to the challenges of growing energy. Renewable energy resources such as solar, wind, biomass, wave and tidal energy are plentiful, inexhaustible and environmentally friendly (Asif and Muneer, 2007). Renewable energy provides us with an alternative source of clean energy in different ways and techniques; one of these sources comes from everyday human activities such as municipal solid waste (MSW) (Omar and Rohani, 2015). Waste is a must, and one of the greatest challenges for future generations is waste management in a sustainable way. One method was to reduce the amount of waste generated and to recycle large volumes of waste. However, there is still a large part of the unwanted end products to be taken care of, and a more appropriate solution should be found from the simple landfill. The waste management sector faces a problem that it cannot solve alone. On the other hand, we find the importance of energy saving due to the need to meet the continuous and increasing demand. Waste is now not only an undesirable product of society, but it is also a source of energy. Waste recovery can solve two problems at once: processing waste after recycling and non-reuse; generating a large amount of energy that can be included in the mix of energy production in order to meet the needs of consumers. The interaction between waste management solutions and energy production techniques can vary greatly, depending on social, economic and environmental criteria and constraints. Different countries around the world choose different strategies, so these differences can have an impact on energy security and environmental sustainability.

If we follow the principles of sustainability and the implementation of waste to energy (WTE) technologies that enable us to provide a sound waste management strategy and produce environmentally friendly energy at the same time and thus solve the challenges in both waste management and energy sectors (council, 2016). Solid waste is defined as undesirable materials, such as cans, bottles, food residues, newspapers, equipment, batteries, dyes, etc. Rapid growth in solid waste makes managing it a major concern and challenge worldwide. Dealing with them as a source of concern may lead to a real crisis (Arıkan et al., 2017, Ekmekçioğlu et al., 2010). Solid waste management is an integral part of every human community. Solid waste management practices must be compatible with the nature of any community (Shekdar, 2009). The key step towards an environmentally sound integrated management system is to reduce waste generation levels (Beyene et al., 2018). Waste landfills have played a key role in solid waste management and are expected to remain the most important component of the waste management system. The implementation of the waste management hierarchy of waste avoidance through reuse and recycling, energy recovery, treatment, containment and final waste disposal has led to significant conversion (Victoria, 2001). The technologies used to convert waste into energy are thermal convergence methods (combustion, pyrolysis, gaseous), biological treatment and landfill. The main products of these technologies are electricity, heat, fuel gases.... etc. (Beyene et al., 2018). The most common method in the industrialized world is the landfill relative to the low cost of its implementation and operation, provided that it is operated properly (Endalew and Tassie, 2018, Khan, 2011).
Solid waste is buried in the landfill as layers of dirt in a way that reduces pollution of the surrounding land. The dumps should be lined up with layers of absorbent materials and plastic sheeting to prevent contaminants from leaking in soil and water and known as a sanitary landfill (Masood, 2013, Reno, 2016). Landfill gases, mainly methane, are produced through anaerobic degradation of organic waste. Methane is one of the strongest greenhouse gases and waste landfills are one of the main sources of methane in the atmosphere (Scheutz et al., 2009). Methane production from sanitary landfills through anaerobic digestion of energy crops and organic waste would benefit in providing clean fuels from renewable raw materials. Replaces energy derived from fossil fuels and thus reduces environmental impacts such as global warming and acid rain. It is difficult to find accurate figures on the number of plants implemented worldwide because only a few countries have centralized data on landfill gas projects (Masood, 2013). One of the main advantages of landfills is the simplicity of implementation and operation as well as the ability to adapt to fluctuations in the quantity or composition of waste (Chandrappa and Das, 2012). According to this feature, the landfill is the process used in this study to treat solid waste.

1.2 Problem statement:

Energy supply has become the basic demand of humankind for cooking, heating, manufacturing, generating electricity and transportation. Sudan has been suffering from an oil crisis after its separation into two countries since 2011 although there are many renewable energy sources in Sudan. Khartoum is known for its rapid population growth and industrial development, with a population of about 8 million persons by this year. This leads to an increase in energy demand as well as an increase in waste generation, with municipal solid waste reaching 1,984,074 tons annually (P. Failler, 2016) . They are the most important problems facing the state of Khartoum, and thus the waste to energy is the solution to both problems.

1.3 Objectives of the study:

Objectives of the study are:

- To develop the landfill tests rig in faculty of engineering Sudan University of science and technology.
- To estimate of LFG potential gases by measuring experimental landfill gases.
- To analysis of current trends in waste management and assessment of the efficiency of the driving forces of the waste sector in Khartoum.

1.4 Significance of the study:

The importance of the study lies in analyzing and assessing current waste management trends in Khartoum State and seeking to improve them. The study also explains the importance of recovering energy from waste through landfills, thereby reducing the dangerous emissions from burning fossil fuels. Waste is a renewable resource and converted into energy that helps solve waste problems and increase energy demand while reducing the environmental impact.

1.5 Scope of the study:

The study focuses specifically on the transfer of waste to energy through landfill technology, where organic waste was used only within the landfill cell.

In general, the study shed light on waste management in Khartoum state and tries to improve it.

Chapter two

Chapter two

Literature Review

2.1 Introduction:

Energy can generally be defined in several ways; energy is the ability of a person, animal, or physical system (machine) to do work and make a difference. It can also be used to describe anyone who does active things like running, talking, and acting in a vital way (CHANDRAKAR).

Today, energy is an essential requirement for almost all economic activities and has become a priority for improving life. In fact, all infrastructures depend mainly on energy. The energy consumption of the genome reflects the index for its development. Around 24 per cent of the world's energy consumed is used for transport, 40 per cent for industries, 30 per cent for domestic and commercial purposes, and the remaining 6 per cent for other uses, including agriculture. There is considerable variation between developed, industrialized and developing countries in their energy consumption. About 2 billion people, a third of the world's population living in developing countries, lack access to adequate energy supplies. Three billion people rely on fuel wood, coal, coal, manure, kerosene, etc. for cooking and heating. On the other hand, industrialized countries, which comprise only 25% of the world's population, account for 70% of commercial energy consumption (Spellman, 2018).

2.2 Sources of Energy:

Energy sources are classified as Conventional and Non-conventional sources:

2.2.1 Conventional Sources of Energy:

Conventional sources of energy are **non-renewable** sources of energy in general (CHANDRAKAR). Those have been used for several decades and have been widely used - for example, fossil fuels, nuclear resources, and hydropower (Khan, 2006). These energy sources are widely used in a way Depleted its well-known reserves. At the same time, it has become increasingly difficult to discover and exploit their new deposits. It is expected to run out of the known deposits of oil in our country in the coming decades (CHANDRAKAR). In relation to the negative effects associated with fossil fuels to the environment, most countries began to search for environmentally friendly alternatives and renewable to maintain the growing demand for energy (Solangi et al., 2011).

2.2.2 *Non-Conventional Sources of Energy:*

Non-Conventional Sources are **Renewable sources** such as biofuels, solar, photovoltaic, wind, and hydro, wave, tidal and geothermal. These sources do not cause environmental pollution. Moreover, it does not require excessive expenses (CHANDRAKAR).

2.3 *Renewable energy:*

Renewable energy is the energy produced by energy sources that are constantly renewed by nature such as the sun, wind, water, heat of the earth and plants. Renewable energy technologies convert these types of fuels into often usable forms of energy, such as electricity, but also in heat, chemicals, or mechanical energy. Fossil fuels are often used to heat homes and refuel cars.. It is convenient to use coal, oil and natural gas to meet our energy needs, but these supplies are limited and with their continued use will run out over time as well as environmental concerns as greenhouse gases are produced from burning fossil fuels and released into the atmosphere, thus blocking the sun's heat and contributing to global warming. Climate scientists generally agree that the average temperature of the Earth has risen in the last century. If this trend continues, sea levels will rise, and scientists predict that floods, heat waves, droughts and other harsh climatic conditions may occur frequently. Other pollutants are released into the air, soil and water when burning fossil fuels. These pollutants have a significant impact on the environment and on humans. Air pollution contributes to diseases such as asthma. Acid rain caused by sulfur dioxide and nitrogen oxides damages plants and fish. Nitrogen oxides also contribute to smog. Renewable energy will also help us to develop energy independence and security. Renewable energy technologies are called "clean" or "green" because they do not produce pollutants and therefore conform to the Clean Air Act (CAA) (Tromly, 2001). Most renewable energy investments are spent on materials, manufacturing, construction and maintenance, not expensive energy imports. This means that your energy dollars remain at home to create jobs and feed local economies, rather than going abroad (Lovins, 1976). And are available throughout the year through a one-time investment, we can attract energy for decades without affecting the environment (Alrikabi, 2014). The advantages and disadvantages of various energy sources are shown in table (2.1).

Table (2.1): Advantages and disadvantages of various energy sources (CHANDRAKAR)

No	Energy Source	Type of energy source	Advantages	Disadvantages
1	Coal	Conventional Non-renewable	• Extensively available • Efficient Conversion to	• Polluting source • Bulky to transport

			electricity	
2	Oil and Natural Gas	Conventional Non-renewable	• Easier to transport (tankers) • Basis of petrochemical industry • Easier to transport (Pipelines) • Cleaner than oil and coal • Cheaper than oil	• Depletion of oxygen due to oil spillage and gas leakage • Pollutants released causes acid rain • Exploration of new fuel is not easy
3	Fire wood	Conventional Non-renewable	• Easy access • Provides energy to a large number of people	• Collection is time consuming • Polluting • Promoting greenhouse effect • Deforestation
4	Hydro-power	Conventional Renewable	• Non-polluting • Promotes irrigation and fishing • Cheap	• Displacement of local community • Inundates low • Expensive to setup
5	Nuclear energy	Conventional Non-renewable	• Emits large amount of energy	• Generates radioactive waste • Expensive
6	Solar energy	Non-conventional Renewable	• Inexhaustible • Non-polluting	• Expensive • Diffused source, so gets wasted

7	Wind energy	Non-conventional Renewable	• Non- polluting • Low cost production of electricity once setup • Safe and clean	• Noise pollution • Wind mills costly to setup • Disturbs radio and TV reception • Harmful to birds
8	Tidal energy	Non-conventional Renewable	• Non-polluting • Inexhaustible	• Destroys wildlife habitat • Difficult to harness
9	Geothermal energy	Non-conventional Renewable	• Clean eco-friendly and always available	• Located far away from cities and so costly to transport the electricity
10	Bio gas	Non-conventional Renewable	• Low cost • Easy to operate • Make use of bio waste	• Some of its production method Generate greenhouse gases

2.3.1 Examples of Renewable energy resources:

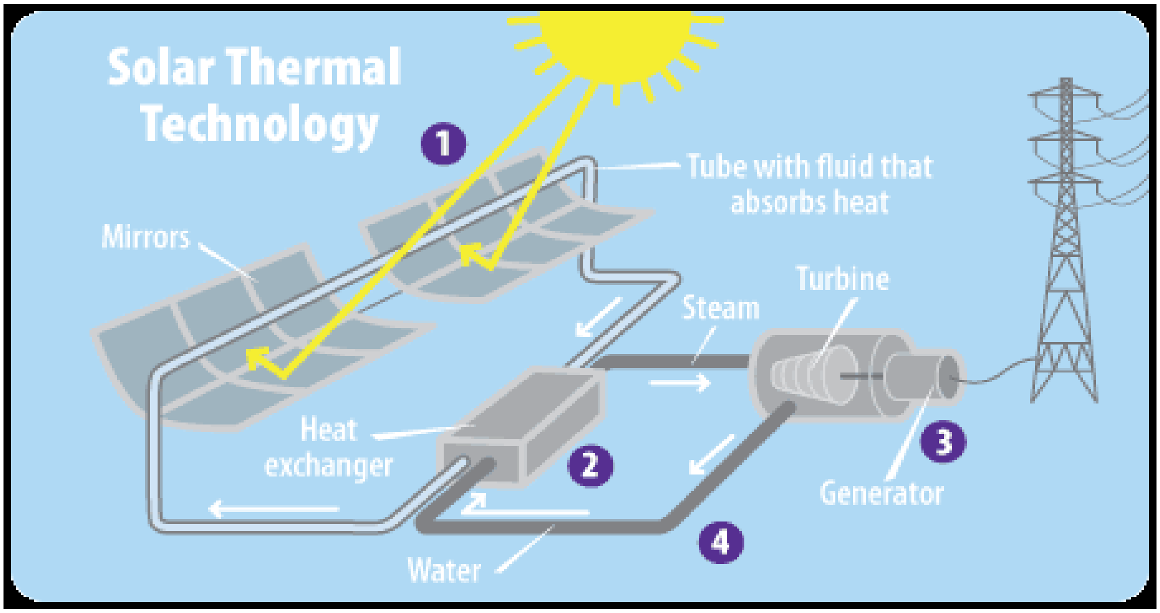
2.3.1.1 Solar Energy:

The sun is the largest source of energy on the Earth is the most abundant energy sources where all other sources of energy derive their strength from the sun. Solar energy can be used directly or indirectly for human well-being. Directly used solar energy is radioactive energy, while indirect is obtained from materials such as biomass, where radioactive solar energy is integrated from plants (CHANDRAKAR).

Solar energy is generated by certain techniques, such as the use of solar energy to provide hot water through solar thermal systems or electricity through photovoltaic (PV) and concentrated solar power systems ($CSPS_S$). These techniques have proven their technical feasibility through many proven systems around the world over the past few decades (Byrne et al., 2010).

Worldwide solar energy is equivalent to approximately 15 days of energy stored in all known reserves of fossil fuels on earth. Continuous input from the sun increases by 1.600

times the current consumption. Many countries are now making more efforts to harness solar energy for domestic, commercial or industrial purposes. Solar energy can also be used for direct heating or heat conversion to electricity to generate thermal electricity. Photovoltaic cells, solar cells and solar batteries convert solar energy directly into electricity (CHANDRAKAR). As shown in figures (2.1) and (2.2).



Fig(2. 1): Solar Energy **(CHANDRAKAR)**

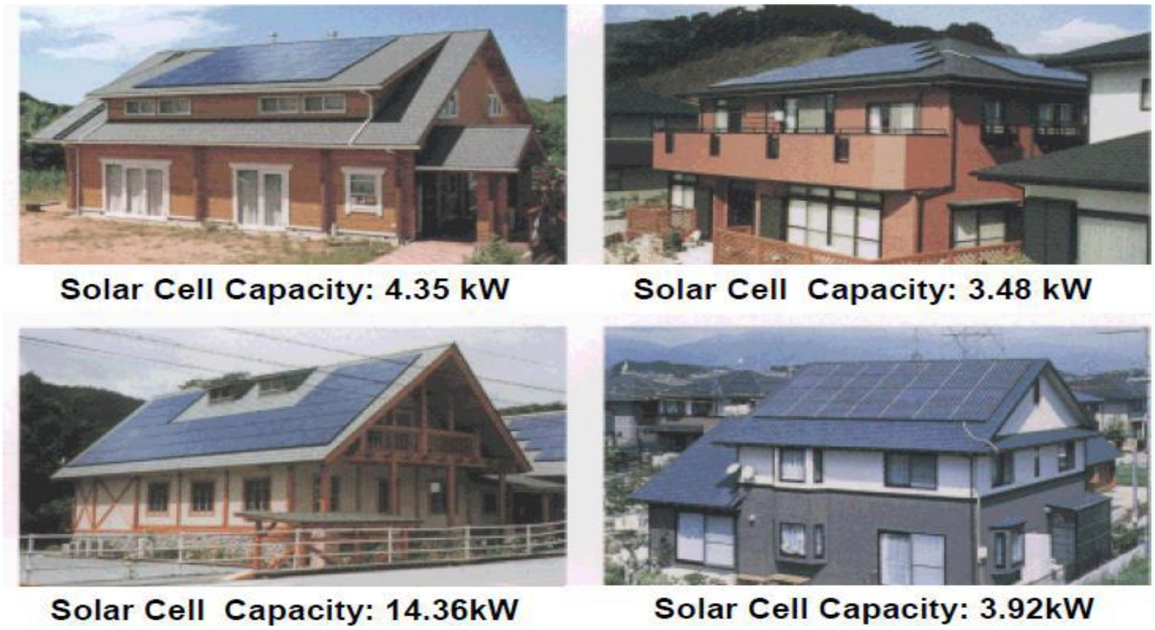


Fig (2. 2): Solar cells in homes **(Ford, 2011)**

2.3.1.2 Wind Energy:

Wind-driven air in the end can be considered another way to collect energy (Alrikabi, 2014). It meaning that winds are local sources that can help reduces reliance on fossil fuels. Wind is an indirect form of solar energy where it is always replenished by the sun. It is caused by the differential heating of the surface of the earth by the sun (Herbert et al., 2007). Wind turbines operate on cloudy days and rainy season. The location of wind turbines is a very important factor that affects the performance of the machine. Windmills are generally located at the top of the tower at a height of about 30 meters in order to avoid the possibility of disturbances. Windmills operate in the horizontal axis and the vertical axis where the basic mechanics of the two systems are similar.

The wind is converted into mechanical energy and then fed through a transfer to an electric generator.

Wind turbines do not operate in winds less than 13 km per hour. It works better when the wind speed is 22 km per hour. Most current wind turbines are three-blade horizontal axis turbines; they are 15-30 meters in diameter and produce 50-350 kilowatts of electricity. Wind energy produces no air or water pollution, does not contain any toxic or hazardous substances, and poses no threat to public safety (Alrikabi, 2014). It is estimated that about 10 million megawatts of energy are constantly available in the earth's wind (Herbert et al., 2007). As shown in figure (2.3).

Fig (2.3): Wind Energy (Letcher, 2017)

2.3.1.3 *Tidal Power:*

Tides are a large source of renewable energy that can be converted to electricity using proven technology (Baker, 1991). Sea water continues to rise and fall alternately twice a day under the influence of gravitational pull from the moon and the sun. This phenomenon is known as tides. Tidal energy is a form of hydropower that converts tidal energy into electricity. Water turbines are placed in the tidal current, which converts to an electric generator, or a gas compressor that stores energy until needed. Although tides are a source of clean and renewable energy, power generation can have serious environmental effects such as water salinity and sediment movement (CHANDRAKAR).

2.3.1.4 *Geothermal Energy:*

Geothermal energy is found as heat in the ground. Geothermal flow and geothermal energy, as well as geothermal field types, the geological environment of geothermal energy, geothermal energy resource exploration methods including drilling and resource assessment (Barbier, 2002).It is clean and sustainable. Geothermal energy resources range from shallow earth to hot water and hot rocks a few miles underground. Ground heat pumps can benefit from this resource for heating and cooling buildings. The geothermal pump system consists of a heat pump, an air delivery system (air ducts) and a heat exchanger - a system of pipes buried in shallow ground near the building. In the winter, the heat pump removes heat from the heat exchanger and pumps it into the internal air delivery system. In the summer, the process is reflected, the thermal pump moves heat from the internal air to the heat exchanger. Heat from indoor air can also be used during the summer to provide a free source of hot water (Alrikabi, 2014). As shown in figure (2.4).

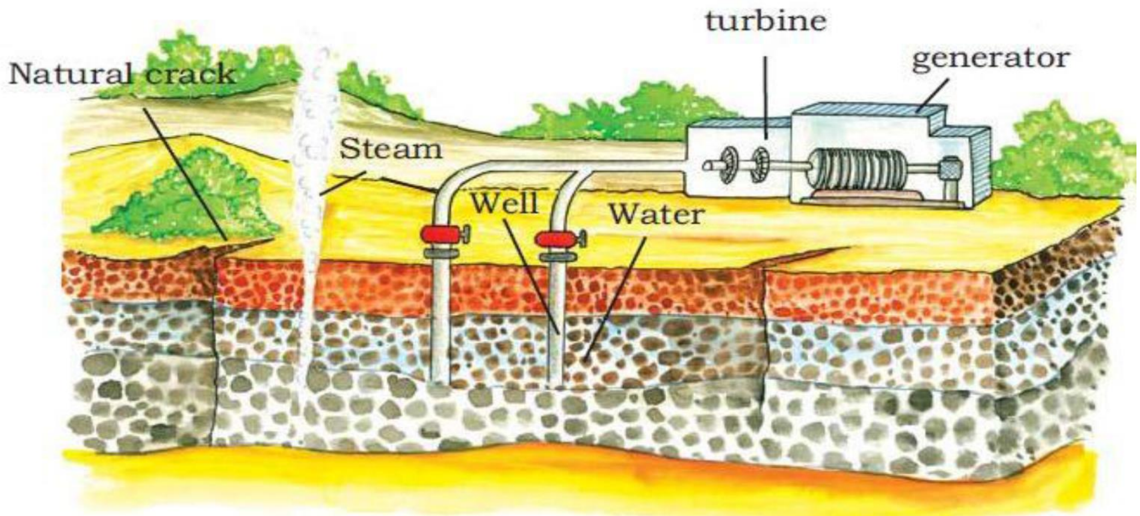


Fig (2.4): Geo-thermal energy (CHANDRAKAR)

2.3.1.5 Biomass Energy:

Biomass energy refers to plant and animal fuel. A biomass resource is an organic matter when the bonds between carbon, hydrogen and oxygen molecules are broken through digestion, discovers the combustion (or) material to release stored energy. Biomass energy is created when organic matter is converted to energy. In alcohol fermentation, starch is converted into organic matter to sugar by heating. This sugar is then fermented and ethanol is distilled and mixed with another fuel (Alrikabi, 2014). Biomass resources include many natural and derived substances mainly classified as: Agricultural waste, wood and wood waste, animal manure, municipal solid waste (Islam et al., 2008). Especially municipal solid waste and market waste as shown in table (2.2). In this process, optional bacteria destroy organic matter in the absence of oxygen and produce methane and carbon dioxide. Bio magnification is a non-polluting, environmentally sound and cost-effective process (Alrikabi, 2014). Residues of liquid waste and its future are rich in nitrogen and phosphorus (Midilli et al., 2005). Using this method we can extract 70% of the energy. The biomass is mixed with water and stored in an airtight tank. Organic wastes are collected separately and shredded into a storage unit stored in a plastic container (Alrikabi, 2014).

Table (2.2): Sources of biomass (CHANDRAKAR)

Field and plantation biomass	Industrial biomass	Forest biomass	Urban waste biomass	Aquatic biomass
Agricultural crop residues: Cobs, stalks, Straw, Cane thrashes and etc. **Edible matters from crops**-Environmentally spoiled grains, pulses, fruits, nuts, spices, seeds and lint etc. **Plantation debris:** Leaves, stubbles, barks and trunks etc. **Livestock wastes** from fields, slaughter houses and animal husbandries etc.	Agro-industrial processed biomass and their wastes: Husk Oil cake Sugar biogases Sugar molasses, Whey Hides and skin wastes Fruit and pulp debris Saw dust Wood pulp and paper shavings Fermented microbial mass etc.	Timber Log residues Forest floor debris Animal carcass	Municipal solid wastes Sewage sludge's Kitchen and canteen wastes	Microalgae blooms Sea weeds (E.g. Kelp) Fresh water weeds (E.g. Water Hyacinth) Dead fishes

2.4 Waste:

Wastes are unwanted or non-usable materials (wikipedia, 2019). It produced by human activity, in general the breed of anything living. In order to survive humans must constantly convert some of the products they have at their disposal to other products they can absorb and thus generate part of the waste. Natural systems do not generate accumulated waste (BAHIA et al., 2015). Waste is any material that is discarded after use to be considered to be worthless, defective or useless.

The Directive of the European Union Environment Committee also defines waste as "any substance or object that the owner ignores or intends to dispose of".

Each community produces different types of solid waste. The local area is responsible for organizing an appropriate health program for solid waste management (M. A. Abdullah Mohammed, 2016).

2.4.1 Solid Waste Sources:

2.4.1.1 Domestic / Residential Solid Waste:

This category includes solid waste generated from individual household units and multiple households:

• **Garbage:** includes the remains of marketing, preparation and consumption of food for residential units. It contains rotting organic matter that requires special care because of its nature in attracting insects (mice and flies) and producing odors.

• **Rubbish / trash:** includes waste paper, paper products, plastic, cans, bottles, glass, metals, ceramics, dirt, dust, yard, garden waste and the like. Except yard and garden waste which are non-rotten.

• **Ashes:** This includes waste from combustion processes (e.g. fireplaces, wood or coal heating units, etc.) resulting from household activities.

• **Bulky wastes:** includes furniture waste, household appliances, mattresses, springs and similar large objects. Due to the size of these elements and their weight mostly cannot be assembled using regular assembly equipment but special treatment and collection is needed.

2.4.1.2 Industrial Solid Waste:

Industrial wastes include commercial or institutional components and process waste. It is important to distinguish between the two quantities and the characteristics of the waste resulting from these two components are significantly different.

a) Commercial / Institutional:

The activities of the support staff are related to the plant where the garbage is produced by office staff, cafeterias as well as quality control laboratories.

b) Process waste:

Are the remnants of manufacturing processes and these residues are unique to each industry and are unique to each plant within a particular industry. Such as the use of chips (wood panels) resulting from the planning and sawing process (either as fuel for energy production or for use in wood panels).

2.4.1.1 Agricultural waste:

In rural areas, the disposal of solid waste from agricultural activities is one of the major and unique problems, namely, the residues from the feeding of confined animals and the residues of agricultural crops such as maize, wheat and soybeans, the remaining crops left on the fields for reintroduction in the soil (Xiaodong, April 2017).

2.4.1.2 Municipal Solid Waste:

Municipal solid waste is a waste that includes both heterogeneous and homogenous materials consist of waste and garbage. There are different categories of municipal solid waste such as food waste, commercial waste, Agricultural waste, institutional waste, industrial waste, construction waste, garbage, and streets. Municipal solid waste is made up of recyclable materials such as paper, glass, plastic and metal. As well as toxic substances such as pesticides, paints, medicines and batteries used; and organic waste such as fruits, vegetables, food waste and others (Garcia, 2015). Table (2.3) shows the components of MSW in a typical community.
According to the Solid Waste Law, municipal solid waste is divided into organic and non-organic waste:

a) Organic waste:

It is biodegradable organic matter (BOM), including living organisms, animals and vegetables. They include a wide range of wastes that arise naturally during the "life cycle" as a result of physiological functions of maintenance and sustainability.

b) Inorganic waste:

All substances that are not organic; they may have economic value when reused or recycled Metal, plastic, glass... etc.

It also includes pesticide residues and wafers, as well as chemicals residues such as those from veterinary or agricultural activities, including: glass, paper, cardboard, plastics, recyclable chips, aluminum, non-hazardous metals and others. This means they include all original materials, materials or vehicles that are manufactured by human. Inorganic waste can be considered an important source of raw materials from some productive sectors (Cofie et al., 2016).

Table (2.3): Estimation (components of MSW in a typical community) (David C. Wilson, 2015)

Waste category	Range (%age by weight)	Typical (%age by weight)
1.Residential & commercial excluding special & hazardous Wastes	50 – 75	62.0
2.Special (Trash) (bulky items, consumer electronics, yard wastes collected separately, batteries , oil, tires , etc.	3 – 12	5.0
3.Hazardous	0.01 - 1.0	0.1
4.institutional	3 – 5	3.4
5.Construction and demolition	8 – 20	14.0
6.Municipal services		
6.1 street and alley cleanings	2 – 5	3.8
6.2 Trees & landscaping	2 – 5	3.0
6.3 parks and recreational areas	1.5 – 3	2.0
6.4 catch basin	0.1 – 1.2	0.7
6.5 Treatment sludge’s	3 – 8	6.0
TOTAL		100

2.4 Waste Management:

2.4.1 Solid waste management (SWM):

Has become an issue of increasing global importance as population continues to increase and consumption patterns change. The health and environmental impacts associated with solid waste management are increasing rapidly, particularly in developing countries (Marshall and Farahbakhsh, 2013).

2.4.2 Integrated solid waste management (ISWM*):*

It is the management that combines waste stream systems, waste collection, and treatment and disposal methods, with environmental benefits, economic improvement and community acceptability. This will lead to a practical waste management system in any given region (McDougall et al., 2008).

2.4.3 The concept of integrated solid waste management on a 3R (Reuse, Reduction, Recycling) basis:

It reflects the challenges of integrated waste management. The 3R concept means (reduction, reuse and recycling) to reduce the final amount of waste as well as to convert most waste to reuse and recover resources. Low waste volumes can significantly reduce waste management costs. Increase resources by diverting waste into material or energy that enables us to expand the revenue base to support solid waste management expenditures. Initially, this 3R approach was promoted in each waste sector individually because of the institutional framework in most countries where local government is responsible for municipal waste and construction waste and demolition, and the national government is responsible for industrial waste and agricultural waste. However, it has been recognized that by integrating various sectors into the concept of Integrated Solid waste management (ISWM), there will be different gains. First, resources available for waste collection, material recovery, treatment and efficient resource recovery can be used with better scheduling and higher resource efficiency. Second, there will be large quantities of recovered material and energy available to facilitate the creation of industries, which can be used for their production. Thirdly, savings will be achieved in waste management costs, since the total amount of final waste available for disposal will be significantly reduced through the transfer of waste to recover materials and resources. Fourth, there will be active coordination among different stakeholders that can lead them to work on other development projects such as water and sanitation. Fifth, the results of integrated solid waste management with respect to clean and safe neighborhoods will improve the quality of life, improve economic activities and increase the value of property. Last but not least, governments can build trust among the public because ISWM brings the most tangible results in terms of public health, jobs and economic gains from the recycling and hygiene industry and effective interactions among stakeholders. Thus, the ISWM concept can improve 3R gains on the one hand and improve the waste management system on the other (Memon, 2010).

2.4.4 (3Rs) means order (reduction, reuse and recycling):

- **Reduction:**

  The first priority in waste management should be the total reduction of the quantities of solid waste, for example waste of food, packaging, unnecessary waste of raw materials and energy during production processes. Waste minimization also reduces the cost of waste collection and treatment.

- **Reuse:**
  The second priority should be given to material reuse i.e. the neglected product is cleaned and repaired to be used again.
- **Recycling:**
  The third priority in the concept of 3Rs is the recycling of materials, i.e. to collect waste and convert it into secondary raw material. Recycling for example, plastics or paper can usually provide greater energy in the production of energy products that can be produced at waste-to-energy conversion plants (Mutz et al., 2017).
  Below waste management systems in some countries:

2.5 Waste Management in Turkey:

2.5.1 Waste generation and collection:

Turkey is one of the largest countries in terms of population and has about 75 million people on an area of 78362 square kilometers. Consequently, the amount of municipal waste generated is about 409 kilograms per capita. Although around 98 per cent of urban dwellers received municipal waste collection services in 2012, most rural areas lack assembly services. The dual system of waste collection has been followed and adopted by separate waste collection groups for packaging in dry and wet boxes. The system is reinforced with additional boxes for other fractions (e.g. paper, cardboard, metal, plastic and glass (G. Tbilisi, Şekercioğlu and Yılmaz, 2012).Municipalities are responsible for solid waste management services throughout Turkey. Solid waste collection methods tend to change according to the characteristics of each region. Waste collection and transport trucks with dedicated staff are the main solution for municipal waste control, especially in large cities and towns. These trucks collect MSW daily or twice a day for areas with low population and amount of waste. Vehicles used by municipalities for the transport of solid household waste are owned by the municipalities concerned (Tekinel, 2017). As shown in figure (2.5).

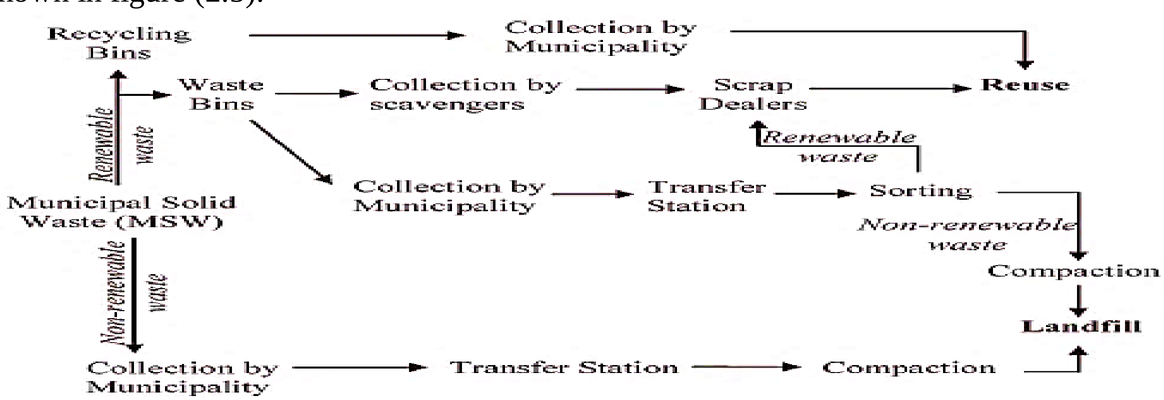


Fig (2.5): Current waste collection system for the city of Istanbul, turkey (Senol Yildiz, April 2012).

2.5.2 Waste separation and recycling:

In recent years, there has been increasing support for the concept of integrated waste management and waste reduction strategies. Waste is first sorted for reuse and recycling. Municipal and industrial solid waste is a special focus because it is a major source of pollution (Tahtalıoglu and Kulac, 2019).

In Turkey, waste disposal sites are controlled; restrictions imposed by environmental agencies are respected; and rules and techniques for proper management of waste dumps are not ignored where municipal solid waste management (MSW) is undergoing an important phase because of the availability of appropriate solid waste disposal facilities and the treatment of the increase in their quantity (Ozturk, 2014). Solid waste recovery and recycling is a long-term business activity in Turkey. Glass and paper recycling has been carried out on industrial ranges since the 1950s (Neyim et al., 2001). With recent investments in the recycling industry, all kinds of plastic, glass, paper and metal can be recycled almost at industrial levels. As shown in figure (2.6).

As one of the world's largest steel scrap importers, Turkey recycles more than two million tons of steel scrap annually. Recycling of non-ferrous metals is widespread and is carried out on an industrial scale, including aluminum, copper, lead and silver. The scrap recycling industry is built mainly on small and medium scrap dealers that spread throughout the country. This type of operation is also valid for most collection and recovery of municipal solid waste recyclable (Berkun et al., 2011). The overall objective of the waste sector is to improve environmental protection and improve the quality of life of citizens by making progress in harmonizing Turkish legislation in the field of waste. Activities to comply with the guidance of the waste framework, including infrastructure investments, are expected to increase the amount of recycled waste, Biodegradable materials entering landfills and improving final disposal. In principle, landfill investments will be agreed upon where there is a waste management plan and a landfills plan accordingly (Tahtalıoglu and Kulac, 2019).

Fig (2.6): Packaging Waste Separation Facility in Ankara, Turkey (KÖSE et al., 2007).

2.5.3 landfill in turkey:

Turkey's energy consumption is increasing every year, so it seeks to reduce its dependence on imported oil and natural gas and encourages the generation of electricity from renewable sources, primarily gas landfills and biogas where sanitary landfill is the most common disposal of solid waste at present. As shown in figure (2.7). Over the years, the waste management mechanism from landfills in urban areas has been re-used and restored first, and the useless part has been buried by regulation. Today, almost all solid waste is disposed of in landfills or in landfills in Turkey. There were 15 urban landfills in 2003, and this number rose to 38 in 2008, 59 in 2011, and 69 in 2012. Furthermore, there are 29 landfills in the construction and progress phase, and 21 in the planning phase of the project (ALTAN, December 2015).

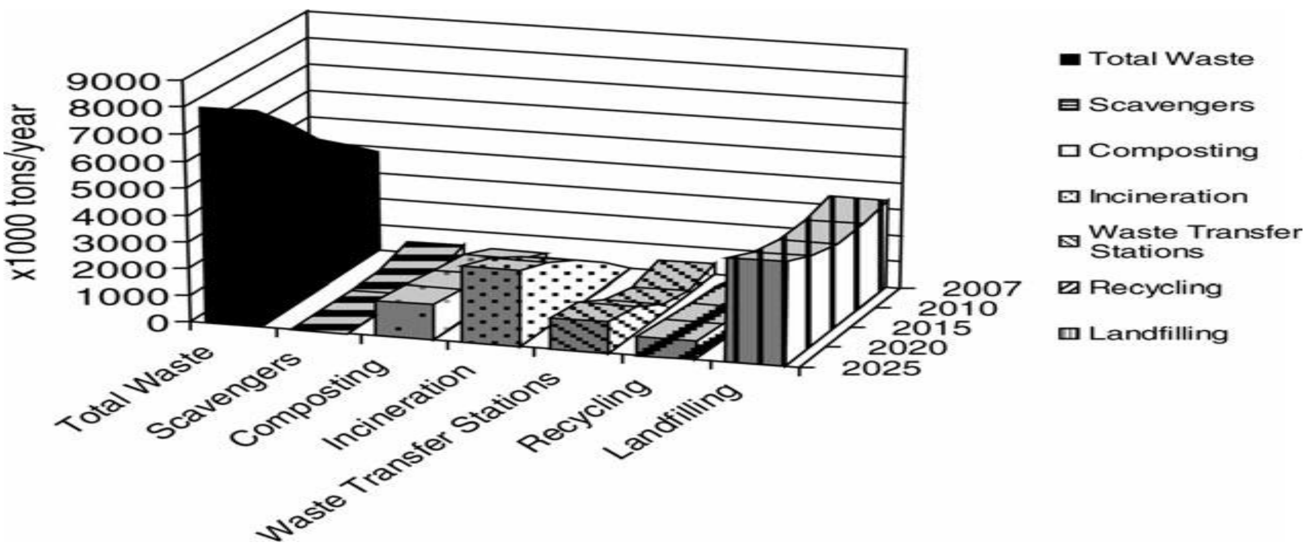


Fig (2.7): Quantity projections for waste management system components in turkey (Senol Yildiz, April 2012).

2.6 Waste Management in China:

2.6.1 Waste generation and Collection:

With China's rapid economic growth and massive urbanization, many cities face the problem of municipal solid waste disposal with no space for new landfills. MSWM in China requires special attention. China has become the world's largest solid waste generator and the total amount of solid waste it produces is still increasing. But in recent years, central and local governments have made great efforts to improve solid waste in China. New regulations and policies have been promulgated, urban infrastructure improved, and commercial marketing and international cooperation promoted (Chen et al., 2010, Cheng et al., 2007).

In general, MSW is assembled in major cities in China with a two-tier system: primary and secondary. Primary collection includes the storage and transport of waste from homes to local assembly points and is done by multiple means. Secondary collection includes storage and transport from local assembly points to treatment points and disposal and is done by municipalities.

Waste collection services vary greatly between Chinese cities and even within different parts of cities. In Beijing, waste collection services for modern and high-rise residential buildings in the city center are adequate, while waste collection systems in poorer suburban areas are more primitive.

For residential areas, there are two types of urban solid waste collection methods: road collection and family collection. First, collection of waste on the side of the road is a way for people to recycle recyclable materials in specific collection containers provided by local authorities. Second, household collection systems that include what is known as "bell and rings collection" By assembly bell to collect garbage to the street level for disposal. This type of operation is very common in southern China (for example, Guang Zhou) (Zhang et al., 2010). As shown in figure (2.8).

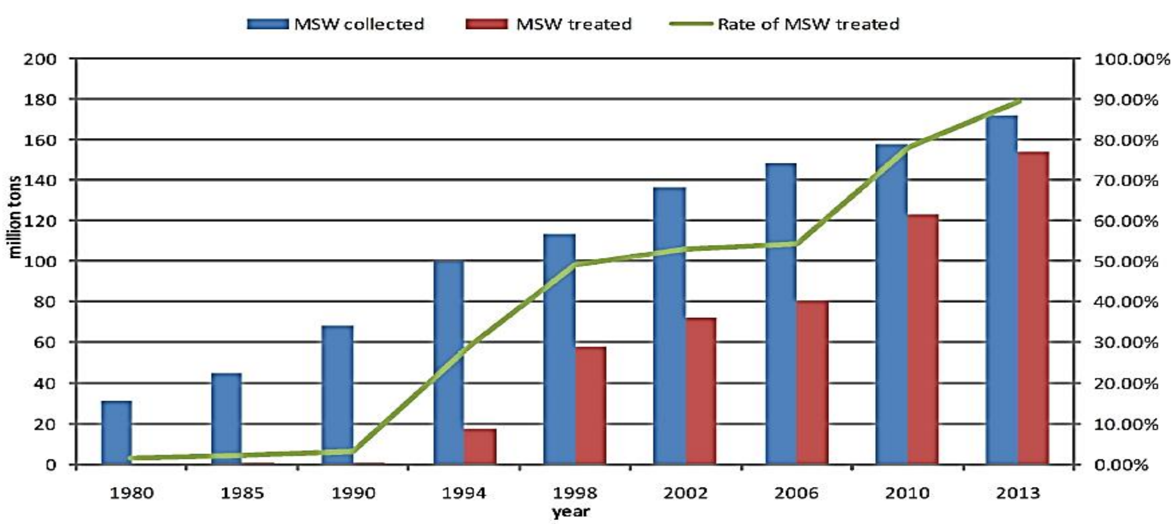


Fig (2.8): MSWM of China (Dongliang Zhang, 16 December 2015).

2.6.2 Waste Separation and Recycling:

High water content and high percentage of food waste are the main factors limiting the recovery of recyclable materials so household sorting is a very helpful factor (Zhuang et al., 2008). However, municipal solid waste is collected in China in a mixed case, but residents can volunteer and participate in the screening process from the source. Recyclable materials are often collected from daily use from the source by scavengers and waste collectors who patrol residential areas to purchase recyclable materials. People sell their recycling materials to door-to-door buyers or sometimes deliver recyclable

materials to service sites themselves. Buyers sell materials to a nearby recycling center where materials are sorted and sold to factories as raw materials or processed.
In China, because there are few government recycling initiatives, recycling and recovery is usually done by the "informal" sector, which occurs at all levels and at every stage of waste management (Zhang et al., 2010)

2.6.3 Landfill in china:

Urban population and waste generation are increasing worldwide, and most of the waste is disposed of in landfills as shown in figure (2.9). More than 80 percent of China's waste is dumped in different ways. More than 5 per cent of landfills are health landfills that meet global standards, about 40 per cent of landfills do not meet these criteria, and more than 50 per cent are open landfills. Landfills are a major source of methane emissions, a powerful greenhouse gas. Increasing the proportion of waste placed in sanitary landfills increases methane emissions due to increased anaerobic reaction. As shown in figure (2.10). However, China's National Action Plan for the collection and use of municipal solid waste on health waste landfills confirms the recovery of methane, which may have benefits such as greater sustainability, improved public health, increased energy efficiency and reduced global warming. The lack of reliable data on solid waste generation and management is a fundamental problem in assessing landfills' contributions to CH_4 emission inventories, determining methane recovery, and identifying the best candidate sites for CH_4 recovery projects in developing countries (Robinson et al., 2003).

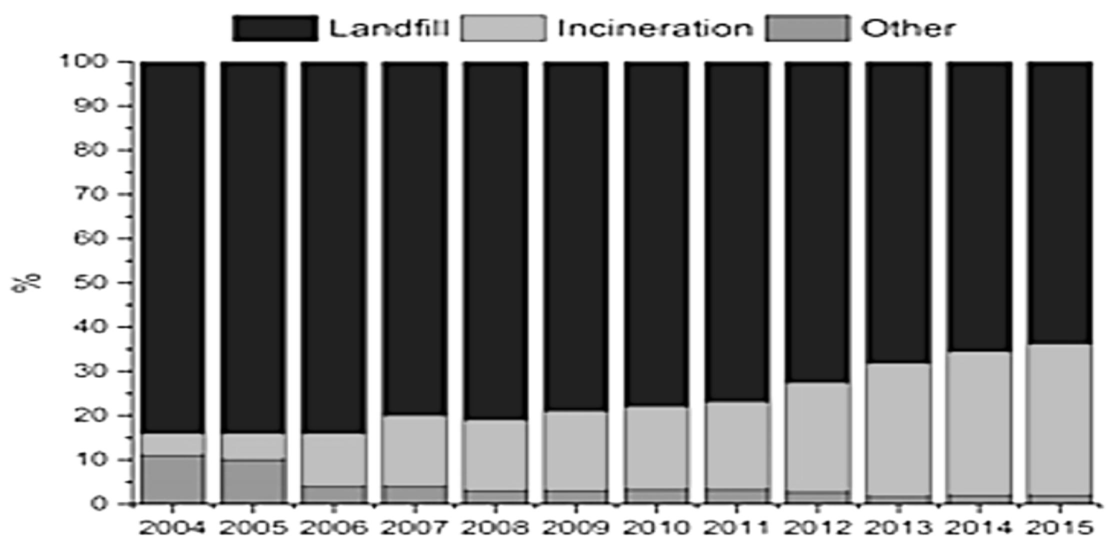


Fig (2.9): Treated MSW by incineration and landfilling and others in china (Xiaodong, April 2017).

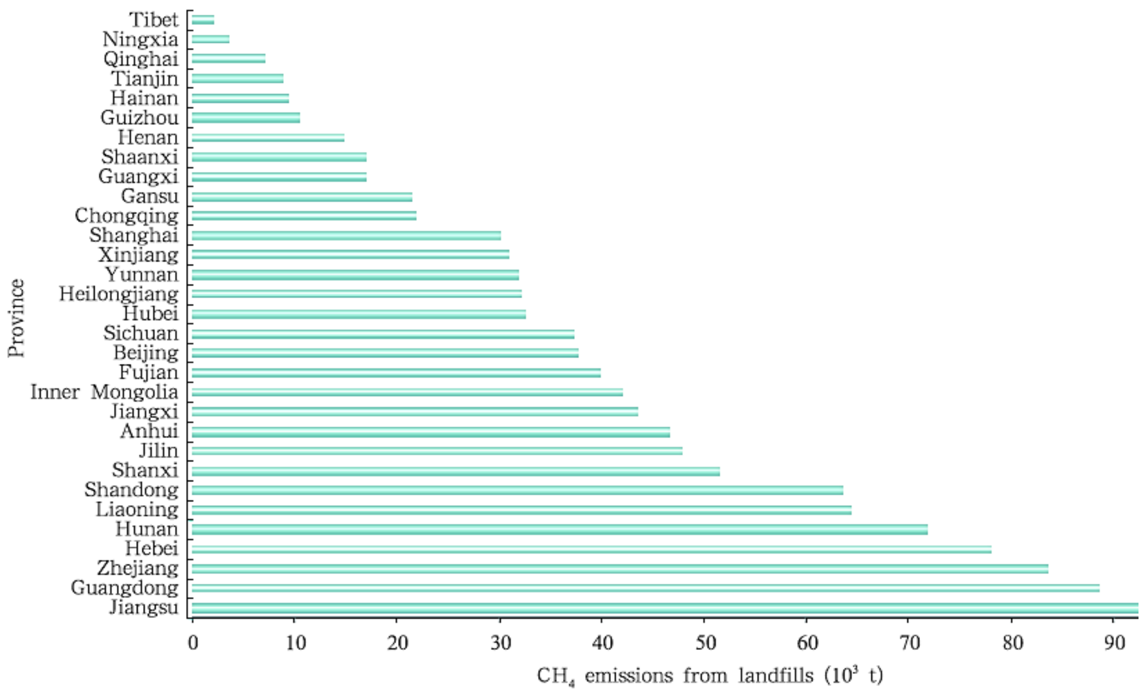


Fig (2.10): Landfill CH4 emissions at the provincial level in China (CAI Bo-Feng, 2014).

2.7 Waste Management in Khartoum:

2.7.1 Waste generation and collection:

Sudan is the world's most populous country with an annual growth rate of 2%. About 15% of Sudan's population is in Khartoum, with an area of 2236 square kilometers. It consists of Khartoum, Omdurman and Bahri. Khartoum has a population of 7,993,851 people in 2018. The total number of wastes in the same year is about 5436 tons per day and about 1,984,074 tons / year (P. Failler, 2016, T. M. H. M. S. Saad Awad, 2017). Solid waste, especially municipal solid waste, is a growing problem in Khartoum various factors contribute to increased waste generation in Khartoum, such as changes in dietary habits and misuse of collection containers. In addition, the improper collection and disposal of these wastes in the streets and drainage channels leads to a major health threat, which will become breeding sites for insects and rodent carriers that lead to the spread of various diseases (M. A. A. M. Abubaker BM A, 2014)

2.7.2 Disposal of waste Khartoum:

In Khartoum state waste is collected and dumped outside the state in rural areas without treatment. The amount of waste collected may be about 65% of MSW in the state. The common means of waste disposal is the open landfill (open dumping is defined as a land disposal site where solid waste is disposed of in a way that does not protect the environment, is open to open, and susceptible to elements, vectors and waste). Perhaps the biggest advantage of a landfill when compared to open spaces is implementation to ensure that environmental problems do not occur during operation or after closure. Precision design, construction and operation can prevent various problems. The state of Khartoum consists of three main landfills: Tyba landfill, Hattab landfill and Abo Waleidat landfill, as shown in figure (2.11) (FAH, 2017).

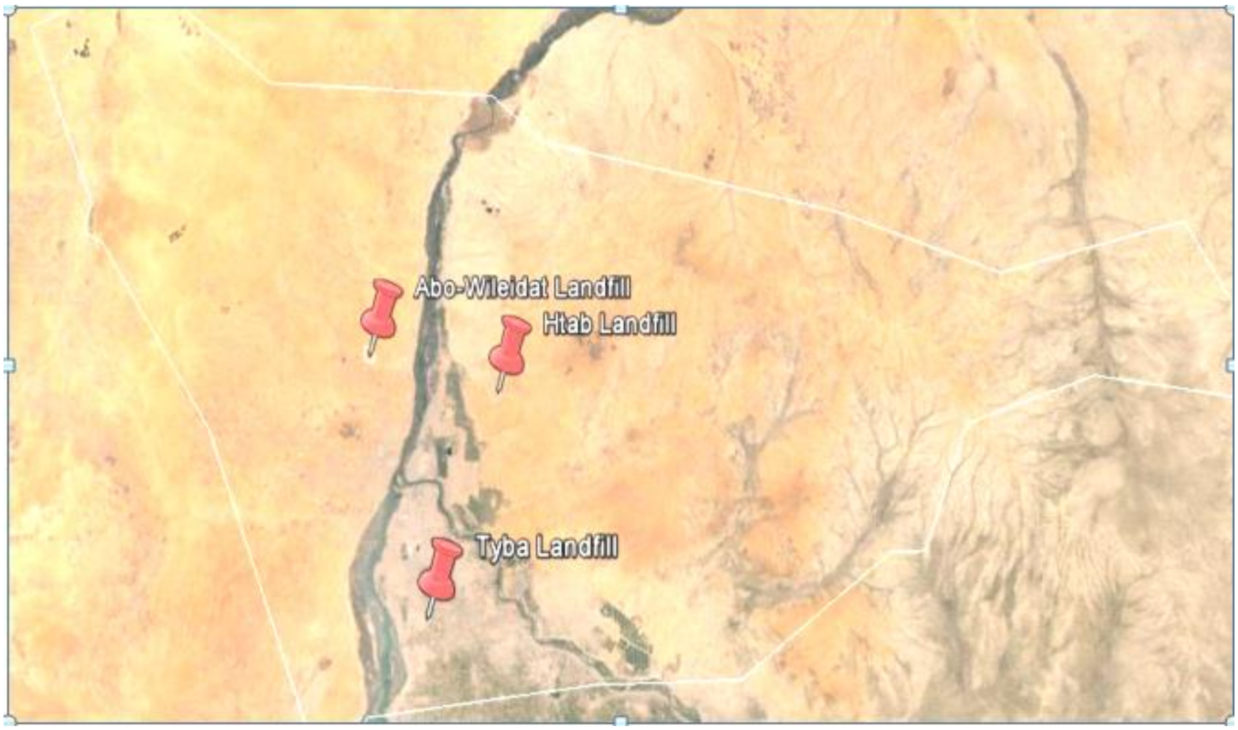
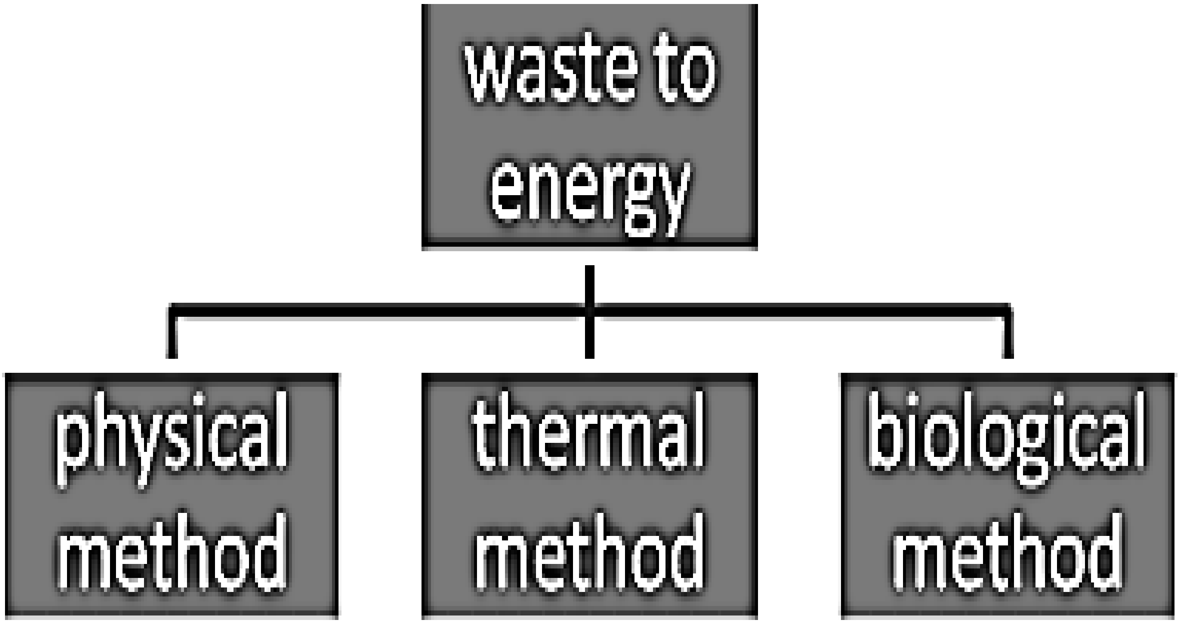


Fig (2.11): Tyba, Hattab and Abo Waleidat landfills (Abdalrahim, 2018)

2.8 Waste to Energy:

WTE refers to a range of technologies that treat waste to recover energy in the form of heat, electricity, or alternative fuels such as biogas. This could include the production of cooking gas in household digesters from organic waste, the collection of methane from landfills, the thermal treatment of waste at utility-burning stations, and the joint processing of waste-derived fuel in cement or gasification plants. This guide takes a very broad view as it refers to the broad concept of waste-to-energy conversion (Dieter Mutz, May 2017).Other benefits of WTE technologies are reducing waste volumes, reducing land use in landfills, and reducing environmental impact on landfills on the environment (Council, 2013). Methods of converting waste into energy from waste can be derived into three types: thermal, physical and biological (Brijesh Kumar Pandey, 2016). The primary recovery products are electricity, heat, fuel gases, liquids and solids (L. Cutz, 1411–1431 (2016)). Types of waste to energy technologies as shown in figure (2.12).



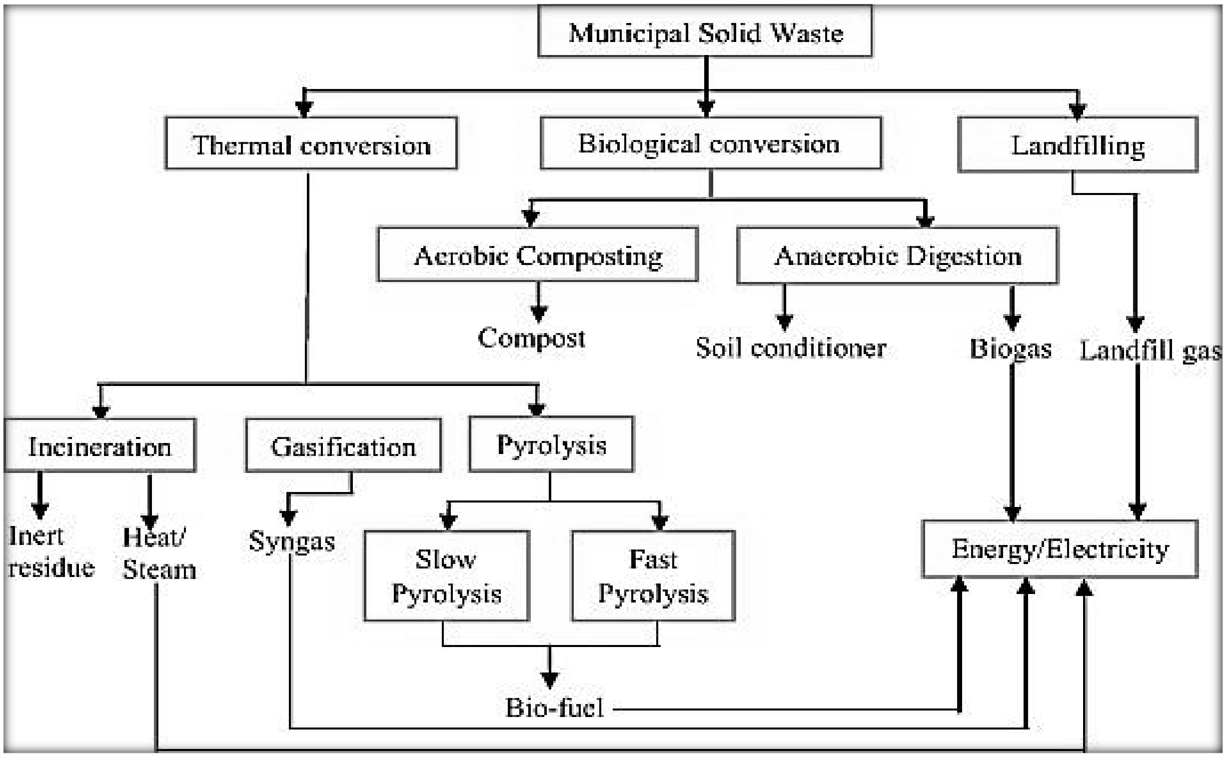
Fig(2.12): Types of waste to energy technologies (Pandey et al., 2016)

Thermal treatment techniques work to burn solid waste to generate energy. It was generating heat that can be used directly or converted into electrical energy. The most common type of technology is conventional incineration. More advanced technologies such as pyrolysis and gasification can produce a more diverse range of products such as gaseous, liquid fuels, steel, heat and electricity. These advanced techniques are in the early stages of commercial development (J. Rawlins, 2014).

In the process of physical processing, the waste is processed mechanically to produce a more durable and durable form and manual control that is used as fuel for further processing. Examples of mechanically derived form: pellets, wood chips, wood molds (Brijesh Kumar Pandey, 2016).

Chemical conversion techniques include the chemical decomposition of organic wastes. This decomposition produces a biogas that can be burned and used directly for heat and energy or can be refined into biofuels. Methods of conversion of key chemicals are anaerobic digestion and recovery of landfill gas (J. Rawlins, 2014).

And the most popular conversion techniques are: Thermal conversion techniques (combustion, pyrolysis, and gasification), biochemical conversion and landfill techniques (Ambaye, March 2018).These technologies are the most appropriate techniques for mixed solid waste treatment, and are expected to remain in use for many years to come in countries with a short history of separating substances from their sources. These are listed below: (Rohani, 2015). As shown in figure (2.13).



Fig(2.13):Waste-to-Energy technologies based on applied conversion process (Ouda OKM, 2016)

2.8.1 Thermochemical conversion technologies:

Thermal conversion includes combustion, gasification, pyrolysis, and related processes that expose all waste to high temperatures but with varying concentrations of oxygen (Whiting et al., 2013).

2.9.1.1 Incineration:

Incineration is the process of destroying the waste inside the kiln for this process. The combustion is controlled by controlling furnace temperatures where the process is performed between 750 and 1000 degrees Celsius. About 70% of the total mass of waste can be reduced when burned, meaning 90% of the total volume. In this process three steps are taken first, burning, secondly restoring energy and thirdly air pollution as shown in figure (2.14). Burning results in some air pollutants such as SO_X, O_X and NO_X, which are harmful to human health (Kumar, 2000, Lam et al., 2016). Waste incineration is very popular in some countries, such as Japan, where land is scarce. Denmark and Sweden have pioneered the use of burning energy for more than a century in combined domestic heating and power plants that support heating schemes in regions (Kleis, 2004). In 2005, waste incineration produced 4.8% of electricity consumption and 13.7% of total household heat consumption in Denmark (Sperling et al., 2011). A number of other European countries also rely heavily on incineration to treat municipal waste, particularly Luxembourg, the Netherlands, Germany and France (Moakley et al., 2010). And multiple incineration chamber as shown in figure (2.15).

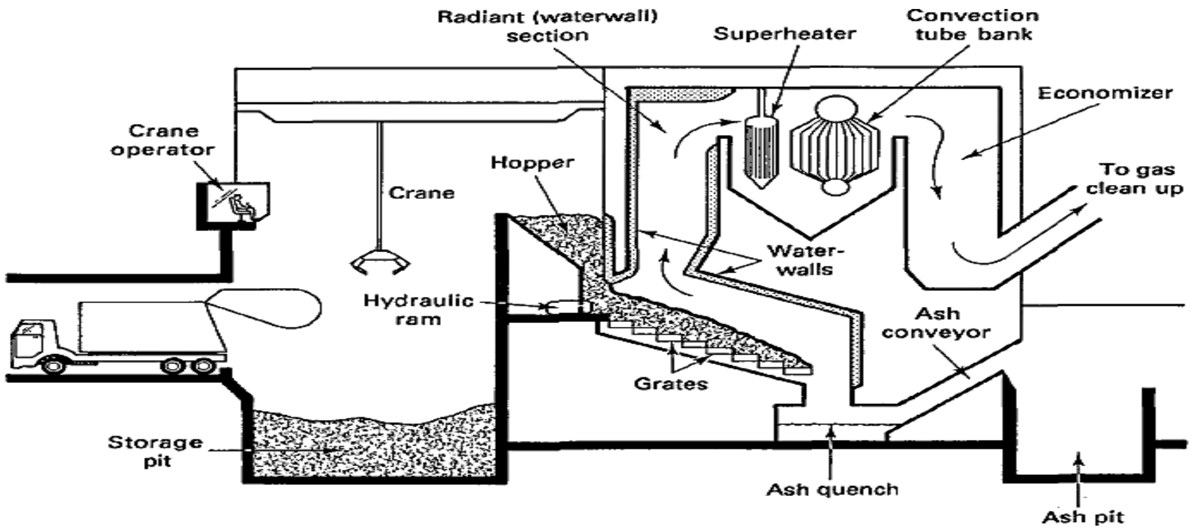


Fig (2.14): Typical waste-incineration system schematic (Pfeffer, 1992).

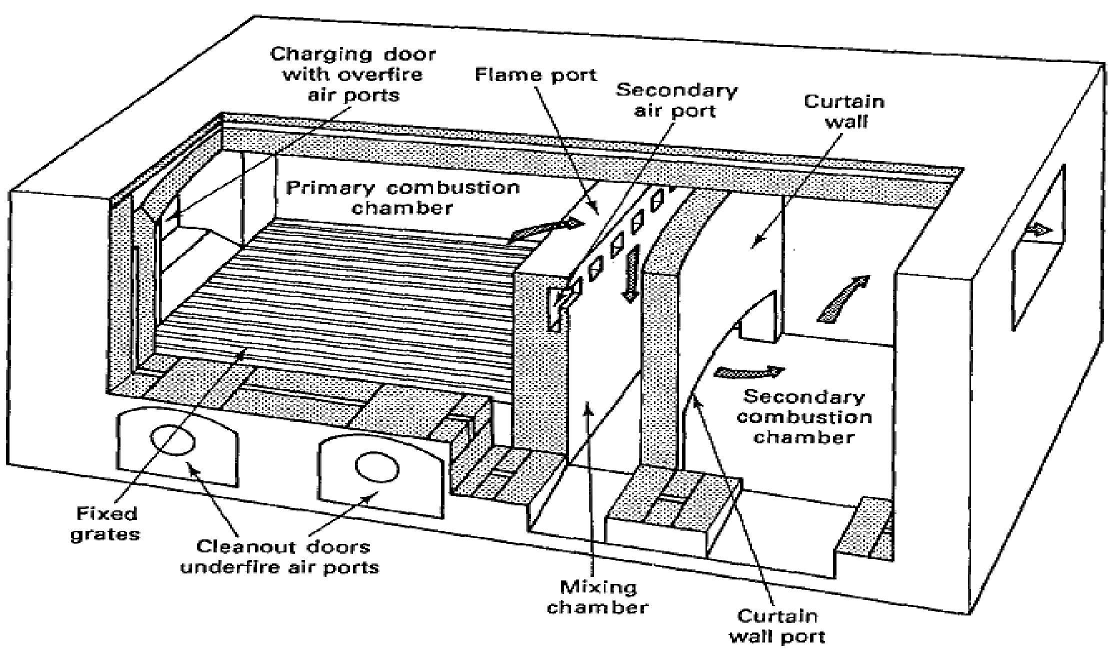


Fig (2.15): multiple incineration chamber (Pfeffer, 1992).

2.9.1.2 Pyrolysis:

Pyrolysis is the thermal decomposition of materials at elevated temperatures in an inert atmosphere. , Which involves changing the chemical composition and irreversible. The word was derived from Greek derivative elements "fire" and decomposition “lysis ".
Pyrolysis is most commonly used in the treatment of organic matter. It is one of the processes involved in coking wood. In general, pyrolysis of organic matter produces volatile products and leaves carbon-rich residues, coal. Severe pyrolysis, which often leaves carbon as residues, is called carbonization.
The process is heavily used in the chemical industry, for example, to produce ethylene, many forms of carbon, and other chemicals from petroleum, coal and even wood, to produce coke from coal. The ambitious applications of pyrolysis work to convert biomass into biochemical and biochemical waste, waste plastics back into usable oil, or waste to safely disposable materials (wikipedia, 2020c).

2.9.1.3 Gasification:

It is similar to thermal decomposition, a process that converts organic carbon or fossil fuels to carbon monoxide, hydrogen and carbon dioxide. This is achieved after removal of recyclable materials and large items. The remaining MSW is fed in gasification and the gasification reactor is heated to temperatures ranging from 1450-3000ºF. Unlike burning, gasification is used in an almost equal amount of oxygen, often called a "hollow air process". This creates a burning interaction that generates gas mixed with combustion products such as carbon dioxide and water vapor. Often, steam is added to the process to promote the production of hydrogen and hydrocarbon gases. As shown in figure (2.16). The resulting gas mixture is called syngas (a synthetic gas) or a gas produced and is itself a fuel. The energy derived from the gasification and combustion of the resulting gas is a source of renewable energy if the gaseous compounds are obtained from the biomass. The syngas is cleaned to remove the hazardous components and can then be used to generate electricity. Because of the meager amount of air involved in the gasification process, the gas produced has a higher thermal value than the pyrolysis process. The traditional gasification process can generate 685 kWh per ton of solid waste. Mixed gases, ash, slag and metals are produced at the end of reactions in the gasification reactor. Residual solids are useful for concrete and asphalt aggregates. As in the process of pyrolysis, mixed gases should be filtered to obtain high-quality gaseous materials and remove hazardous gases such as sulfur, chloride and mercury. For high-quality syngas from the gasification process, pre-treatment is required of raw MSW (Campos et al., 2015, wikipedia, 2020a).

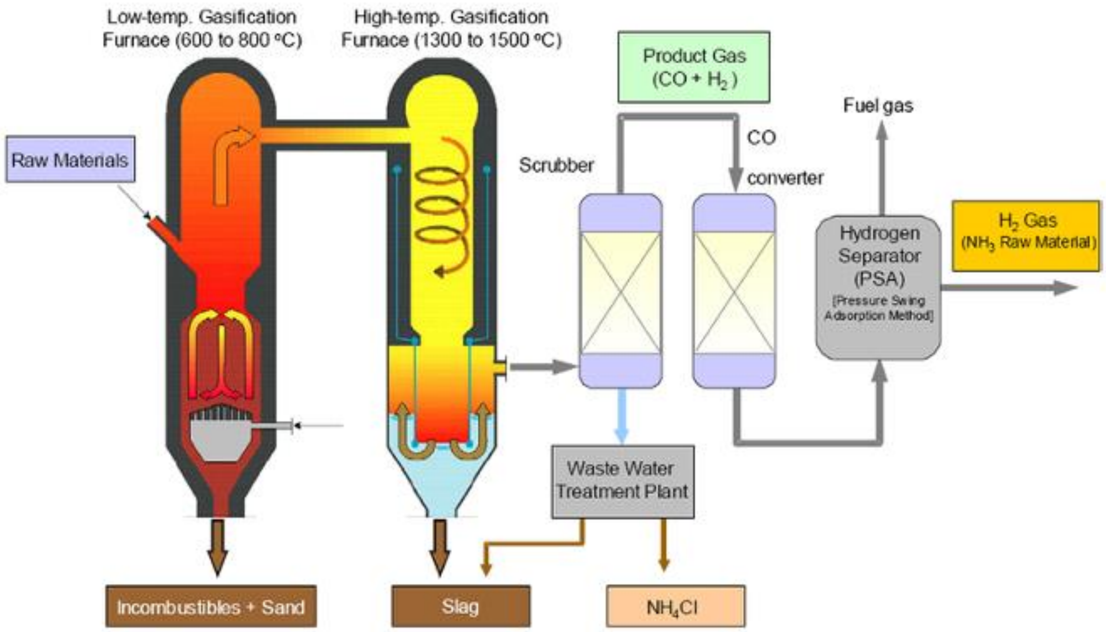


Fig (2.16): Gasification (Bosmans et al., 2013).

2.9.2 The Biochemical conversion technologies:

Biological treatment is the process carried out naturally by microorganisms such as yeast, fungi or bacteria that break down hazardous substances and convert them into less toxic or non-toxic substances where they need the nutrients to survive, and so organic compounds crash in nature to get the energy needed for their growth. Biological treatment is not a magic solution but an alternative "natural process" for other contaminant-producing method (Angelidaki and Batstone, 2011). ***These are the following technologies:***

2.9.2.1 Aerobic Mechanical Method:

The aerobic process relies on a continuous supply of air to be mixed in with the waste material. Again, the waste is ground up into pieces. Recyclable materials are removed before this process. In a typical plant, the waste is ground up and formed on an outdoor pad into long piles called windrows. The windrows are agitated a few times per week to allow all parts of the pile to be exposed to air. The agitation and aerating process can also be conducted in a vessel into which air is forced. The aerobic environment supports a different, but also common microorganism that, like the anaerobic process, feeds on the organic fraction of the waste. The waste is converted to by-products that include CO_2, water vapor, and compost. Typically, a site had to be located in a rural area; otherwise, the odors from the process could become a nuisance (Rogoff, 2013).

2.9.2.2 Anaerobic Mechanical Method:

Anaerobic digestion (AD) is a biological method in which there is no oxygen where organic matter decomposes to generate biogas, which is often composed of methane and carbon dioxide (K.M. Kangle, 2010). Biofuels, compost, wet organic matter and MSW are generally used as intermediates. AD process is performed in three common steps: the first step is the disintegration of MSW by bacteria, Change complex organic species to simple soluble units (i.e amino acids, monosaccharaides and fatty acids). In the second stage, the translation of decomposed material into organic acids (reproduction) is converted to simpler products such as VFA, H_2 and CO_2. Methanogen is the third phase of the AD that converts organic acid to methane. CH_4 gas can replace the energy produced by fossil fuels. Nutrient-rich digestion is formed as a by-product used for fertilizers and a chemical equivalent symbol (Beyene et al., 2018).

2.9.2.3 Composting:

Manure is a process where the organic part of MSW is allowed to decompose under carefully controlled conditions. The natural process of "rotting" or decomposition of organic matter by microorganisms is carried out under controlled conditions. This process is considered biological rather than chemical or mechanical; the degradation and transformation of the waste material is achieved through the work of bacteria, fungi and other microorganisms. Raw organic materials such as crop residues and animals promote waste, food litter, some municipal waste and appropriate industrial waste and suitability to apply to soil as a fertilizer resource after submission. Soil organic matter plays an important role in maintaining soil fertility and thus in sustainable agricultural production. In addition to being a plant nutrient source, it improves the physical, chemical and biological properties of soil. As a result of these improvements, the soil becomes: (1) more resistant to stresses such as drought, disease and toxicity. (2) The crop helps to improve plant nutrient uptake; and (3) has an active nutrient cycling capacity due to strong microbial activity. These advantages are reflected in reducing crop risks, increasing returns and lower costs inorganic fertilizers for farmers (Misra et al., 2003). Various Composting Facilities are shown in figure (2.17).

Composting can be divided into two categories depending on the nature of the decomposition process. Type one is Anaerobic Composting - decomposition occurs where oxygen (O_2) is absent or present in limited supply, under these condition anaerobic microorganisms dominate and develop intermediate compounds including methane, organic acid, hydrogen sulphide and other substances. In the absence of oxygen these compounds accumulate and are not metabolized any further. However anaerobic composting is a low temperature process (Sidahmed, December 2016).

The second type is the aerobic composting which occurs in the presence of abundant O_2 . In this process, aerobic microorganism's crash organic matter and produce carbon dioxide (CO_2), ammonia, water, heat and humus, the organic end product is relatively stable. Although aerobic fertilizer has the production of intermediate compounds such as organic acids and aerobic microorganisms degrades them as well. The resulting fertilizer, with a relatively unstable form of organic matter, has low risk of phytotoxicity. The heat generated accelerates the breakdown of proteins and fats complex carbohydrates such as cellulose and heli cellulose. Thus, the processing times Shorter. Furthermore, this process destroys many microorganisms that are human or plant pathogens, as well as weed seeds, provided they are subjected to a sufficiently high temperature. Although more nutrients are lost from substances by aerobic composting, it is considered more efficient and beneficial than anaerobic composting for agricultural production (Misra et al., 2003).

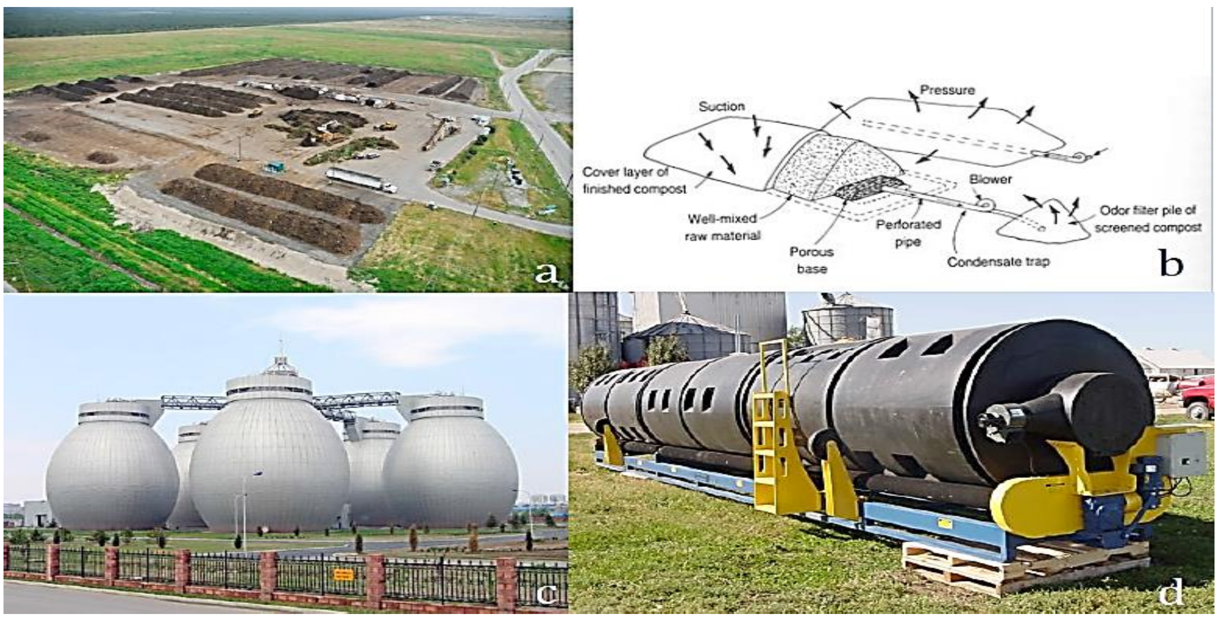


Fig (2.17): Various Composting Facilities (Xiaodong, April 2017).

2.9.3 Landfill:

The oldest and most commonly used method of final disposal of solid waste is the disposal of waste by burying it in the land. Until the middle of the 20th century waste was simply placed in a pile on the ground, and was called a waste disposal site. These uncontrolled open landfills quickly became fertile ground for many pathogens, including mice, mosquitoes and flies. In addition to a direct threat to public health, open dumps were smelly and annoying. They also contaminated surface water and groundwater, and caught fire regularly. Open dumping of solid waste material is no longer an acceptable (or legal) method of disposal in many other countries. However, most municipal waste is still disposed of on the ground. So most countries have used waste disposal through a landfill where they are not simply deposited in a pile on the ground. The landfill is not just a landfill. It is a planned and carefully designed solid waste disposal facility. This means that it has been designed, constructed and operated in an environmentally sound manner and does not threaten public health or safety, nor does it reduce general inconvenience (e.g. wind-blown waste and unpleasant odors) (Tammemagi, 1999).

Sanitary Landfilling is a method of disposing waste for the purpose of processing environment. In landfilling the following process occurs, biological, chemical and physical where waste is composed into leachate and gas. The gases produced consist mainly of Methane, Carbon Dioxide, Water and different traceable materials such as Ammonia Sulphide (H_2S) and volatile organic compounds. Landfill is a source of Methane production which is used to generate electricity. Sanitary landfill can also being used for the production of biofuel gas (Mwangomo, 2018).

Mass balance for MSW landfill:

Waste in → Leachate + gas + transformed mass+ waste remaining (Tarsier, 2004)

2.9.3.1 Landfills Categories:

Landfills range in type from uncontrolled open dumps to secure sanitary landfills. Generally there are three landfill categories:-

- **Open dumps**
- **Controlled dumps**
- **Sanitary landfills**

A number of general characteristics distinguish a sanitary landfill from an open dump, but these characteristics vary from region to region, from nation to nation, and even from site to site. An operated dump may inspect and record incoming waste and include limited compaction by bulldozer and compactor. Engineered landfills embody further attempts to minimize environmental impacts. Sanitary landfills incorporate a full set of measures to control gas and collect and treat leachate, apply a daily soil cover on waste, and implement plans for closure and aftercare long after waste has ceased coming to the site. These three types of landfills are points on a continuum, with facilities in most developing economies often falling somewhere between open dumps and controlled dumps. Open dumps have the lowest initial capital investment and operating cost of the three types of landfills but cause environmental pollution and can potentially affect the health of local residents. Additionally, many open dumps start off as controlled dumps and degrade due to lack of management and other resources. In these cases, the resources expended on a controlled dump have resulted only in an open dump (Schübeler et al., 1996) . As shown in table (2.4).

Table (2.4): Landfill Classifications (Hoornweg and Bhada-Tata, 2012).

	Operation and Engineering Measures	***Unrestricted contaminant Release***	***Landfill Gas Management***
Semi-controlled Dumps	Few controls; some directed placement of waste; informal waste picking; no engineering measures	Unrestricted contaminant release	None
Controlled Dump	Registration and placement/ compaction of waste; surface water monitoring; no engineering measures	Unrestricted contaminant release	None
Engineered Landfill / Controlled Landfill	Registration and placement/ compaction of waste; uses daily cover material; surface and ground water monitoring; infrastructure and liner in place	Containment and some level of leachate treatment; reduced leachate volume through waste cover	Passive ventilation or flaring
Sanitary Landfill	Registration and placement/ compaction of waste; uses daily cover; measures for final top cover and closure; proper siting, infrastructure; liner and leachate treatment in place and post-closure plan.	Containment and leachate treatment (often biological and physico - chemical treatment)	Flaring with or without energy recovery

2.9.3.2 landfill and Environment:

As with any waste management activity, landfill may also have a potential impact on environmental quality due to its gaseous emissions and leaks in air and soil and can be controlled through periodic groundwater and soil inspection as well continuous emissions rate monitoring system (CERMS) as shown in figure (2.18). The environmental impact of the landfill by type is as follows in the table (2.5) (EPA, 2012).

Table (2.5): Comparisons of Solid Waste Disposal Sites (EPA, 2012).

Factor	**Open Dump**	**Controlled Landfill/Dump**	**Sanitary Landfill**
Environmental Factors			
Atmosphere			
Fires	Intentional burning common	Limited, may be present	Unlikely
Release of hazardous gases	Yes, if no collection exists	Yes, if no collection exists	Yes, if no collection exists
LFG collection and control	Possible, poor collection efficiency expected	Likely, collection efficiency will depend on site conditions	Likely
Unpleasant odors	Yes	Possible, depending on site conditions and whether LFG is controlled	Minimal, if the right measures are taken to cover waste and control LFG
Ground/Soil			
Topographical Modification	Yes	Yes	Yes
Contamination (leachate)	Yes	Possible, depending on base or liner conditions	No
Gas Migration	Yes	Possible, depending on site conditions	No
Water (surface and ground water)			
Channeling runoff	No	Possible, depending on site conditions	Yes
Contamination	Likely underground and surface water	Possible if low-permeability liners are not used	Minimal
Monitoring system present	No	No	Yes
Flora			
Vegetative cover alteration	Yes	Yes	Yes
Fauna			
Changes in diversity	Likely	Yes	No
Vector control	No	Potentially, depending on site conditions	No
Socioeconomic Factors			
Landscape			
Alteration of Condition	Yes	Yes, can be mitigated with visual buffer (for example,	Yes, can be mitigated with visual buffer (for example, a forest buffer)

		a forest buffer)	
Humans			
Health hazards	Yes	Potentially, depending on site conditions	Potentially, depending on site conditions
Negative image	Yes	Yes	Yes, improved if there is post-closure utilization of land
Environmental education	No	Yes, in some cases	Yes, with careful planning
Economics			
Decline of land value	Yes	Yes	Yes
Formal employment	No	Yes	Yes
Changes in land use	Yes	Yes	Yes
Social			
Waste pickers	Yes	Yes, in some cases	No

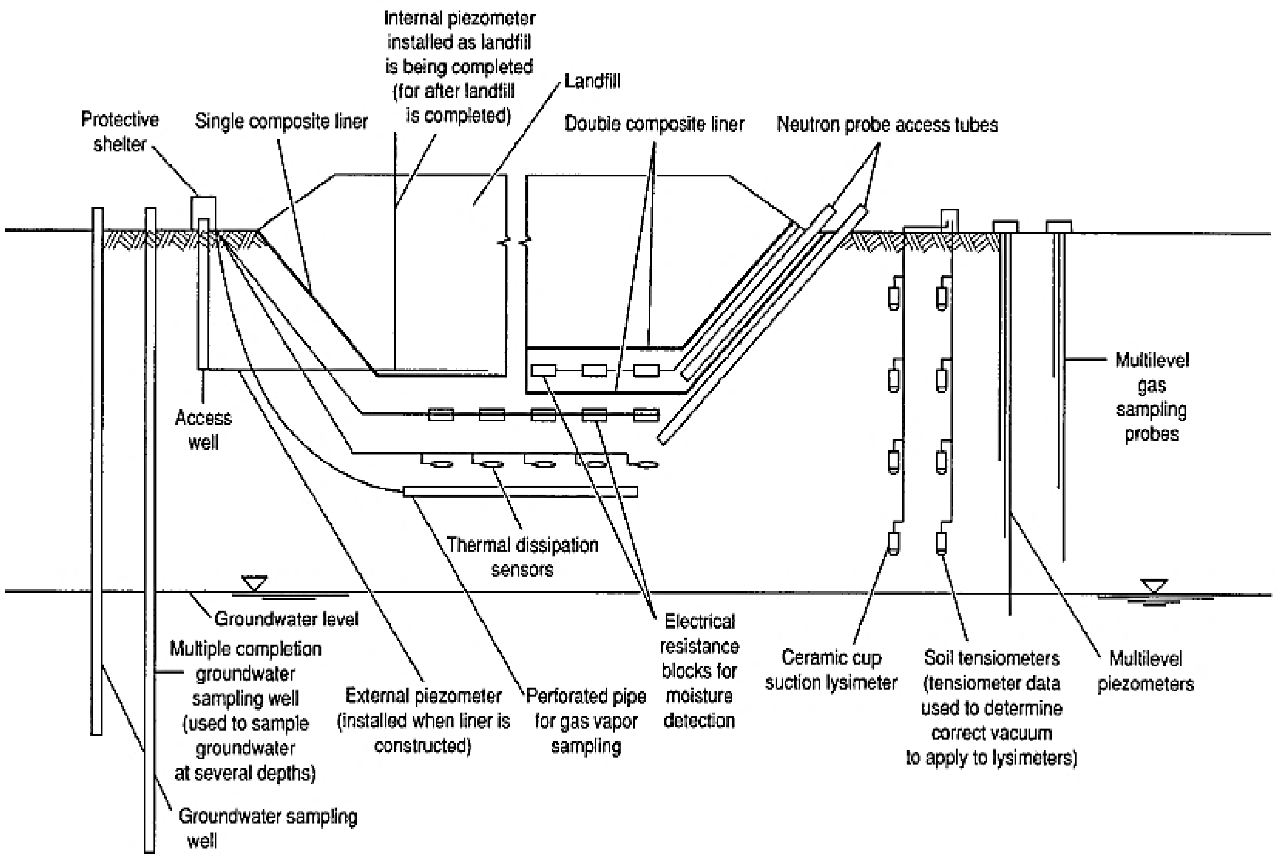


Fig (2.18): Instrumentation of a landfill for the collection of environmental monitoring data (Tchobanoglous and Kreith, 2002).

2.9.3.3 Gases generation of landfill:

The generation of landfill gases can be divided into five-phases:

a) Initial Adjustment Stage:

The organic biodegradable components in MSW undergo a microbial decomposition with the presence of oxygen soon after the waste is placed in the landfill. In this phase, biological composition occurs under aerobic reaction in which oxygen is consumed by aerobic microorganisms. Digested wastewater treatment plant sludge and recycled leachate can be considered as other sources of organisms. The aerobic decomposition generates heat, and temperature (10-20°C) higher than the refuse placement (Warith, 2003).

b) Transition Phase:

In this phase, oxygen is exhausted and the anaerobic conditions begin to develop. Nitrate and sulfate, which serve as electron acceptors, are converted to nitrogen gas and hydrogen sulfide during biological conversion reactions. The onset of anaerobic conditions can be observed by measuring the oxidation/reduction potential of the waste. The generation of methane occurs when the oxidation/reduction potential values are in the range of 150 to 300 millivolts. During the transition phase, the pH of the generated leachate starts to drop due to the high concentrations of carbon dioxide and the presence of organic acids (Warith, 2003).

c) Acid Phase:

Microbial activates which are originally initiated in second phase, accelerate significant amount of organic acid and reduce the hydrogen gas. There are two major reactions that occur in this phase. The first reaction is the enzyme-mediated transformation (hydrolysis) of higher molecular mass components (e.g., lipids, polysaccharides, proteins, and nucleic acids) into compounds that can be used by microorganisms as sources of energy. Acid genesis is the second reaction of this phase, which involves the conversion of microbial compounds resulting from the first reaction into lower molecular mass, compounds such acetic acid (CH3COOH). The microorganisms involved in this conversion are often known as non-methanogenic or acidogens. Carbon dioxide is the primary gas generated during this phase with a small amount of hydrogen gas. The pH of generated leachate drops to 5 or lower due to the elevated concentration of CO_2 inside the landfill. The biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and conductivity of the leachate will increase due to the dissolution of the organic acids in the leachate. Many inorganic constituents in particular heavy metals will be solubilized during this phase due to the low pH value of landfills leachate (Warith, 2003).

d) Methane Fermentation Phase:

A group of microorganisms convert the acetic acids and hydrogen gas to methane and carbon dioxide. The microbes responsible for this reaction are called methanogenic or methanogens. The pH values due to methanogenic reaction will rise to more natural values in the range of (6.8-8). The BOD_5 and COD values of the landfill's leachate will be reduced. Also, the concentration of heavy metals in the landfill's leachate will drop (Warith, 2003).

e) Maturation Phase:

This phase starts after the biodegradable organic matter (BOM) is converted to methane and carbon dioxide. The rate of landfill gas generation is reduced significantly in this phase as most of the available nutrients are removed with leachate during the methanogenic phase and the remaining substrates are slowly biodegradable. CO_2 and CH_4 are the primary landfill gases in this phase. Small amounts of nitrogen may be also found in the landfill gas. During maturation phase, leachate will contain humic and fulvic acids which are difficult to process biologically. The production of CH_4 declines as waste organics get depleted. However, the slowly biodegradable organics generate methane for decades (e.g. cellulosic organics such as wood and paper) (Warith, 2003).

2.9.3.4 Landfill Siting:

Criteria for Selection of Land fill Site:

- Landfill site for solid wastes should be selected on the following criteria:
- Land area and volume should be sufficient enough to provide landfill capacity so that the projected need can be fulfilled for several years. In this way the cost coming on all that procedure can be justified.
- The landfill site should not be at locations where suitable buffer zones between land fill site and population are not available.
- The landfill area having steep gradient (where stability of slope could be problematic) should not be selected.
- The water level in ground water table should be sufficient below the base of any excavation to enable landfill development.
- The land which is significant environmentally (lands of biodiversity); the sensitive ecological area of such a land should be present within potential area of landfill site.

- Public & private irrigation water supply wells should be well away from the boundaries of landfill site because these supply wells will be at risk of contamination.
- Landfill area should not be very close to significant water bodies (water courses or dams). There will be the risk of contamination of water bodies, which can be hazardous for aquatic life.
- No major power transmission or other infrastructure like sewers, water supply lines should be crossing through landfill developmental area.
- No residential development should be near the boundaries of landfill site. The waste disposal site must be very away from residential or commercial areas and water resources.
- Landscaping and protective shelf should be included in the design so that to minimize the visibility of operations.
- Unstable areas that have significant seismic risk which could cause destruction of berms are not recommended for landfill site.
- There should not be fault lines and significantly fractured geological structure. These fault lines can allow the unpredictable movement of gas within 500 meters of perimeter of proposed landfill development.
- Groundwater quality should not be disturbed during the site developmental phase. There should be monitoring facilities at site in order to ensure that ground water quality is maintained.
- In areas under the laws of concerned municipality it should be responsibility of municipality to identify landfill site and handover to operators for operations.
- Selection of landfill site should be based upon the examination of environmental issues.
- The landfill site should be near the wastes recycling facility otherwise, the waste recycling facility should be planned as integral part of landfill site. (Koerner and Daniel, 1997).

2.9.3.5 Factors affecting the generation of landfill gas:

There is several factors influence the rate of landfill gas generation. Theses parameters include moisture content, nutrient content, pH level, bacterial content, oxygen concentration, and temperature. These factors alone may not be critical; however, they may influence other parameters that control MSW degradation rates and activities.

- **Moisture Content:**

This is considered the most important parameter in solid waste decomposition and gas production. It provides the aqueous environment necessary for gas production and also serves as a medium for transporting nutrients and bacteria throughout the landfill.

Landfill gas is produced at all landfills because the substance moisture level required by methanogenic bacteria is very low and occurs even in dry landfill. Gas production is increased as moisture content is increased up to field capacity because nutrients, alkalinity, pH, and bacteria are not transferred readily within the landfill. If the moisture content in the waste exceeds the field capacity, the moving liquid will carry nutrients and bacteria to other areas within the landfill, creating an environment favorable to increase gas production. The overall moisture content of landfill's refuse ranges typically from 15 to 40 percent. The moisture movement in landfill decomposing waste increases gas production by 25 to 50 percent over the production observed during minimal moisture movement.

- **Nutrient Content:**

Microorganisms that participate in anaerobic degradation of solid waste require various nutrients for their growth. These nutrients include carbon, hydrogen, oxygen, nitrogen, phosphorus, sodium, potassium, calcium, magnesium and other trace materials. These nutrients are found in most landfills. However, inadequate homogenization of the waste may result in a nutrient limited environment. Toxic materials such as heavy metals can slow the bacterial growth and consequently retard gas production. The greater amount of digested nutrients the greater rate of gas generation (Warith, 2003).

- **pH Level:**

The pH of the refuse and leachate significantly influences the chemical and biological processes. An acidic pH increases the solubility of many constituents, decreases adsorption, and increase the ion exchange between the leachate and organic matter. The optimum pH range for anaerobic reaction is 6.7 to 7.5. Within the optimum pH range, methanogens grow at high rate leading to maximum methane production. The rate of methane production is seriously limited when the pH level is lower than 6 or higher than 8. The presence of industrial wastes, alkalinity and groundwater infiltration may affect the pH level in a landfill. During the initial stages of AD organic acids forms and result in an acidic PH as these organics begin originate, the pH should rise as the acids are converted to methane (Warith, 2003).

- **Bacterial Content:**

The bacteria involved in aerobic biodegradation and methanogens exist in the soil and refuse. However, the addition of bacteria from other sources to the refuse can result in a faster rate of development of the bacteria population. Digested effluent and wastewater sludge can be the sources of additional bacteria.

- **Oxygen Content:**

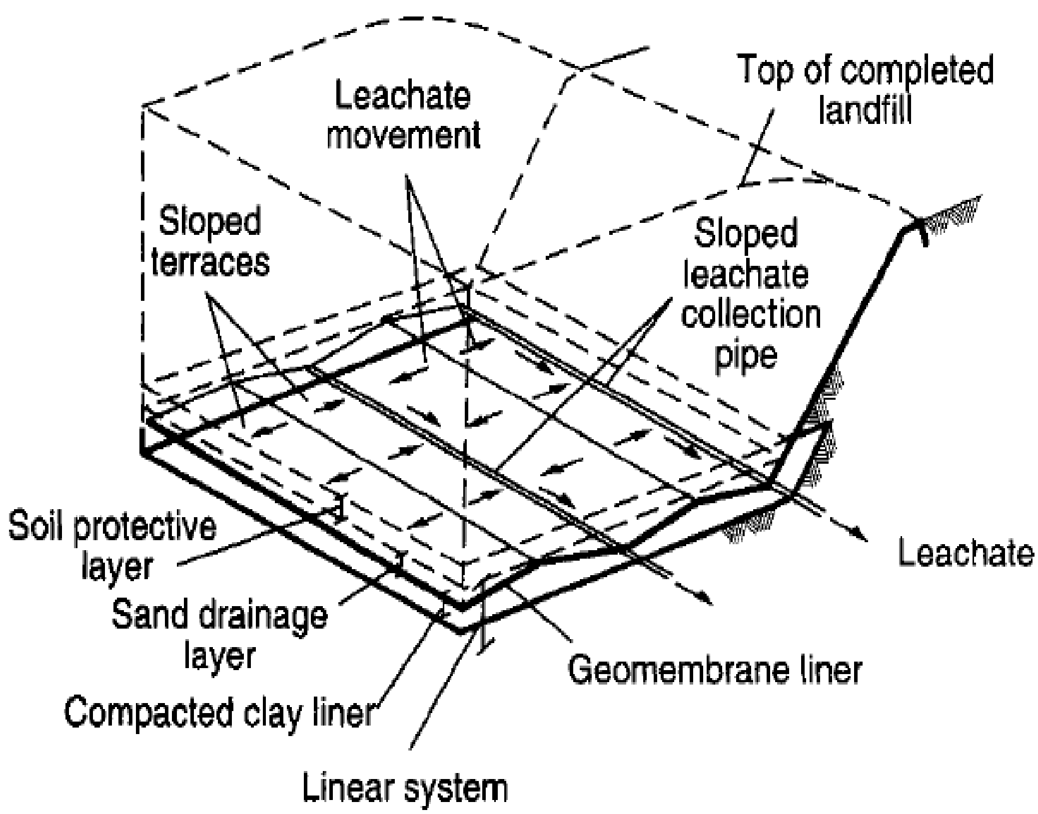
Methanogenic bacteria are particularly sensitive to the presence of oxygen. Extensive gas recovery pumping may create a substantial vacuum in the landfill, forcing air in. This will extend the aerobic zone in the landfill refuse and eventually prevent the formation of methane in these layers. Aerobic bacteria in the top of the landfill, under normal condition, will cause solid waste to readily consume the oxygen and limit the aerobic zone of the compacted waste (Warith, 2003).

- **Temperature:**

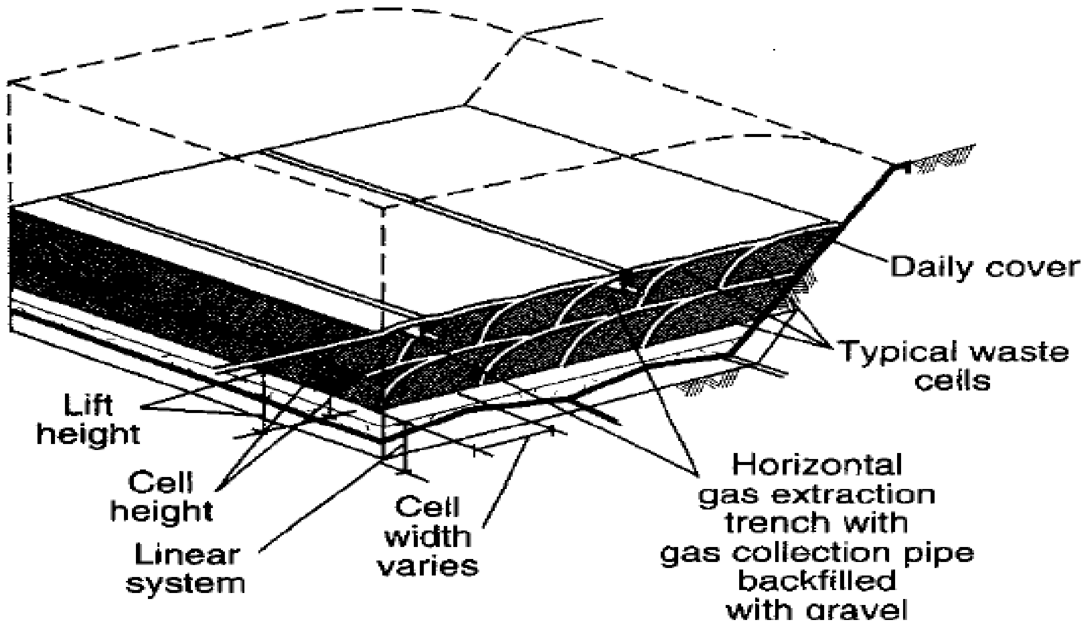
The rate of methane generation can be increased, up to 100 times, when the temperature raises from 20 to 40 ºC (Christensen et al, 1989). Moreover, in a deep landfill with a moderate water flux, landfill temperature of 30 to 45 ºC can be expected for more temperature climates. The heat is a result of AD process that can result in a temperature rise within the landfill environment. The heat flux from the landfill to the surroundings can also be resulted from the insulating effect of the solid waste (Warith, 2003).

2.9.3.6 Landfill Design and Construction:

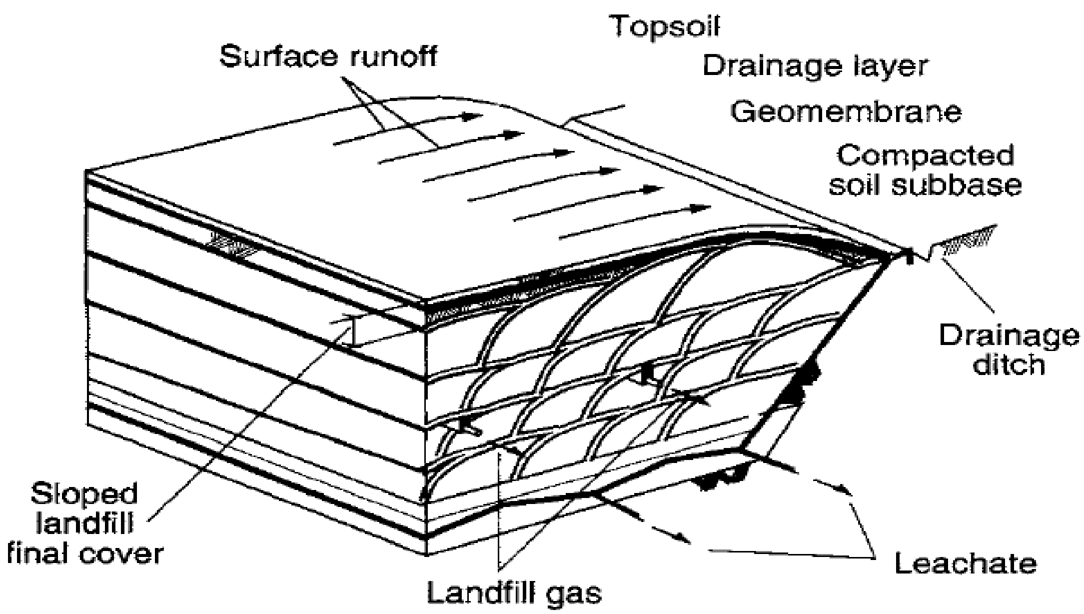
The steps of landfill design are summarized in figure (2.19).



(a)



(b)



(c)

Fig (2.19): (a, b, and c) are design steps of the sanitary landfill (Tchobanoglous and Kreith, 2002).

I Leachate Collection and Removal:

Leachates from MSW landfill sites are often defined as heavily polluted wastewater. Leachate is a liquid formed primarily by the percolation of precipitation water through the open landfill or through the cap of the completed site Leachates may contain large amounts of organic contaminants which can be measured as chemical oxygen demand (COD) and biological oxygen demand (BOD), ammonia, halogenated hydrocarbons suspended solid, significant concentration of heavy metals and inorganic salts. If not treated and safely disposed, landfill leachate could be a potential source of surface and ground water contamination, as it may percolate through soils and sub soils, causing pollution to receiving waters. Landfill leachate has been shown to contain a wide variety of toxic and polluting components. A leachate management and treatment would be required to collect the leachate emanating from the mass of waste and treat it before discharge to a sewer. The generation rate of leachate is estimated based on such factors as the rainfall, the amount of the rainfall infiltrating to the waste through the cover, the absorptive capacity of the waste, the weight of absorptive waste and any removal of the leakage via seepage or discharge. Because of the uncertainties involved in the leachate generation process from real sites, the estimated leachate generation rate would include varied inputs to provide a worse-case scenario for sizing the leachate output and getting discharge consent to allow the leachate into the sewer. The leachate generated from a landfill site will vary in volume and composition depending on the age of the site and stages biodegradation reached. Because of the changes in leachate composition with time, the leachate control systems should adapt to these changes. Leachate treatment is required to remove any contaminating components of the leachate and bring it to a standard whereby it can be released to a sewer, a water course, land or tidal water. Before release, a discharge consent or agreement is required from the local authorities or environmental agency. The consent or agreement may cover a range of potentially polluting components, for example, pH, concentration of organic material, ammonium and nitrate, suspended solids and metal content. Treatment processes for leachate are physico-chemical, attached growth processes, non-attached growth processes, anaerobic/aerobic treatment, land treatment and leachate recirculation (Rui, 2012). As shown in figure (2.20).

LDCRS are components of the design of the main landfill systems, which are proved to be reliable through field use and require low maintenance systems. The LDCRS model consists of the following components:

- Layer: A discharge layer designed to produce little or no liquid head on the base lines, allowing quick detection, collection and removal of leachate.
- Pipe: drainage pipe system of suitable size and spacing to efficiently remove leachate.

- Swamp: sized for the collection of leachate discharged by drainage pipes.
- Measuring methods for measuring and recording fluid volumes in the aquarium.
- Geosynthetics are increasingly used in discharge or filters in LDCRs, which are made of polymers. Synthetic geological materials can be replaced with natural materials if: chemical resistance to waste and leachate, resistance to stress loading and compatible with terrestrial membrane lining (Pacey, 1989).

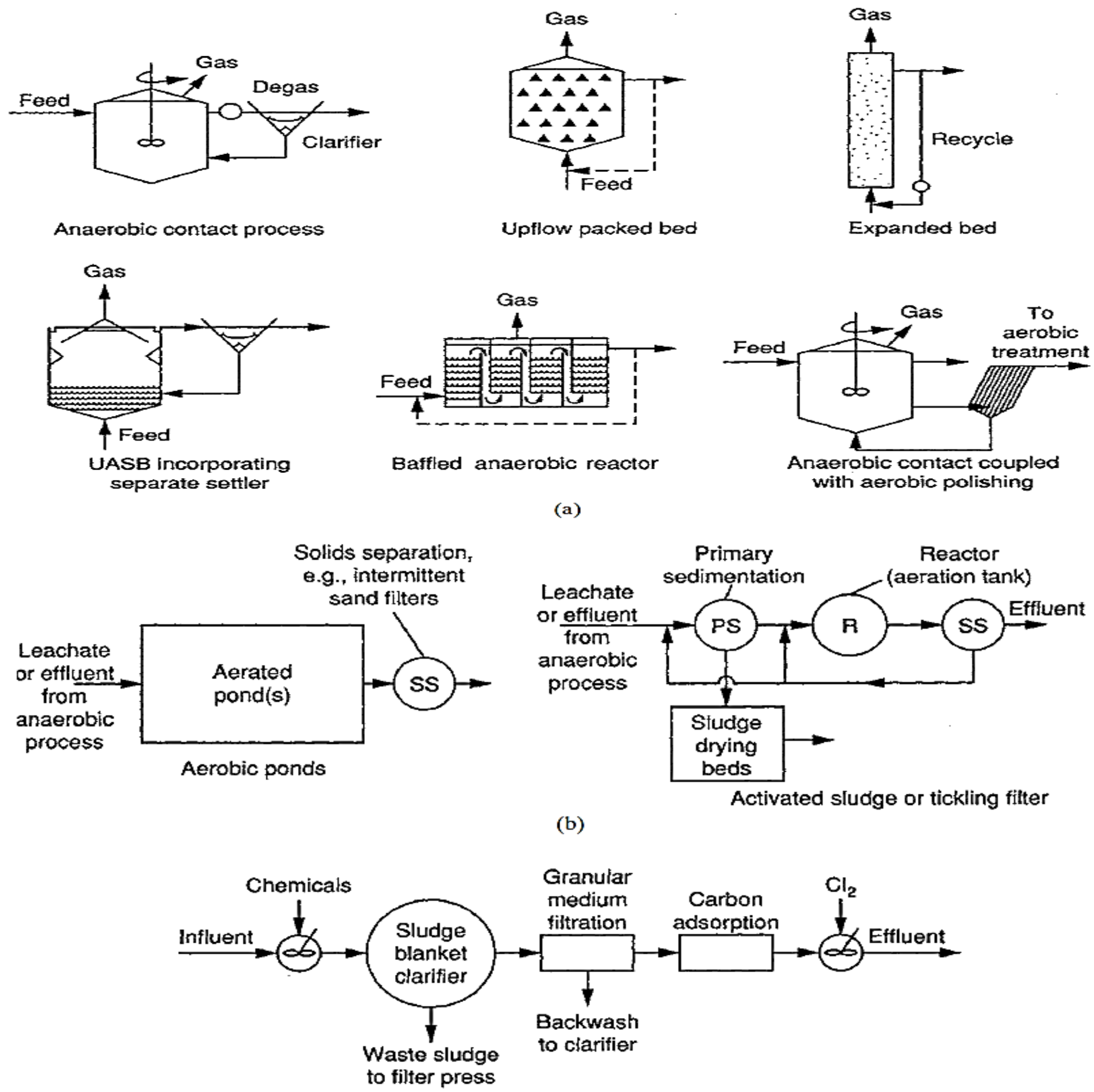


Fig (2.20): Typical processes used for the treatment of leachate:(a) anaerobic processes; (b) aerobic processes; (c) chemical treatment process for the removal of heavy metals and selected organics (Tchobanoglous and Kreith, 2002).

II LFG Collection and Recovery:

Mostly use either vertical wells or horizontal collectors while refuse is being placed. Horizontal collectors may cause less interference with refuse placement. Horizontal collectors must be installed as refuse is being placed. Vertical wells generally produce better quality LFG (higher methane content) and allow greater operating flexibility. Horizontal collectors may be more sensitive to damage from differential settlement and leachate flooding (Ritchie and McBean, 2011). As shown in figure (2.21).

a) Vertical collection:

- In-refuse wells are typically drilled to 75% of the refuse depth or until leachate is reached.
- Boreholes are typically 24" to 36" diameter.
- Typical 200 ft. to 400 ft. between in-refuse wells.
- Casing is PVC, HDPE or carbon steel (infrequently).
- Perforated with slots, holes or screen. Typically perforated in bottom 1/3 to 2/3. Perforations normally start no closer than 20 ft. from surface.
- Deeper perforations increase a well's radius of influence and reduce the potential for air infiltration.
- Wells can be equipped with leachate pumps.
- In-soil wells can be used for migration control and sometimes groundwater $NMOC_S$ migration. They can be equipped with groundwater pumps. (Ritchie and McBean, 2011). As shown in figure (2.22).

b) Horizontal Collection:

- Installed as refuse is being filled.
- Typically spaced 100 to 200 ft. horizontally and 40 to 60 ft. vertically.
- They consist of a pipe in a trench filled with porous material (e.g., crushed stone or tire chips).
- Pipe is typically HDPE with holes drilled within or coated CMP or PVC with alternating diameters (nested within each other).
- When used as a single layer just below the landfill surface, and under a membrane cover, they are sometimes called "surface collectors". (Ritchie and McBean, 2011)

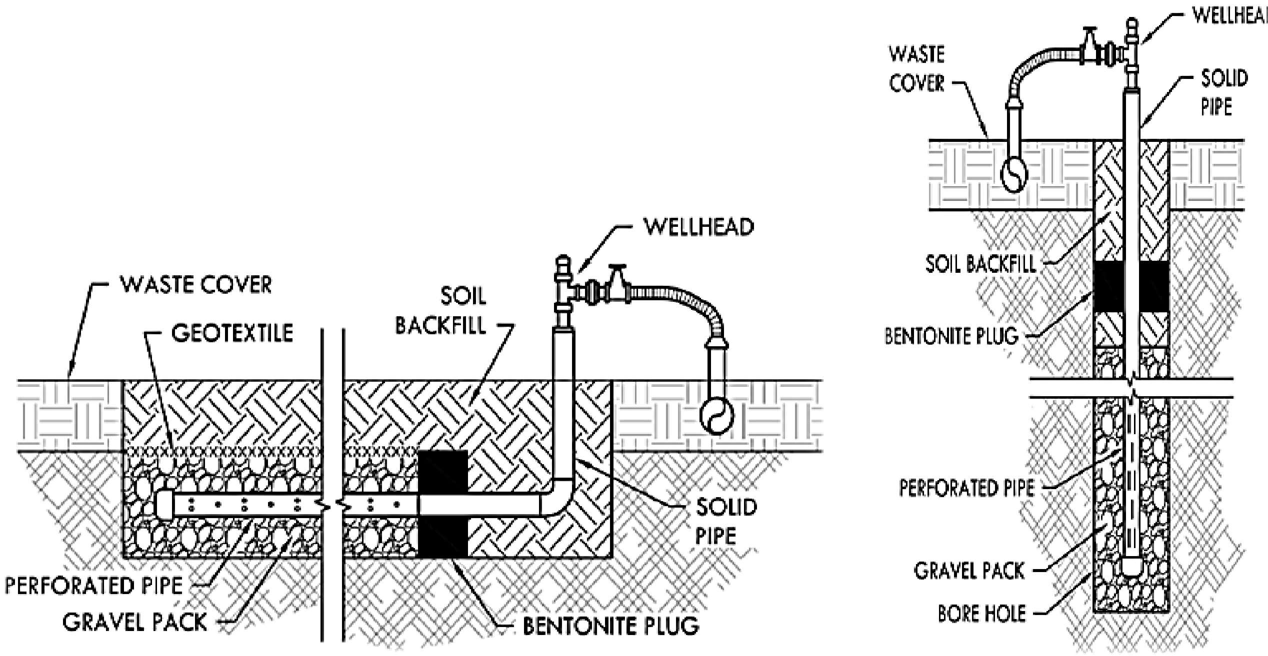


Fig (2.21): Vertical and Horizontal Collection (Ritchie and McBean, 2011).

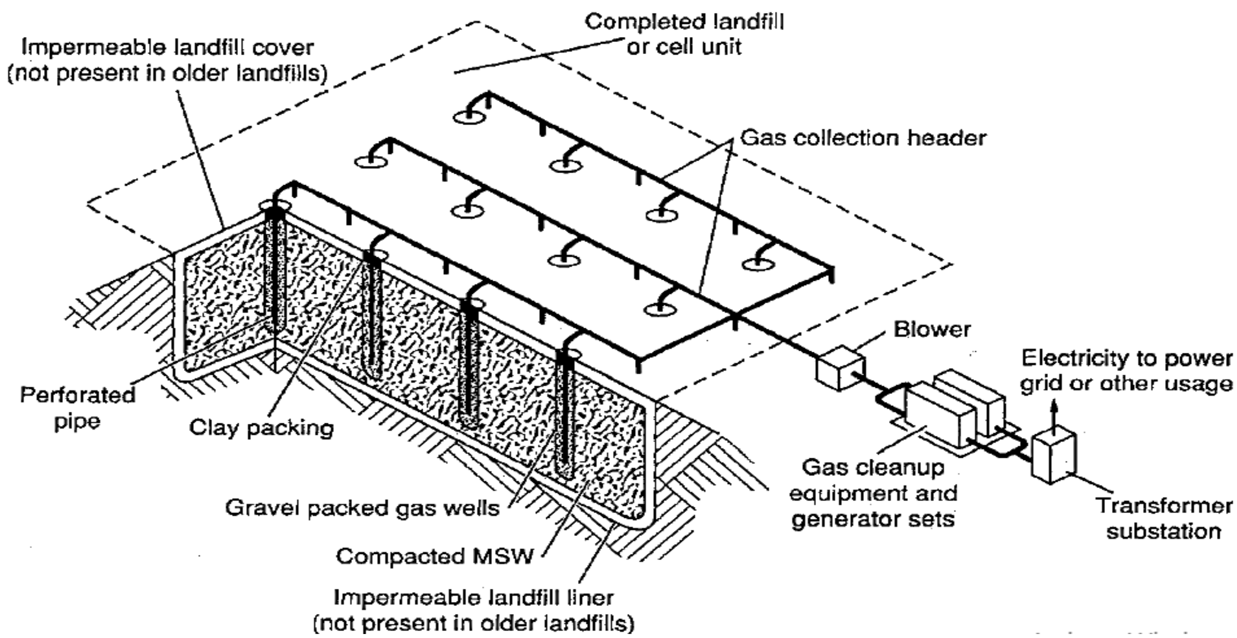


Fig (2.22): Landfill gas recovery system using vertical wells (Tchobanoglous and Kreith, 2002).

2.9.3.7 Landfill Cover design *(*Protective Cover):

In terms of environmental protection, the final cover or cap over a landfill is a key part of its overall design. It is primary objective is to isolate the interior of the landfill from the infiltration of water and thus to prevent the generation of leachate. The cap should be less permeable than the bottom liner to prevent a build- up of water inside the landfill. The cover should be designed to promote the growth of vegetation in order to protect the landfill from erosion and intrusion by humans, burrowing animals and plant roots and also to improve the esthetic appearance (Tammemagi, 1999).

A typical final cover for landfill can be from 0.6 to 2 meters thick. Clay layers and very low permeability plastic liners (Geomembranes), such as a high density polyethylene (HDPE), are used either alone or together to prevent the entry of water. The drainage layer diverts any infiltrating water to a collection and removal system. Other components may consist of, in various combination, geotextiles, sand, coarse sand and gravels, topsoil, and grass. Geotextiles are essentially durable cloth like sheets that prevent the materials of one layer from mixing with the materials of the adjacent layer, usually to prevent a drainage layer from becoming clogged by finer particles; they allow gases and liquids to pass. If there is concern about future human instruction, perhaps after the landfill has been abandoned, a layer of concrete or larger rocks (rip rap) can also be included, although this is not commonly done. The final surface is graded to promote runoff of rainwater, and vegetative cover is planted; this not only prevents erosion but also promotes runoff and evaporation. Surface-water flow usually starts as sheet flow, but it can concentrate over short distances to form rills and then gullies which erode the cap and carry sediments downward. With the modern trend to higher landfills, a heavy rain-storm can cause considerable damage. The choice of soils, topographic shape, and plants, combined with flow velocity and erosion analysis to minimize such erosion, is an important part of landfill design. Overall site drainage needs to direct rainwater away from filled and operating areas, thus preventing it from infiltrating into the landfill. Table (2.6) shows Classification of sanitary level of landfill system.

A significant difference between covers and bottom liners is that the latter are constructed on solid foundations so that there will be very little settlement. Covers, however, will be subjected to considerable settlement as the wastes below gradually decompose and compact. Because of the landfill's heterogeneous contents, settlement will not be uniform, and stress on the cover will cause it to crack. In addition, freeze/thaw cycles during winter, spring downpours, and wind erosion will all act quietly but persistently to degrade the cover. For these reasons, not only must the cover be designed and constructed with extreme care: it will also be necessary to inspect and perform repairs and maintenance for many decades, if not centuries, after closure, until the landfill no longer poses a hazard (Tammemagi, 1999). As shown in figures (2.23), (2.24) and (2.25).

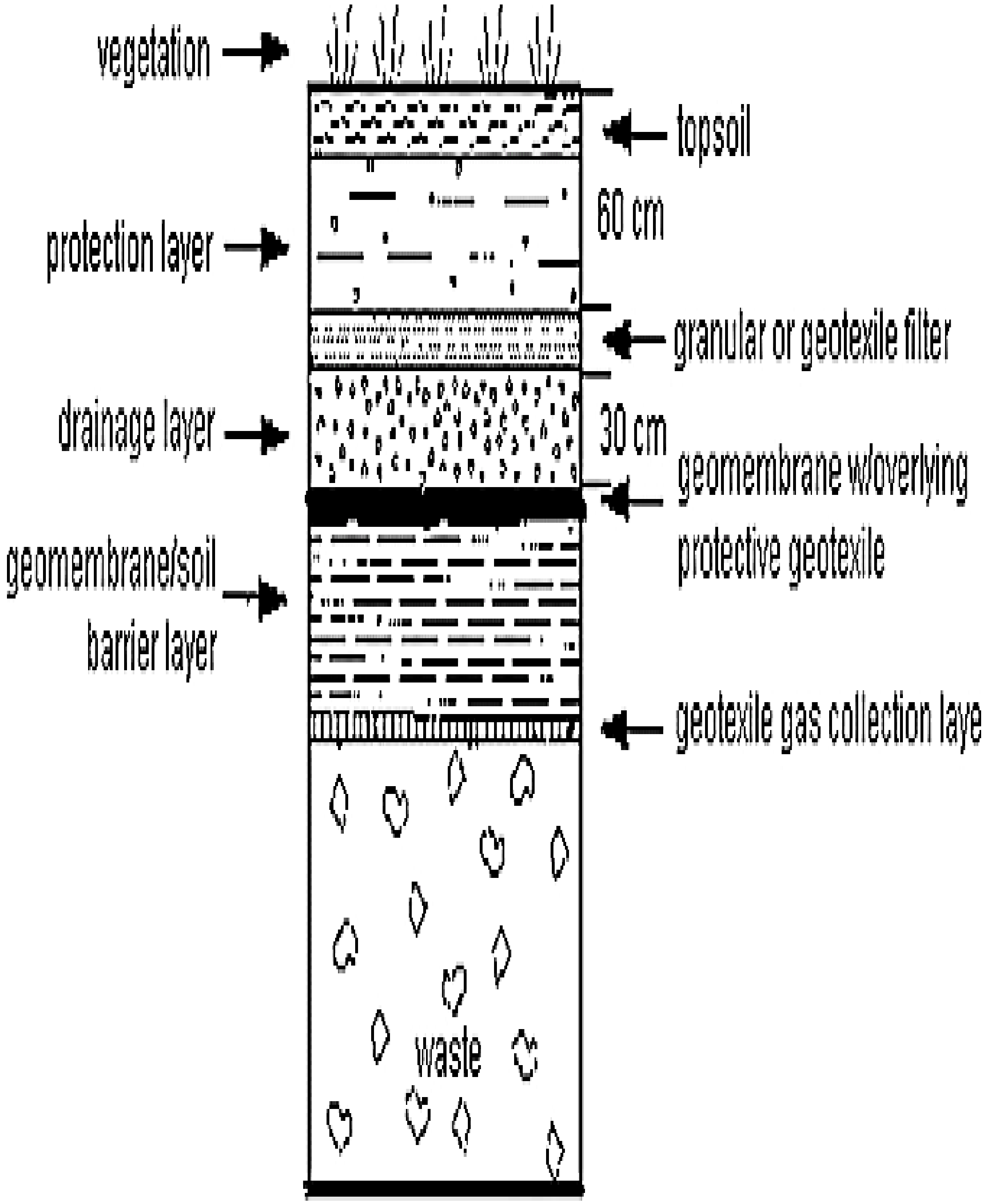


Fig (2.23): Landfill Cover Layers (Tammemagi, 1999).

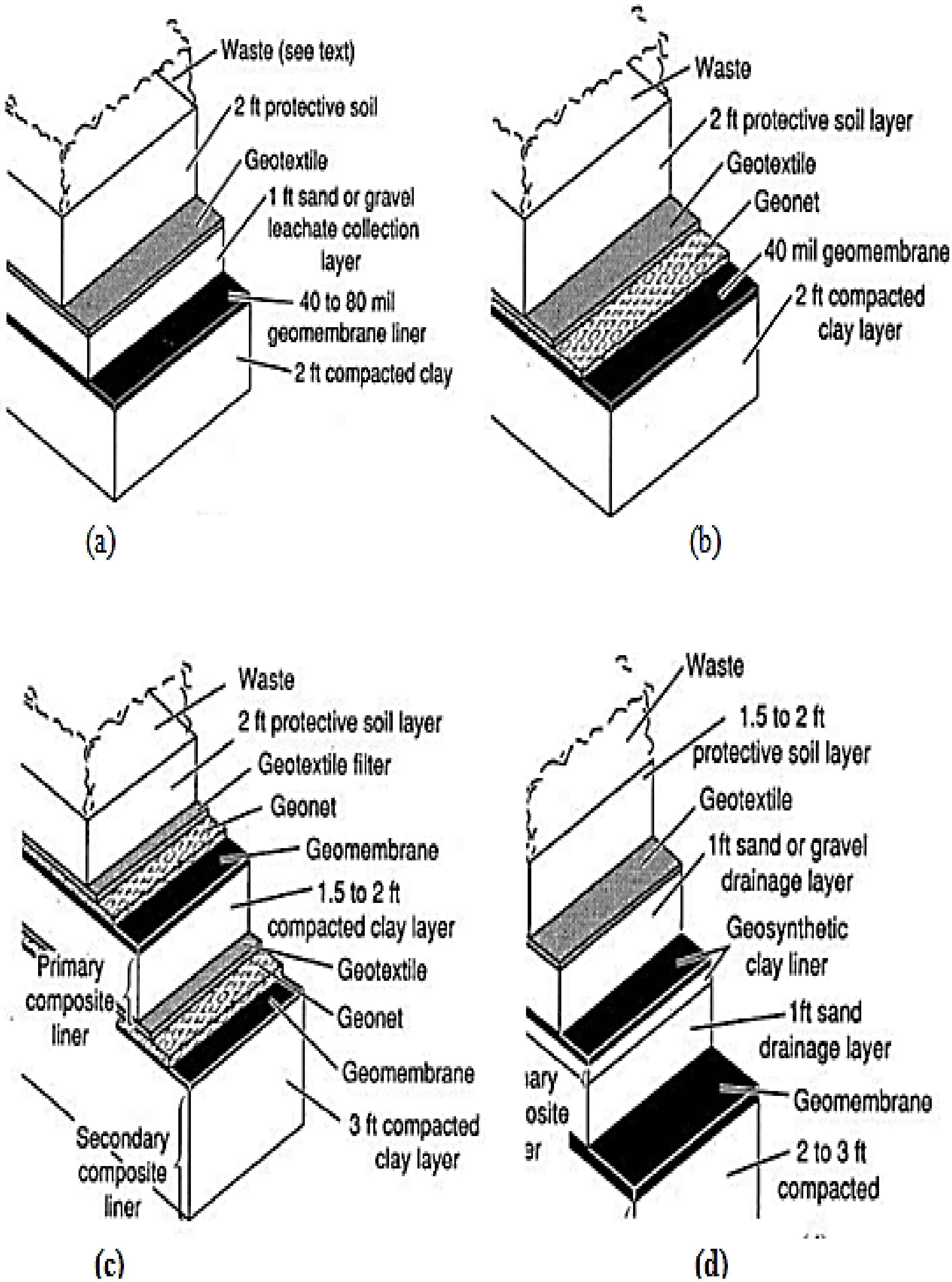


Fig (2.24): Typical landfill liners: (a, b) single composite barrier types; (c, d) double composite barrier types (Tchobanoglous and Kreith, 2002).

Table (2.6): Classification of sanitary level of landfill system (Schübeler et al., 1996).

Level	*Category*	*Achievement*
Level 1	Controlled Tipping	• Establishment of access to site. • Establishment of site boundary. • Introduction of inspection, control and operational records of incoming waste. • Introduction of amenities for the staff such as sanitary facilities and locker room. • Environmental protection measures are not established.
Level 2	Cover soil	• Application of daily cover to disposed of waste. • Establishment of drainage system to divert storm water from surrounding areas and hence reduce leachate production. • Establishment of site boundary to distinguish the disposal site and control scavenging. • Efficient control of landfill operations. • Reduced impacts from landfill operations.
Level 3	Control of Leachate effluent	• Establishment of leachate control by the installation of effluent collection, storage and monitoring facilities. • Installation of gas removal facilities.
Level 4	Leachate treatment System.	• Establishment of treatment by the installation of waste stabilization system etc. • Establishment of seepage control.

2.9.3.8 Factors considered in the design of the landfill:

There are factors to consider when designing sanitary landfills shown in table (2.7).

Table (2.7): Factors considered in the design of the landfill (Schübeler et al., 1996).

Factor	*Proposed*
Access	All-weather access roads to landfill site; temporary roads to unloading areas.
Landfill area	Maximum available area considering acceptable base and final cover slope.
Landfilling method	Cell method of landfilling.
Surface drainage	Storm water drains to divert surface water runoff at the periphery of the landfill area.
Intermediate cover material	Maximize use of onsite soil materials; additional cover material from borrow areas to be identified.
Final cover	Minimum final cover slope of 2% recommended 5%. The allowable minimum slope is to safeguard ponding and hence increased risk of precipitation to percolate through the landfill cover resulting to possible leachate. Multi-layer design to be considered.
Landfill liner	Multi-layer design incorporating the use of a geo-membrane to be considered. Constraints in the use of geo-membranes due to cost and availability of construction technology envisaged. Minimum base slope 0.5%, desirable 2%. Piped bottom type leachate collection system at 0.5%. Slope. Pipe perforation, diameter and spacing of pipes to be determined.
Cell design and construction	Each day's wastes to form one cell; cover at end of day with 150mm of earth. Cell width, lift height, slope of working faces to be determined.
Groundwater protection	Perimeter drains to be provided.
Landfill gas management	Landfill gas management plan to be considered.
Leachate collection	Determine maximum leachate flow rates and size leachate collection pipe and/ or trenches; size leachate pumping facilities; select collection pipe materials to withstand static pressures corresponding to the maximum height of the landfill.
Leachate treatment	Based on expected quantities of leachate appropriate treatment process will be considered.
Environmental requirements	Groundwater monitoring facilities to be provided; locate ambient air monitoring stations.
Equipment requirements	Number and type of equipment to be determined.
Fire prevention	Water to be provided onsite.
Enclosure Dike	Prevent dispersion of solid waste Prevent influx of rain water from outside Limit the range of dumping area Placed along the boundary of the site
Divider Dike	Placed on the boundary of the partition to separate hospital waste from general solid waste Special waste Chambers to be considered.

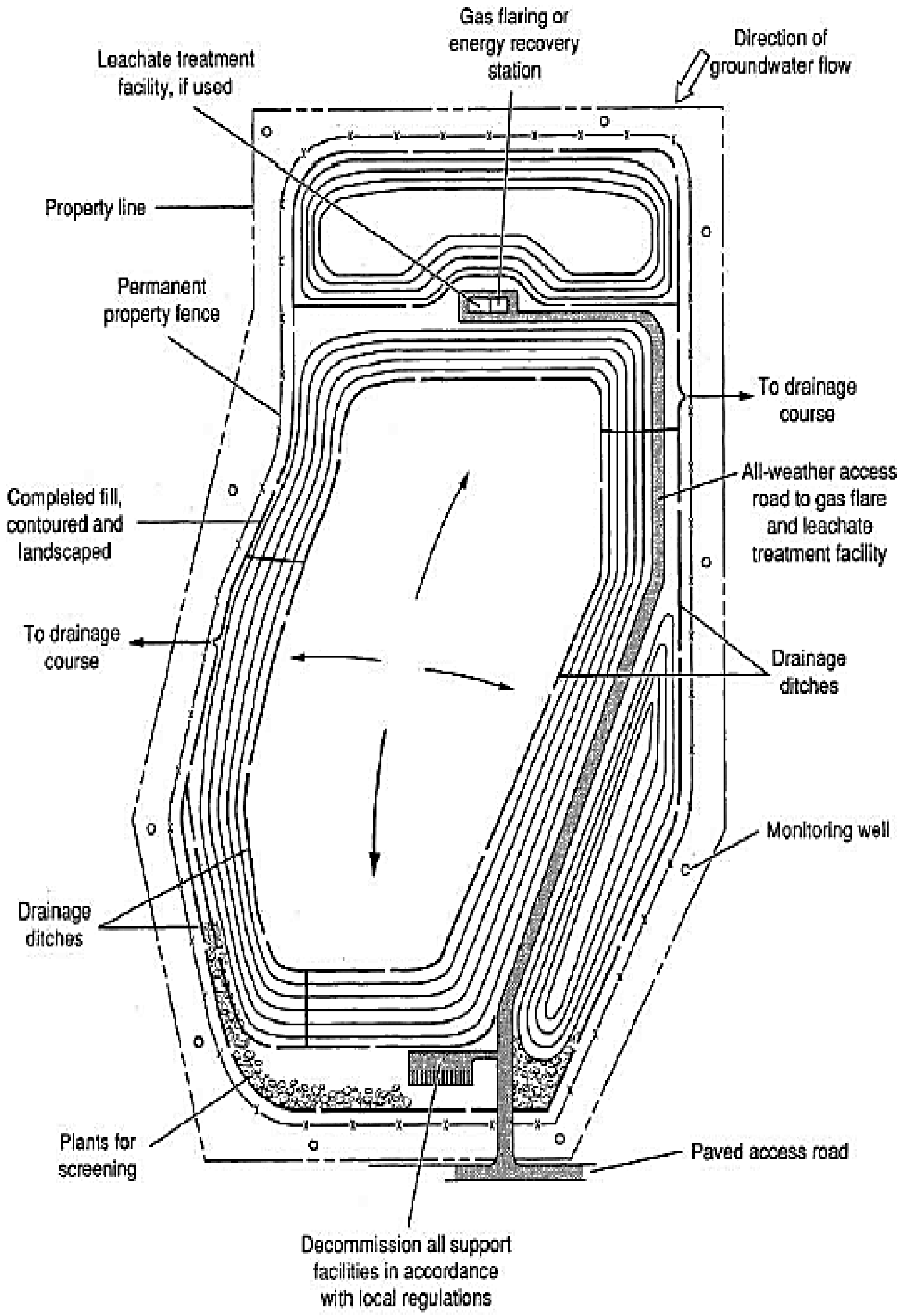


Fig (2.25): Plan view of completed landfill showing all of the elements involved in closure and post closure (Tchobanoglous and Kreith, 2002).

Chapter three

Chapter three
Methodology

3.1 Introduction:

This chapter explains the methodology used to achieve the objectives of this study. Several methods were used to collect data and qualitative and quantitative analysis through observation, reports, books, references, and interviews. The study includes the development and improvement of the existing landfill at the Sudan University of Science and Technology (Southern Campus), which was designed and excavated in October 2017. The landfill was opened and old waste was replaced with a new one and both landfill gas collection systems and leachate were changed. Then the process of monitoring and monitoring the resulting landfill gases started, and the first measurement was carried out three months after the landfill was closed. And compare the readings with previous studies. And work to improve landfill performance and increase gas production through periodic hydration by increasing water at intervals to activate the CH_4-producing bacteria. The gas analyzer was used to measure and monitor landfill gases.

On the other hand, a questionnaire was conducted to help evaluate the waste management in Khartoum State and to know the methods and techniques used for waste disposal. Highlighting the landfills in Khartoum State and comparing these landfills to international standards. As well as knowing the extent of citizens' acceptance and support to improve waste management through the use of modern methods and technologies that treat waste to benefit from it.

3.2 Flow Chart:

The work flow chart is shown in figure (3.1).

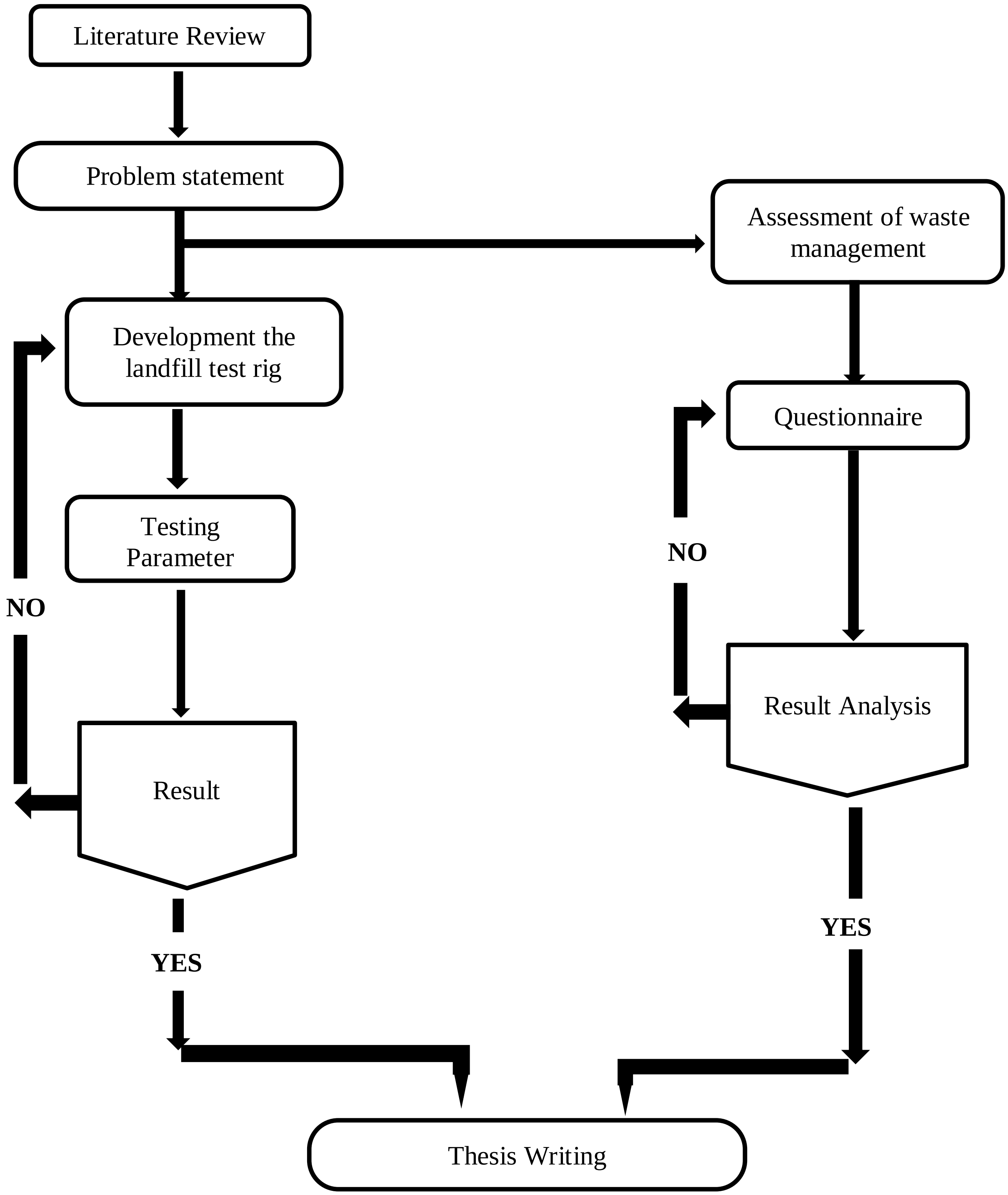


Fig (3.1): work flow chart.

3.3 Experimental Procedures:

The experimental study was conducted within the Sudan University of Science and Technology (Southern Campus).

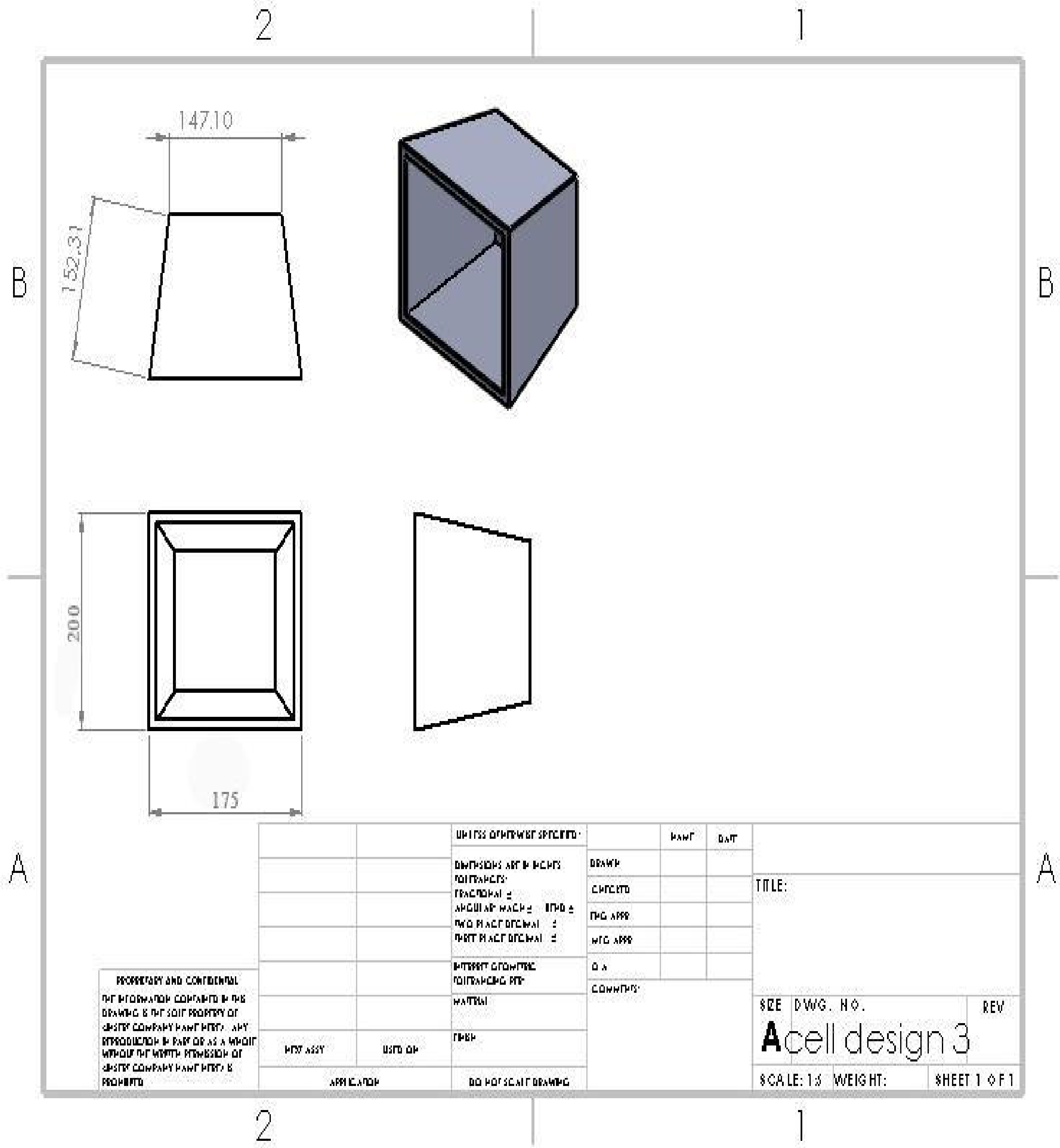
3.3.1 The Siting:

Figure (3.2) illustrates the landfill that was designed specifically within the university in the south-west of the air-conditioning and refrigeration workshop, mechanical engineering, energy department.

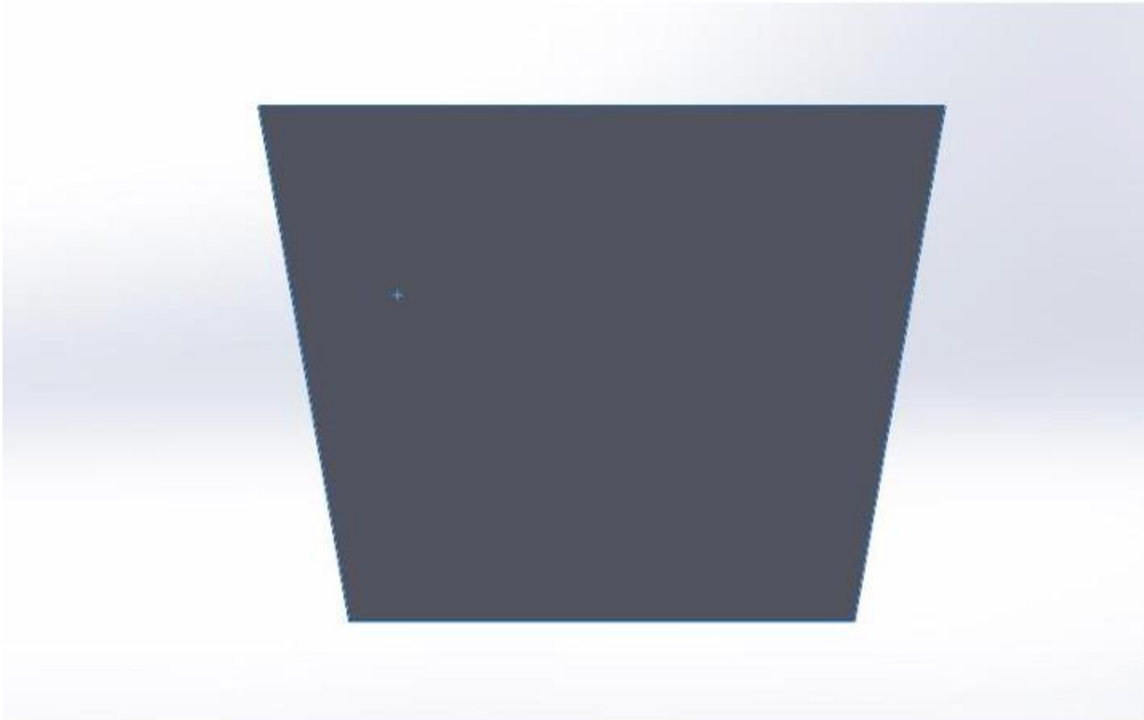
Fig (3.2): Cell location

3.3.2 Landfill Design:

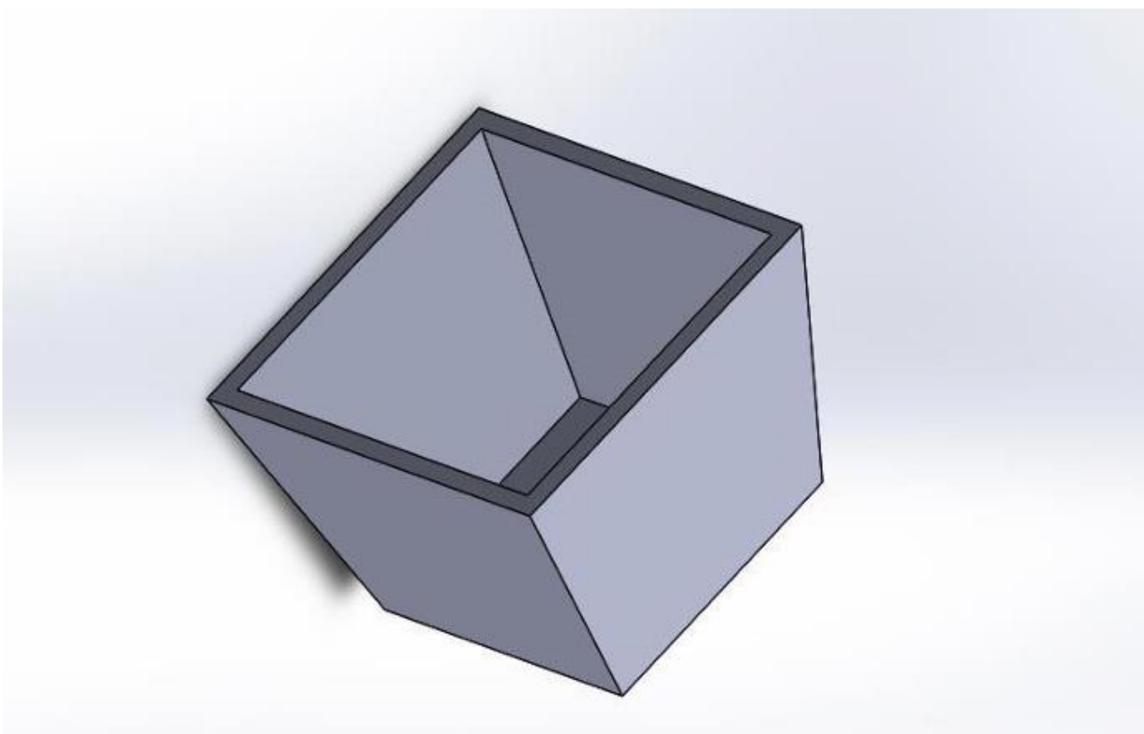
The landfill was designed in October 2017; the cell was dug with dimensions (2x1.75x1.4) m3 (Abdullah et al., October 2017). Show figures (3.3), (3.4) and (3.5).



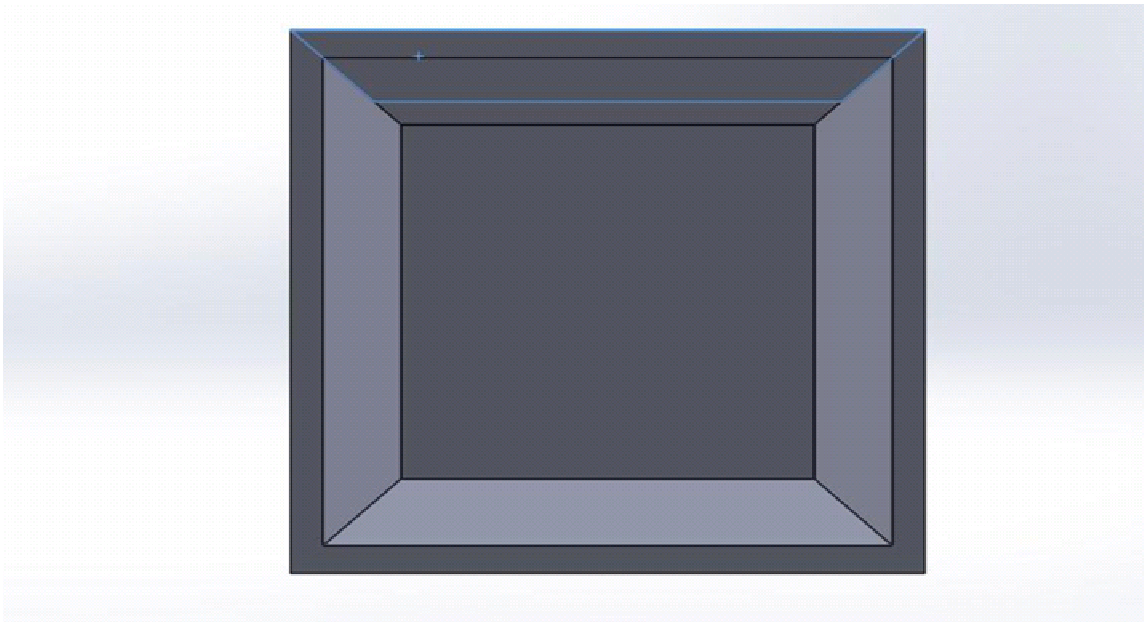
(a)



(b)



(c)



(d)

Fig (3.3): a, b, c, and d show a lab-scale landfill design by Solid works ver2015 (Abdullah et al., October 2017).

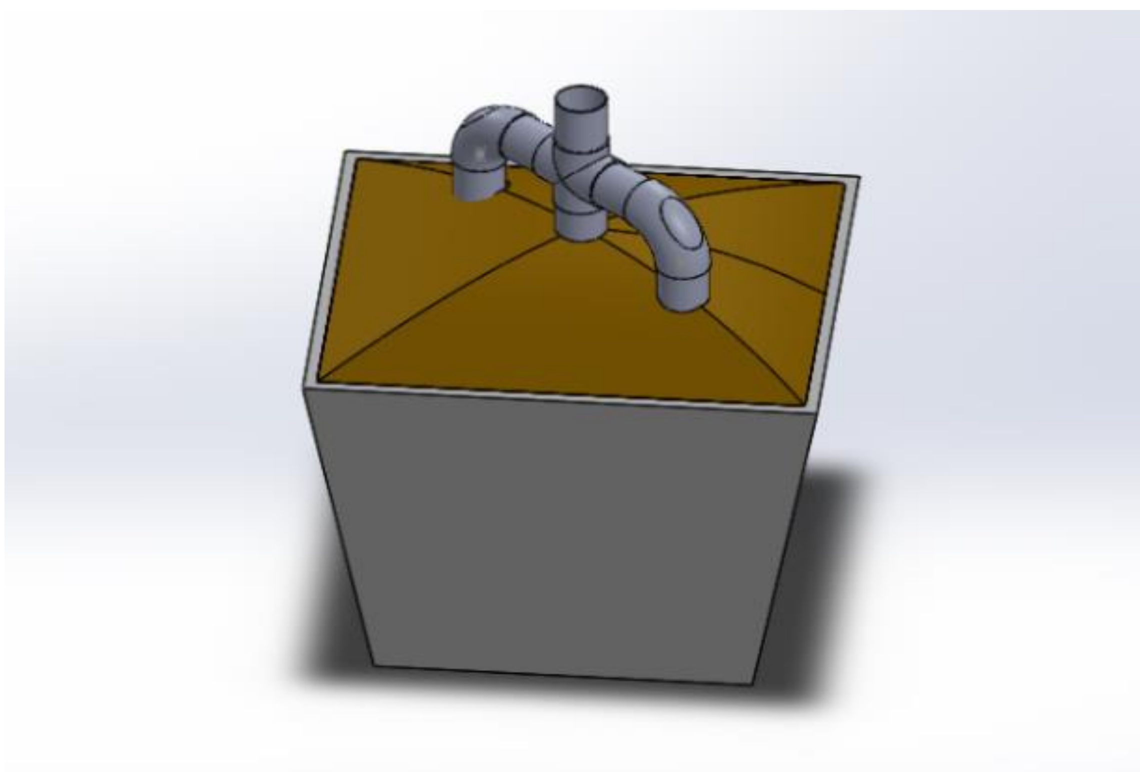


Fig (3.4): landfill shape (Ahmed et al., October 2018).

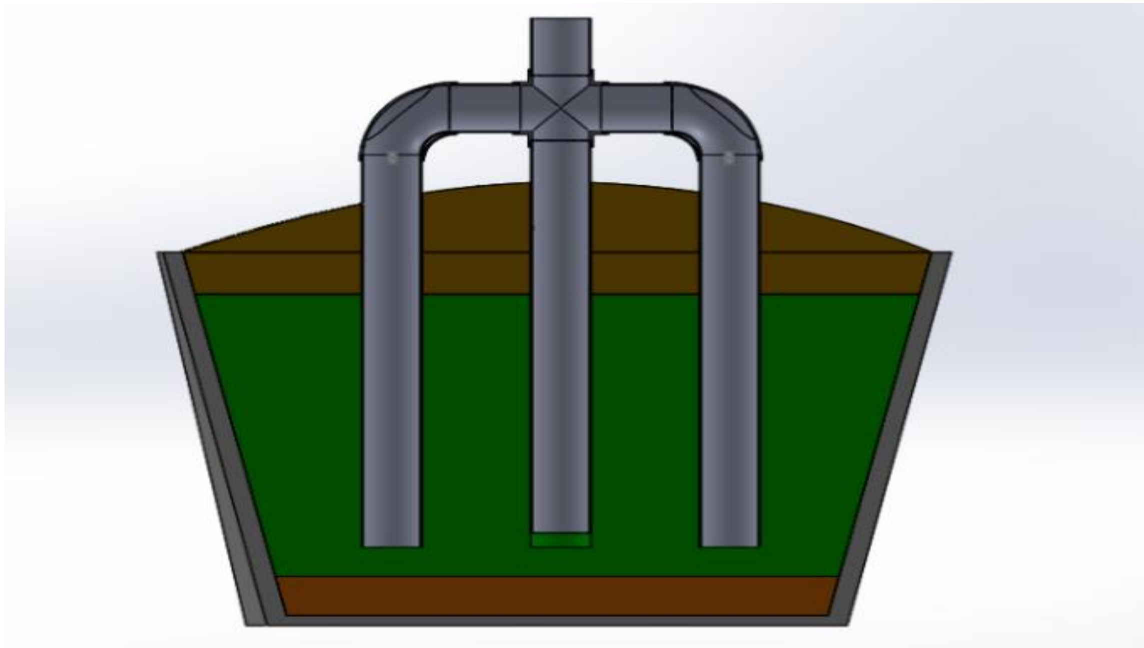


Fig (3.5): shape of gas collection pipes (Ahmed et al., October 2018).

3.3.3 Experimental Steps:

1. Locate and prepare the ground by cleaning the area around the site.
2. Open the old landfill and remove the final cover and re-prepare it by removing the old waste and putting new waste and also to change the gas collection system).
3. Uncover the Geomembranes layer and removal of the collection and extraction pipes of waste and gases as shown in figure (3.6).

Fig (3.6): old gas extraction pipes.

4. Welding protective layer: This layer protects groundwater from leakage of leachate. It also prevents LFG loss. This layer consists of HDPE paper.
5. Preparation of the second layer includes the protective layer Geomembranes or flexible membrane linings (FML) consisting of a variety of plastics including polyvinyl chloride (PVC) as well as HDPE. As Shown in figure (3.7)

Fig (3.7): setup Geomembranes layer

6. leachate collection system has been prepared and contains:
   - Perforated PVC pipes to collect the leachate (1 inch).
   - An initial layer of gravel (0.15 m) used as drainage lines for leachate from waste.
   - Thin layer of sand. Show in Figure (3.8).
7. Prepare the geotextile layer as in figure (3.9). Which reduce clogging in the collection system of the juice and protect the membranes from the holes (protective layer) that caused by the movement of fine waste and soil particles.

Fig (3.8) the leachate collection system

Fig (3.9): Geotextile layer

8. Preparation of gas collection system containing:
   - Three perforated Polyvinyl Chloride (PVC) pipes with a diameter of 2 inches with one side open, as shown in figure (3.10) and figure (3.11) illustrates the process of pipe hole.

- The vertical system is used to collect the LFG product instead of the horizontal system because the horizontal system proves low collection efficiency; the horizontal load resulting from the weight of the waste layers leads to pressure on the tubes and may over time break them as shown in figure (3.6) (The old landfill). All this leads to shortening the life of the pipes and thus loss of gas.
- The iron fences shown in figure (3.12) were used to increase the protection of the gas collection system from the waste particles and against the collapse.

Fig (3.10): Hole process of pipes

Fig (3.11): The perforated pipes

Fig (3.12): The iron barrier

9. Waste collection: The waste was collected from the cafeteria of the Sudan University of Science and Technology (Faculty of Engineering) and the Central Market in Khartoum. With all waste used as organic waste.
10. The iron barrier is installed and start filling the cell by organic waste collected as
11. Then prepare the layers of the landfill cell:
    The layers of waste are separated by ground cladding and sand. The second and third waste layers are prepared with a thickness of 0.3 m per layer; the layers are then pressed and then the gaps are filled with gravel.
12. Prepare the pre-final cover layer that is contains: Geotextile, Geomembrane and Fill the cell with a layer of sand and then compress it, as shown in figures (3.13) and (3.14).
13. Finally the final closing layer as shown in the figure (3.15).

Fig (3.13): Geotextile in final cover.

Fig (3.14): Geomembrane in final cover.

Fig (3.15): Final closure layer.

3.4 Development of landfill test rig:

To improve the landfill condition, water is added to the landfill periodically to moisten it and thus improve its performance. Since water acts as a catalyst for bacteria that produce biogas, it increases the fermentation process and mold to complete the anaerobic decomposition process and thus increase the production of landfill gas.
Water was added at three intervals to the landfill.

3.5 Landfill Testing and Monitoring:

The objective of the LFG test and monitoring is to identify, detect and analyze the percentage of methane (CH_4), Carbon Dioxide (CO_2) and other emissions from the landfill.

3.5.1 Landfill Monitoring:

Methane (CH_4) and carbon dioxide (CO_2) are the main constituents of decomposition gas; other gases are in very small quantities.
We address the following information that may be useful for monitoring evaluation:

- Ambient temperature of the landfill during measurements of the amount of gases.
- pH values that are monitored by the waste extractor test.
- LFG quantity in volume by volume (methane CH_4).

- LFG Quantity by volume (CO_2).
- LFG Quantity by volume of other gases.
- Social effect of the landfill.

3.5.1.1 Temperature:

The ambient temperature is the normal air temperature. The table (3.1) below shows average temperatures in Khartoum state throughout the year.

Table (3.1): Average temperatures of Khartoum during the months According to IPCC (Osman and Sevinc, 2019).

Month	Temperatures °C		
	Maximum	***Medium***	***Minimum***
January	31.2	23.2	15.4
February	33.2	24.8	16.4
March	37.0	28.3	19.7
April	40.3	31.5	22.8
May	42.1	34.1	26.2
June	41.3	34.3	27.0
July	38.4	32.2	25.9
August	36.5	30.7	25.3
September	38.5	32.0	26.0
October	39.9	32.4	25.5
November	35.3	28.2	21.0
December	31.9	24.5	17.0

3.5.1.2 PH values:

The pH is a scale of the degree of alkalinity or acidity (from 0 to 14). The most acidic solutions have the lowest pH. Alkaline solutions have a higher pH. Non-acidic or non-alkaline substances (i.e. neutral solutions) usually have a pH_7 (wikipedia, 2020b).

3.5.1.3 LFG:

A gas analyzer GFM410 was used to detect the percentage of gases from the landfill.

3.5.1.4 Social impacts of landfills:

Those who were often around the landfill were interviewed, such as workers who guarded the university and cared about it and others**.**

3.5.2 Landfill Testing:

3.5.2.1 Laboratory Testing*:*

A sample of the waste leachate was taken and the pH was examined inside the chemistry laboratory at Sudan University of Science and Technology (Southern Section).

3.5.2.2 Field Testing:

Field operations consist of cell work, landfill waste liners, layers, gas systems, and leachate filters.

Data were collected and the first measurement was performed three months after the final completion of the landfill. Then add water at intervals to improve the performance of the landfill gas production where water was added at intervals, especially in the summer during the drought,

LFG concentrations were measured using the gas analyzer from 10/2018 to 8/2019 (several experiments were performed five or three times per month and then averaged).

3.6 Instruments:

The main instruments of the study will show in details below:

3.6.1 Gas Analyzer:

The GFM410 gas analyzer shown below in figure (3.16) is only 750 gm. The GFM410 gas analyzer is an ideal portable tool for monitoring and analyzing gas content from landfill, biogas and contaminated land sites.

3.6.1.1 Work method:

The GMM410 gaseous gas analyzer analyzes methane (0-100%) and carbon dioxide (0-100%) using infrared sensors as well as oxygen (0-25%) and hydrogen sulfide (0-1500ppm) using electrochemical sensors.

Other features include fixed pressure options **(+/-** 400mbar), air pressure options (800-1200 mbar), data recording facilities to store more than 1000 readings, a powerful sample pump with a suction rate of 300 ml / min and a battery life of 10 hours (Ross, 1979).

Fig (3.16): Portable gas analyzer GFM410.

3.6.1.2 Measurement Uncertainty:

In the following section, measurement error $\boldsymbol{\varepsilon}(\%)$ is used to express the difference between measured $(\boldsymbol{X_{meas}})$ and expected $(\boldsymbol{X_{exp}})$ values (in ppm) as a proportion of $\boldsymbol{X_{exp}}$;

$$\varepsilon(\%) = 100\frac{X_{meas} - X_{exp}}{X_{exp}}$$

The expected value is estimated using mean loop volume (V_{loop}) for the given instrument;

$$X_{exp} = X_{stn}\frac{V_{loop} + V_{samp}}{V_{loop}}$$

Where, X_{stn} is the standard gas PP (ppm) and V_{samp} is the volume of sample injected into the loop. Show figure (3.17).

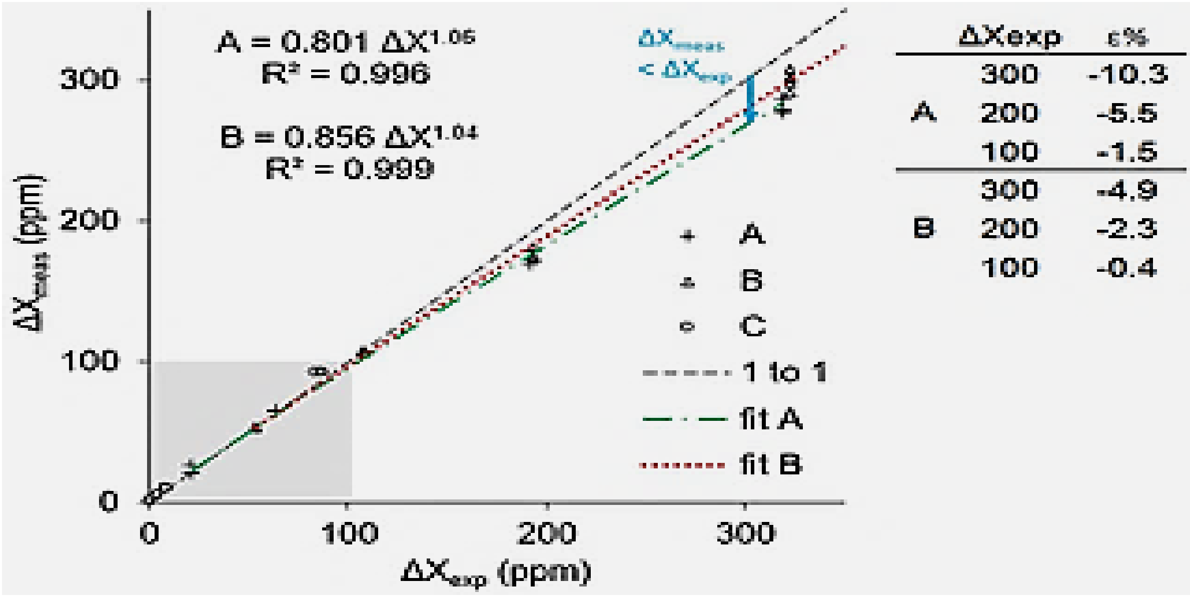


Fig (3.17): measured and expected methane ΔX demonstrating instrumental drop-off (indicated by arrow) for X_{CH_4} values > 100 ppm (shaded area = linear range).

Data for three instruments A, B, and C. Equations for A and B give the correction from measured to expected values. The table inset shows percentage error for A and B. (Wilkinson et al., 2018)

3.6.2 pH Indicator Paper:

A pH indicator shown below in figure (3.18) is a halo chromic chemical compound added in small amounts to a solution so the pH (acidity or basicity) of the solution can be determined visually. Hence, a pH indicator is a chemical detector for hydronium ions **(H_3O^+**) or hydrogen ions (**H^+)** in the Arrhenius model. Normally, the indicator causes the color of the solution to change depending on the pH.

Fig (3.18): show the pH indicator paper.

3.7 Questionnaire Design:

A questionnaire on waste management in Khartoum State was designed on a sample of 200 people. The questionnaire was not directed to any particular party but was addressed to the public. It designed electronically for easy deployment. The questionnaire design was integrated between questionnaires with closed and open questions to expanding the exchange of opinion by providing opportunities to express opinions and proposals to improve solid waste management in Khartoum State. The questionnaire consists of 41 questions and three sections. The first section consists of three questions related to age, gender and area of residence. The second part consists of 18 questions related to waste management in the state, assessment of the environmental awareness of the population about the dangers of waste and dealing with it, and assessment of the efficiency of collecting and transporting waste to the designated disposal sites. The third part contains 20 questions related to the disposal methods used in landfills, the identification of these dumps and the knowledge of the attitude of citizens towards improving the waste sector.

The objective of designing the questionnaire was to know the awareness and awareness of citizens to deal best with waste and to identify ways of managing waste in Khartoum state and to limit landfill in the state and methods of disposal and techniques used within it and the damage caused to citizens and the surrounding environment and seek to improve them by knowing the extent of citizens accept to improve dumps and sorting waste from Houses and the use of recycled materials and the utilization of fertilizers and gas.

Chapter four

Chapter four

RESULT AND DISCUSSION

4.1 Introduction:

This chapter presents the experimental landfill study and the results of questionnaire.

It shows the landfill gas readings that were measured by the gas analyzer over a period of seven months, and each reading is an average of three or five readings made during the month. Excel was used to display the results by means of a chart showing the measurements of co2 and ch4.

The results were compared with previous study readings for the same landfill. It show the effect of both the periodic moisturizing (adding water) of the landfill and the pH on gas production.

On the other hand, the questionnaire was collected and analyzed by statistical analysis (spss), and results were found that clarify the current trend of waste management in Khartoum State and assess its performance, and identify the extent of citizens' response to the questionnaire and their ability to help and support to improve waste management in the state.

4.2 Landfill Results and Discussion:

The first measurement was performed three months after the landfill was closed, and the measurements continued at intervals with periodic wetting of the landfill by adding water from one period to another.

Each test result in a month is the average of tests performed over a period of three or five days in the same month.

The experimental study gave the result of methane (CH_4) and carbon dioxide (CO_2) as shown in figure (4.1) showing the methane and carbon dioxide ratios as well as the months that were measured. The horizontal axis (X) shows the measurement time and the vertical axis (Y) shows the percentages of methane and carbon dioxide.

The increase in methane is evident by comparison with the previous study (Ahmed et al., October 2018) as shown in Figure (4.2).

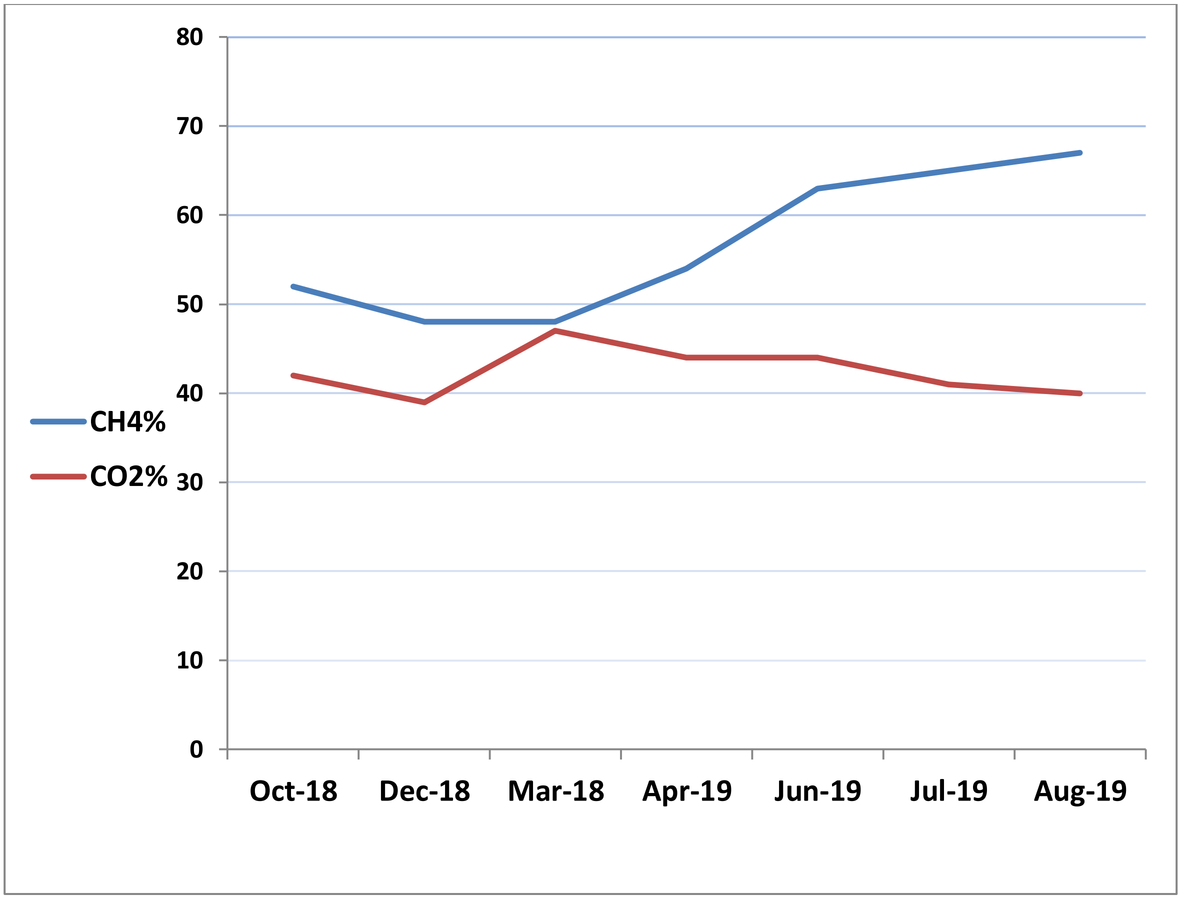


Fig (4.1): the Landfill gas measured (CH_4 and CO_2)%

Figure (4.1) shows the average landfill gas measurements conducted during the test period. it can noticed that a decrease in methane gas and then rise again due to climate change (temperature affects the production of landfill gas where high temperature increases the rate of gas production and low temperature reduces the rate of gas production). This effect is caused by the fact that the temperature accelerates the process of fermentation and decomposition. Some measurements were made in winter and some in summer (the city enjoys a cold climate in winter from December to March, then hot climate in summer from April to July and then rainy season in autumn starting in August).

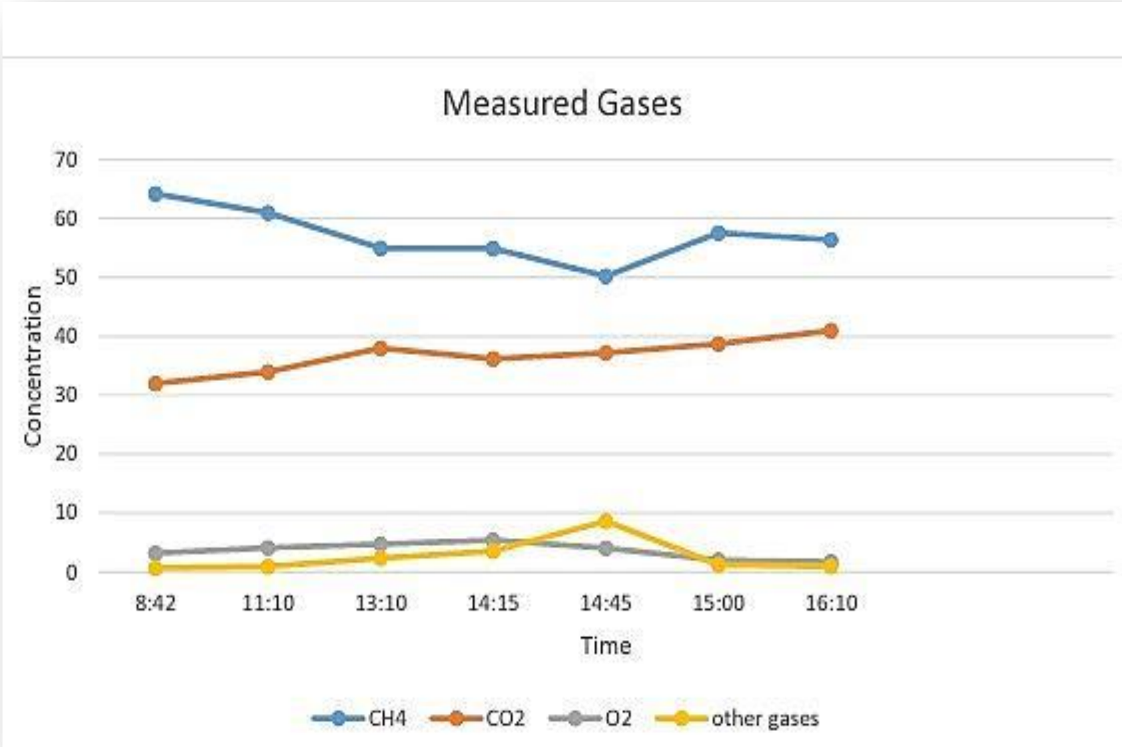


Fig (4.2): the Landfill gas measured (CH_4 ,CO_2 , O_2 and other gases) % (Ahmed et al., October 2018).

Figure (4.2) shows the gas measurement results for the same landfill during September (Ahmed et al., October 2018).

When looking at the figure, we find that the readings were taken on the same day of the month and accordingly of that the average rate of methane 56% and the average percentage of carbon dioxide 36%.

When comparing (4.1) and (4.2): landfill gas production rate during all the months from September 2018 to July 2019 ; it can be noticed that decrease in methane gas and then the rise and as mentioned earlier this is due to the change in temperature according to the climate of the season.

In Figure (4.1) the readings gradually decreased from 52% to 47%, so water was added in February, then April and finally June (humidification twice during the summer, due to the drought in that period). As a result, the proportion of methane gas gradually increased to 67%.

All these results were agreement with previous studies (Ahmedelbdawy et al., 2018, Curry and Pillay, 2009, Zahedi, 1994).

4.2.1 Ambient temperature of sanitary landfill:

Ambient temperature is normal air temperature and varies from season to season. As we mentioned earlier, the temperature affects the rate of landfill gas production. In other words, the relationship is direct.

4.2.2 PH Effect on LFG Production:

Previous studies have shown the effect of pH on landfill. It also found that the increase in gas is associated with increasing pH (Abdullah et al., October 2017).
It is desirable that the pH of organic matter be neutral or in the range of (6 to 8), because most decomposing organisms need a neutral pH. Therefore, the presence of base or acidic substances in organic matter limits the efficiency of decomposition processes (McCauley et al., 2009).
The pH test for the landfill waste leachate sample is shown in the table (4.1) below. The pH values range from 7 to 8 and are suitable as mentioned above.

Table (4.1): The values of PH Test for collected leachate sample

Day	*NO. of reading*	*PH Value*	*Average of reading*
20/8/2019	1	7.8	7.7
	2	8.0	
	3	7.5	

4.3 Questionnaire:

A. Check the validity of the questionnaire:

Cranach's alpha method*:* Where reliability was calculated using Cranach's alpha equation shown below:

Cranach's alpha method:

$$Reliability\ coefficient = \frac{N}{N-1} * \frac{1 - Total\ variations\ questions}{Total\ variation\ grades}$$

$$Validity = \sqrt{\frac{N}{N-1} * \frac{1 - Total\ variations\ questions}{Total\ variation\ grades}}$$

Where: *N= number of sample.*

Cranach alpha coefficient = (0.80), a reliability coefficient is high and it indicates the stability of the scale and the validity of the study.
Validity coefficient is the square of the islands so reliability coefficient is (0.89), and this shows that there is a high sincerity of the scale and that the benefit of the study.

B. Questionnaire Data Analysis:

The total number of survey forms was 200 all for public. The respondent's percentage form males were 115 and from females were 85.
In all figures of questionnaire analysis bellow the horizontal axis (X) shows the options for responses and the vertical axis (Y) shows the percentages of persons.

The analysis of responses Based on the questions in the questionnaire is shown below:

1) Age?

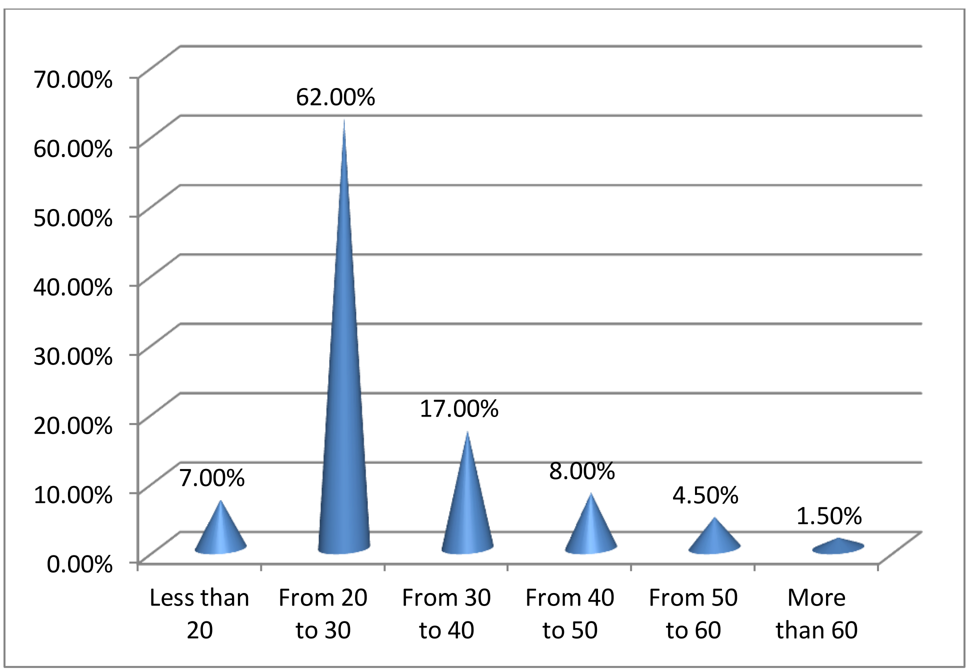


Fig (4.3): Illustrates the views of the sample distribution by Less than 20 is (7.0%), From 20 to 30 is (62.0%), From 30 to 40 is (17.0%), From 40 to 50 is (8.0%), From 50 to 60 is (4.5%) and More than 60 is (1.5%).It is noted that the largest percentage of responses to the questionnaire are the age group of (20 – 30).

It can be noticed that interaction of young people with the questionnaire and their concern to improve waste management in Khartoum state.

2) Type?

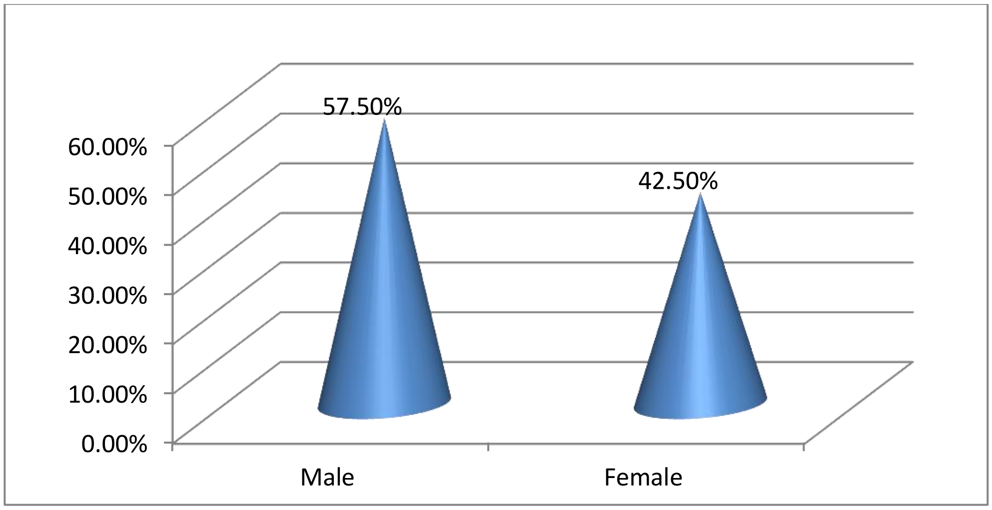


Fig (4.4): Illustrates the views of the sample distribution by Male is (57.5%) and Female is (42.5).

It was noticed that responses by males are higher than females but slightly increased, indicating the interaction of the two groups and everyone seeking to improve waste management

3) Live?

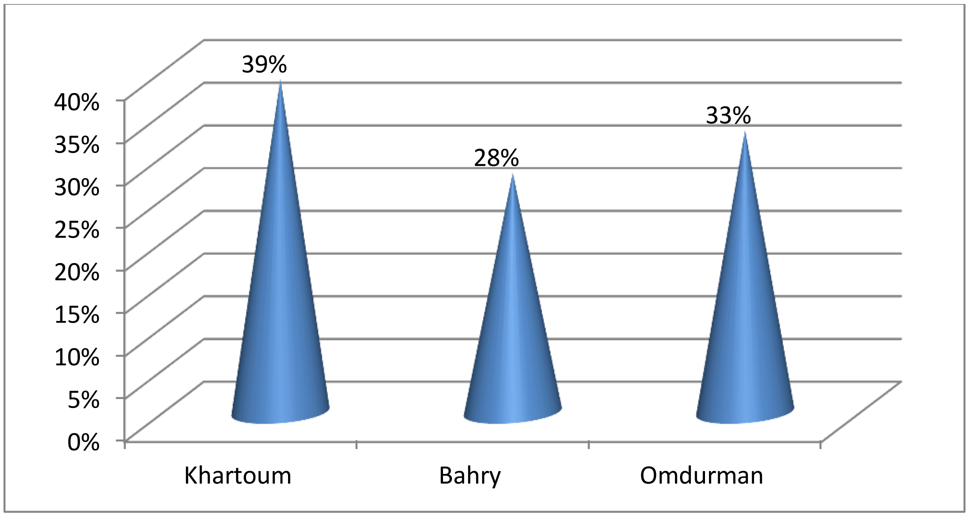


Fig (4.5): Illustrates the views of the sample distribution by Khartoum is (39%), Bahry is (28%) and Omdurman is (33%).

The interaction of all parts of Khartoum state (Khartoum, Bahri and Omdurman) can be noticed that waste is a general problem in the state.

4) Who is based on waste sector services in your area?

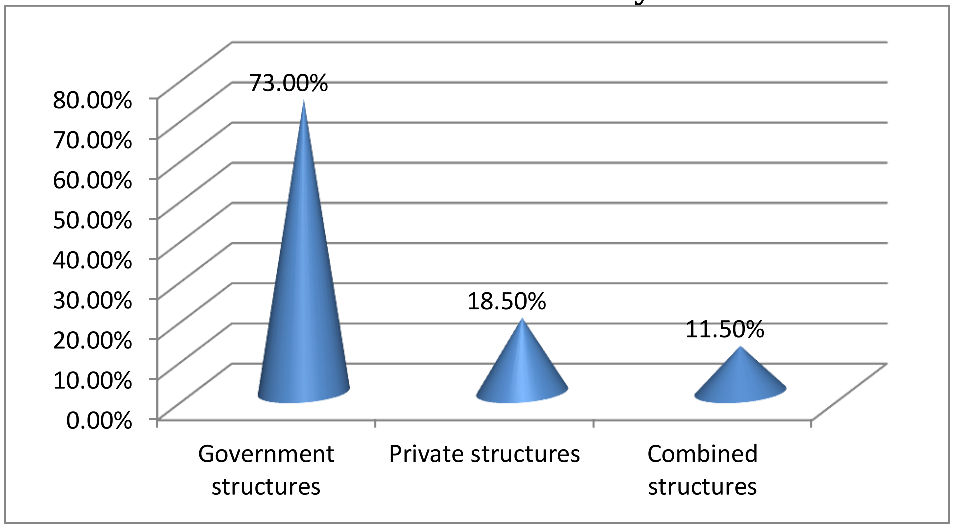


Fig (4.6): Illustrates the views of the sample distribution by Government Structures is (73.0%), Private Structures is (18.5%) and Private Structures is (11.5%).
It can be noticed that most of the responses to government structures are due to the fact that the primary responsibility for servicing the waste sector rests with the government.

5) Is there a waste problem in the area where you live?

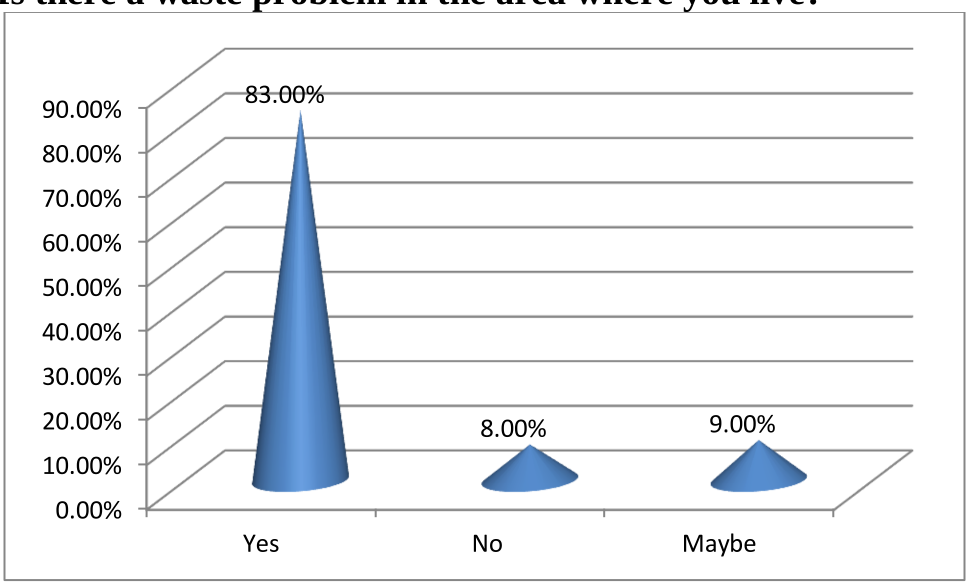


Fig (4.7): Illustrates the views of the sample distribution by Yes is (83.0%) and No is (8.0%) and Maybe is (9.0%).

This can be noticed that most areas in Khartoum state suffer from waste problem.

6) If (yes) in the previous question, would you agree to consider this problem as a crisis?

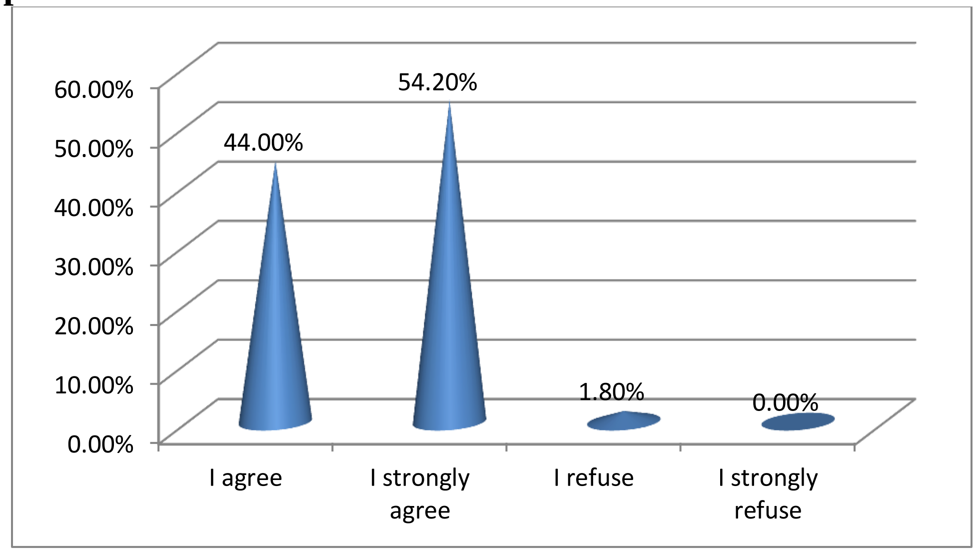


Fig (4.8): Illustrates the views of the sample distribution by I agree is (44.0%), I strongly agree is (54.2%), I refuse is (1.8%) and I strongly refuse is (0.0%).

The greater proportion of responses can be noticed that waste is a real crisis in the state.

7) Do you have a previous background on how waste management is handled in Khartoum state?

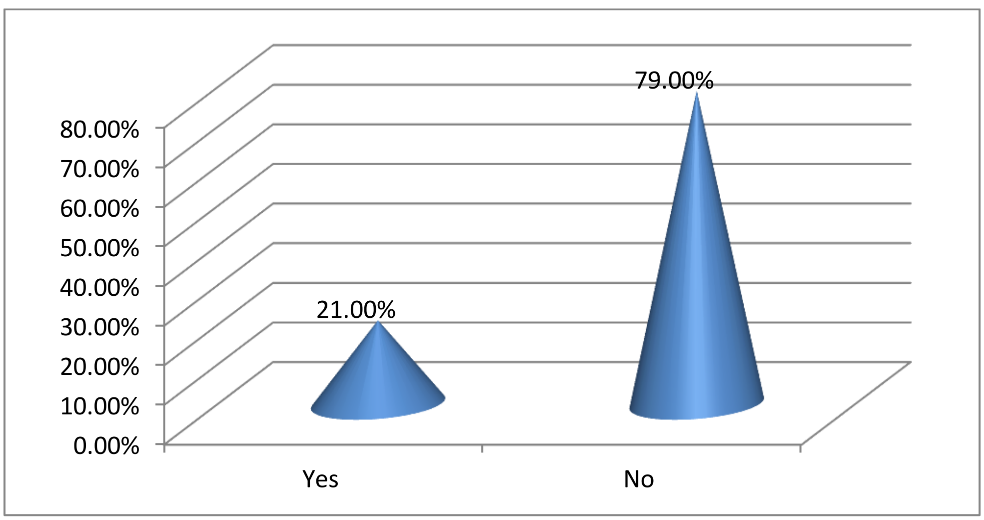


Fig (4.9): Illustrates the views of the sample distribution by Yes is (21.0%) and No is (79.0%).

The highest response rate was (**No**) indicating poor awareness of waste management and how it is handled.

8) If (yes) in the previous question; mention how:

- Some are transported to landfills, others are rotting and spread in the streets, causing pollution and collecting flies and insects.
- The waste is transported to the intermediate stations to be compressed and then transferred to the final berths on the outskirts of Khartoum.
- Waste builds up in the streets because of the lack of vehicles that citizens collect and burn in neighborhoods.
- The authorities responsible for the waste collect them and transfer them to an open dump in the city to burn or bury them in random ways.
- The waste is collected and transported to intermediate stations for manual sorting, where plastic, metal and other materials are produced and sold in illegal ways.
- Waste transported to the outskirts of the city and bury indiscriminately without any sort.

9) What is the collection method of solid waste in the areas where you live?

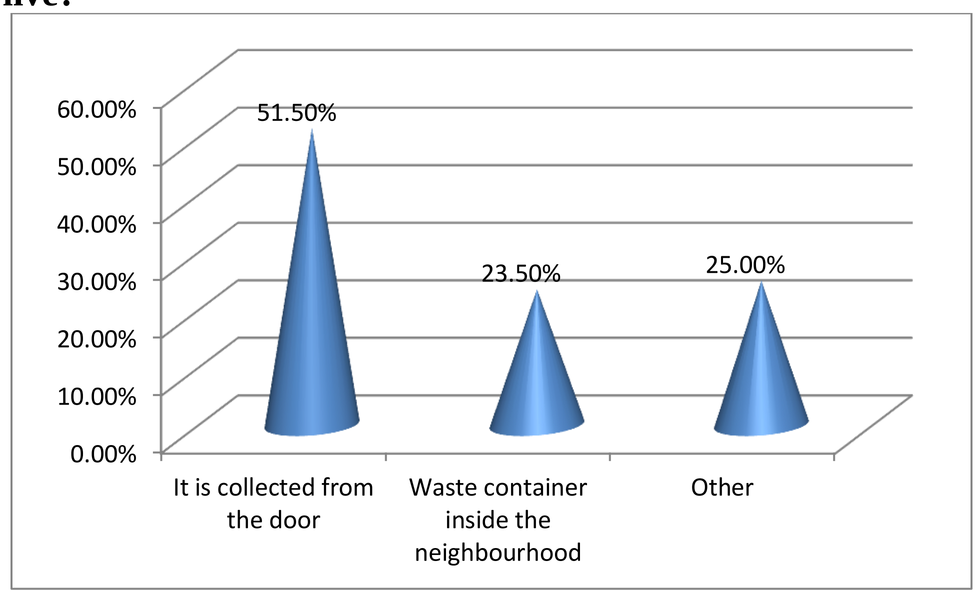


Fig (4.10): Illustrates the views of the sample distribution by It is collected from the door is (51.5%), Waste container inside the neighborhood is (23.5%) and other is (25.0%).

It can be noticed that collection from the door takes the highest response rate **(51.5%)**, but nonetheless is a low percentage for the services of the waste sector of the capital of Sudan (Khartoum).

10) If the answer in the previous questions (other); please mention it:

- They are not collected regularly and if collected they are sorted in unorganized ways and then buried in a random manner.
- There are collection containers on the main streets to carry garbage, but these containers are limited in quantity so as not to satisfy all citizens and thus put some waste on the public street.
- The burning of waste by some citizens or let it accumulate on the outskirts of the streets.
- With the personal effort of the citizens in the neighborhood, we have allocated a place to throw the waste and are burned at intervals in the space allocated.
- We hire workers to carry the garbage to the outskirts of the neighborhood.
- There are no services by competent authorities, waste stacked in the streets.

11) How many times is waste collected and transported?

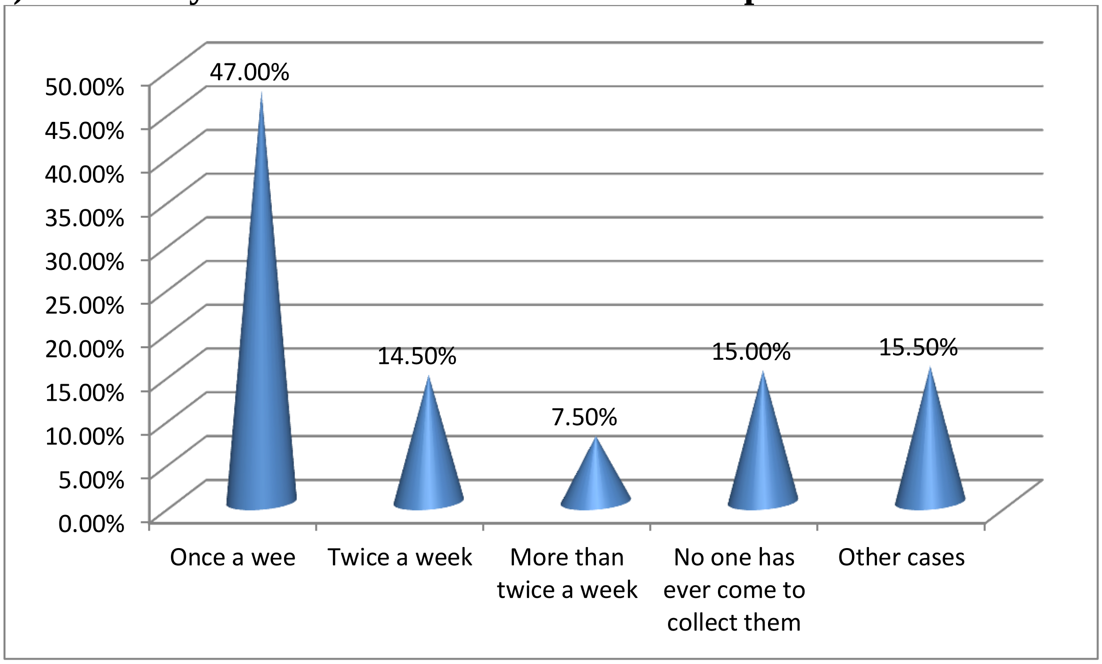


Fig (4.11): Illustrates the views of the sample distribution by Once a week is (47.0%), Twice a week, (14.5%), More than twice a week is (7.5%), No one has ever come to collect them is(15.0%) and Other cases is (15.5%).

The fluctuation of the number of times the collection of waste shows irregularity and non-compliance with specific dates, which indicates the lack of attention to waste and problems that can cause.

12) Please mention other cases in previous question:

- Once every two weeks or more.
- Once a month.
- Twice a month.
- Weekly.
- Every two or three months.
- There is no time limit for attendance.

13) What is your assessment of the efficient collection and removal of waste by competent department?

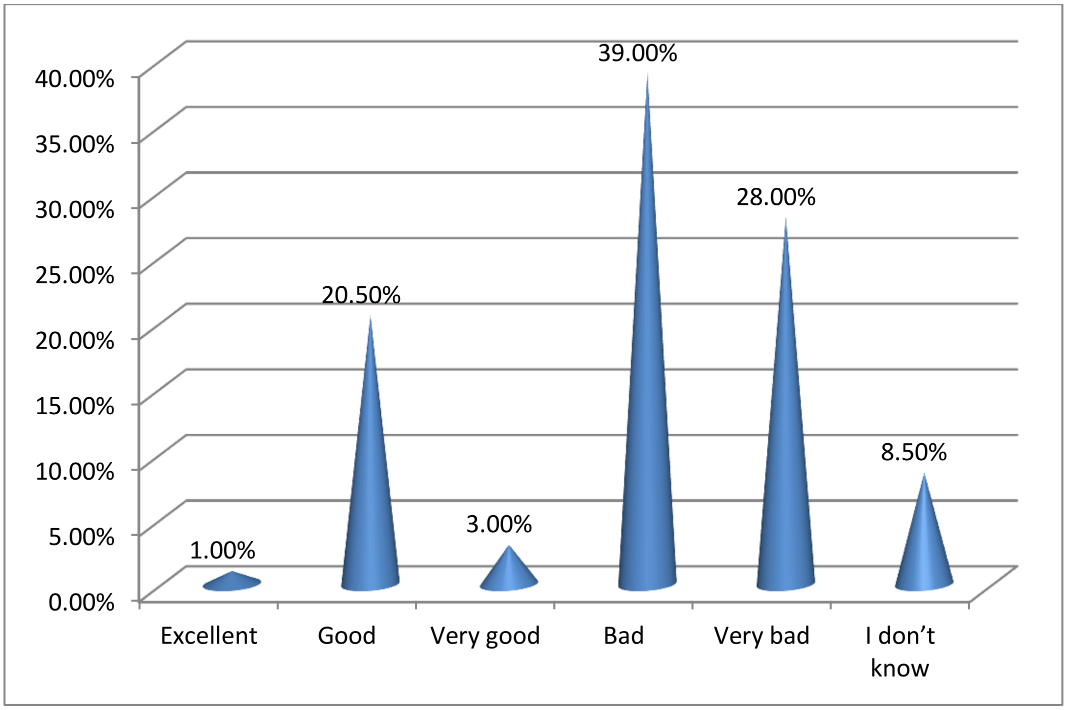


Fig (4.12): Illustrates the views of the sample distribution by Excellent is (1.0%), Good is (20.5%), Very good is (3.0%), Bad is (39.0%), Very bad is (28.0%) and I don't know is (8.5%).

This shows the poor management of waste in the state in terms of collection and transfer from sources.

14) What is the way in your home to store the waste produced before taking it to the places of collection and deportation by the competent department?

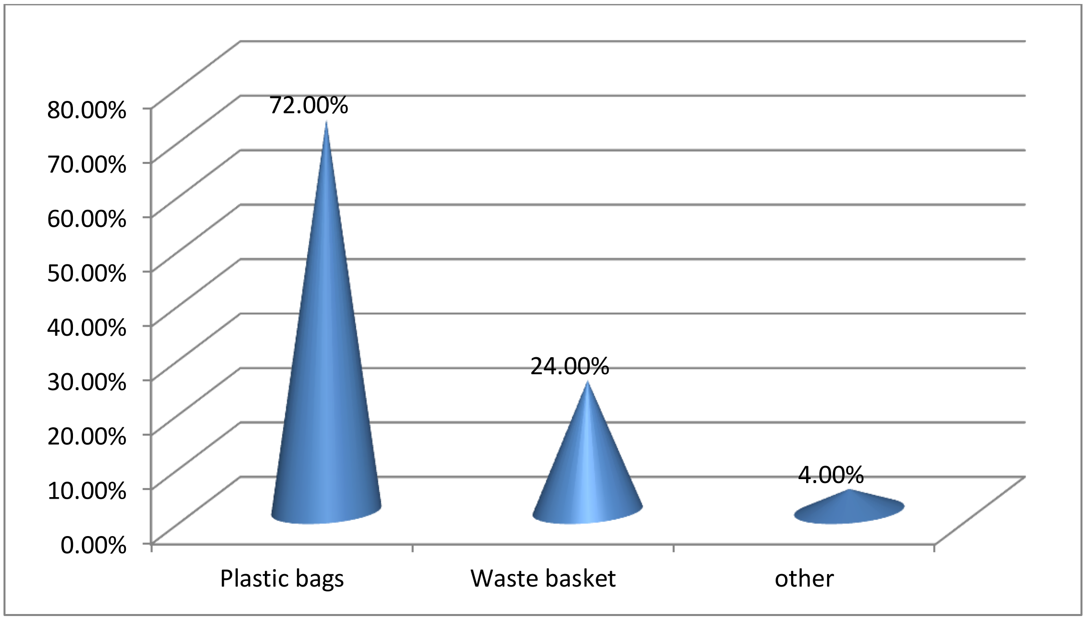


Fig (4.13): Illustrates the views of the sample distribution by Plastic bags is (72.0%), Waste basket is (24.0%) and other is (4.0%).

It can be noticed that plastic bags are the most used and common where they entail many risks to humans, animals and the environment. Most plastic materials do not rust and do not biodegrade and remain in the environment for long period. Continued unconsciousness and accumulation in large quantities year after year in the environment will sooner or later lead to numerous environmental and health risks and hazards.

15) Please mention other ways in previous question if it found:

- No answers.

16) Are wastes incinerated, buried or dumped in the neighborhood at random?

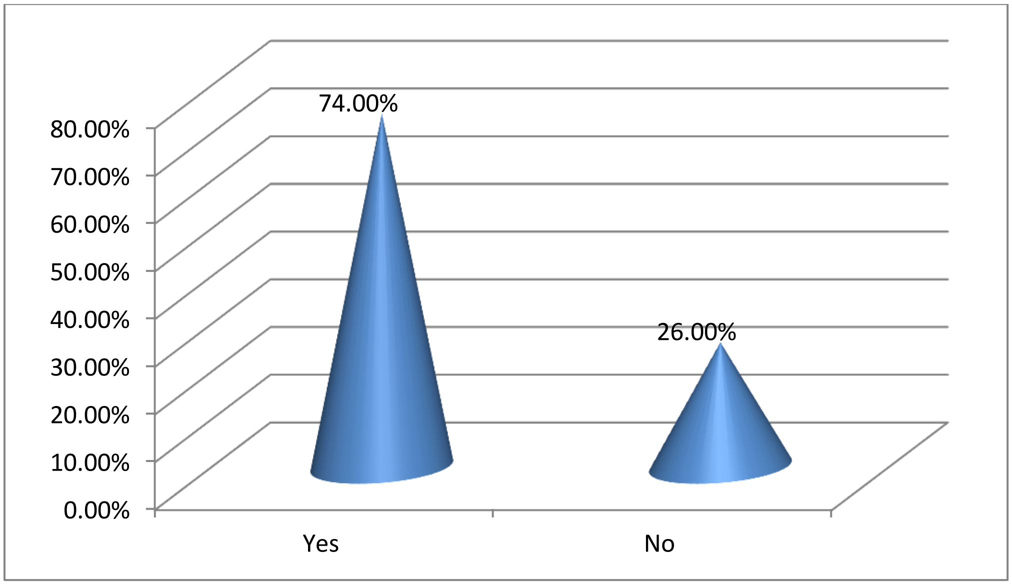


Fig (4.14): Illustrates the views of the sample distribution by Yes is (74.0%) and No is (26.0%).

This indicates the lack of environmental awareness among citizens about the dangers of waste.

17) If (yes) in the previous question; is there any concern about health and environmental risks?

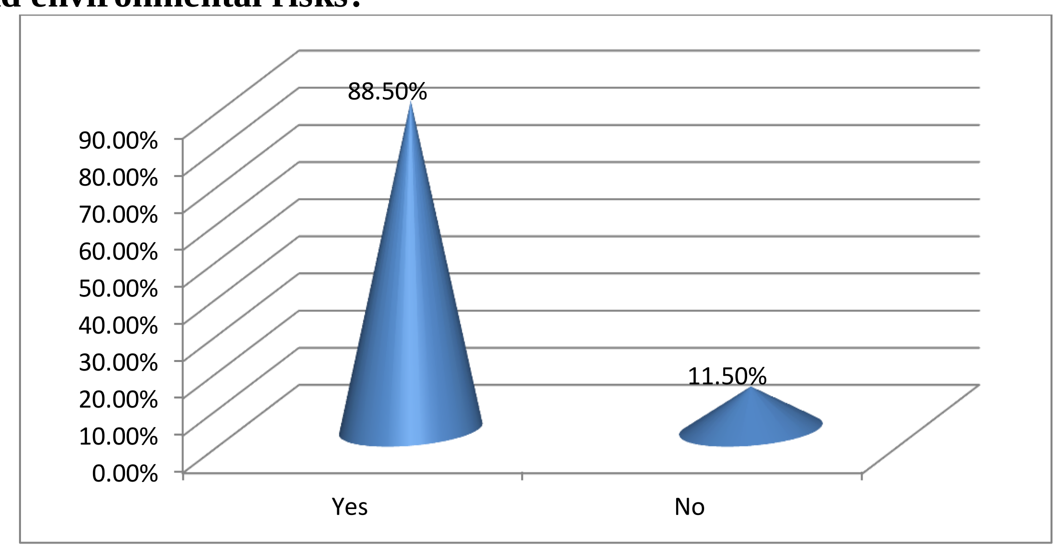


Fig (4.15): Illustrates the views of the sample distribution by Yes is (88.5%) and No is (11.5%).

It shows that knowing of environmental health hazards, the waste is handled in an improper way, which indicates indifference and insufficient awareness among the citizens in general.

18) If (yes) in previous question; Please mention those risks:

- The random burning of waste causes respiratory diseases such as asthma, pneumonia, and allergies.
- Air pollution.
- Burning waste leads to environmental pollution by the escalation of toxic gases.
- Visual pollution.
- Random superficial burial leads to contamination and foul and disturbing odors.
- Soil damage.

19) In your opinion; what is the reason for obstruction of waste collection?

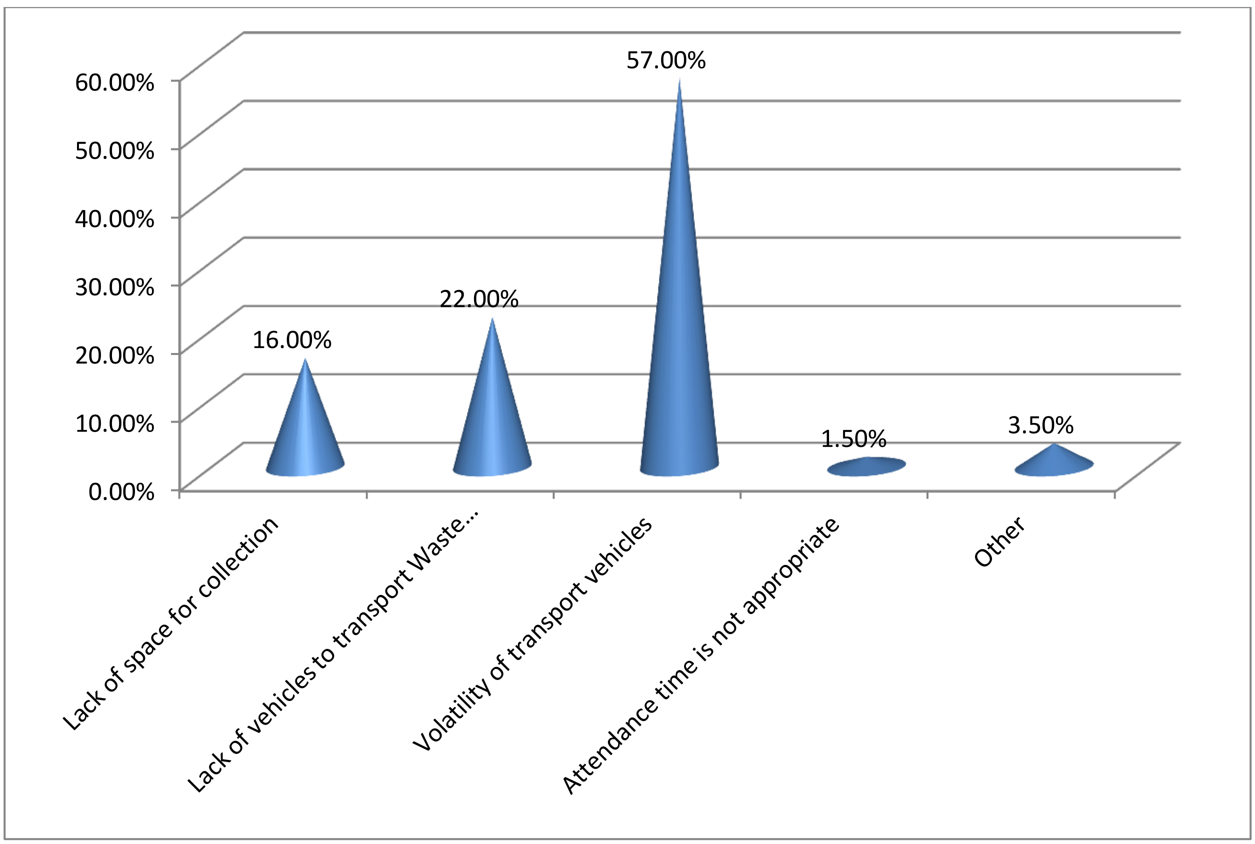


Fig (4.16): Illustrates the views of the sample distribution by Lack of space for collection is (16.0%), Lack of vehicles to transport Waste from neighborhood's is (22.0%), Volatility of transport vehicles is (57.0%), Attendance time is not appropriate is (1.5%) and other is (3.5%).

This shows the fluctuation of transport vehicles and the scarcity of these vehicles and the time of their inappropriate presence, etc. All these reasons indicate the deficiencies in the waste management system in Khartoum State.

20) If (other) in previous question; mention those other reasons:

- Lack of collection containers.
- Container locations are too far from the hands.
- The containers are filled with waste and left for days to rot and become a shelter for flies and insects.
- Waste collectors' negligence in dealing with them, leading to the loss of part of them in the streets.
- Lack of interest of citizens to collect and transport waste to waste containers.
- Lack of adequate vehicles and containers that need high cost.
- There are no clear places for waste collection.
- Carelessness of the cleaners in picking up and carrying the waste.
- Do not attend collection vehicles regularly.

21) In your opinion; what is the main cause of the waste crisis?

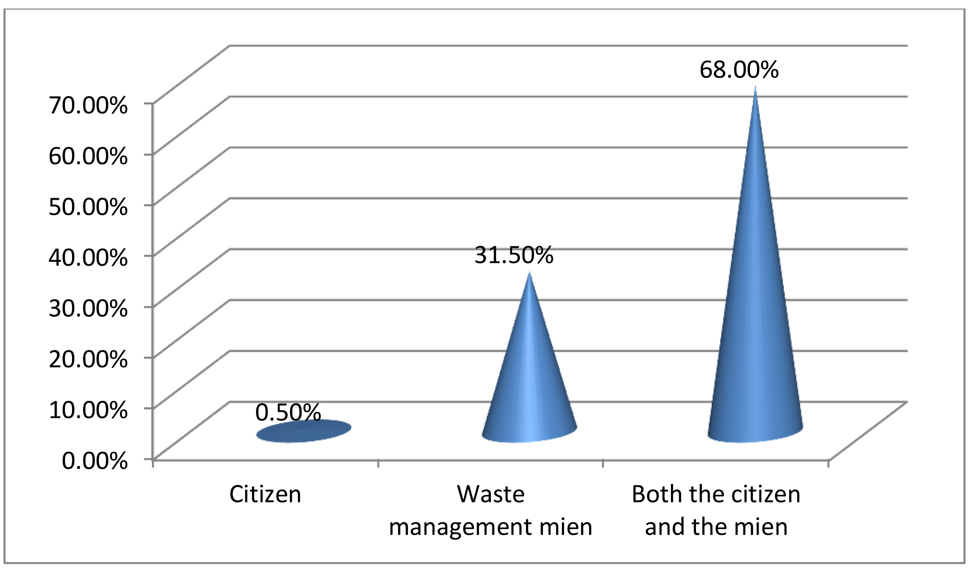


Fig (4.17): Illustrates the views of the sample distribution by Citizen is (0.5%), Waste management mien is (31.5%) and both the citizen and the mien is (68.0%).

The consensus is that the waste crisis is caused by both citizens and waste management officials. It is the duty of officials to provide an integrated waste management system.

Citizens must comply with waste collection and handling regulations and seek a clean and healthy environment.

22) Do you think municipal waste has a commercial and industrial importance? And can be utilized?

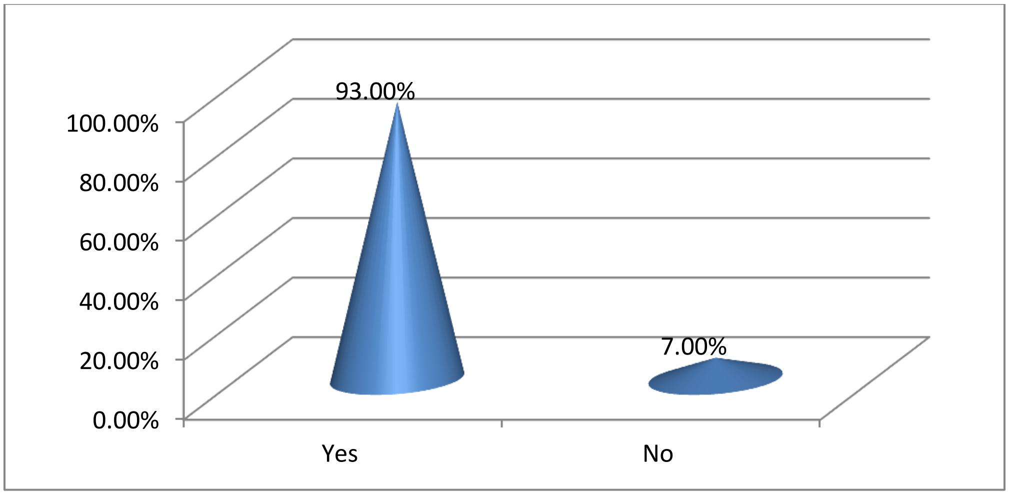


Fig (4.18): Illustrates the views of the sample distribution by Yes is (93.0%) and No is (7.0%).

This shows awareness of the benefits of waste, not just considering it as redundant material.

23) If (yes); do you want to be an effective element to benefit from municipal waste?

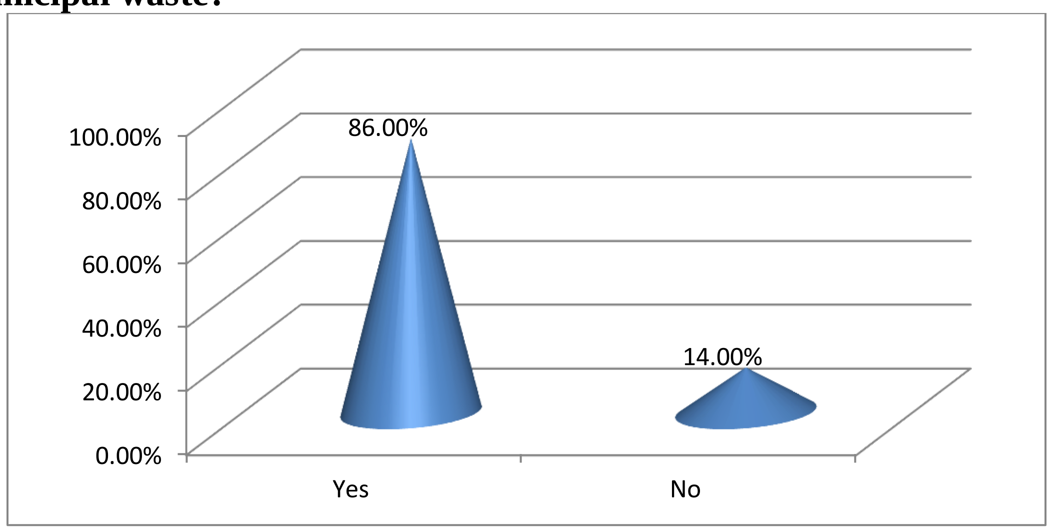


Fig (4.19): Illustrates the views of the sample distribution by Yes is (86.0%) and No is (14.0%).

This shows the interaction of citizens and their willingness to participate in the improvement and development of waste disposal technologies to benefit from them.

24) What is the method you would like to share to benefit from waste?

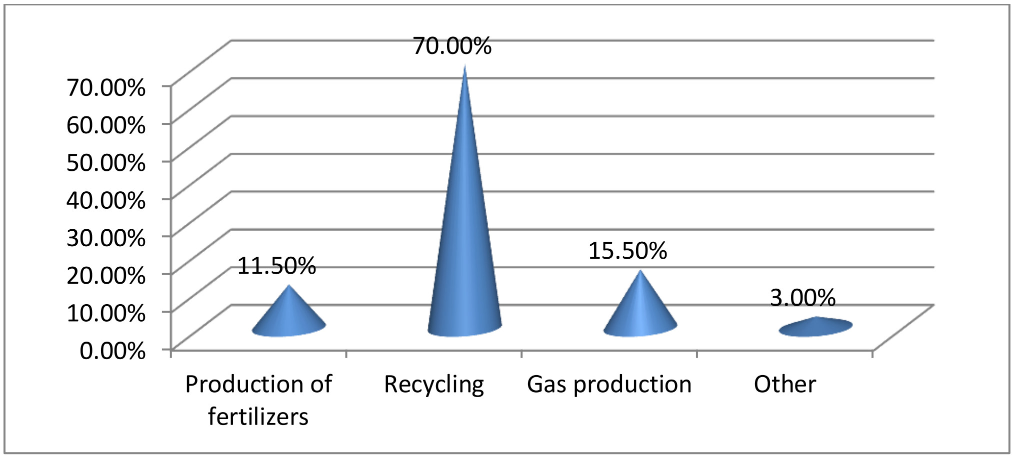


Fig (4.20): Illustrates the views of the sample distribution by Production of fertilizers is (11.5%), Recycling is (70.0%), Gas production is (15.5%) and other is (3.0%).

This shows the interaction of citizens with the methods of utilization of waste (recycling on top of it and then the production of biogas and organic fertilizer and others).

25) If (other) in previous question; please mention it:

- No answers.

26) Can you use recycled materials?

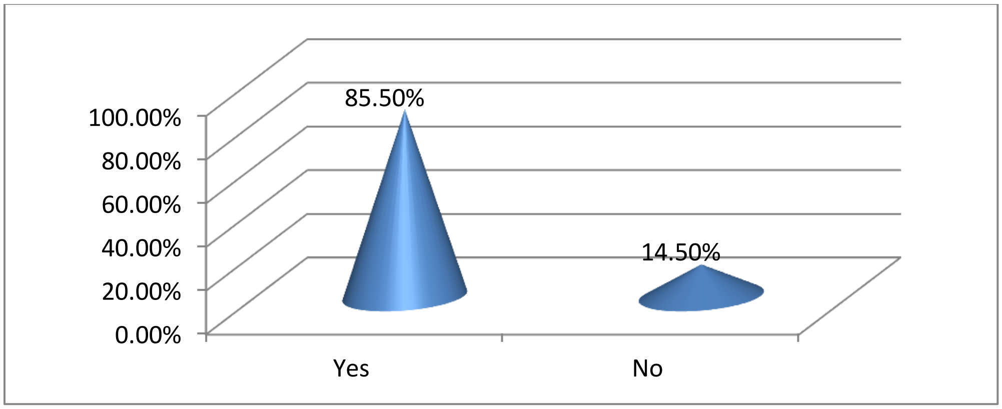


Fig (4.21): Illustrates the views of the sample distribution by Yes is (85.5%) and No is (14.5%).

This indicates that citizens can use recycled materials.

27) Do you separate the waste inside your home (i.e organic waste matter in special container, paper in another container, plastic and glasses also... etc.)?

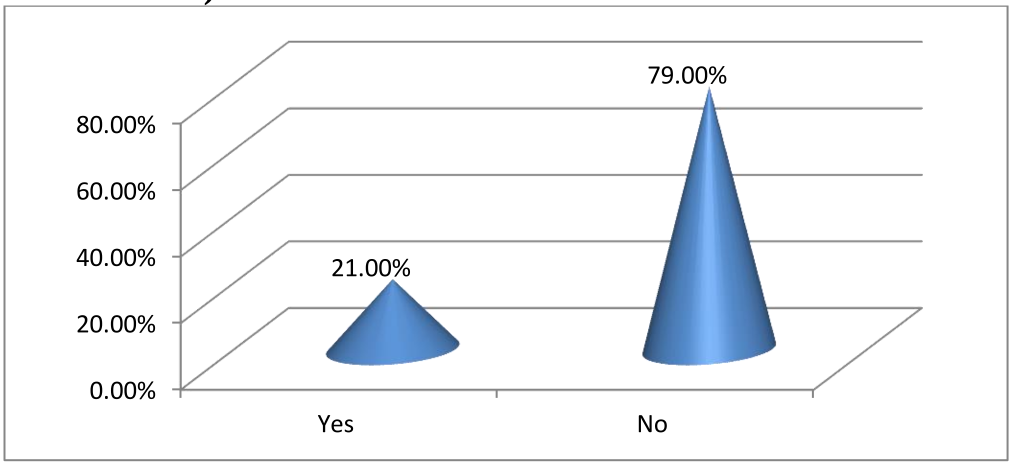


Fig (4.22): Illustrates the views of the sample distribution by Yes is (21.0%) and No is (79.0%).

This indicates a lack of awareness and lack of knowledge among citizens about the importance of waste separation.

28) If Khartoum state waste management asks you to separate the waste by type; will you are:

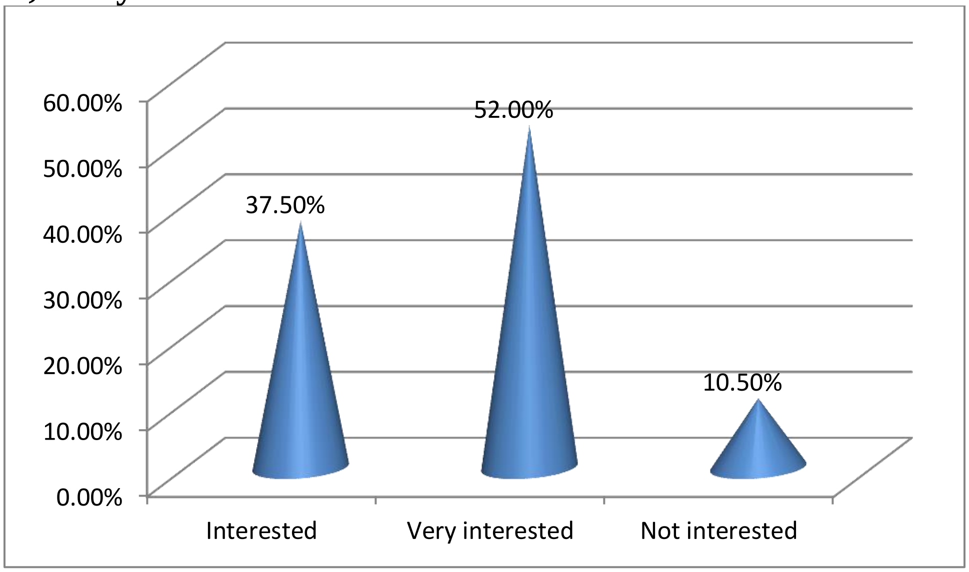


Fig (4.23): Illustrates the views of the sample distribution by Interested is (37.5%), Very interested is (52.0%) and not interested is (10.5%).

This indicates a high acceptance of the idea of sorting from the source.

29) Do you have a background on the landfills in Khartoum state?

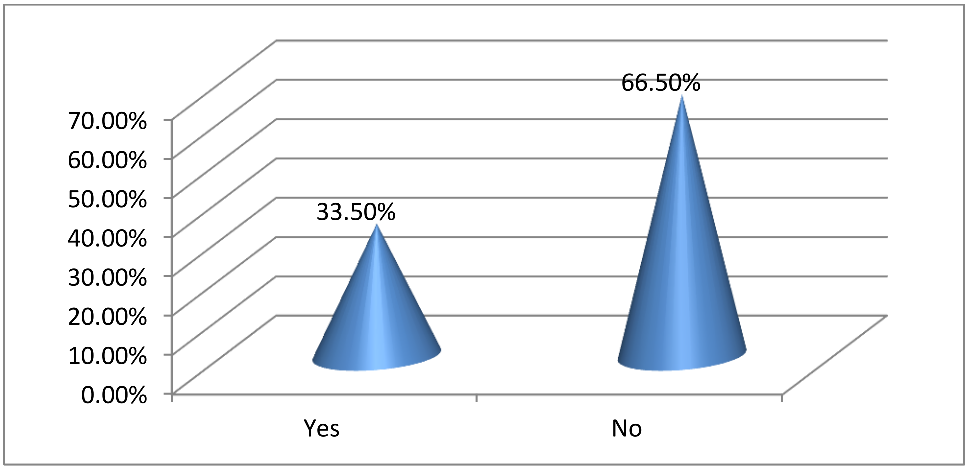


Fig (4.24): Illustrates the views of the sample distribution by Yes is (33.5%) and No by (66.5%).

The majority have no background on waste disposal methods in landfills, indicating poor environmental awareness.

30) If (yes) in the previous question; what are the methods used to treat and disposal waste in Khartoum state?

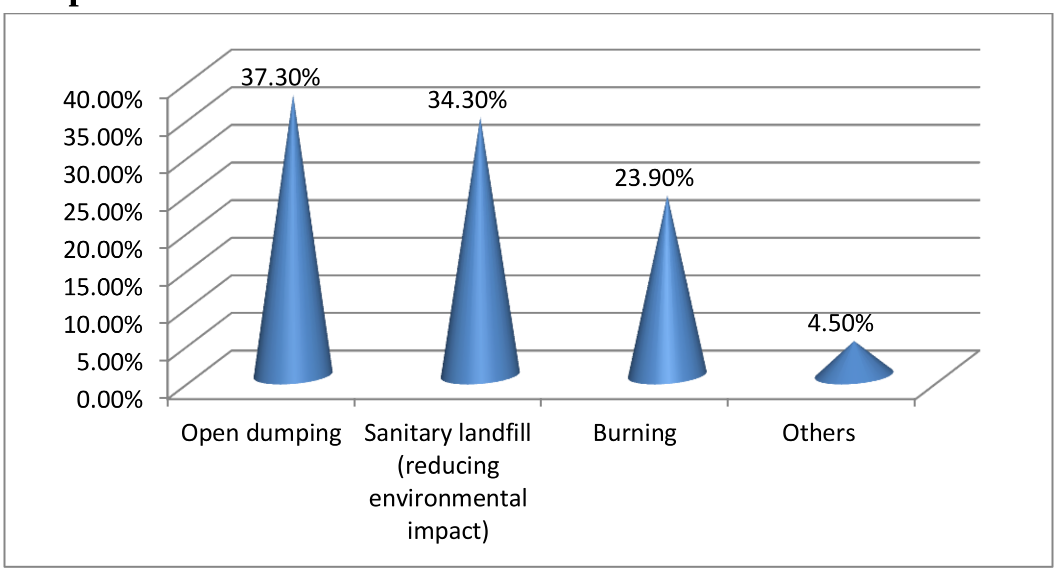


Fig (4.25): Illustrates the views of the sample distribution by open dumping is (37.3%), Sanitary landfill (reducing environmental impact) is (34.3%), and Burning is (23.9%) and by others is (4.5%).

Open dumping takes the highest response rate. Open dumping is considered harmful to the environment and health, as it has great risks.

31) If (other) in previous question; please mention it:

- Only gathered at the outskirts of the city without burial or burning.
- All waste is buried without sorting.
- There is a plant for sorting and composting in Omdurman but has not yet been operated for unknown reasons.
- Was randomly received in landfills that have become a source of breeding flies and insects.
- They are placed in open pits on the outskirts of the city and then buried after being filled.
- Collected and deported to places far from the presence of residents to the outskirts of the city.

32) Mention the landfills you know in Khartoum state:

- Abu Waleidat landfill in Omdurman.
- Hattab landfill in Bahri.
- Tayba landfill in Khartoum.
- A landfill in Al - Wadi Al - Akhdar.
- A landfill in Jadeen Al Salha.
- A landfill in Haj Youssef area.
- Others.

33) Do you think there is a noticeable or implicit environmental impact due to these landfills?

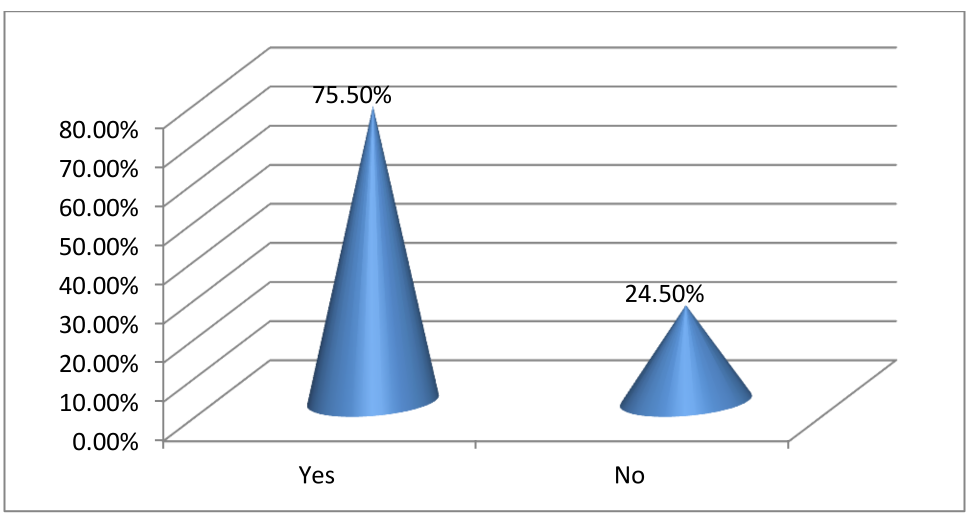


Fig (4.26): Illustrates the views of the sample distribution by Yes is (75.5%) and No is (24.5%).

This indicates the presence of significant and implicit environmental effects caused by landfills in Khartoum State.

34) If (yes) in previous question; explain the effect:

- Pollution of surrounding areas and impact on the population living near these dumps pimple flies, insects, mosquitoes and bad odours.
- Soil pollution and impact on neighbouring agricultural lands.
- These landfills are located near populated areas, which adversely affect the surrounding environment and the spread of diseases transmitted by flies in addition to the problems of chest diseases such as asthma caused by fires that occur within these dumps.
- Air pollution due to gases emitted from landfill, waste volatilization and air transport.
- Distorting the landscape, the landfill is a place for the generation and accumulation of insects, birds and flies.
- Not to follow the security and safety means inside these dumps and in addition to the existence of traders roaming the waste of waste for manual sorting without any legal control or control of the basis of security and safety.

35) Did you know that landfills can be a source of energy?

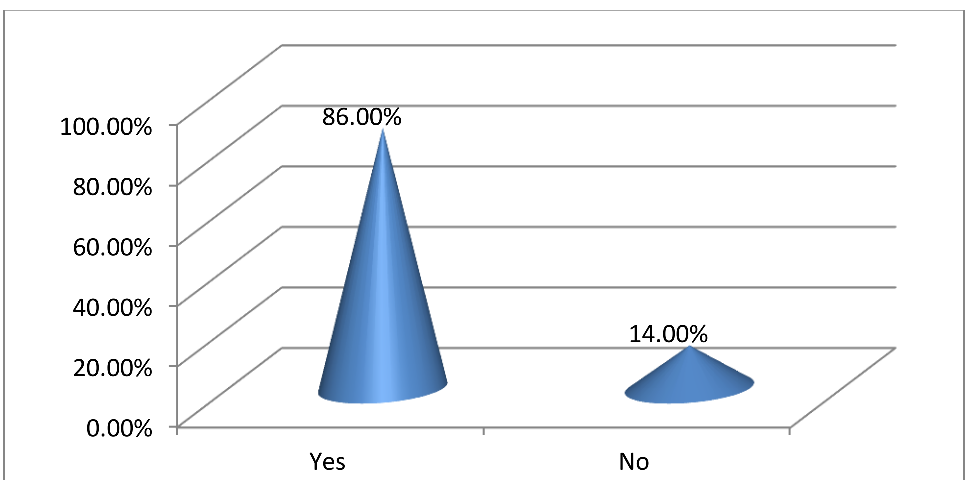


Fig (4.27): Illustrates the views of the sample distribution by Yes is (86.0%) and No is (14.0%).

This shows citizens realizing of the benefits of waste and their knowledge of sanitary landfills, which are a source of energy.

36) If there a landfill in Khartoum where methane is produced (methane is used for cooking, lighting, generating power …etc.)?

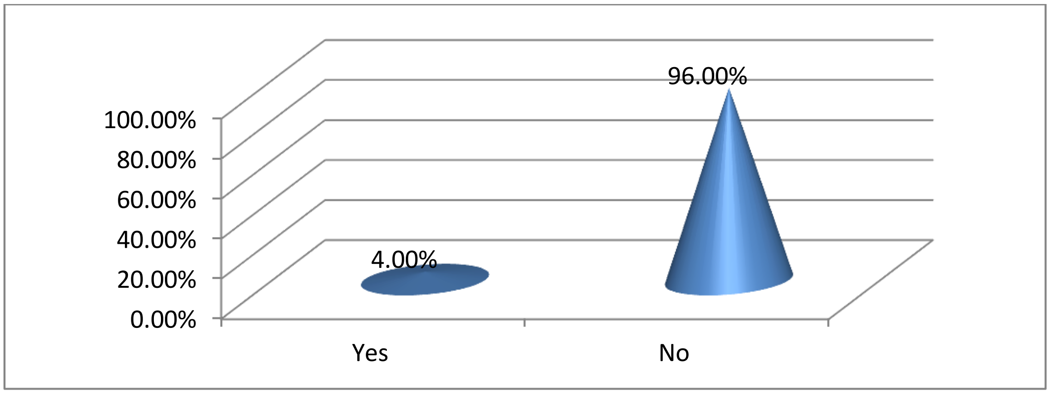


Fig (4.28): Illustrates the views of the sample distribution by Yes is (4.0%) and No is (96.0%).

This demonstrates the lack of appropriate waste management techniques that allow waste utilization.

37) If (yes) in previous question; list these landfills:

- No answers.

38) If answer is (No); what are the obstacles to the establishment of such landfills?

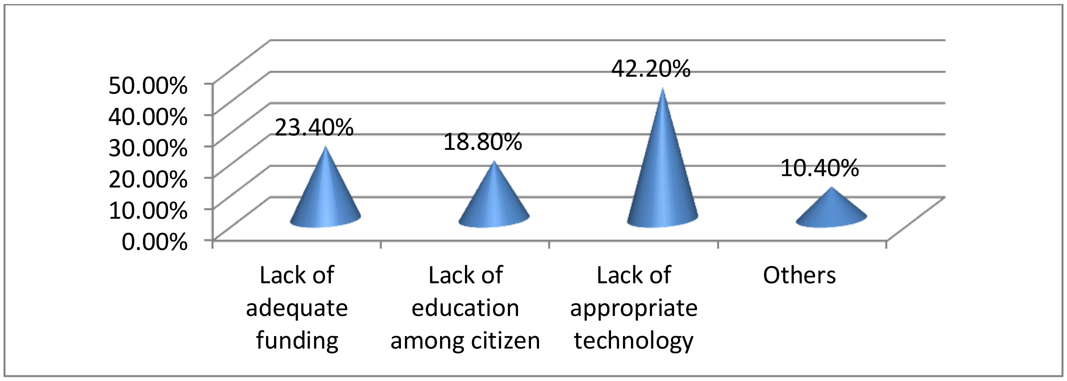


Fig (4.29): Illustrates the views of the sample distribution by Lack of adequate funding is (23.4%), Lack of education among citizen is (18.8%), Lack of appropriate technology is (42.2%) and others by (10.4%).

All of these reasons prevented the establishment of such sanitary landfills (the lack of adequate technologies by the officials of the waste sector and the lack of adequate funding for them and poor environmental awareness).

39) If (other) in previous question; mention it:

- Citizens are not aware of the benefits of waste.
- Lack of interest from the competent official authorities.
- Not thinking positively.
- Poor planning and management.
- Lack of interest by citizens.
- The indifference of both citizens and waste officials.

40) Do you have any suggestions that may help improve waste management (collection, transportation, treatment and disposal) in Khartoum State?

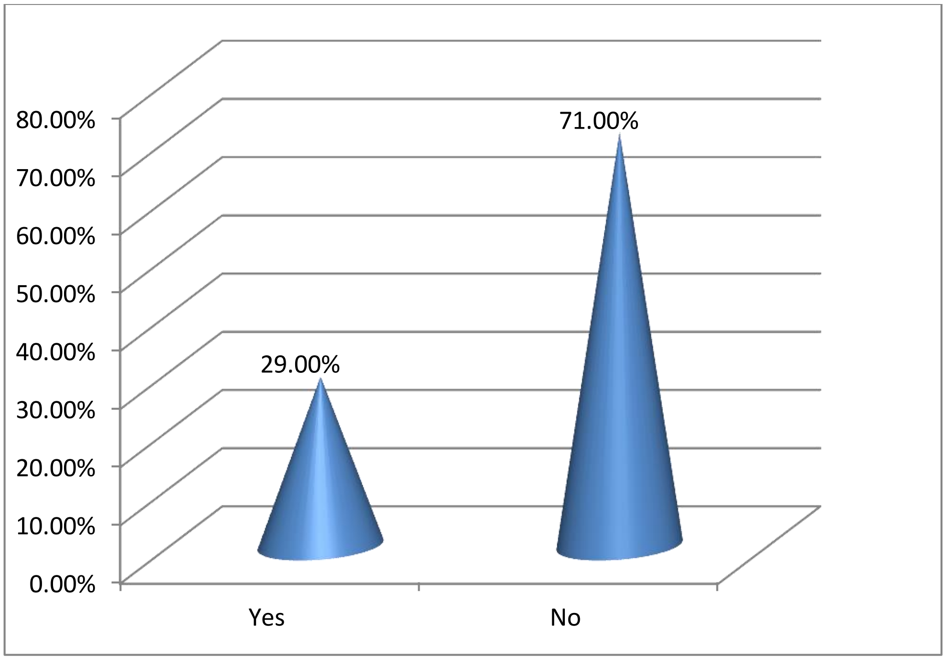


Fig (4.30): Illustrates the views of the sample distribution by Yes is (29.0%) and No is (71.0%).

It can be noticed that high rate of response to the (No suggestions); this indicates the weakness of environmental awareness among citizens and the lack of sufficient knowledge to enable them to propose opinions to improve management.

41) If (yes) in previous question; mention these suggestions:

- Determination of colours for the collection of different waste e.g. organic green bags, yellow and paper bags, plastic red bags, etc. Therefore, the different types of waste are collected and sorted and distributed free of charge.
- Arranging the presence of waste transport vehicles and making laws for waste collectors not to be reckless and absent.
- Apply scientific research and the creation of new research to support this field.
- The use of an integrated system in the collection and education of the environment and the introduction of incentives for families as well as accounting for those who fail to sort and collect waste and put them in the place allocated to them.
- The provision of containers as well as waste trucks with high specifications and the link between the clean and the state of Khartoum and private companies and projects in this area and support manufacturing plants.
- Raising environmental awareness and educating citizens through lectures and seminars on the seriousness of waste and its accumulation, proper disposal methods and utilization, and the importance of sorting from sources.

Chapter five

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion:

According to the standards of the American Environmental Protection Agency for the design of landfills; an engineering landfill was designed in the form of trapezoid by dimensions (2 * 1.75 * 1.4) m3 and built inside the Sudan University of Science and Technology (southern campus) on 10/2017. The study aimed to develop the above landfill and improve its performance by stripping hole of its components, which include waste layers, sand layers, LFG collection system, LFG monitoring, waste leachate collection system and all the contents of the hole. And then put new waste (organic waste) collected from Khartoum markets and the university cafeteria .In addition to gas and leachate collection systems. Gas monitoring was started three months after the hole was closed by the LFG gas analyzer GFM410. The landfill was supported and the performance of bacteria inside was improved by the addition of water (humidification) at intervals, resulting in 68% of the gas by volume and pH of the waste leachate (7 - 8) and it is suitable for the growth of most bacteria responsible for the anaerobic decomposition process. 68% methane is considered a high percentage and flammable, proving that the landfill can be an energy source and the resulting methane can be used in many projects.

On the other hand, a questionnaire was conducted to evaluate the waste management of Khartoum State and highlight the dumping sites in the state and compare them with the international landfills. The questionnaire also aims to know the extent of acceptance and support of citizens to improve management by developing landfills and the use of global technologies to benefit from waste. The questionnaire sample is 200 and it showed that the waste management system in the state of Khartoum is very bad; the state suffers from a weakness in the number of collection vehicles and lack of punctuality and disregard by workers and officials, as well as poor environmental awareness among citizens of the dangers of waste all this results in the accumulation of waste in the streets Which negatively affects the aesthetic appearance of the state in addition to the spread of diseases. The study also showed the poor quality of landfills in Khartoum state and considered as a source of pollution instead of being a solution to the problem of waste where it is followed open dumping method (harmful to the environment); without the sorting process. This made these landfills shelter for insects and flies and sources of harm to the environment and health.

5.2 Recommendations:

Based on the findings of the study that the waste is a crisis in the state of Khartoum due to poor management, although this waste can be an alternative source of energy; the study recommended the following points to improve the results:

- Adequate funding must be provided to improve management.
- Increase the number of vehicles dedicated to garbage collection in sufficient quantities to cover the entire country.
- Increase environmental awareness of waste collection workers and provide safety equipment.
- There must be regulations in place for these workers and deterrent penalties for absenteeism and recklessness.
- Increase environmental awareness among citizens about the dangers of waste and the proper ways to deal with waste and collection through the conduct of comprehensive awareness seminars and lectures throughout the state.
- Attention should be given from those responsible of the waste sector and strive to improve management and provide a satisfactory integrated system.
- Involve citizens in the process of improving waste management and enforce the process of sorting from the homes with the provision of baskets to collect waste in different colors depending on the type of waste to facilitate the process of sorting.
- The application of this study and technology of sanitary landfill (waste to energy) on Khartoum landfills in general to get rid of waste with benefit by saving energy and solve the problem of the ongoing fuel crisis in Khartoum state.
- Continuing the study and continuing to humidify the landfill and monitor gas production and collection by using a blower (blower is air conveying equipment that generates pressures up to 103 KPa (15 psi)) to extract the LFG, store it in appropriate conditions and use it to generate power through multiple projects.
- Further studies are recommended and to make use to done study.
- Recruitment of specialists in this field and use them to invest waste through sanitary disposal, which provides energy and solve the waste crisis in the state.

References

REFRENCES:

ABDALRAHIM, M. I. O. 2018. Evaluation of Solid Waste Landfills in Khartoum State Case study: Abo-Wileidat Landfill in Omdurman).

ABDULLAH, D., ROA, A. & SADAH, A. October 2017. Experimental Study on Food Waste Landfill as Energy Source and Waste Management in Khartoum.

AHMED, S., AMMAR, M. & IBRAHIM, I. October 2018. Waste to Energy as an Alternative Source of Energy in Khartoum.

AHMEDELBDAWY, W. M., ABUELNUOR, A. A., OMARA, A. A. & TAHA, S. A. An experimental study on landfill technology to produce an alternative source of energy from organic waste. 2018 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), 2018. IEEE, 1-5.

ALRIKABI, N. 2014. Renewable energy types. Journal of Clean Energy Technologies, 2, 61-64.

ALTAN, H. S. December 2015. THE EFFECTS OF BIODEGRADABLE WASTE DIVERSION ON LANDFILL GAS POTENTIAL IN TURKEY.

AMBAYE, A. A. W. A. H. D. B. A. T. G. March 2018. Current updates on waste to energy (WtE) technologies: a review. Volume 24.

ANGELIDAKI, I. & BATSTONE, D. J. 2011. Anaerobic digestion: process. Solid Waste Technology and Management. Wiley.

ARıKAN, E., ŞIMŞIT-KALENDER, Z. T. & VAYVAY, Ö. 2017. Solid waste disposal methodology selection using multi-criteria decision making methods and an application in Turkey. Journal of Cleaner Production, 142, 403-412.

ASIF, M. & MUNEER, T. 2007. Energy supply, its demand and security issues for developed and emerging economies. Renewable and Sustainable Energy Reviews, 11, 1388-1413.

BAHIA, E. T., TOLEDO, V. D. C., FERREIRA, W. R. & TISSOT-LARA, T. A. 2015. GESTÃO DE RESÍDUOS SÓLIDOS URBANOS: CENÁRIOS NA DINÂMICA DE SISTEMAS.

BAKER, C. 1991. Tidal power. Energy Policy, 19, 792-797.

BARBIER, E. 2002. Geothermal energy technology and current status: an overview. Renewable and sustainable energy reviews, 6, 3-65.

BERKUN, M., ARAS, E. & ANıLAN, T. 2011. Solid waste management practices in Turkey. Journal of Material Cycles and Waste Management, 13, 305-313.

BEYENE, H. D., WERKNEH, A. A. & AMBAYE, T. G. 2018. Current updates on waste to energy (WtE) technologies: a review. Renewable Energy Focus, 24, 1-11.

BOSMANS, A., VANDERREYDT, I., GEYSEN, D. & HELSEN, L. 2013. The crucial role of Waste-to-Energy technologies in enhanced landfill mining: a technology review. Journal of Cleaner Production, 55, 10-23.

BRIJESH KUMAR PANDEY, S. V., MUKESH PANDEY AND ANURAG GAUR 2016. Municipal solid waste to energy conversion methodology as physical, thermal, and biological methods.

BYRNE, J., KURDGELASHVILI, L., MATHAI, M., KUMAR, A., YU, J., ZHANG, X., TIAN, J., RICKERSON, W. & TIMILSINA, G. 2010. World solar energy review: technology, markets and policies. Washington, DC: Center for Energy and Environmental Policy of the University of Delaware, World Bank.

CAI BO-FENG, L. J.-G., GAO QING-XIAN, NIE XIAO-QIN, CAO DONG, LIU LAN-CUI, ZHOU YING, ZHANG ZHAN-SHENG 2014. Estimation of Methane Emissions from Municipal Solid Waste Landfillls in China Based on Point Emission Sources.

CAMPOS, U., ZAMENIAN, H., KOO, D. D. & GOODMAN, D. W. 2015. Waste-to-Energy (WTE) Technology Applications for Municipal Solid Waste (MSW) Treatment in the Urban Environment. Int. J. Emerg. Technol. Adv. Eng, 5, 504-508.

CHANDRAKAR, A. K. An Assignment on.

CHANDRAPPA, R. & DAS, D. B. 2012. Issues in disaster affected area. Solid waste management. Springer.

CHEN, X., GENG, Y. & FUJITA, T. 2010. An overview of municipal solid waste management in China. Waste management, 30, 716-724.

CHENG, H., ZHANG, Y., MENG, A. & LI, Q. 2007. Municipal solid waste fueled power generation in China: a case study of waste-to-energy in Changchun city. Environmental science & technology, 41, 7509-7515.

COFIE, O., NIKIEMA, J., IMPRAIM, R., ADAMTEY, N., PAUL, J. & KONE, D. 2016. Co-composting of solid waste and fecal sludge for nutrient and organic matter recovery, IWMI.

COUNCIL, W. E. 2013. Council, W.E ,World energy resources.

COUNCIL, W. E. 2016. World Energy Resources - Waste to Energy.

CURRY, N. & PILLAY, P. Converting food waste to usable energy in the urban environment through anaerobic digestion. 2009 IEEE Electrical Power & Energy Conference (EPEC), 2009. IEEE, 1-4.

DAVID C. WILSON, L. R. W., PRASAD MODAK, REKA SOOS, AINHOA CARPINTERO ROGERO, COSTAS VELIS, MONA IYER AND OTTO SIMONETT 2015. Global Waste Management Outlook.

DIETER MUTZ, D. H., CHRISTOPH HUGI, THOMAS GROSS May 2017 Waste-to-Energy Options in Municipal Solid Waste Management

DINCER, I. 2000. Renewable energy and sustainable development: a crucial review. Renewable and sustainable energy reviews, 4, 157-175.

DONGLIANG ZHANG, G. H., YIMIN XU 3 AND QINGHUA GONG 16 December 2015. Waste-to-Energy in China: Key Challenges and Opportunities.

EKMEKCIOĞLU, M., KAYA, T. & KAHRAMAN, C. 2010. Fuzzy multicriteria disposal method and site selection for municipal solid waste. Waste management, 30, 1729-1736.

ENDALEW, B. & TASSIE, K. 2018. Urban households' demand for improved solid waste management service in Bahir Dar city: A contingent valuation study. Cogent Environmental Science, 4, 1426160.

EPA, U. S. 2012. International Best Practices Guide for LFGE Projects - global methane initiative.

FAH, A. 2017. Evaluation of solid waste management in Khartoum state and selection of landfill sites, Using GIS technique.

FORD, M. 2011. Shoreline changes on an urban atoll in the central Pacific Ocean: Majuro Atoll, Marshall Islands. Journal of Coastal Research, 28, 11-22.

G. TBILISI, F. S. T. S. I., TURKSTAT," P. FATIHSAHIN@TUIK.GOV.TR, 2012.

GARCIA, P. E. E. 2015. Evaluation and Proposed Development of the Municipal Solid Waste Management System in Mexico City. University of Manchester.

HERBERT, G. J., INIYAN, S., SREEVALSAN, E. & RAJAPANDIAN, S. 2007. A review of wind energy technologies. Renewable and sustainable energy Reviews, 11, 1117-1145.

HOORNWEG, D. & BHADA-TATA, P. 2012. What a waste: a global review of solid waste management, World Bank, Washington, DC.

ISLAM, M. R., ISLAM, M. R. & BEG, M. R. A. 2008. Renewable energy resources and technologies practice in Bangladesh. Renewable and Sustainable Energy Reviews, 12, 299-343.

J. RAWLINS, J. B., J. LAMPREIA, AND F. TUMIWA 2014. Waste to energy in Indonesia: Assessing opportunities and barriers using insights from the UK and beyond.

K.M. KANGLE, S. V. K., V.S. KORE, G.S 2010. Kulkarni, Univ. J. Environ. Res. Technol. 210–221.

KHAN, A. S. 2011. Feasibility of waste-to-energy recovery technoligies in Lahore, Pakistan. Norwegian University of Life Sciences, Ås.

KHAN, B. 2006. Non-conventional energy resources, Tata McGraw-Hill Education.

KLEIS, H. D., SøREN 2004. 100 Years of Waste Incineration in Denmark (PDF).

KOERNER, R. M. & DANIEL, D. E. 1997. Final covers for solid waste landfills and abandoned dumps, Thomas Telford.

KÖSE, Ö., AYAZ, S. & KÖROĞLU, B. 2007. Waste Management in Turkey.

KUMAR, S. 2000. Technology options for municipal solid waste-to-energy project. TIMES (TERI Information Monitor on Environmental Science) Volume, 5, 1-11.

L. CUTZ, P. H., D. SANTANA, F. JOHNSSON, RENEW 1411–1431 (2016). Renew. Sustain. Energy Rev. 58.

LAM, S. S., LIEW, R. K., JUSOH, A., CHONG, C. T., ANI, F. N. & CHASE, H. A. 2016. Progress in waste oil to sustainable energy, with emphasis on pyrolysis techniques. Renewable and Sustainable Energy Reviews, 53, 741-753.

LETCHER, T. M. 2017. Wind energy engineering: a handbook for onshore and offshore wind turbines, Academic Press.

LOVINS, A. B. 1976. Energy strategy: the road not taken. Foreign Aff., 55, 65.

M. A. A. M. ABUBAKER BM A, M. A. A. H. G. 2014. Investigating the Solid Waste Management Problems in Urban Area (sudan).

M. A. ABDULLAH MOHAMMED, M. N. A. W. M. 2016. Waste to energy technologies for municipal solid waste management in Khartoum.

MARSHALL, R. E. & FARAHBAKHSH, K. 2013. Systems approaches to integrated solid waste management in developing countries. Waste management, 33, 988-1003.

MASOOD, F. 2013. Solid Wastes use as an alternate Energy source in Pakistan.

MCCAULEY, A., JONES, C. & JACOBSEN, J. 2009. Soil pH and organic matter. Nutrient management module, 8, 1-12.

MCDOUGALL, F. R., WHITE, P. R., FRANKE, M. & HINDLE, P. 2008. Integrated solid waste management: a life cycle inventory, John Wiley & Sons.

MEMON, M. A. 2010. Integrated solid waste management based on the 3R approach. Journal of Material Cycles and Waste Management, 12, 30-40.

MIDILLI, A., AY, M., DINCER, I. & ROSEN, M. 2005. On hydrogen and hydrogen energy strategies: I: current status and needs. Renewable and sustainable energy reviews, 9, 255-271.

MISRA, R., ROY, R. & HIRAOKA, H. 2003. On-farm composting methods. Rome, Italy: UN-FAO.

MOAKLEY, J., WELLER, M. & ZELIC, M. 2010. An evaluation of shredder waste treatments in Denmark. Report, Worcester Polytechnic Institute.

MUTZ, D., HENGEVOSS, D., HUGI, C. & GROSS, T. 2017. Waste-to-Energy Options in Municipal Solid Waste Management A Guide for Decision Makers in Developing and Emerging Countries. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

MWANGOMO, E. A. 2018. Potential of Waste to Energy in African Urban Areas.

NEYIM, O., METIN, E. & EROZTURK, A. Packing waste in Turkey, recovery implementations and recycling industry. Proceedings of the 2nd International Packaging Congress and Exhibition, proceedings book, 2001.

OMAR, H. & ROHANI, S. 2015. Treatment of landfill waste, leachate and landfill gas: A review. Frontiers of Chemical Science and Engineering, 9, 15-32.

OSMAN, M. M. & SEVINC, H. 2019. Adaptation of climate-responsive building design strategies and resilience to climate change in the hot/arid region of Khartoum, Sudan. Sustainable Cities and Society, 47, 101429.

OUDA OKM, R. S., NIZAMI AS, REHAN M, AL-WAKED R, KORRES NE 2016. Waste to energy potential: a case study of Saudi Arabia. Renew Sustain Energy Rev. 61, 328e40.

OZTURK, M. 2014. The Roadmap of Turkey on Waste Managemen.

P. FAILLER, P. K., AND W. SEIDE 2016. Assessment of the Environment Pollution and its impact on Economic Cooperation and Integration Initiatives of the IGAD Region. National Environment Pollution Report - Sudan.

PACEY, J. 1989. Landfill Design Concepts in the United States. IN: Sanitary Landfilling: Process, Technology, and Environmental Impact. Academic Press, New York. 1989. p 559-576, 2 fig, 11 ref.

PANDEY, B. K., VYAS, S., PANDEY, M. & GAUR, A. 2016. Municipal solid waste to energy conversion methodology as physical, thermal, and biological methods. Curr. Sci. Perspect, 2, 39-46.

PEREZ-LOMBARD, L., ORTIZ, J. & POUT, C. 2008. A review on buildings energy consumption information. Energy and buildings, 40, 394-398.

PFEFFER, J. T. 1992. Solid waste management engineering, Prentice Hall.

RENO, J. 2016. Waste away: working and living with a North American landfill, Univ of California Press.

RITCHIE, S. & MCBEAN, E. 2011. Assessment of operations and design strategy controls to improve landfill gas utilization opportunities. Canadian Journal of Civil Engineering, 38, 519-529.

ROBINSON, A., SEWELL, G., WU, S., DAMODARAN, N. & KALAS ADAMS, N. 2003. Landfill data From China: addressing information needs for methane recovery. Environmental Protection Agency, US.

ROGOFF, M. J. 2013. Solid waste recycling and processing: planning of solid waste recycling facilities and programs, Elsevier.

ROHANI, H. O. A. S. 2015. Treatment of landfill waste, leachate and landfill gas: A review. vol. 9, 15-32.

ROSS, T. C. 1979. Optical gas analyzer. Google Patents.

RUI, L. M., DAUD, ZAWAWI, LATIF AND ABDUL AZIZ ABDUL 2012. Treatment of Leachate by coagulation-flocculation using different coagulants and polymer: A review. International Journal on Advanced Science, Engineering and Information Technology, 2, 114-117.

SCHEUTZ, C., KJELDSEN, P., BOGNER, J. E., DE VISSCHER, A., GEBERT, J., HILGER, H. A., HUBER-HUMER, M. & SPOKAS, K. 2009. Microbial methane oxidation processes and technologies for mitigation of landfill gas emissions. Waste management & research, 27, 409-455.

SCHUBELER, P., CHRISTEN, J. & WEHRLE, K. 1996. Conceptual framework for municipal solid waste management in low-income countries, SKAT (Swiss Center for Development Cooperation) St. Gallen.

ŞEKERCIOĞLU, S. & YıLMAZ, M. 2012. Renewable energy perspectives in the frame of Turkey's and the EU's energy policies. Energy Conversion and Management, 63, 233-238.

SENOL YILDIZ, C. Y., GOKSEL DEMIR, KURTULUS OZCAN, ASLI COBAN, HATICE ESER OKTEN, KADIR SEZER AND SAMI GORENE April 2012. Characterization of Municipal Solid Waste in Istanbul, Turkey. wileyonlinelibrary.com.

SHEKDAR, A. V. 2009. Sustainable solid waste management: an integrated approach for Asian countries. Waste management, 29, 1438-1448.

SIDAHMED, N. E. M. December 2016. The Effect of Compost, Rhizobium Inoculation and Urea on Peanut Plant Growth (Arachis Hypogeal).

SOLANGI, K., ISLAM, M., SAIDUR, R., RAHIM, N. & FAYAZ, H. 2011. A review on global solar energy policy. Renewable and sustainable energy reviews, 15, 2149-2163.

SPELLMAN, F. R. 2018. Environmental engineering dictionary, Rowman & Littlefield.

SPERLING, K., HVELPLUND, F. & MATHIESEN, B. V. 2011. Centralisation and decentralisation in strategic municipal energy planning in Denmark. Energy Policy, 39, 1338-1351.

T. M. H. M. S. SAAD AWAD, A. M. K. 2017. Waste Management in Sudan: A case of Waste Characterization in Khartoum State.

TAHTALıOGLU, H. & KULAC, O. 2019. The Role of Education in Realizing Sustainable Development in Turkey. Agathos, 10, 201-229.

TAMMEMAGI, H. Y. 1999. The waste crisis: landfills, incinerators, and the search for a sustainable future, Oxford university press.

TARSIER, R. 2004. Leachate and gas production in landfills.

TCHOBANOGLOUS, G. & KREITH, F. 2002. Handbook of Solid Waste Management Second Ed.

TEKINEL, B. 2017. Comparison of the Turkish and the Finnish Municipal Solid Waste Management Systems With a Regard to Waste to Energy Possibilities in Turkey.

TROMLY, K. 2001. Renewable Energy: An Overview. National Renewable Energy Lab., Golden, CO (US).

VICTORIA, E. 2001. Siting, design, operation and rehabilitation of landfills. Melbourne.

WARITH, M. 2003. Solid waste management: new trends in landfill design. Emirates Journal for Engineering Research, 8, 61-70.

WHITING, K., WOOD, S. & FANNING, M. 2013. Waste technologies: Waste to energy facilities. A report for the Strategic Waste Infrastructure Planning, Department of Environment and Conservation of Western Australia.

WIKIPEDIA. 2019. Waste [Online]. Available: https://simple.wikipedia.org/w/index.php?title=Waste&oldid=6698282 [Accessed].

WIKIPEDIA. 2020a. Gasification [Online]. Available: https://en.wikipedia.org/w/index.php?title=Gasification&oldid=935205313 [Accessed].

WIKIPEDIA. 2020b. PH [Online]. Available: https://en.wikipedia.org/w/index.php?title=PH&oldid=933763202 [Accessed].

WIKIPEDIA. 2020c. Pyrolysis [Online]. Available: https://en.wikipedia.org/w/index.php?title=Pyrolysis&oldid=935742380 [Accessed].

WILKINSON, J., BORS, C., BURGIS, F., LORKE, A. & BODMER, P. 2018. Measuring CO2 and CH4 with a portable gas analyzer: Closed-loop operation, optimization and assessment. PloS one, 13, e0193973.

XIAODONG, L. April 2017. Waste to Energy in China.

ZAHEDI, A. Investigation of feasibility of establishing waste to energy facility in Australia. Proceedings of IEEE International Conference on Systems, Man and Cybernetics, 1994. IEEE, 2701-2705.

ZHANG, D. Q., TAN, S. K. & GERSBERG, R. M. 2010. Municipal solid waste management in China: status, problems and challenges. Journal of environmental management, 91, 1623-1633.

ZHUANG, Y., WU, S.-W., WANG, Y.-L., WU, W.-X. & CHEN, Y.-X. 2008. Source separation of household waste: a case study in China. Waste management, 28, 2022-2030.

Appendices

Appendices

Removal of soil layer

Welding of Geomembrane

Old waste

New waste (organic waste)

Brining new waste

Landfill filling process

Landfill filling process

إستبيان لبحث تكميلي لنيل درجة الماجستير في الهندسة البيئية

حول إدارة ومعالجة النفايات في ولاية الخرطوم ومعرفة مدى تقبل المواطنين لفرز النفايات والاستفادة منها (النفايات المقصودة في هذا الإستبيان هي النفايات البلدية)

القسم الاول:

1. العمر؟
   - دون ال20
   - من 20 الى 30
   - من 30 الى 40
   - من 40 الى 50
   - من 50 الى 60
   - اكثر من 60
2. النوع؟
   - ذكر
   - انثى
3. السكن؟

....

القسم الثاني:

4. ما هي الجهة التي تقوم بخدمات قطاع النفايات في منطقتك؟
   - جهات حكومية
   - جهات خاصة
   - جهات مشتركة
5. هل توجود مشكلة متعلقة بالنفايات في المنطقة التي تسكن بها؟
   - نعم
   - لا
   - ربما
6. اذا كانت الاجابة (نعم) في السؤال السابق ؛هل توافق على إعتبارهذه المشكلة كأزمة؟
   - اوافق
   - اوافق بشدة
   - ارفض
   - ارفض بشدة

7. هل لديك خلفية مسبقة عن الكيفية التي تتم بها ادارة ومعالجة النفايات في ولاية الخرطوم؟

- لا
- نعم

8. اذا كانت الاجابة (نعم) في السؤال السابق ؛ اذكر الكيفية:

....

....

9. ما هو نظام جمع النفايات المطبق من قبل ادارة النفايات في الحي الذي تقطنه؟

- يتم جمعها من الباب
- حاوية نفايات داخل الحي
- اخرى

10. اذا كانت الاجابة (اخرى) في السؤال السابق ؛ اذكرها:

....

....

11. كم عدد المرات التي يتم فيها اخذ و ترحيل النفايات من اماكن تجميعها؟

- مرة واحدة بالاسبوع
- مرتين بالاسبوع
- اكثر من مرتين بالاسبوع
- لم يتم الحضور لجمعها مطلقا
- حالات اخرى

12. أذكر الحالات الأخرى ؛ السؤال السابق:

....

....

13. تقييم كفاءة عملية جمع وترحيل النفايات من قبل الادارة المختصة؟

- ممتاز
- جيد
- جيد جدا
- سيئ
- سيئ جدا
- لا اعرف

14. ما هي الطريقة التي تتبعها داخل المنزل الخاص بك لتخزين النفايات المنتجة قبل أخذها لأماكن تجميعها أو ترحيلها من قبل الادارة؟

- أكياس بلاستيكية
- سلة نفايات
- أخرى

15. أذكر الطرق الأخرى المتبعة في السؤال السابق ان وجدت :

....

....

16. هل يتم حرق النفايات، دفن عشوائي للنفايات أو القاء عشوائي للنفايات داخل الحي؟

- نعم
- لا

17. اذا كانت الاجابة (بنعم) في السؤال السابق هل يوجد قلق بشأن وجود مخاطر صحية و بيئية؟

- لا
- نعم

18. اذا كانت الاجابة (بنعم) ؛ عدد المخاطر :

....

....

19. ما هو السبب في إعاقة عملية جمع النفايات ؟

- عدم توفر أماكن مخصصة للجمع
- عدم توفر عربات لنقل النفايات من الأحياء
- تذبذب حضور عربات النقل
- زمن الحضور غير مناسب
- أخرى

20. أذكر الأسباب الأخرى ان وجدت:

....

....

21. برأيك ما هو السبب الرئيسي لهذة الأزمة ؟

- المواطن
- هيئة ادارة النفايات
- المواطن والهيئة معا

القسم الثالث:

22 هل تعتقد أن للنفايات البلدية أهمية تجارية وصناعية يمكن الإستفادة منها ؟

- نعم
- لا

23 إذا كانت الإجابة (نعم) ، هل ترغب أن تكون عنصر فعال للإستفادة من النفايات البلدية؟

- نعم
- لا

24 ما هو الأسلوب الذي ترغب في المشاركة به للاستفادة من النفايات؟

- انتاج الاسمدة
- اعادة التدوير المختلفة
- انتاج الغاز
- أخرى

25 اذا كانت الاجابة(أخرى) في السؤال السابق ؛ أذكرها:

....

26 هل يمكنك استخدام المواد المعاد تدويرها؟

- نعم
- لا

27 هل تقوم بفصل النفايات داخل المنزل (أي المواد العضوية في وعاء خاص والاوراق في وعاء أخر وكذلك المنتجات البلاستيكية ، الزجاج)؟

- نعم
- لا

28 اذا طلبت منك ادارة نفايات ولاية الخرطوم بفصل النفايات حسب نوعها هل ستكون؟

- مهتم
- مهتم جدا
- غير مهتم

29 هل لديك خلفية عن مكبات النفايات في ولاية الخرطوم؟

- نعم
- لا

30 إذا كانت الإجابة في السؤال السابق (نعم) ، ما هي الطرق المتبعة لمعالجة النفايات والتخلص منها في ولاية الخرطوم؟

- الدفن المفتوح
- الطمر الصحي (تقليل التأثير على البيئة)
- الحرق
- أخرى

31. أذكر الطرق الأخرى في السؤال السابق ان وجدت:

....

....

32. أذكر مكبات النفايات التي تعرفها بولاية الخرطوم:

....

....

33. هل تعتقد وجود تأثير بيئي ملحوظ أو ضمني بسبب هذه المكبات؟

- نعم
- لا

34. إذا كانت الإجابة (نعم) في السؤال السابق ؛ قم بتوضيح هذا الأثر:

....

....

35. هل تعلم أن المكبات الصحية (Sanitary Landfills) يمكن أن تكون مصدر للطاقة ؟

- نعم
- لا

36 هل يوجود مكب نفايات في ولاية الخرطوم يتم به انتاج غاز الميثان(CH_4) ، غاز الميثان يستخدم في الطبخ ، الإنارة ، توليد الطاقة...الخ ؟

- نعم
- لا

37 واذا كانت الاجابة (بنعم) في السؤال السابق ، عدد أسماء هذه المكبات؟

....

....

38 واذا كانت الاجابة ب (لا) ما هي المعوقات التي تحول دون انشاء مثل هذه المكبات؟

- عدم وجود تمويل كافي
- عدم وجود تثقيف بين المواطنين
- عدم وجود التكنولوجيا المناسبة
- أخرى

39 أذكر المعوقات الأخرى في السؤال السابق ان وجدت:

....

....

40. هل يوجد لديك أي إقتراحات قد تساعد في جمع وإدارة ومعالجة النفايات بولاية الخرطوم؟

- يوجد
- لا يوجد

41. أذكر اقتراحاتك في السؤال السابق ان وجدت :

....

....