ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

School of Civil and Environmental Engineering

Utilization of Underground Solid Waste Management System
for Addis Ababa City, Ethiopia:
Case study on ‘Lideta’ sub-city condominium

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Addis Ababa, Ethiopia

Utilization of Underground Solid Waste Management System for Addis Ababa City, Ethiopia:

Case study on 'Lideta' sub-city condominium

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APPROVAL SHEET

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This thesis entitled with "***Utilization of Underground Solid Waste Management System for Addis Ababa City, Ethiopia: Case study for 'Lideta' Sub city condominium***" is approved by Advisor, Examiners, Chairman and School of Civil and Environmental Engineering of Addis Ababa University for partial fulfillment of the requirement for the Degree of Master of Science in water supply and environmental Engineering at Addis Ababa Institute of Technology University, Addis Ababa, Ethiopia.

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Dedication

I dedicate this work to:

The Almighty of GOD and for all my family.

Abstract

Managing wastes has become a problem especially in highly urbanized areas. There are a lot of human activities that contribute to waste generation. If these waste materials failed to be disposed in the proper manner and in the proper place, create a serious problem to humans and threat to nature. Solid Waste Management plays a big role on the preservation of life and nature. Ethiopia is considered as the tiger economy of Africa for its fast growth and development, this advancement also affects a solid waste management. There had been some attempt to implement policies to promote proper solid waste management. This study is concerned on the implementation of u*nderground waste management system for a more efficient, economical and environmentally-friendly waste management solution. Design of UGSWM has been proposed based on varies parameter including solid waste generation, number of population, area of existing bin, number of building. Analytical formula are applied to compute different solid waste rates. A case study is conducted for reasonably selected (i.e., Lideta sub city condominium) site and proper design had investigated to meet the required objectives on various components of the system used for installation process. In conducting this study, interview questionnaires were answered by 60 household residents, 2 hospitals and 6 business/commercial establishments' respondents of Addis Ababa community. The survey was conducted to gather information on the knowledge and practices respondents have on solid waste management. The awareness of the residents in the Addis Ababa about solid waste management is low. The practices and compliance of residents indicates the knowledge and training they have acquired. Solid waste management is a human obligation to fulfill. The inefficiency and failure to sustain proper solid waste management is a societal, environmental, economic, and political issue. This paper concludes that a truly integrated solid waste management system could be realized by implementing underground solid waste management and should be implemented to Addis Ababa city to ensure for healthy environment, economically.*

Keywords: Waste Management, underground solid waste disposal, installation process

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Acronyms

AVAC	Automated vacuumed waste collection system
AU	African union
DV	Discharge valve
EAC	East African City
FDRE	Federal democratic republic of Ethiopia
GSM	Global system of mobile
ISWA	International solid waste association
MSE	Municipal and small enterprise
MSW	Municipal solid waste
MSWM	Municipal solid waste management
PWCS	Pneumatic waste collection system
RCRA	Resource Conservation and Recovery Act
UGSWM	Underground solid waste management
WHO	World health organization

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Waste refers to any defective and worthless substance that is discarded or cannot be used after the first use. It is an early problem of mankind, and it is also an increasingly serious problem that causes serious concerns in all countries in the world [1]. Throughout history and human life, waste is a problem for all mankind, but it is still a problem. It is developing rapidly and affects all countries in the world. According to [1], there is specific form of solid waste that are generated from specific elements of the society. Those are Biodegradable waste: (meals and kitchen waste, green waste, paper (may be recycled)); Recyclable material: (paper, glass bottles, cans, metals, sure plastics, etc.) Inert waste: (creation and demolition waste, dirt, rocks, debris) Composite wastes: (waste closing, Tetra Packs, waste plastics which include toys) Domestic hazardous waste & poisonous waste :(medication or pills E-waste, paints, chemicals, light bulbs or fluorescent tubes, spray cans, fertilizers and insecticides and their containers, batteries, shoe polish materials, etc.)

Now a day those solid wastes become a big issue in different areas of rural or city as well as country side areas all over the world due to rapid growth of population. As the population grew and prospered, it is obviously difficult to manage those solid and other kinds of wastes generated from the community. As a result, this waste management problem can be seen in most urban areas of the world especially in developing countries with a lot of population.

The generation of solid waste is an important byproduct of socio-economic activities. The definition of solid waste varies among countries. Generally, waste generated from industrial sector, commercial, domestic, institutional and municipal services are included in municipal solid waste (MSW).

Solid waste management is not only concerning about collecting wastes from different sources but also it is the process of collection, transporting, processing, recycling, disposal and monitoring of waste material [2]. The treatment of Municipal solid waste has to be

efficiently good and important; it have to be environmentally friendly [3]. According to [4], the main source of health problem and environmental related issues are directly connected to improper waste management system, especially in developing countries. As suggested by [5], currently many health and environmental related issues are regarding outdated methods of waste management and results in an emission of greenhouse and other toxic gases from properly uncontrolled collection and disposal waste procedures.

The urban center is important for different activity that are done in the national and international level. They play important role in manufacturing, processing, commercial activities, employment and income creation. For this matter the cities must become aesthetically attractive and environmentally safe for doing these activities. The major problem is that how to create aesthetically safe and free of health problems solid waste management in Addis Ababa.

The underground waste treatment system uses the technology of long-distance transportation of underground solid waste to collection stations through pipelines, and then compresses them in airtight containers. The system uses air to transport waste. This system has an advantage of releasing valuable surface space, enhance urban living condition, minimizing air pollution, noise pollution, aesthetic pollution and odor nuisance form MSW [6].

The way municipal solid waste (MSW) of Addis Ababa currently has many problems due to unsustainable and inefficient handling. The open dumping site and open temporary storage with in the community Couse many problems related to health risk for human being, environmental pollution (water, air and land), domestic and wild animals.

Thus, the MSWM question is very critical and need to be solved from its source to the final disposal in order to reduce problem caused by poor SWM. There is a need of putting legal procedures, introducing appropriate, efficient and sustainable technology that will solve the problems.

Although there are different studies conducted on solid waste management in the case of Addis Ababa, there is no attempt in considering the case of underground solid waste management and its appropriateness for the city of Addis Ababa. This research mainly focused on how is underground solid waste management is appropriate for Addis Ababa city, and can solve the existing problem.

Figure 1.1: *Current solid waste disposal habit at some parts of Addis Ababa*

Source: Photo taken by researcher, 2020 G.C.

1.2. Statement of the problem

Ethiopia, like any growing countries in East Africa, presently faces waste control challenges associated with over-accumulation on open land, water pollution, and overall public nuisances along with pests, diseases, and odors [7].

Addis Ababa is the capital city of Ethiopia and the seat for African Union. As the population and the city development increase the demand and activities of the community also increase. Due to rapid growth of population of the city and other factors, the generation of solid and other kinds of wastes became out of control for management and remain a challenge. As a result, the city suffers from dirtiness which has a direct impact on the country's image. Unless those wastes are not managed properly, they will become headache and will cause social, political and environmental effects.

The researcher believes these problems are caused due to the lack of integrated, modern and easy system of solid waste management. So, the use of underground is an alternative solid waste management and it can be cost-effective, healthy, efficient and easy tackling for Addis Ababa.

1.3. Objective of the study

The general and specific objectives of this research work are outlined below:

1.3.1. General objective

The primary objective of study is to examine applicability of underground solid waste management (UGSWM) for Addis Ababa city and to conduct a case study of the system at 'Lideta' Sub _city Condominium site.

1.3.2. Specific objectives

The specific objectives are:

- Identify the impact of conventional solid waste management system on public health issue
- Showing the public opinion about underground solid waste management against the conventional solid waste management system
- Analyzing the benefits of underground waste management (UGSWM) for waste disposal.
- To construct the design of UGSWM for Lideta condominium.

1.4. Research questions

To fulfill the above specific objectives, some of the research questions are as follows:

- What are the impacts of the conventional solid waste management system on public health issues?
- What is the public's opinion about underground solid waste management (UGSWM) against the conventional solid waste management system?
- What advantage would the underground solid waste management (UGSWM) bring to the administration?
- What parameters is used to design UGSWM for the specific site?

1.5. Research methodology

As it can be seen on the below schematic diagram, the methodology that the researcher follows are depicted as follows.

At first the problem were identified and the required data are collected from primary and secondary data and input information are compiled. Since some of the data are raw data, analysis of such data were necessary to check whether the noticed problem is there or not. GIS and STATA software are used for locating the skip points and for data analysis. After the problem is checked and proven, the researcher introduces the new system or technology for the problem. And finally, feasibility of the system is checked for its applicability for the Lideta condominium site.

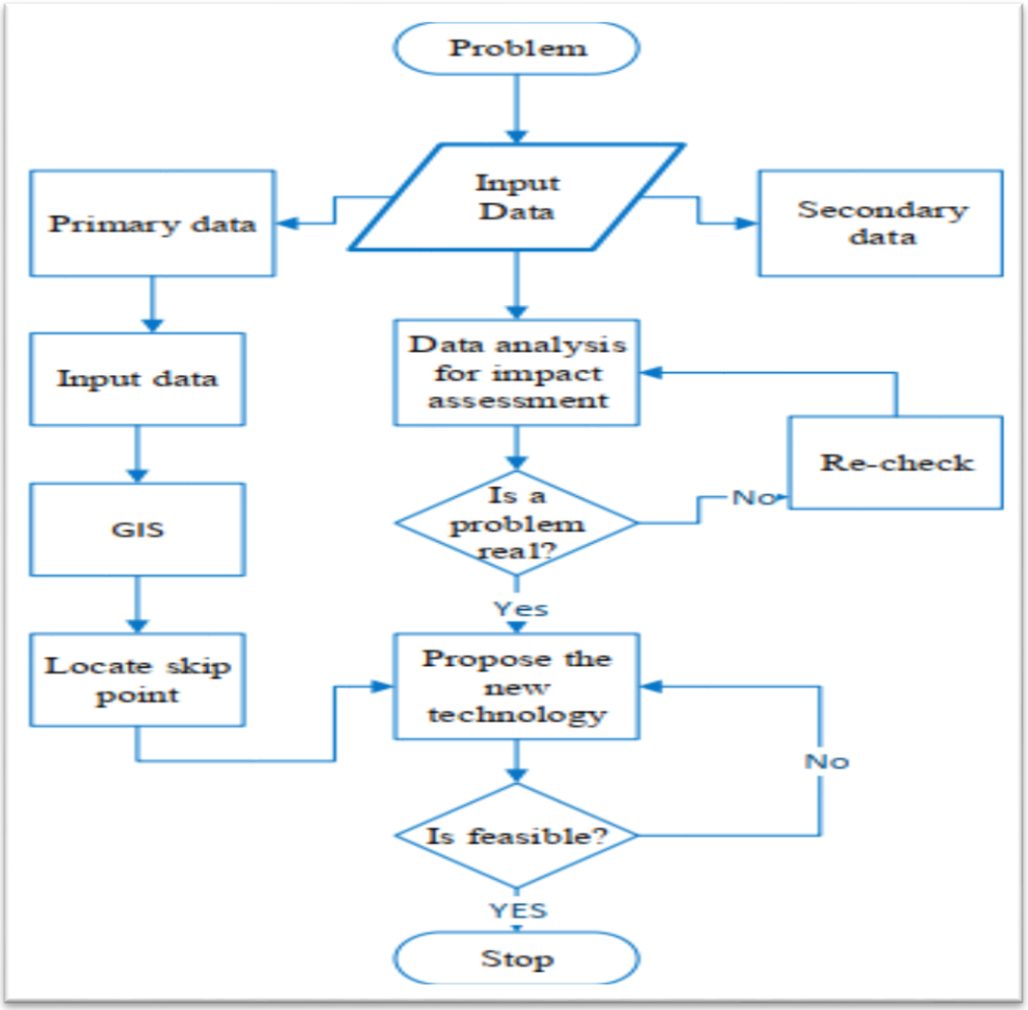

Figure 2.2: *Schematic diagram for methodology*

1.6. Significance of the study

After the completion of this research work, the community will have a better understanding and awareness on behaving the task of avoiding solid waste using UGSWD. The proposed system will bring a good opportunity to minimize health problems arising due to waste products which is poorly managed. For the municipality, it will bring a suitable situation to provide necessary rules and regulations so as to manage underground solid waste disposal system properly.

1.7. Scope and Limitation of the study

The system design of solid waste management is primarily used only in Addis Ababa. Besides, it is considered and applied only for appropriately collected and sorted wastes. The primary objective of this research is to introduce underground waste management system for Addis Ababa city and conducting a case study for ‘’Lideta’’ sub city but the design is limited to households, hospitals and small business houses which have a low volume of solid waste disposal in the vicinity of the study area. The research does not consider industries which produces large volume of solid wastes.

1.8. Organization of the rest of the thesis

The remaining of this thesis report is organized as follows. Chapter two presents literature review on the theoretical backgrounds of UGWDM. Besides, this chapter reviews related research works that has been done on the same area. Research design and methodology are discussed under chapter three. The fourth chapter focus on showing design of the proposed solid waste management system. Chapter five analyze the results and discussion of the research whereas the last chapter i.e., chapter six contains conclusion and possible recommendations,

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Concept and definition

2.1.1. Solid waste

As it is stated by [8], Solid waste is waste or garbage from sewage treatment plants, water treatment plants or air pollution control facilities, sludge, and other waste materials from industrial, commercial, mining, agricultural and municipal activities.

Similarly, other literature such as [9] define waste as ‘’Solid waste refers to the variety of rubbish arising from animal and human activity which might be discarded as unwanted and useless’’. This will be generated from industrial, residential and business activity in a given area.

2.1.2. Municipal Solid Waste (MSW)

More commonly municipal solid waste referred to as trash or rubbish consists of regular objects used, after which throw away, together with product packaging, grass clippings, furniture, clothing, bottles, meals scraps, newspapers, appliances, paint, and batteries. This comes from our homes, schools, hospitals, and businesses. [10]. Not only this but any solid which cannot contain liquid that is created by any individual person, household, small business, or institution, such as a college or medical institution can be also defined as a municipal solid. This waste is taken into consideration as a trash or rubbish and includes regular appliances, matters or gadgets which are damaged, meals that has spoiled, or more simply any devices someone now not makes use of or wants. Most of the time things which are disposed as a municipal solid waste are paper, meals, plastics, metals, rubbers, and textiles. (Environmental science 101: Environment and humanity, chap 12).

2.1.3. Classification of sources of municipal solid wastes

The source classification of solid waste covers three areas: urban, industrial and rural; each is represented as a separate object.

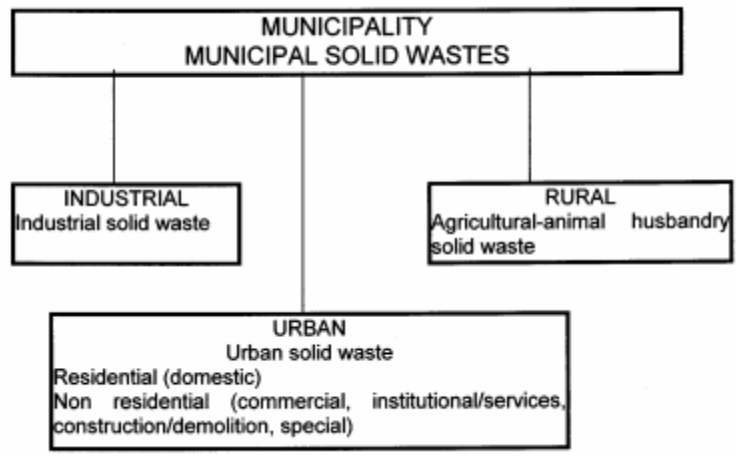

Figure 2. 1:Factor influencing Solid Waste Management in Ethiopia

Each category generates different solid wastes, which are classified as follows according to the source of generation:

- Household waste: Waste from houses, houses or apartments.
- Commercial waste: Waste from commercial establishments, department stores, supermarkets, restaurants, markets and street markets
- Institutional and service waste: Governmental and Private offices, education centers, museums, libraries, archaeological sites and entertainment centers, such as movie theaters and stadiums.
- Construction and demolition waste: Construction site and demolition waste.
- Hazardous waste: This is a waste that requires special control methods, either because it is relatively dangerous because of its state or conditions, or because the control is subject to applicable environmental regulations. These wastes are generated in areas such as research, healthcare, industry, and automobile maintenance. Including shops, human and veterinary drug stores, airports and ground transportation terminals.
- Industrial waste: This is the waste generated in each process of the extraction, extraction, transformation and manufacture of goods.
- Agriculture and animal husbandry: Waste from agriculture and animal activities.

2.2. Innovation of Municipal solid waste administration in developed country

Countries like Italy, Japan, USA and UK are presently rehearsing zero waste concept municipal waste administration. They presented modern methods of waste collection and storage, strategies for incineration, pyrolysis, plasma gasification, high-impact and anaerobic digestion, check and profound slurry infusion. [11]. Other than advance treatment and arranging innovations they are stringently executing the idea of 3R's, reduce, reuse and reuse. [12].

Researches such as [3] proposed a latest and modern collection and transportation of MSW which includes numerous technologies and newly emerging innovations in incorporated waste administration framework that is an arrangement of garbage removal that incorporate isolating material as per type and tracking down the best utilized for disposed of items, which might possibly incorporate saving them in a land fill. As per [13], most recent innovation incorporates underground collection framework, electronic GIS innovation, waste canister checking framework utilizing GSM.

- **Underground collection system**

New advancements for waste collections are underground and semi underground frameworks. In these advances waste compartments or containers are being replaced by underground collection stations. This advancement consists of placing plastic holder in 2-3m excavated ground with only exposed inlet mechanism [14].

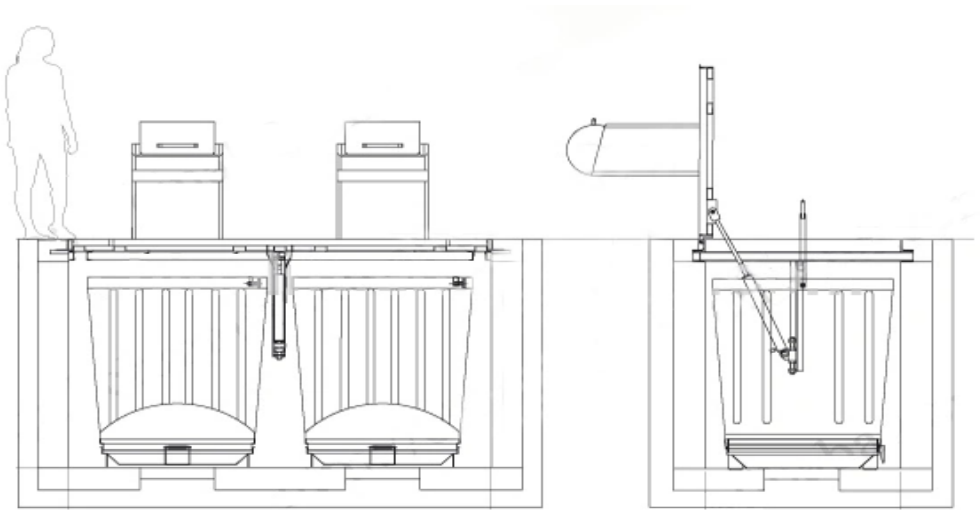

Figure 2. 2:Underground waste container

The collection and transportation of waste is done utilizing unique kinds of trucks. These kinds of holders are being utilized worldwide since years. They have very broad scope of utilization from recyclables, to natural waste and oils. The innovation is helpful for the districts with amazingly hot climatic conditions as the waste would be put away underground in generally low temperature. Then again, the innovation requires less support and is all the more stylishly worthy [11].

2.3. Trends in solid waste management in Africa

One of the serious issues in urban communities these days is the collection, treatment, transportation, storage, and proper disposal of waste [15]. Therefore, individuals have witnessed a poor waste management practices characterized by indiscriminate dumping of refuse in water bodies and isolated places which further exacerbates the already low sanitation level in most African countries.

The common expansion in the degree of urbanization in Africa is expected to increase in the near future. However, a significant concern is that there are no sufficient infrastructural facilities and appropriate land use planning to match up with the demands posed by the urban growth rate especially the slums and ghettos in Africa [16].

❖ **Collection and transportation of waste**

Waste collection in Africa is mainly divided into three levels: informal level, primary and secondary level. Informal and primary level-these levels are mainly from home to public collection points.

Figure 2. 3: Primary waste collection

Official institutions (such as municipalities and private operators) level. Waste is usually sent from public places to landfills or disposal sites. Waste collectors have also been used to collect waste directly from door-to-door households.

Figure 2. 4:Secondary waste collection

In African countries, another common collection method is the telephone pickup system. In this system, the collection vehicle has a specific time and date to collect garbage from the public.

I. Compact garbage collection trucks

Most recent innovations presented waste disposal units in authority trucks to expand the collection capacity of vehicle. With consistent change as of now these trucks have accomplished high pressure rate as they can convey 1.5 occasions more waste as contrast with flat pile trucks [17].

Figure 2. 5: Garbage collection trucks

II. Web based GIS (Geographic information system) technology

It is a kind of waste management system in an organized and integrated application, devoted, by and large to, singular Municipalities or to Municipalities and Multi-Utilities Associations, for dealing with the whole system cycle of waste, from the place of waste production to the landfill or to the reusing/treatment plants, via computerizing and optimizing each progression of the chain. [3]. As per the Italian and European investigations the execution of electronic GIS innovation enhanced the waste collection and source separation for reusing had performance up to 80% [18].

As GIS can demonstrate and model the world milestones and streets, it can assume a significant part in waste collection area. GIS in mix of other programming can give data in regards to the most reliable routs, number of occupants, number of agreements, their approval, and expected or potential frauds. [18].

III. Waste bin monitoring technology using Global System of Mobile (GSM)

In this innovation sensors are set in open trash bins to detect and identify a designed level of waste. As the trash arrives at the limit level, sign will be moved to the regulator which will additionally offer sign to driver of collection truck for discharging the collected wastes immediately. The sign for the driver is sent through SMS utilizing Global System for Mobile Communications (GSM) [19].

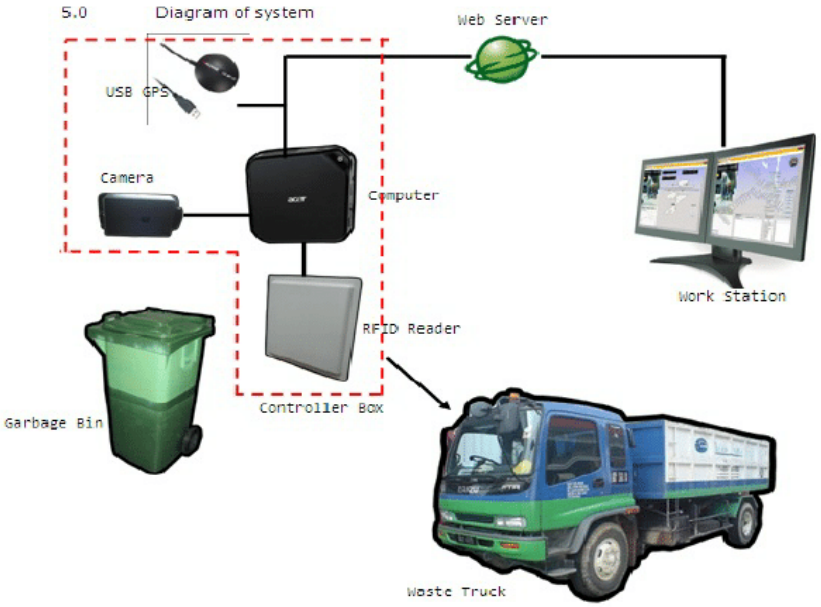

Figure 2. 6: Waste bin monitoring technology using Global System of Mobile (GSM)

- **Final disposal of the waste**

According to [20], the final disposal of waste in East African cities occurs on uncultivated land, such as old quarries or valleys near wetlands. In Uganda, the city of Kampala has turned the Kitezi landfill into a landfill. The plant showed some leaks in front of the sewage treatment plant, which caused heavy metal pollution to the environment [21].

- **Waste transfer station**

The created waste is moved to move point (skip, shelter, reserve trailers, open parts) generally waste produced by family, business premises, market dealer) themselves or recruited (casual) work before collected by metropolitan(city) laborers or private administrator. Businesses, huge institution (e.g., educational, hospitals), shopping centers, huge market have their own depot served by skips, fortifications, trailers and other waste control offices.

2.3.1. Waste management

Waste management is one of the biggest challenges in urban planning. The amount of waste (household, industry, hazard) generated annually worldwide exceeds 4 billion tons. Nearly 45% of them are regarded as municipal wastes, and the rest are industrial wastes, including hazardous wastes.

2.3.2. Solid Waste Management

Solid Waste Management is the discipline associated with control of generation, storage, collection, delivery or transfer, processing and disposal of solid waste substances in a way that best addresses the range of public health, conservation, economics, aesthetic, engineering and different environmental considerations. [22].

2.3.3. Solid waste generation of Addis Ababa city

Solid waste generation means quantity of materials or products that enter a waste stream before composting, incineration, and land fitting or recycling. In the early 1980s and mid-1990s, data were composed from research undertaken in Addis Ababa by Nure consultancy with the help of Louis Berger Company to show the volume, weight and density of waste generated in the city. The result indicated that the estimates of waste generated varies in volume of waste generated in between 0.4 and 1.23 L/capital/day and varies in weight between 0.11 to 0.25 kg/capita/day and 205 to 370 kg/m^3 in density. [23].

From the report of [24], the daily waste generation estimated as 0.35 kg/capita/day. Regardless of increasing volume of waste generated, the performance of the city's solid waste collection, disposal system and waste management system are poor [25]. According to [24] report, only 65% of the solid waste produced per day is collected and disposed by the

municipality in the dumpsite, whereas 5% of the collected waste is recycled, of the total waste collected 5% is composted and the remaining 25% are uncollected and dumped in unauthorized areas such as open fields, ditches, sewers, streets and many other available spaces in the city.

However, uncollected garbage results in a very serious health and environmental hazard for all, especially in areas where the waste collector personnel are not present for collection. These cause bad smells and attract various disease vectors and pests resulting in deteriorated aesthetic quality of the city. Thus, the health situation of the community is under serious threat [26].

2.4. Factor influencing Solid Waste Management in Ethiopia

Ethiopia's poor management structure and institutional inefficiencies regarding waste have led to poor coordination, inadequate supervision, monitoring and evaluation systems, and aggravated the existing barriers [27].Communities should start waste disposal at home, and houses should participate in waste classification from the source, and be responsible for strict control of warehouse hygiene [28].
For a better understanding, some of these factors will be discussed below.

2.4.1. Management factors

Take the example of some authors [29] the local authorities responsible for manipulation are mismanaged. In addition, when considering the lack of equipment in recycling plants, the disposal of municipal waste is a key factor [30].
Low-skilled workers; lack of sensitivity and awareness to understand the needs of the population is also an important factor in the poor management of urban waste [31]. Developing countries also lack methods to track and monitor all waste management activities [31] [32].

2.4.2. Lack of skills, knowledge and equipment in solid waste management

The management system is inefficient, lacks appropriate and systematic methods, defects in the provision of equipment used to provide services, and underdeveloped infrastructure [33].

Other factors include insufficient knowledge in the field of waste disposal and limitations of technical work. It hinders the effective disposal of solid waste [34]. It is important to mention the limitations of knowledge in waste management organizations, including weaknesses in government action policies, and take actions to improve them [35].

2.4.3. Lack of Policy Enforcement and Responsibility

Usually, the problem is not the environmental legislation itself, but the weak enforcement, which is the real challenge for sustainable waste management in Ethiopia.

This kind of non-compliance with standards and laws is a serious institutional problem and the main reason for the abuse of solid waste. An example can be seen in Addis Ababa. Although waste management legislation is inadequate, local authorities have not been able to implement it [36].

People's habits and attitudes towards unethical dispersion, community ignorance, solid waste disposal support and public interest [37].

2.4.4. Risks and problems associated with solid waste

The fact is that improper handling of solid waste can have many negative effects on aesthetics, human health and the environment [38]. Therefore, in order to fully control management activities and actively measure these negative impacts, you need to be aware of the consequences and risks (85%) caused by improper solid waste disposal [39]. Automated pneumatic waste collection systems

2.4.5. Definition and how the system works

The underground system has two main types. Namely, stand-alone collection and Automated vacuumed waste collection system.

I. Stand-alone collection

This is a more traditional solid waste collection system compared to another solid waste collection system that replaces garbage containers with underground collection points. Most of these points are underground, and the entrance is only on the ground. The advantages over conventional collection containers, such as:

- The receiving capacity is larger than the same place. Container/bath bucket.
- The waste is compacted, and the usable capacity is increased by 1.5-2.5 times.
- Improve appearance.
- Higher hygiene standards control the growth of bacteria and odor problems.
- Limited maintenance requirements and Prevent vandalism

II. Automated vacuum (pneumatic) waste collection systems (AVAC)

The second category of solid waste collection and disposal from various sources is the automatic vacuum (Pneumatic) waste collection system (AVAC). Nowadays, this type of collection and processing system is very common. They provide not only temporary storage, but also transportation. Waste is generated through an underground pipeline network and reaches the waste collection terminal. The system transports waste from different locations to a central collection system through pipelines.

This is due to the fact that waste is processed through an inlet in a special underground container and is automatically transported through the underground pipeline infrastructure to the main station by vacuum suction at selected time intervals. Vacuum suction is produced by the pressure difference in the system. They are an attractive alternative to collecting waste with conventional vehicles because they have advantages in reducing traffic-related problems (such as noise, accidents, CO2 emissions, traffic congestion, and improving overall safety and hygiene). Compared with an autonomous collection system, in this system, trucks only need to collect waste from a central collection station. In addition, the system provides great flexibility in the placement of trash cans, which can be placed in public places or even houses. In this way, municipalities can easily dispose of their waste without having to carry large amounts of waste for disposal or collect them in the trash can.

In addition, it should be noted that in the absence of pipeline infrastructure, mobile vacuum devices (mounted on trucks) can be used to literally suck waste from underground containers and take them out for recycling or processing.

Some advantage of using AVAC

- The AVAC system minimizes the operating costs of MSWM, thus ensuring long-term savings.
- The system can effectively collect all types of waste.
- The system can easily adapt to various changes.
- The system minimizes the use of garbage trucks in urban areas.
- The system minimizes air pollution, noise pollution, aesthetic pollution, and unpleasant odors from solid waste.
- The system creates space for community or development needs.
- The system is safe and hygienic for waste collectors.

The Automatic Waste Collection System (AWCS) is an underground pipeline network that can transport municipal and/or industrial/commercial waste to a designated collection point at a high speed (60-70 km/h). The system can be broken down into three components:

I. The user interface (inlets)
II. The transportation method (pipe network)
III. The waste disposal interface (the collection station)

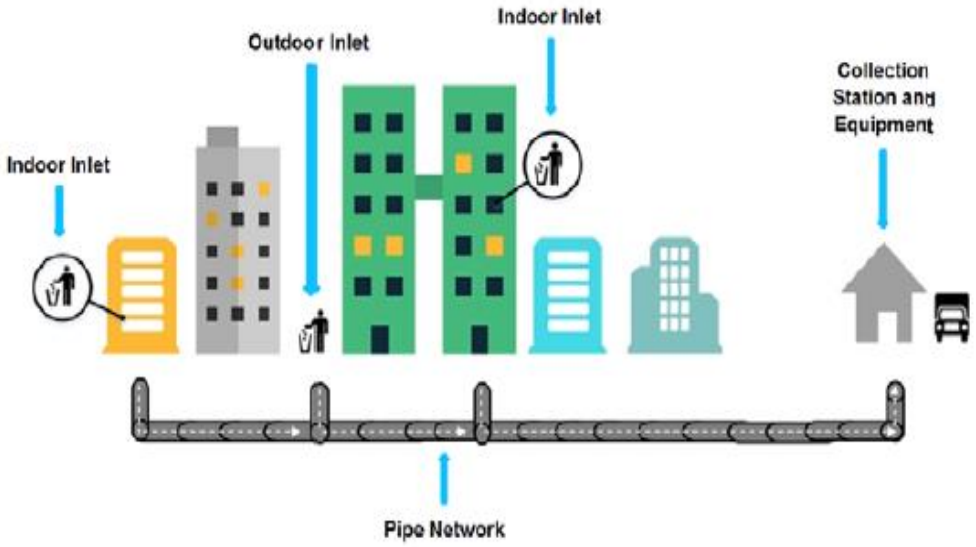

Figure 2. 7 *Schematic of automated waste collection system*

2.4.6. Terms and components of AVAC system

Air inlet

a) primary air inlet

The air inlet point of the PWC system is used to transport waste to the collection point.

b) Secondary air inlet

Usually, an additional air inlet near the DV is used to maintain the pressure required for the entire transmission line.

Air intake

Air coming into the pipe network

Collection station

Receiving station for waste introduced via the pipe network

Compactor

Machine, which includes compacting unit and container that compacts loose substances right into a box. Loose substances can include, however are not limited to paper, plastics, textiles, cans, cardboard and blended waste. The compactor in a PWCS device is typically linked directly among the cyclone and the container maintaining the full vacuum seal.

Compressor

A device which is used for compressing gases like air and others

Container

Sealed box under negative pressure placed in the collection station for temporary storage of waste, prior to haulage to a municipal waste station or treatment facility.

Container separation

Device for isolating mixed size debris from a gas stream

Control system

Network of electrical and digital devices for remote computer-controlled operation of the PWCS. Control cabinets, control boxes, software, cables and junction boxes are seemed as elements of the control system.

Cut-off valve

Valve used for air stream control in the collection station which has two positions only, open or closed.

Cyclone

A device that uses vortex flow to separate mixed-size particles from an air stream. The particulate gas enters the cyclone and is guided in a spiral shape, causing the particles to fall and collect at the bottom. The gas is discharged from the top of the cyclone separator.

Discharge valve (DV)

A valve that prevents waste from the warehouse from entering the pipeline network. DV is normally closed. The discarded waste is temporarily stored beside or behind the DV. When collecting waste, DV opens.

Erosive material

Material such as glass or metal which causes the pipe to erode rapidly.

Exhauster

One or more configurations of vacuum pumps or fans are used in series or parallel to generate negative pressure and air flow in the conveying pipeline.

Fan

Rotary blade equipment that generates electric current to cool or ventilate. In PWCS, centrifugal fans are often used as exhaust engines. Axial fans are usually used in ventilation systems.

Filter

A porous device through which gas (or liquid) flows to remove contaminants. This dust and deodorizing filter are placed in the collection room of the collection station or the on-site filter room after the exhauster, and then released into the atmosphere.

Fraction

The percentage of all waste put into the entrance before source sorting. Typical fractions include mixed dry recyclable waste, residual waste and organic waste.

Full vacuum

It maintains a constant vacuum at all inlets, and the storage part at each inlet is limited in size, such as waste inlets.

Gravity chute

A ventilated, substantially vertical duct used to move garbage/stirring or clothing to the lower deck by gravity.

Inlet station

Internal or external waste disposal stations, including entrances for disposal of waste and recyclables.

Mixed dry recyclables

Are wastes being consists of Paper, cardboard, plastics, cans, glass, polystyrene ready for recycle.

Organic waste

Wastes which contains organic foods such as garden wastes

Peak load

The ultimate waste load carried by the PWCS

Pipe network

A series of pipelines which connects waste inlets to the inlets of collection point

Residual waste

Wastes which remains not recyclable and exist as waste after extracting the recyclable ones

Rotating screen

The rotating device located in the cyclone separates large particles from the conveyed air. Prevent large waste particles from entering the exhauster.

Screw tank

Waste container used for intermediate storage underneath one or several inlets, connected to the transport pipe network by a slide valve with a rotating screw used to empty the tank.

Sectioning valve

It is a valve that controls and divide the system pipeline to different sections of the system to enhance the efficiency of the overall system.

Separator

Basically, it is a part of the system used for separation of the conveyed waste from the air flow and usually it is cyclone.

Silencer

A material used for decreasing or reducing the sound created inside the system specifically in exhaust air pipeline.

Solid mixed waste

A mixture of wastes consisting of recyclable and non-recyclable

Storage in bend

Shortened storage section below last inlet, with a 90-degree bend connection to a slide valve on the transport pipe

Storage section

Section of pipe between the DV and the gravity chute for temporary storage of waste. The storage station typically includes an inspection opening and air intake.

Transport pipe

A network cylindrical pipes constituting for transport of air and material

Vacuum (partial)

Negative pressure in the system created by running the exhausters or vacuum pumps

Vacuum pump

A pump used to produce negative pressure to counterpart the transport of wastes

Venturi pipe

A contracted pipe which helps to measure air speed. It increases the velocity of the wastes by reducing the pressure of the air passing through the venturi. It is located between the waste separator and the exhausters

Vertical slide valve

Valve used for air stream control with two positions only, open or closed.

Waste inlet

Opening for depositing waste into the system. A waste inlet can be:

- Indoor inlet on a single floor;
- Outdoor inlets;
- Attached to a screw tank; or
- Attached to a gravity chute in compliance

2.4.7. Working principle of Vacuum waste collection

Vacuum waste collection frameworks have gotten to be progressively predominant around the globe. The completely encased, stationary and computerized frameworks are known as pneumatic waste collection. They comprise of a number of waste containers (chutes) connected together by underground channeling to a central collection station. Waste is kept in channels over ground (indoor or open air) where it is put away incidentally within the

chute on best of a release valve. A preset control mechanism opens the valve within the chute and pulls the waste by gravity into the organize of channels where it is at that point sucked to the centralized collection station utilizing fans and discuss gulf valves to form the vacuum suction. The waste is picked up by trucks from a central office.

2.4.8. Principles of pneumatic waste collection system (PWCS)

- **Deposit**

Clients store waste into waste inlets, which can either be inside or outside. The waste/recycling sacks are put away temporarily inside the waste channel above a closed discharge valve (DV). All full waste inlets are at that point emptied at standard intervals. Automatic purging is administered by a control system within the collection station, which is typically found on the edges of the development it serves and connected to the inlets through a network of underground channels.

- **Transport**

When the control system senses that it is time to empty the waste inlets, the PWCS exhauster/vacuum pump system is initiated and a vacuum is created in the pipe network. A supply air valve is opened in order to allow air into the pipe network to transport waste from the waste inlets to the waste collection station. The DVs beneath the waste inlets are then opened one by one. The waste/recycling bags fall down into the pipe network and are sucked away to the waste collection station at speeds of up to 70 kph and over distances as long as 3 km from the waste inlets.

- **Collect**

Waste at the collection station is sucked through a cyclone or separator, where it is separated from the transport air. It then falls down into a compactor where it is compacted and fed into a sealed container. The transport air is released via a flue after having passed through a series of cleaning filters and silencers.

- **Treat**

The system can be designed to feed into a range of downstream technologies.

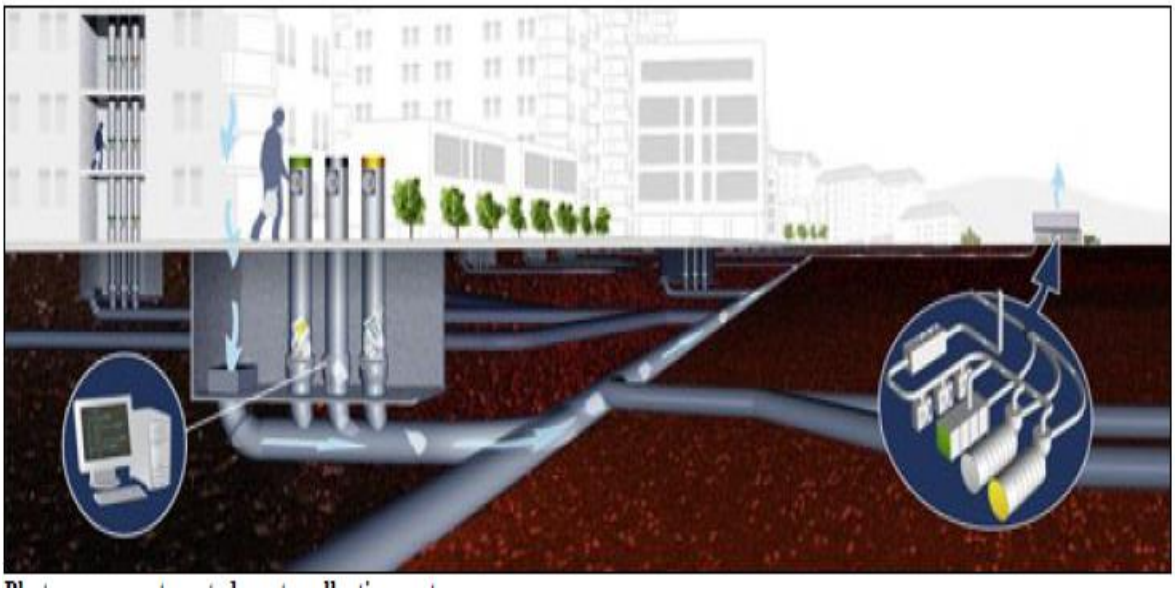

Figure 2. 8 *Indore and outdoor underground waste disposal system*

In order to design a PWCS, there are six key steps to follow

General requirement

Step 1 – Waste Definition

Step 2- Operational factors

Performance requirement

Step 3- Waste deposit- inlet system

Step 4- Transportation system- pipe network

Step 5 – Collection station

Step 6- optimize the solution

The design of the system for each specific development, should be informed as a minimum by the defined waste types and volumes to be handled and the operational timings and associated system capacity requirements. These can be identified as described in step 1 and step 2.

Step 1 – Waste Definition

In order to establish baseline waste data for the system, the following shall be identified and recorded:

a) Waste types and densities, including:

i. Waste fractions (i.e., mixed dry recyclables, organic waste, and residual waste)
ii. Average density
iii. Erosive materials

c) Waste volume

A. Waste types and densities

i. Waste fraction

The number of waste fractions to be sorted and collected separately or as a whole (mixed) shall be identified in consultation with the customer to input in to the system design.

ii. Average density

The average density (kg/m^3) of the waste in each identified fraction shall be calculated to input in to the system design.

iii. Erosive materials

Any types of erosive materials that might be transported through the system shall be identified. Example of erosive material include glass and metal. These materials should not exceed 10% of the total weight of the waste collected.

B. Waste Volume

The estimated volume of each waste fraction shall be calculated, dependent on building type, function (e.g., commercial, residential) and locality/demographic.

Step 2 – Operational factors

2.5. Design inputs to determine system capacity

The following design inputs shall be identified in order to determine system capacity:

a) Average performance values – system availability/in-use period.
b) Storage capacity – the amount of waste the gravity chutes can temporarily store.

c) Collection times – the time it takes to collect waste from each sub-system, including number of discharge valve openings.
d) Disposal patterns/peak periods – the pattern of disposal for each of the waste fractions, consisting of average load and peak load times.

The collection time shall be less than the time it takes the system to fill up to storage capacity.

2.5.1. Average performance value

The average performance values for PWC system shall be calculated as per Table 1.1.

Table 2. 1 *Average performance values calculations*

Parameter	Value	Definition
Time in operation	[h/day]	The time in operation is defined as the time the system is working in collection mode (each system)
Time in standby	[h/day]	The time in standby is defined as the time the system is ready to start a collection cycle.
Down time	[h/day]	The downtime is defined as the time the system is stopped due to an alarm or maintenance.
Time in service	[h/day]	The time in service is defined as the time the installation is activated (time in stand-by plus time in operation).
Availability	[%]	The system availability is defined as the time in operation plus the time in standby minus downtime, in relation to the time in service.

2.5.2. Number of valves and gravity chutes

The number of valves and gravity chutes shall be calculated from:

a) Waste volume
b) Storage capacity of the gravity chute.

Each gravity chute shall have at least one DV (discharge valve). Where a chute diverter is used to collect two fractions there shall be 2 DV's per chute.

2.5.3. Storage capacity per gravity chute

The storage capacity per gravity chute shall be calculated using the formula:

Storage capacity (m^3) = available storage volume (m^3) x Filling rate %

The filling rate depends on the waste fraction, but for mixed fraction a rule of thumb is between 50%–75%. of the storage section volume based on the maximum storage height It defines the level at which the storage section is signaled as full and is a balance of frequency of collection and the actual height of the storage section.

2.5.4. Storage section – gravity chute to PWCS transition

The storage section shall be placed between the loWaste section of the gravity chute and the DV.

2.5.5. Collection times

The number of DV openings required per day for the system shall be calculated using the formula:
Number of DV opening required per day =

$$\frac{\text{Total waste volume per day (m3)}}{\text{average storage capacity per gravity chute (m3)}}$$

The maximum recommended average number of DV openings per minute is two for all systems. Dividing the total number of DV openings per day by two will therefore provide a collection time per fraction.

Step 3 – Waste deposit – Inlet system

Inlets can be located indoors (most commonly wall mounted) and/or outdoors (most commonly free-standing). This flexibility allows maximum user accessibility.

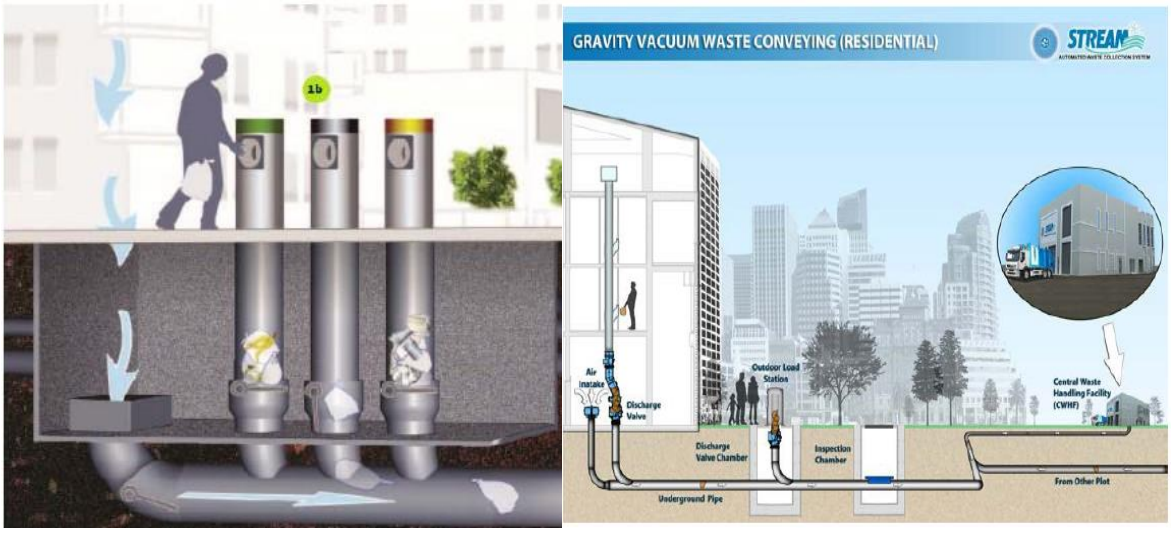

Figure 2. 9 *Outdoor waste inlet and Indoor waste inlet*

Step 4 – Transportation system – Pipe network

The transportation network consists of welded pipelines built of carbon or stainless steel fixed inside concrete service tunnels or buried in a trench with various inspection chambers incorporating key technical elements. In order to avoid damage due to external corrosion the pipes are provided with external painting and polyethylene coating, as well as cathode protection. Inspection points are installed every 50-80 meters, providing the possibility to periodically inspect the conveyance network. Sectorization valves in concrete chambers are installed to limit the network to chosen operating sections (branches). Together with the waste transport pipeline, various cables and pipes are installed as compressed air is used to operate the valves and other key elements, communication cables, and electrical power cables for electrical cabinets are also included.

Straight pipes, bends and Y junctions are dimensioned to avoid obstructions during waste conveying and to minimize charge losses. In order to avoid any waste blockages or loss of speed in the conveyance stream network design parameters and also the control system which take into account the theoretical waste speed within the pipeline is utilized.

The pipe network shall connect and transport the waste from the storage section to the collection station. Before designing the pipe network, the following information shall be determined:

a) Location and number of DVs and AVs;
b) Estimated type and volume of waste per fraction; and
c) Location of the collection station.

Step 5 – Collection system – Collection station

The deposit of waste at the inlet, waste falls naturally by gravity and is held temporarily at the bottom of the chute in a storage section. When the collected waste material reaches a particular maximum capacity at the bottom of the chute or at the designated time, it triggers the exhausters in the pneumatic system to start and immediately convey the waste material to the collection station.

Collection stations are comprised of collection units (made up of a separator (mandatory), a compactor (optional) and a container) and supplementary equipment including:

- Pipe diverter valve (PDV);
- Filters; Container
- Separator;
- Silencer;
- Compactor;
- Odor equipment;
- Exhaust air control;
- Compressed air system;
- Cut-off valves;
- Container conveyor;
- Non-return valves;
- Building requirements; and
- Exhausters/pumps and frequency drives;
- Gantry crane;
- Compressor;
- Welfare facilities.
- Power and control system;
- Air speed regulating system;
- Ventilation system;
- Control room/office; and
- Isolation flanges;

Step 6 – Optimize solution

CHAPTER THREE

3. MATERIALS AND METHODS

In this chapter, description of the study area, location, topography, climate condition and demographic characteristics are presented. In addition to this, primary and secondary data collected through questionnaire, interview and direct observation are presented, analyzed and discussed. Farther more, a case study could be also conducted to implement UGSWD system on the selected site (Lideta condominium). On top of that, validity, reliability and ethical issues would be also looked through.

3.1. Description of the study area

Geographically, Addis Ababa is located between $8^0$55' and 90^0 5' North latitude and $38^0$40' and $38^0$50' east longitude. The city is located in the center of Ethiopia, covering an area of 540 square kilometers, of which 18,174 square meters is a rural area with an altitude range of 2000 m-2800 m above sea level [40]. Addis Ababa is the seat of the government of the Federal Democratic Republic of Ethiopia (FDRE) and Oromia State. With the Oromia National Regional State in all directions.

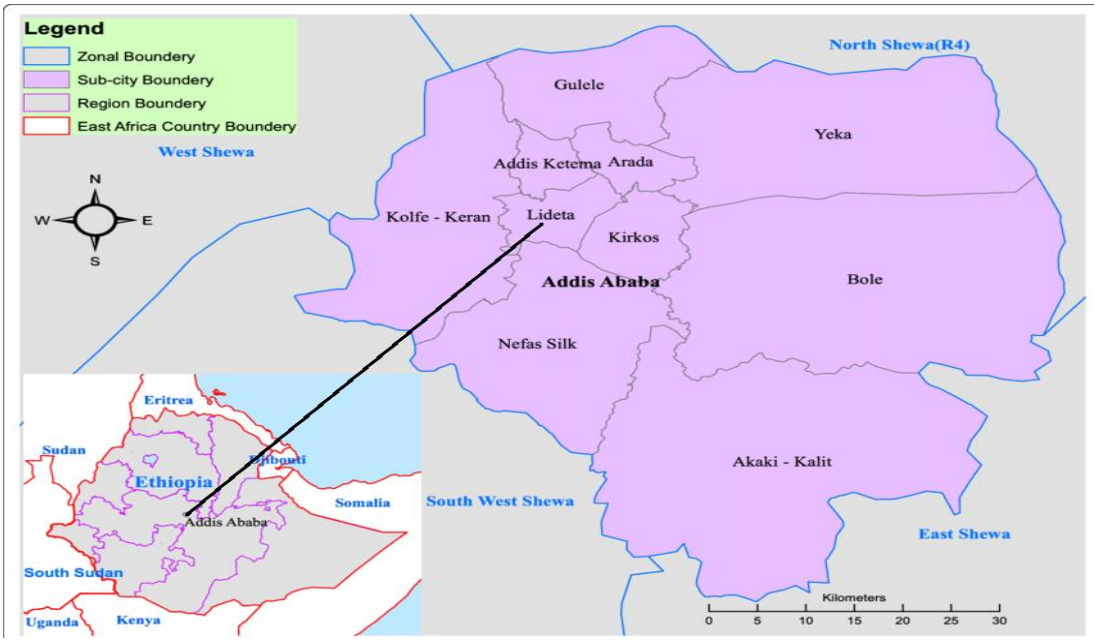

Figure 3. 1: Addis Ababa with the 10 sub cities map

There are 10 sub cities (Kifleketema) and about 99 Kebeles [40]. Even though the study is primarily for Addis Ababa city the case study only focuses on Lideta sub city to show the application of system. Lideta is located at Latitude of 9.0063 and Longitude of 38.7316.

3.2. Research setting

The study was conducted in Addis Ababa regional state which is the center and the capital city of Ethiopia, and also Addis Ababa is a seat both for Federal Democratic Republic of Ethiopia (FDRE) and Oromia National Regional State Government. It is bordered with Oromia National Regional State in all directions.

3.3. Research design

The collection of primary and secondary data is used. The collection of raw data is done with the help of structured questionnaires of communities/individuals with different demographic characteristics. The questioners tried to explore the current solid waste collection system and to know if they are willing to a new technology if they are not satisfied with the current system.

3.4. Sampling size and sampling techniques

The study was employed with a range of sampling techniques called systematic random sampling. On the hand, key informant was selected for an interview from sub-city sanitation administration officers, woreda sanitation administration, and micro and small enterprise waste managers.
The number of buildings in the site is chosen to be fourteen. Fourteen is selected due to the fact that all the required data or information needed for this study is found to be sufficient.

3.5. Source of data

In order to achieve the goals pursued by this research, this research requires relevant data, which are collected from primary and secondary sources. Therefore, first collect raw data from formal and informal surveys, then use questionnaires to conduct formal surveys, and then conduct informal surveys through face-to-face observation of the area. Secondary data is also an important source of information for this research. The secondary data of this study is collected from related, published and unpublished materials, books, journals, manuals, various research articles and

government publications, and can be found in the SWM library, website, rules and regulations, and report from the Addis Ababa Sanitation Administration Agency.

3.6. Instruments of data collection

The following data collection tools are used to obtain sufficient and reliable information. Researchers use questionnaires, interviews, and field observations to collect primary data, and researchers use documents to collect secondary sources.

3.6.1. Questionnaire

This study uses closed and open questionnaires to examine existing solid waste collection and disposal methods in households, hospitals and businesses. The questionnaire was first written in English and then translated into Amharic to make it easier for respondents to understand. Then send the questionnaire to the respondent.

3.6.2. Interview

Raw data on existing recycling and solid waste collection systems and the location of waste containers were also collected through semi-structured and unstructured interviews with city administrative and woreda-sanitation administration head, workers, micro and small enterprises about the current solid waste disposal and collection system and also location of solid waste-storage container (skip- points). Therefore, an interview schedule was prepared because of its advantages like the chance of obtaining in-depth data related to the problems.

3.6.3. Observation

The researchers also used field observation as a key data collection method for this study. On-site observations are used to assess the spatial distribution of urban solid waste infrastructure, solid waste disposal methods, illegal disposal, solid waste collection and transportation systems, and container locations. In each incident, photos were taken during the field observation period to view the working conditions of the main solid waste storage at home, illegal burial of residents, and the main solid waste storage installed at the location of the jump point relative to its location, therefore, the method is performed through face-to-face on-site observation, a checklist was created to obtain data on the status of the study area and to assess health risks and environmental issues in the study area.

3.6.4. Document Analysis

In addition, secondary data was extracted from various sources, including published and unpublished materials on solid waste management standards, as well as other necessary information from sanitation administrative agency, sub-city administration, municipality, sanitation administration of the sub-city.

3.7. Method of data analysis

The researcher conducts quantitative and qualitative analysis and interpretation based on the type of data provided by the respondent. In the qualitative method, the data related to the current problem situation is systematically, summarized and thematically explained in order to compare and analyze the characteristics. Use various statistical techniques (such as descriptive and logical statistics) for analysis and interpretation to compare, contrast, and explain individual and current sampling methods. The social science statistical software package computer program is used for extended statistical analysis. Finally, conclusions and recommendations are made based on the data obtained.

3.8. Validity, reliability and ethical issues

- The quality of data is assured by using a pretested questionnaire and continuous supervision was made to control the data collection procedure.
- Consent was sought before administering questionnaire and conducting interview from each participant to confirm their willingness.
- Confidentiality was ensured throughout the process of the study. Before administering questionnaire and conducting the interview the researcher was inform the study subjects, purpose and significances of the study to get the consent of the respondents.
- The information that respondents provide was completely confidential and used only for the research purpose. Each respondent or interviewee was have full right to refuse to take part or to stop at any time during the study.

CHAPTER FOUR

4. CASE STUDY CONDUCTED ON SOLID WASTE DESPOSAL SYSTEM

The main purpose of this survey is to construct underground solid waste container for a specific area (Lideta Condominium). Hence, a survey conducted on underground solid waste in the context of its site identification, price schedule, block (floor) arrangement and selection criteria are considered. Besides, various devices are identified and selected accordingly. The major tools (device) used in the survey includes buried containers, public trash can, checker plate, Concrete holes, etc.

Figure 4.1 shows that a complete view of underground container after installation of several components.

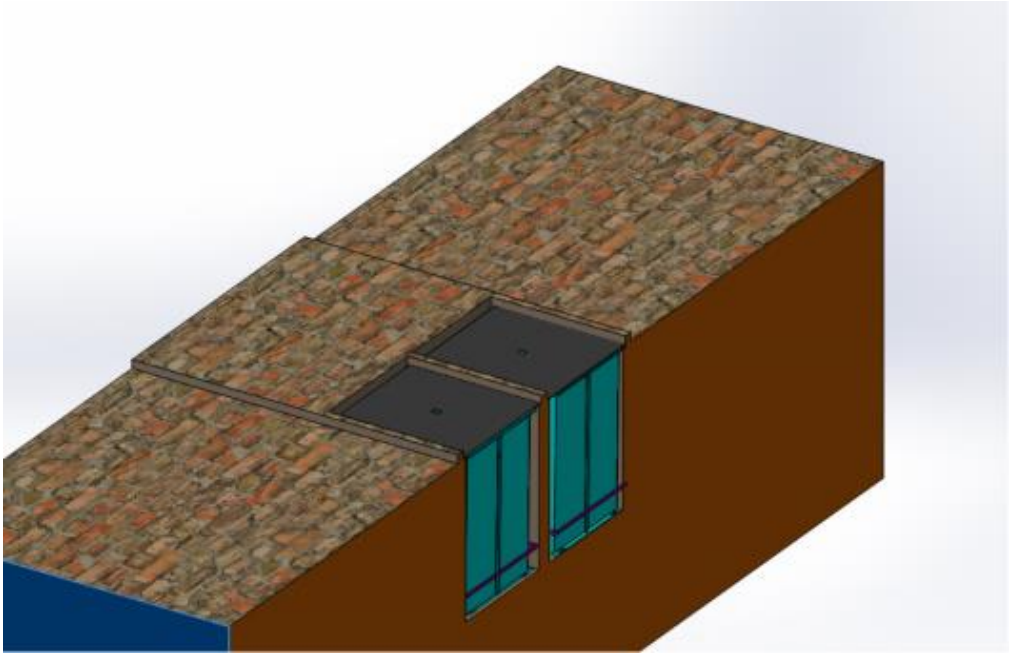

Figure 4. 1*: Complete view of underground Buried Container*

To conduct the survey, the researcher selected Lideta condominium. This site is chosen due to the fact that it is one of those sites which have high frequency of collection and more wastes generation center. Furthermore, now a days it become commercial center and also it is residential area.

The selected site has a total number of 64 blocks. Each block is arranged in different manner. For example, one block is ground plus 11 where each floor containing 5 rooms.

Furthermore, 13 blocks are ground plus 6 where each floor containing 6 rooms. Finally, 50 blocks are ground plus 3 containing 6 rooms in each floor.

In this site the bin that is mostly used for collecting solid waste temporally is 240-liter wheeled bin. The frequency of making the garbage collection is 2 times per week and the number of Bins localized in the block depends on the size of the building which is directly related to the number of populations.

Therefore, from those building the researcher selected 14 sample blocks which is ground plus 3. The fact that those samples are selected due to the reason mentioned in the sampling size section.

4.1. Estimation of waste generated per day in Lideta condominium

Waste generation can be calculated by analytical method which is based on number of population and waste generation per capital per day of the city.

Grs= current p * Gpc ---------- Equation 1

Where Grs= current amount of waste (ton/day)

Current P = Current population (person)

Gpc = Generation per capital (kg/ inhab/ day)

Based on the data collected in Lideta condominium the average people live in a house is four. And based on previous study, the waste generation per capital is 0.45 kg/ c/ day. From this data the researcher calculate the waste generation in Liteta condominium.

Case I: G +11

- Has a total of 1 block.
- Each floor contains five rooms

Number of population = 4*12*5 = **240**

Grs = 240 people * 0.45 kg/c /d

= **108 kg/d = (0.10 ton/d) = (0.10 m^3/d)**

Case II: G +6

- Has a total of 13 blocks

- Each floor contains six rooms

Number of population = **2184**

Grs = 2184 people * 0.45 kg/c /d

= **982.8 kg/d = 0.98 ton/d = 0.98m^3/d**

Case III: G + 3

- Has a total of 50 blocks.
- Each floor contains six rooms

Number of population = **4800**

Grs = 4800 people * 0.45 kg/c /d

= **2160 kg/d = (2.16 ton/d) = (2.16 m^3/d)**

The total volume which is generated from the site per day is the total of each blocks which is **3.24m^3/day**.

The total number of wheeled bin used in the site is 208 bins (6+ (4*13) + (3*50)). From the previous study, the area that is covered by one bin is 0.41m^2 which is used to calculate the area covered by bins in each cases (case I, case II, case III)

Case I: G +11

- Has a total of 1 block.
- Contains a total of six Bins per block

Area covered by bins = 6* 0.41m^2 = **2.46 m^2**

Case II: G +6

- Has a total of 13 blocks
- Contains a total of four Bins per block

Area covered by bins = 4*13*0.41m^2 = **21.32m^2**

Case III: G + 3

- Has a total of 50 blocks
- Contains a total of three Bins per blocks

Area covered by bins = 3* 50 *0.41m^2 = **<u>61.5m^2</u>**

It is possible to know the area covered by selected blocks (14 blocks) from the above calculation and hence, the area covered by the existed container is **17.22 m^2** (42 * 0.41m^2) which is calculated for 42 bins in the site. The waste generated in the area selected, by using the same procedure above is **604.8 kg/ d (0.604 m^3/d)**.

4.2. Underground Container Design

The underground container is used for temporary disposal or collection of solid waste before it discharges to the permanent disposal area. The material used is rectangular stainless steel with thickness of 2mm which have an advantage of resisting corrosion and also more durable, reusable and applicable in different sizes than the plastic containers. The dimension of the container is show in Figure 4.2 and the capacity of the container to collect the solid waste is 3.42 m^3. It is flexible to open at the bottom, which helps to dispose the collected solid waste to the crane (truck mounted) that helps to collect and make empty the underground container. From the finding the collection of wastes from this container is one times per eleven days. For one selected site we have 2 such types of containers which is for recycle and non-recycle municipal solid wastes.

The compaction process is done by gravitational force which increases the capacity of the container. Components of the container are at the bottom it has spring which help to open the bottom layer of the container, holes at the upper sides which is used the container to simply carried by the crane.

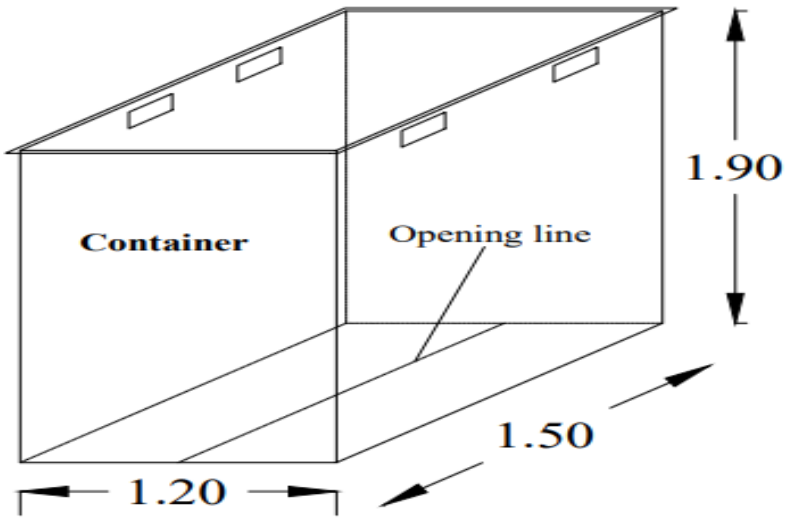

Figure 4. 2 *:The underground container dimensional view*

4.3. Dimension of underground container

All dimensions and weights are approximate as containers vary from manufacturer to manufacturer. Underground containers have easiness of installation and stability – all types have fixed anchor flanges. Anchoring of the container is made by bottom fixed metal profile that will ensure stable standing of the container in the ground even in heavy conditions, e.g., when the groundwater will cause uplift. Crushed stone or other filling material is not needed during installation, because excavated soil can be refilled around the container (for round containers).

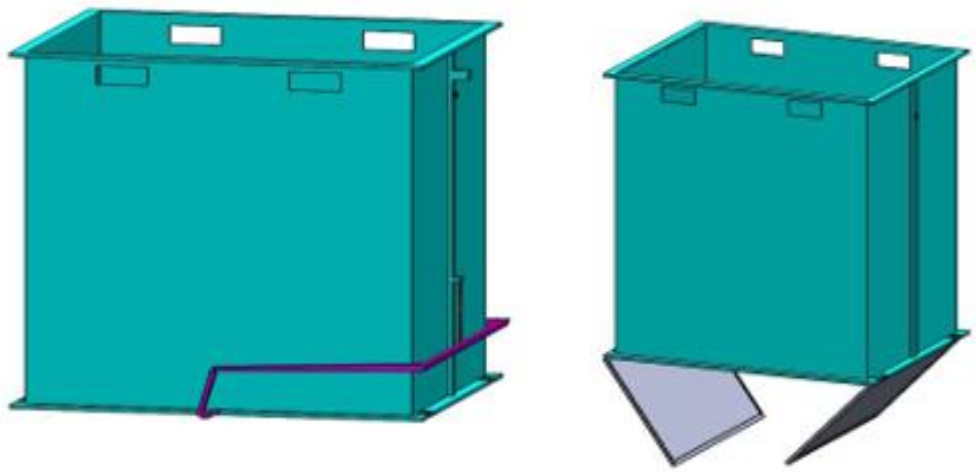

Figure 4. 3 *:The complete view of the proposed container*

4.4. Components of underground container

Checker plate

Stainless steel plate which is used to cover the underground container from the environment and also on the above it is used to locate the trash can (dust bin). The material is stainless steel which resist corrosion and also due to their aesthetical appeal. The thickness of the plate is 2.5mm, which is easy to open the plate.

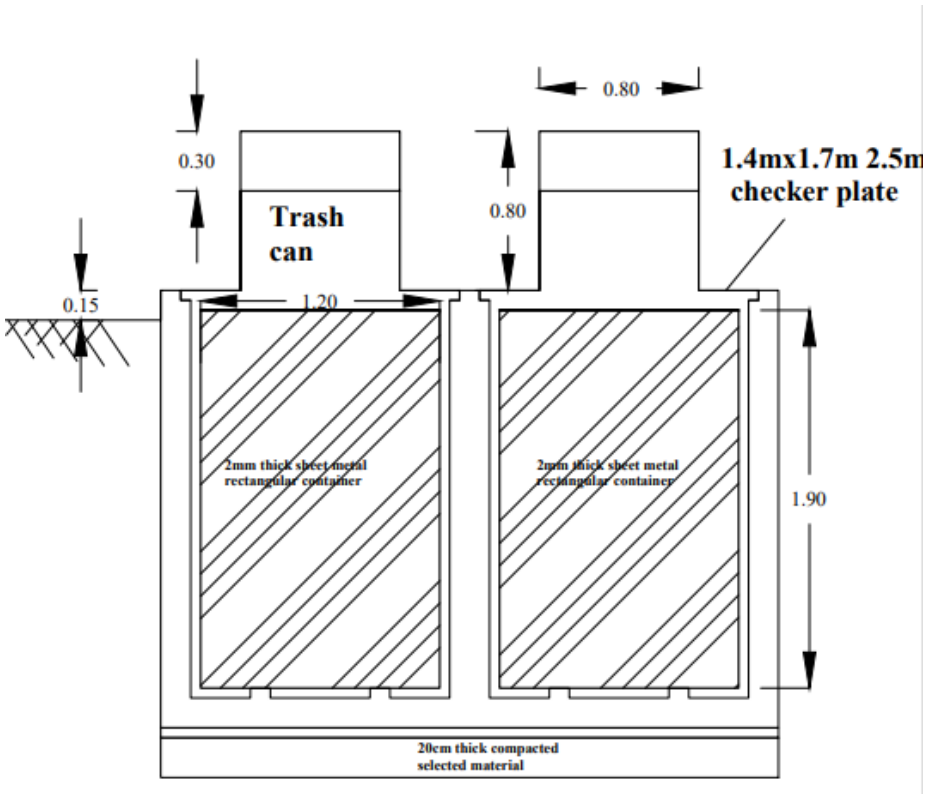

Figure 4. 4*: The dimension of underground checker plate*

4.5. Dimension public trash can

This bin is placed on checker plate. It is made from stainless steel and its thickness is 2.5mm. It allows to easily dump their trash in an underground container. No trash will remain in the bin because it is open at the bottom and all waste will be transferred to the bottom container.

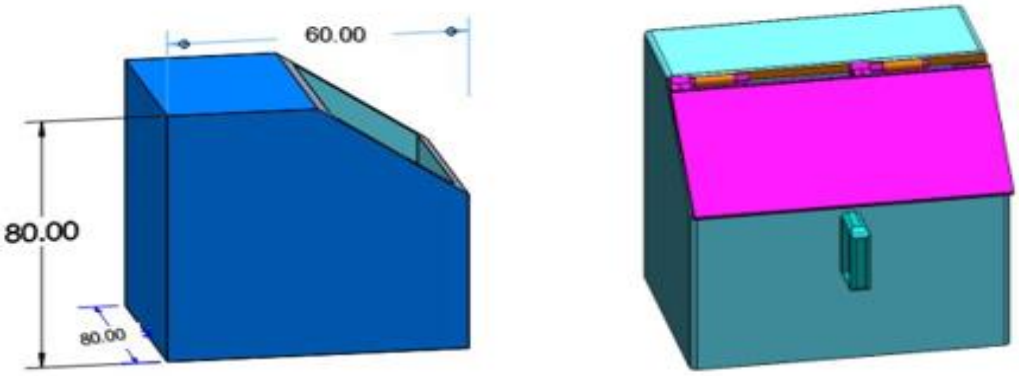

Figure 4. 5*: The dimension of public trash can*

Let see the new proposed design according to the area that cover and also the accessibility to the community (distance). To collect the total waste in the site the dimension of the container is fixed and also the frequency making the garbage bin empty is one times per eleven days, to decrease transportation cost.

Accessibility of the container

Based on investigation, the researcher have found that the number of the container used to collect the total waste generated in the site is 6, which is for one site we have 2 container which is one is for recycle and the other one is for non-recycle.

The site that the container is placed is selected using GIS. This helps the selection is based on the accessibility to the community (distance of container from the household), infrastructure in the site, green areas and roads. The maximum and minimum distance of the container from household is 70m and 10m respectively, which is within the recommended distance (150m). The more detail report is attached in the annex section.

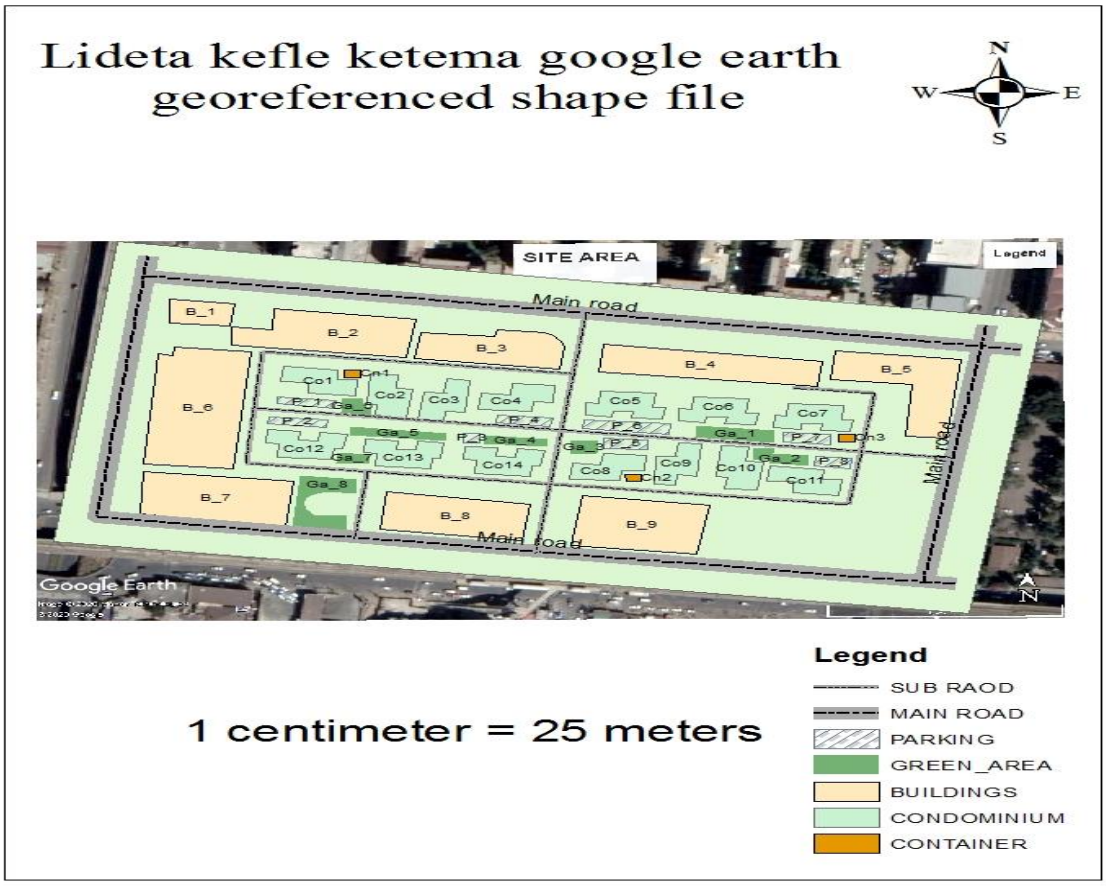

Figure 4. 6*: The map of selected site for container placement*

Area covered by the containers

The total area of the containers include Rc structure which is used for protection of the containers from entering of water and liquid sewage in to the container, and to remove waste seepage from the containers in to the ground. The outside Rc structure is 30 cm for both (right and left side) and dividing wall which is located in the middle to separate the two containers have a space of 20cm with a wall which helps to put the flap (checker plate) of the underground container and the other area that is considered is spacing between Rc structure and the containers which is 5cm for each 4 sides. Width of the container with spacing is 1.6m (1.5m + 0.05m + 0.05m) as shown in figure 4.8 below. Therefore, the total area covered by one site is 4.96 m^2. From the investigation for 14 blocks there are 42 number of bins are located to collect the generated waste, while in the new proposed system three site are selected to collect the generated waste. This means that 14 bins can be substitute by two underground container that is buried in one site. The area covered by 14 bins

is 5.74 m^2 (14* 0.41m^2) while the underground container has an area of 4.96 m^2 which increase the free surface on the ground compared to the existed bins.

Capacity of the container

The capacity of one selected site to collect the solid waste is 6.84 m^3 (3.42m^3* 2). As discussed above the waste that is generated from the site is 0.604 m^3/day. Therefore, the proposed container can store the waste that is collected up to eleven days (0.604m^3 * 11 days = 6.644 m^3)

4.6. Installation of the container

The selected site has black cotton soil which is not suitable for construction even the construction is simple. This black cotton is replaced by compacted selected material. From this selected material RC concrete is used which helps the structure for stability and durability. The thickness of wall and also the floor is 15 cm with double mesh. For walls internal and external ring bar is used. Detail work on the floor and wall is reported by using table, which is attached on annex. The total excavation depth is 2.3m form GL and the structure is 0.15m above from GL, this protect the structure from runoff when the season is rainy.

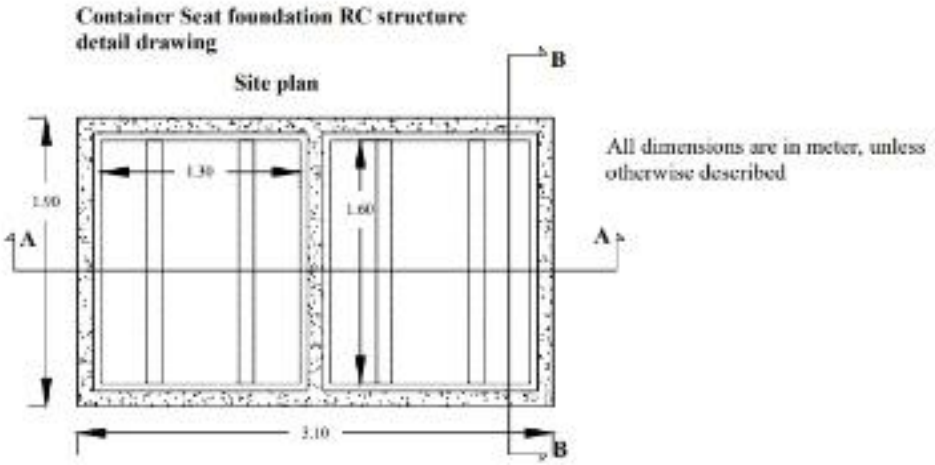

Figure 4. 7*: RC structure site plane*

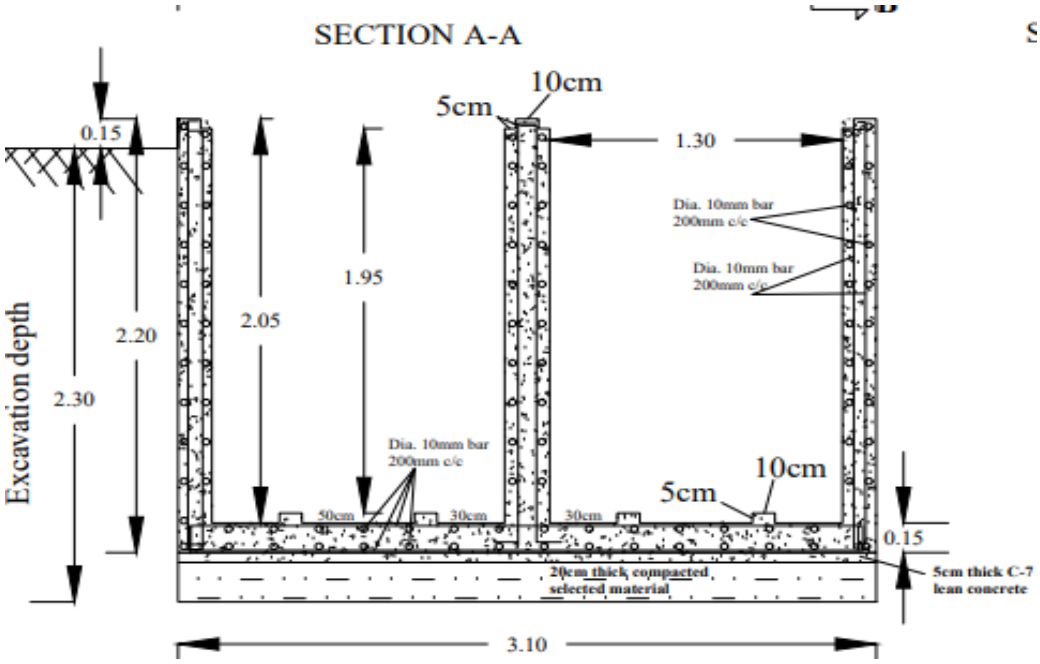

Figure 4. 8*: RC structure section A-A*

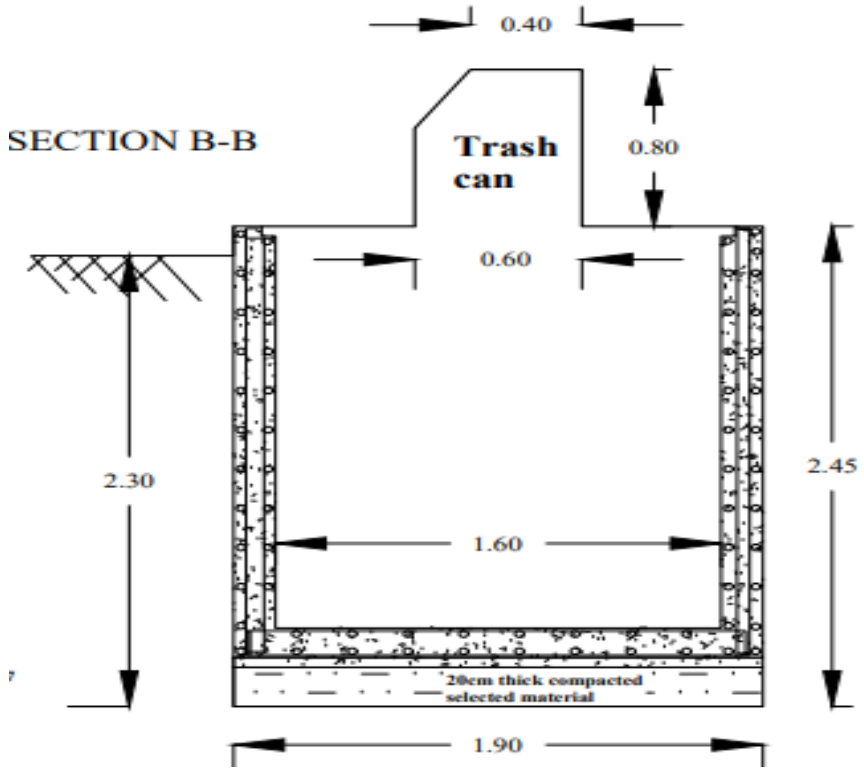

Figure 4. 9: *RC Structure section B-B*

4.7. Total cost of the proposed system

The cost includes installation of the proposed system. This contains cost of earth work, concrete work, frame work, finishing work and metal works.

Table 4. 1 *The costs required to perform the installation process*

S. No	Description	Unit	Qty	Unit Rate (Birr)	Amount
1	**Earth work**				
1.1	Clearing of Site to remove top soil up to an average depth of 200mm	m2	16.74	16	267.84
1.2	Bulk excavation in ordinary soil (black cotton soil) to a depth not Exceeding 2.7m from Reduced Ground level Taking work space 0.5m	m3	29.13	160	4660.88
1.3	Load and Carting away surplus excavated material to a Distance not exceeding of 5km	m3	14.43	125	1803.75
1.4	Borrow fill the foundation With the selected material from quarry site and compact in layers not exceeding 10cm thick by sprinkling water ot insure AASHTO standard 95% modified max.dry density.	m2	1.18	424	500.32
2	**Concrete work**				
2.1	Providing and laying plain cement concrete of grade C-7 (180 Kg of cement/m³) to a thickness of 100 mm inclusive of, shoring, strutting, and bailing out of water wherever necessary, formwork, ramming and curing etc	m2	9.24	200	1848
2.2	Providing cement concrete grade of C-25 (312.5kg cement/Cum) design mix 1:1.5:2.5 for all reinforcement cement concrete works, namely foundation floor slab and shear wall with water cement ratio not exceeding 0.45 including use shuttering and centering the concrete also vibrating laying, curing etc	m3	4.56	3000	13681.5
3	**Formwork**				
3.1	Providing formwork for reinforced cement concrete work in foundation floor slab and shear wall	m2	46.28	400	18512
4	Supply and fix in position Reinforced Steel Bar,all According to Structural Drawing.Price includes cutting, bending, placing & tying wires				
4.1	ø 10 mm	kg	429.82	80	34385.6
5	**Fnishing work**				
5.1	Providing 12mm thick two coat of plaster in cement mortar 1:3 (One part of cement and three part of sand) for internal / external wall finished with neat cement including, hacking for necessary area, scaffolding curing etc.	m2	46.28	350	16198
6	**Metal works**				
	Note:The metal work include cleaning of the metal from unnecessary material ,paint anti-rust and two coats of enamel paint, all necessary bolts and welding plates				
6.1	2mm thick sheet metal container	m2	3.6	2223	8002.8
6.2	1.4m x 1.7m,2.5mm thick checker plate with hing and lock	m2	3.8	102	387.6
6.3	2.5mm sheet metal trash can with welding	m2	0.96	1000	960
	Total				101,208.29
	Total for three container				**303,624.87**

CHAPTER FIVE

5. RESULT AND DISCUSSION

This chapter deals with analyzing data collected from different sources. The analysis covers the findings from the questions, interview and questionnaire with different household (residential) from different locations selected randomly. The major objective of this chapter is to interpret and analysis the challenges of current conventional solid waste management system in Addis Ababa, specifically Lideta sub city area house holders. The basic issues to be discussed here include about waste disposal system from residential, impacts of poor solid waste disposal on the environment, assessment of waste collection system and skip points around the community, examine whether they have challenges on the current solid waste system, and finally investigate whether the underground solid waste management is appropriate to the city. The data collected are presented, analyzed and interpreted using quantitative and qualitative methods.

In addition, observation on different locations in the city and interview was held with some selected municipal and small enterprise (MSE) and from sub-city sanitation administration and woreda sanitation administration officers. The primary data collected in the manner indicate above, and secondary data are collected from different literatures. The data were collected mainly through different methods such as questionnaires, interview, focus group discussion, observation and other important document to search appropriate answer for the basic questions raised at the beginning of this research study.

This chapter also consists of two main parts. The first section is concerned with description of the background characteristic of the respondents and second section is concerned with the analysis and interpretation of the data gathered through questionnaire, interview or focus group discussion and observation in regards to basic research question.

5.1. Socio-Economic and demographic characteristics of sample households

In this study, researchers tried to collect samples of different families with different socioeconomic and demographic characteristics. The socio demographic characteristics of the respondents include age structure, gender, education level, employment status, average monthly income and

homeowner. This group of people has its own meaning for understanding questions and obtaining effective answers for researchers, which has a high influence on the overall decision made from the question.

Table 5. 1 *socio demographic characteristics of the respondents*

Characteristics of the Respondent	Description of Characteristics	Frequency	Percentage
Age of the respondent	Between 18-25	16	28.1%
	26-35	27	47.4%
	36-45	5	8.8%
	45-60	6	10.5%
	Greater than 60	3	5.3%
Sex of respondent	Male	32	56.1%
	Female	25	43.9%
Education	Preparatory	2	3.5%
	Diploma	11	19.3%
	Degree	37	64.9%
	MA,MSc	5	8.8%
	Above MA,MSc	2	3.5%
Income	Below 1000	1	1.8%
	1000 - 5000	27	47.4%
	5000-10000	22	38.6%
	Above 10000	5	8.8%
	Other	2	3.5%
Household head	Yes	13	22.8%
	No	44	77.2%
Work status of the household head	Government Institution	27	47.4%
	Self-employee	14	24.6%
	Private company	8	14.0%
	Unemployed	3	5.3%
	Pensioner	2	3.5%
	Other	3	5.3%
Valid		**57**	**100.0%**
Missing		**3**	
Total		**60**	

The percentage of male and female respondent account 56.1 percent and 43.9 percent respectively. This result shows that there is a fair distribution while participating both gender class. Besides, out of the total respondent, 28.1 percent of the respondents belong to the age between (18-25) and age between (26-35) score 47.4 % whereas 8.8 % goes to the age between (36-45). The rest have an age of between (45-60) and above 60, which have 10.5% and 5.3% respectively. This age profile indicates that most of the respondent are matured enough to understand the question and answer properly.

The education levels given in the above table are 3.5%, 19.3%, 73.7%, and 3.5% respectively, and they have high school status, diplomas, first and second degree, or even higher. Regarding the level of education, more respondents (73.7%) have completed the first level of education. This diploma level (19.3%) has a relatively large degree of participation. From the collected data, it can be concluded that most respondents have degrees and diplomas. They have relatively sufficient information on the solid waste disposal system.

Income is another socio-economic factor leading to the increase in the amount of solid waste and the growing problem of solid waste disposal. In terms of socio-economic conditions, the size of the family's annual income affects the management of urban waste. According to the monthly income of the family, they are divided into five groups.47.4% of the average household income in the sample belongs to the second category, that is, monthly income of 1,000 to 5,000 birr, but the lowest number of households (8.8%) belongs to category 4, with an income of 10,000 and more. Some respondents did not state their income (7.1%). This data is important because as discussed in the literature section when the income of the population increase the rate of waste generation become high.

On the other hand, most of the respondent 77.2 percent is not the owner of the house which lives in the house rent and the rest of the respondent (22.8 percent) have their own living house.

When we see the employment states of the respondents, as indicated in table 5.1, out of the total respondent 24.6 percent are self-employee, 14 percent are private sector workers and constitute the highest percent of the respondents, 47.4 percent are government sector workers.

5.2. Current solid waste disposal system in Addis Ababa

In Addis Ababa, solid waste disposal is one of major problems in the city that the government and also the community must give attention. There are so many research works conducted in this topic but still the problem continued. So first to solve this problem it should be known the perspective of community on the meaning of solid waste.

To know the perspective of the community on the meaning of waste is important to know how much is the community give attention to solid waste. This also indicate that if the community have positive perspective on the meaning of solid waste, it has the probability to use 3R principle (Reduce, Recycle and Reuse) of solid waste management which is very important to decrease the amount of solid waste dispose from the community.

Table 5. 2 *Frequency distribution of how the community understand the meaning of wastes*

What is the meaning of waste?	Frequency	Percent	Valid Percent	Cumulative Percent
Good perspective(waste is wealth, if we reuse it properly)	25	41.7	41.7	41.7
Waste is useless once it disposed	35	58.3	58.3	100.0
Total	60	100.0	100.0	

Based on the above Table 5.2, the response to the survey question on the meaning of solid wastes, most of the respondent (58.3 percent) have the opinion on waste is useless once it disposed and the rest (41.7 percent) agree with the idea of waste have some advantage if we reuse it properly. The above information shows that there is an information gab on the meaning of solid waste which is generated from different residential. This has a negative impact on reduction of solid wastes using different techniques.

5.3. Existing municipal solid waste management and its effect

Dealing with solid waste management in Addis Ababa it is a hot issue that are currently receiving wide attention which is covered by different Medias. This is due to the fact that solid waste that are generated in the city are not appropriately handled and managed.

On top of that, by realizing the target of the study the following table shows how the respondents respond on the major effect of environmental pollution that are currently occurred due to poor waste disposal.

Table 5. 3 *Priority of the major impact on the community due to poor solid waste management*

In your opinion which of these alternatives will you give a priority concern about Environmental pollution due to pure waste disposal		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Look bad	5	8.3	8.8	8.8
	Offensive odor	13	21.7	22.8	31.6
	Effect on human health	37	61.7	64.9	96.5
	Other	2	3.3	3.5	100.0
	Total	57	95.0	100.0	
Missing	System	3	5.0		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

According to Table 5.3, 64.9 percent of the respondent reported that there is effect on human health, while 22.8 of the respondents argue with there is a priority of offensive odor on the environment and the rest 8.8 percent respond that it has aesthetically poor on the environment whereas the rest 3.5 person respond as a combined effect and additional reason for the question. Three percent of the respondent didn't give their opinion. This result shows that the effect of poor management of the solid waste in the city highly affect human health.

In Addis Ababa there are skip points (garbage bins) around the community which is use to collected solid waste from different residential to dispose temporarily. But there are also different inappropriate ways to dispose solid wastes. To know how many of the community use the garbage

bins (skip points) there is a question below to identify whether the community use the garbage bins or not. Around the garbage bins there are huge amount of solid waste is disposed, even the garbage's are not full.

Table 5. 4 *Assessment on where the community dispose its generated waste.*

Where do you dispose your generated waste		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Nearby container	41	68.3	77.4	77.4
	Near home(digging and dispose)	4	6.7	7.5	84.9
	Open space/ river	7	11.7	13.2	98.1
	Other	1	1.7	1.9	100.0
	Total	53	88.3	100.0	
Missing	System	7	11.7		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

Fortunately, the result from the above table shows that 77.4 percent of the respondent dispose the waste in to the garbage container (skip points) while 7.5 percent of the respondent drop by digging and composting the waste and 13.2 percent of the respondent dispose nearby river or open spaces. Other 1.9 percent answers, even they don't consider where they dump wastes. This shows that there is a knowledge gap in disposing waste products. Also, there are different type of solid waste that are generated and disposed from the community. Which helps to know which of the municipal solid waste is highly dominant over the others. This result is very important to manage the solid wastes after disposal. The next table shows the result of this question.

Table 5. 5 *Type of wastes that mostly generated by respondent*

What type of waste mostly generated in your house		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Kitchen waste	40	66.7	87.0	87.0
	Plastic	3	5.0	6.5	93.5
	Electronics	2	3.3	4.3	97.8
	Other	1	1.7	2.2	100.0
	Total	46	76.7	100.0	
Missing	System	14	23.3		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

As indicated in Table 5.5, 87 percent of the respondent responds most generated waste in their house derived from kitchen. Besides, 6.5% of the respondents respond that the generated wastes are plastics and 4.3 percent for electronics. There is also some respondent who respond both kitchen wastes and electronics with a percent of 2.2. This result shows huge amount of kitchen wastes are generated and disposed from the community. But still different waste materials mixed with kitchen wastes are disposed to the garbage bins. The next table shows the result whether the community know there are different types of wastes or not. This also useful on separation of the waste in the houses.

Table 5. 6 *Response by respondent in knowing different types wastes*

Do you know there are different types of waste generated		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	55	91.7	91.7	91.7
	No	5	8.3	8.3	100.0
	Total	**60**	**100.0**	**100.0**	

Source: Completed from survey data, 2020

Fortunately, the result from above Table shows that 91.7 percent of the respondent knows there are different solid waste generated and the rest 8.3 percent of the respondent didn't know the existence of different types of waste generated. Which entails that there is little awareness on the occurrence of different wastes that generates from the houses.

The next table will show if the community know there are different type of waste so there will be easy understanding on separation and reduction of the waste.

Table 5. 7 *Habit of the community to separate wastes at home*

If you know, do you separate different type of waste in your home		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	22	36.7	37.9	37.9
	Partially	24	40.0	41.4	79.3
	No	12	20.0	20.7	100.0
	Total	58	96.7	100.0	
Missing	System	2	3.3		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

But here the table shows that 37.9 percent of the respondent separate their wastes but partially, 41.4 percent of the respondent know different types of wastes and separate them and the rest 20.7 percent of the respondent know there are different types of wastes generated from the houses but didn't separate theme in their houses. This will affect the collectors of wastes from houses. And also have a negative effect on the reduction of waste in the houses.

5.4. Current solid waste collection and skip point

Recently in Addis Ababa city there are small enterprise which collect solid waste from different household around. And also, there are temporary garbage bin (skip points) to collect the disposed solid waste. But still there is huge problem around the garbage cause negative impact on the environment and also on human health (Table 5.3).

There are some questions to the respondent about the disposal and temporary collection system.

Table 5. 8 *Type of waste collection and disposal system around the community*

What type of waste collection or disposal system is used around your community		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Use garbage bins	28	46.7	48.3	48.3
	Give the collected waste to people that gives the service	25	41.7	43.1	91.4
	Open spaces	5	8.3	8.6	100.0
	Total	58	96.7	100.0	
Missing	System	2	3.3		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

As the result shows form the table above only 48.3 percent of the community use garbage bin to dispose the solid waste that generate in their house the rest 43.1 percent give the collected waste to the people that give the service but the other 8.6 percent of the community dump their waste on the open spaces which can cause serious problems on the environment. Still the result shows that large number of the respondent uses temporary garbage bins to dispose the collected waste. But how frequently the bin has been collected, this question is very important by showing the gabs where the poor disposal of the waste in the community occur. The next table will show the results of the question.

Table 5. 9 *The frequency of collecting garbage using Bin taker*

If you use the garbage bins, how frequently the bin has been collected		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Weekly	15	25.0	25.0	25.0
	Within two weeks	15	25.0	25.0	50.0
	More than two weeks	25	41.7	41.7	91.7
	Other	5	8.3	8.3	100.0
	Total	**60**	**100.0**	**100.0**	

Source: Completed from survey data, 2020

Here 41.7 percent of respondent reported that the frequency of collecting the garbage bin taken more than two weeks, while 25 percent of the respondent says the bin has been collected within

one week and the rest 25 percent reported the collection of the garbage bin is within two weeks where the others 8.3 % did not specify exactly the period. From the result most respondent agree with the collection of garbage bins collected more than two weeks this cause high frequency to full the garbage and has a probability to drop around the bins.

Table 5. 10 *Community satisfaction on the current disposal system*

Are you satisfied with your current waste disposal system		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	19	31.7	31.7	31.7
	No	41	68.3	68.3	100.0
	Total	**60**	**100.0**	**100.0**	

Source: Completed from survey data, 2020

It is very important question because the main purpose of this research is to know the community opinion on the current system and proposing relatively better technology. It will be the beginning of planning a new technology which can solve the above problem mention by the community. As it shown in the table 68.3 percent of the respondents are not satisfied with the current waste disposal system while the other 31.7 percent of the respondent are satisfied with the current waste disposal system. Here most of the respondent have negative image on the current system, and it is important to know the major problem why the community is not satisfied.

Table 5. 11 *Reason if it is not satisfied on the current system*

If no, what is the main reason		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Distance of garbage	10	16.7	22.2	22.2
	Time difference with people that collect the waste	10	16.7	22.2	44.4
	Less frequency of collection	14	23.3	31.1	75.6
	Bad behavior of people that collect the waste	4	6.7	8.9	84.4
	Any other	7	11.7	15.6	100.0
	Total	45	75.0	100.0	
Missing	System	15	25.0		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

As can be noted from Table 5.11 the main reason why the respondent not satisfied with the current solid waste disposal about 31.1 percent of the total respondent give a reason due to less frequency of collection, while the rest 22.2 percent is due to distance of the garbage bin (skip points) from their houses. 22.2 percent of the respondent gives the reason due to time difference with people that collect the waste from houses. 24.5 % of the respondent put their answers as a problem of behavior of the waste collector and other reasons. This result shows that there is less frequency of collecting the wastes and there is no formal as well as informal sector around the community to control this gab.

Table 5. 12 *Opinion of the community on dumping of waste inside the garbage bin*

Do people dump their waste inside the garbage bins		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	10	16.7	16.7	16.7
	Partially	40	66.7	66.7	83.3
	No	10	16.7	16.7	100.0
	Total	**60**	**100.0**	**100.0**	

Source: Completed from survey data, 2020

In Addis Ababa there is huge amount of solid waste disposed around the garbage bins which can cause different problem in the city. As we can see from (Table 5.12) the respondent gives their opinion on improper disposal of solid waste cause huge problem especially on human health. This show that it must give solution to the problem. The next table will show why people damp their wastes around the garbage bin rather than inside the bins.

Table 5. 13 *Reason if dumping of waste in the bin is not practiced*

If no, why, in your opinion, people behave like this		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Due to offensive odor	17	28.3	37.0	37.0
	Due to high of the bins	10	16.7	21.7	58.7
	Stray animals (dogs, mouth...etc.)	1	1.7	2.2	60.9
	High frequency of full garbage bins	18	30.0	39.1	100.0
	Total	46	76.7	100.0	
Missing	System	14	23.3		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

As the table above shows that 39.1 percent of the respondent reported that people dump their wastes around the garbage bin due to there is high frequency of full garbage bins, while the other 37 percent of the respondent due to offensive odor around the garbage bins and the other respondent 21.7 percent is due to height of the bins. From site measurement, the height of conventional solid waste container is 1.6m which is difficult to dispose waste easily. And the rest 2.2 % responder reflect their ideas on problems related to stray of animal. As it shows most of the respondent argue with high frequency of full garbage bin and there is no regular time to pick up the bin and replace with empty one. This cause that the community dump the waste around the garbage bins. The other factors is due to offensive odor around the garbage bins this also have negative impact on the community to dump the waste very closely to the garbage bins and also there is a conflict due to the proximate of the garbage bins due to offensive odor around the bin. Due to this problem the community doesn't dump their wastes inside the garbage bins and these cause problems to the community.

Table 5. 14 *Response on the cause of disease due to improper waste disposal cases*

Has anyone in your household suffer disease due to solid waste disposal system		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	40	66.7	69.0	69.0
	No	18	30.0	31.0	100.0
	Total	58	96.7	100.0	
Missing	System	2	3.3		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

As the table indicates that around 69 percent of the respondent reported that due to poor solid waste disposal, they suffer different disease, while the other respondent 31 percent they didn't suffer different disease due the current system of waste disposal. Out of sample population 3.3 percent of the respondent has no response towards the question. According to Annual morbidity report of Addis Ababa there are different disease that is occurred by poor solid waste disposal around containers. Some common disease are parasite infection, bronchitis, skin disease, bronchial asthma and allergic conditions, typhoid and influenza are listed. And this data also shows when the year increase the number of population affected by those disease become high. There must be responsible to manage this problem and reach some solution to solve the problems.

There is question on who is the responsible to collect and disposed solid wastes. The next table will show the results for this question from the community.

Table 5. 15 *The opinion towards responsibility of collecting and disposing wastes*

In your opinion, who is responsible to collect and dispose waste		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Community	8	13.3	13.8	13.8
	Government	3	5.0	5.2	19.0
	Both community and government	47	78.3	81.0	100.0
	Total	58	96.7	100.0	
Missing	System	2	3.3		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

As indicated on table above, 81 percent of the respondent has reported that both the government and the community have the responsibility on the collection and disposal process of solid waste materials. This shows that most of the community believe that it has the responsibility of managing solid waste and create good environment. On the other hand, 13.8 percent of the respondent responds that the responsibility lies on community that disposes the waste from their houses. And the other 5.2 % reacts on the responsibility of waste on government. So, there must be some other solution to solve the above problem mention by the community. This lied to the question to the community if there is a chance to solve the problems occurred by current solid waste management is there a possibility to use it or not.

5.5. Acceptance of the community on the new technology of SWM

As mentioned above there are so many problems due to poor solid waste management and perception of the community on waste. If there is a probability to change the system in to a new technology, which can solve the above problem and make the city clean and attractive, then what will be the acceptance of the community to allow the construction and willing to pay?

Table 5. 16 *The opinion towards acceptance on the proposed system*

If the system change to environmentally safe and modern waste collection system, do you think you will use it		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	49	81.7	84.5	84.5
	No	1	1.7	1.7	86.2
	I do not know	8	13.3	13.8	100.0
	Total	58	96.7	100.0	
Missing	System	2	3.3		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

As the table indicates that 84.5 percent of the respondent have positive response while 1.7 percent of the respondent are not willing to use it and the rest 13.8 percent reported that they don't know whether they use the new technology or not. This result shows that most of the respondent agree with the new solid waste management method that could solve the current problems.

Table 5. 17 *The opinion towards willingness to pay*

For the proposed system, will you be willing to pay		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	38	63.3	65.5	65.5
	No	9	15.0	15.5	81.0
	I do not know	11	18.3	19.0	100.0
	Total	58	96.7	100.0	
Missing	System	2	3.3		
Total		**60**	**100.0**		

Source: Completed from survey data, 2020

Finally, the finding result indicates that 65.5 percent of the respondent willing to pay for the new solid waste management technology while 15.5 percent of the respondent are not willing to pay and the rest 19 percent of the respondent reported that they don't know whether to pay for the technology or not. About 3.3 percent of the respondent has no response towards the payment issue. The researcher observed if there is chance to give awareness about the advantages of new technology over the current solid waste system, the community become more willing to pay for the system.

5.6. Opportunities to enhance utilization of UGSWM

All the respondents need to use UGSWM in the city. This is the main opportunity for the advancement of the technology. All of the respondents indicated that because of the lack of UGSWM they feel that the current problem will not be solved.

As per the observation of researcher and the results of the interview pointed out the Sanitation Administration Agency professionals and solid waste administration, are willing to enhance utilization of UGSWM. Moreover, the commitment and support of the manager are promising. And as well the subordinates are also interested and keen to use and apply updated and value adding technology and system to multiply their performance.

5.7. Summary

The main purpose of this study is to evaluate the possibility of using UGSWM in Addis Ababa. Therefore, in order to achieve the previous goals, the following main questions were raised:

1. What are the impacts of the conventional solid waste management system on public health issues?
2. What are the public's opinion about underground solid waste management (UGSWM) against the conventional solid waste management system?
3. What advantage would the underground solid waste management (UGSWM) bring to the table for solid waste administration in the city?

The study was carried out in Addis Ababa city. The researcher used all populations as a source of data which are householders, municipal administrators, hospitals and hotels. In addition, the researcher includes the small enterprise that gives service to pick up the solid waste from different households. In order to conduct the research questionnaire, interview and direct observation has been employed.

The total populations were taken from; 60 respondents from the community that live in Addis Ababa city in different sub cities, 2 hospital administrator and one from Addis Ababa municipal administration. A total of 22 functional questionnaires were provided and collected from the community and similarly two of structured interview questions were delivered for interviewing for municipal administrator and one interview question for hospital administrator are addressed. To strengthen the collected data, the researcher used observation based on prepared check list. The data obtained were analyzed using statistical tools such as SPSS. Depending on the result of the analysis made in chapter four, the study summarizes as follow.

- Personal information of the respondents and the result of interview have revealed that, the majority of respondents were in the range of mature age. With regard to their educational background, most of the respondents have Diploma, and first-Degree holders. And almost all the respondent has the capacity to understand and responded the question.
- About impact of the conventional solid waste management system, the study shows most of the respondent reported that there is a high difficulty of human health due to poor solid

waste disposal. In addition to this there are also some problems due to poor solid waste disposal those are aesthetically unattractive and cause offensive odor. This problem affects the community massively.

- Environmental comparison: as we see from the above the UGSWM system can give more advantage than the conventional door-to-door collection system. The conventional door to door collection system has different disadvantages i.e., the system is aesthetically poor, have air pollution, noise pollution and odorous. From the questionnaire collected from the community show that majority of the community doesn't satisfy with the current system due to such problems. And also, the community can't use the garbage bins due to height of the garbage bins, offensive odor around the garbage bins, stray animals around the garbage bins and distance of the collection bins. But the one is known UGSWM can solve effectively the problem mentioned by the community.

i. Safety

Since the UGSWM system can discharge its refuse directly into any sort of collection container (compactor, incinerator, shredder, baler, or haul-away container), the need for any secondary or tertiary handling of the waste is eliminated. The hazardous work involved in the handling and loading of residential or commercial waste into a collection vehicle will no longer be necessary. Thus, the number of accidents and injuries suffered by waste collection operators will be reduced.

ii. Convenience

The use of a UGSWM system greatly simplifies the chore of trash disposal for both residents and business owners. All trash materials can be handled loosely without the need for any pretreatment or bagging. Additionally, users can dispose of their garbage whenever they wish. They no longer have to ensure that their garbage cans get pushed out to the curve prior to the weekly arrival of the garbage truck. And finally, the collection of refuse is no longer impacted by adverse weather conditions such as rain, snow, or high winds. The only inconvenience created will be that caused by the actual construction of the piping system. Unfortunately, certain services will be disrupted and traffic delays will most likely occur. Thus, certain inhabitants and businesses within the collection network will undoubtedly suffer inconveniences during the construction phase.

However, these inconveniences are only temporary and, upon completion, the overall conditions within the area will improve significantly.

iii. Aesthetics

Since the solid waste will be removed immediately, there will no longer be any unsightly and odorous accumulation of waste along residential or commercial thoroughfares. Trash will never again have a chance to overflow and spill out of containers, creating both a public eyesore and a possible vector for disease and pests. Instead, residential and commercial areas will reflect a neat and orderly appearance, creating a conducive environment for both trade and recreation.

One of the main purposes of this study is to explore the opportunity to enhance the UGSWM in Addis Ababa city. As per the observation of researcher and the results of the interview pointed out the administration has a challenge in human experts and skilled manpower, and cost for various infrastructure to deploy the system. However, they believe that the realization of UGSWM on the city would bring secure environment and they are motivated to apply UGSWM in the city to insure the long-term environmental risk.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATION

In this chapter, on the basis of major findings of the study, conclusions are drawn and recommendations are forwarded as the way out.

6.1. Conclusion

The management of solid wastes in recent time has become a very big challenge. On the bases of our study's findings, the indiscriminate dumping of solid wastes in the streets, gutters open spaces and flood during rains leads to the spread of diseases and pollution of the environment. The inability of the adult citizens to segregate, reduce, reuse and recycle their wastes has further compounded the management of wastes by the contractors involved in wastes management in Addis Ababa city (Lideta subcity).

The result of the study also revealed that the people's awareness towards solid waste and its disposal process is low. Besides, there is no proper schedule and follow-up to perform waste disposing process.

Dealing with frequency to collect the garbage and the attitude towards the level of satisfaction on the conventional approach, the study's findings showed that frequency of collecting the garbage is not sufficient. The level of satisfaction on the conventional waste disposal management system is low.

The finding of the study shows that the impact of solid waste in the study area has a negative impact on secure and healthy environment system. It has also a limitation in saving space, non-disturbance odors.

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6.2. Recommendation

Based on the research findings and conclusion, the researcher would like to forward the following recommendations to concerned body.

❖ **To Addis Ababa community members**

i. **Education and awareness creation**

Awareness creation is used to provide holistic capacity building for the society. Educating the citizens both formally, informally should be sustained. The print, electronic media, environmental education materials should all be utilized in creating awareness. Hence, it is essential to create a strategy for education and raising awareness on solid waste. This could be realized through the following.

- Infusion of solid waste management themes in to academic curricula
- Establishment of environmental club and programs
- Public awareness on solid waste management

ii. Developing experience to clean its surrounding with regular schedule

The society should organize within its nearby cluster to perform regular schedule for cleaning its surrounding in addition to the regular bin collection process. This has its own contribution to realize the creation of neatness area in Addis Ababa.

❖ **To Sanitation Administration Agency professionals and solid waste administration**

We recommend the administration should have a solid rules and regulations upon controlling and monitoring.

Furthermore, the administration should take a measure by implementing the proposed system upon creating a joint action with NGOs and external bodies.

Finally, dealing with the impact of solid waste on the environment, we recommend the proper use of our proposed system in the study area so that there could not be limitation on space, odor, etc.

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ANNEX

Annex A

GIS REPORT TABLE

CONDOMINIUM

No.	Name	Short name	Area (m^2)
1	Condominium1	Co1	397.35
2	Condominium2	Co2	418.09
3	Condominium3	Co3	394.51
4	Condominium4	Co4	407.13
5	Condominium5	Co5	445.90
6	Condominium6	Co6	445.90
7	Condominium7	Co7	445.90
8	Condominium8	Co8	388.52
9	Condominium9	Co9	377.11
10	Condominium10	Co10	422.28
11	Condominium11	Co11	399.46
12	Condominium12	Co12	468.53
13	Condominium13	Co13	468.01
14	Condominium14	Co14	468.53

GREEN AREA

No.	Name	Short name	Area (m^2)
1	Green_area_1	Ga_1	259.05
2	Green_area_2	Ga_2	171.53
3	Green_area_3	Ga_3	103.20
4	Green_area_4	Ga_4	145.48
5	Green_area_5	Ga_5	213.59
6	Green_area_6	Ga_6	108.19
7	Green_area_7	Ga_7	93.09
8	Green_area_8	Ga_8	537.53

MAIN ROAD

No.	Name	Short_name	Length (m)
1	Main+_road	Mr	536.90
2	Main+_road	Mr	362.10
3	Main+_road	Mr	182.10

PARKING

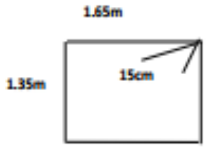
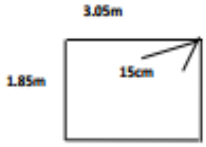
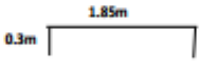
No.	Name	Short_name	Area (m^2)
1	Parking_1	P_1	127.76
2	Parking_2	P_2	124.39
3	Parking_3	P_3	44.15
4	Parking_4	P_4	125.77
5	Parking_5	P_5	123.47
6	Parking_6	P_6	249.57
7	Parking_7	P_7	134.83
8	Parking_8	P_8	103.11

SUB_ROAD

No.	Name	Short_name	Length (m)
1	Sub_road1	Sr1	169.41
2	Sub_road2	Sr2	248.38
3	Sub_road3	Sr3	288.36
4	Sub_road4	Sr4	78.26
5	Sub_road5	Sr5	127.71
6	Sub_road6	Sr6	77.43
7	Sub_road7	Sr7	48.22
8	Sub_road8	Sr8	33.92

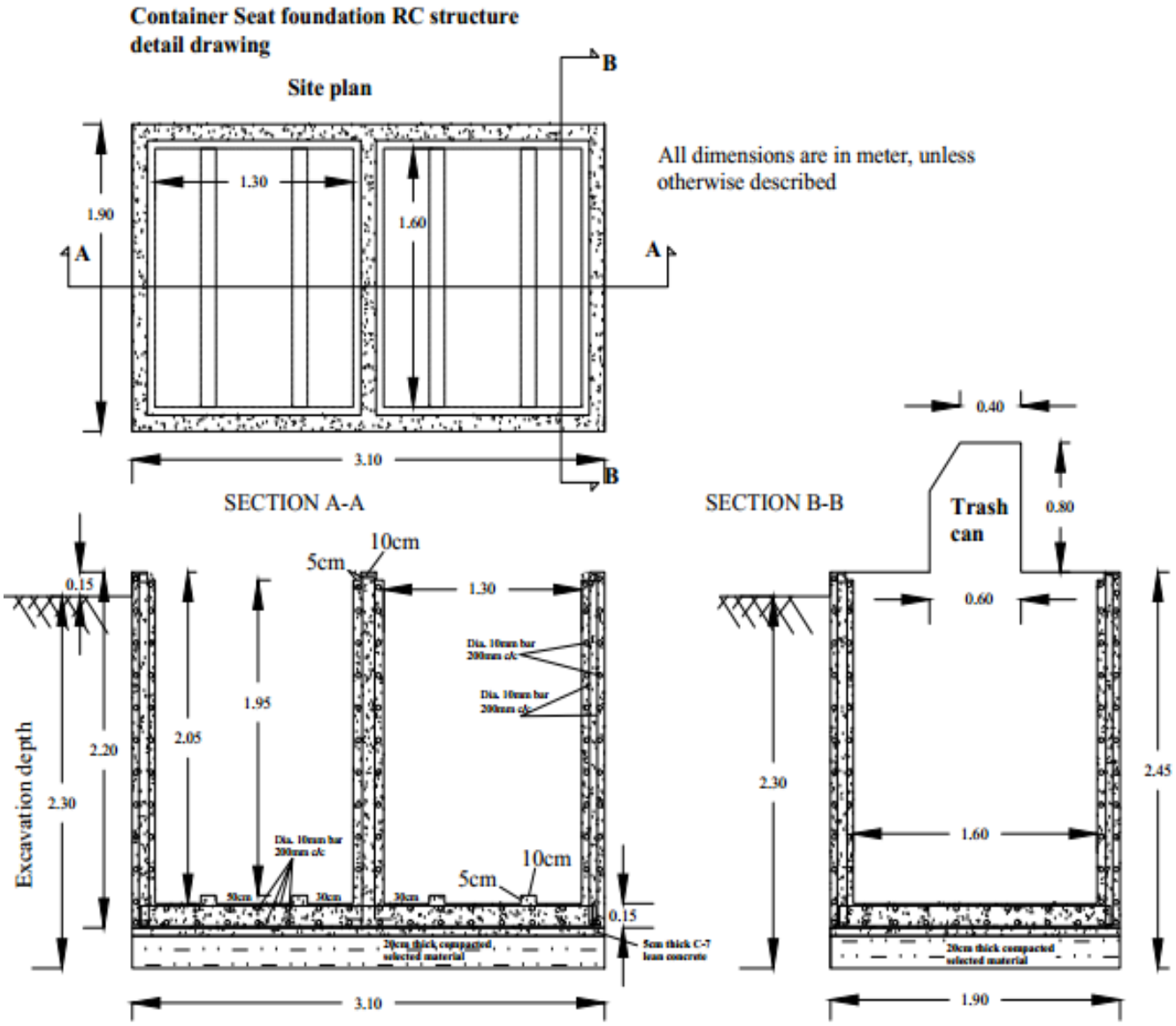
Annex B

Container seat foundation Bar Schedule

Member	Shape	Dia. (mm)	Spacing (mm)	Length(m) Before Hook	length(m) After Hook	Number of members	No. of bar in each member	Length (m) Total	Weight (kg)
Wall		10	200	2.150	2.750	1	104	286.000	176.367
	Internal ring bar 	10	200	6.000	6.600	2	11	145.200	89.540
	External ring bar 	10	200	9.800	10.400	1	11	114.400	70.547
Floor slab double mesh		10	200	3.050	3.650	2	10	73.000	45.017
		10	200	1.850	2.450	2	16	78.400	48.347
								Total	**429.82**

Annex C

Container seat foundation RC structure detail drawing



Annex D

Assembled detail drawing of the overall system