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| An Integrated Approach For Sustainable Solid Waste Management In Low-income Countries.  Mohamed E M Elkhider  Diploma in Water Sanitation and Hygiene  **A RESEARCH REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DIPLOMA IN WATER SANITATION AND HYGIENE TO STRATEGIA NETHERLAMDS**  October 2019 | |

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**Declaration**

I hereby declare that this research report with title “An Integrated Approach for Sustainable Solid Waste Management in Low Income Countries” was generated by me for obtaining the Diploma degree in Water Sanitation and Hygiene (WASH) under the guidance and moderators of Strategia Netherlands.

Mohamed Elkhider **30. October. 2019**

**Dedication**

I am dedicating this research report to my loving parents who stand with me during my study from starting of my Diploma till now. Also I dedicate this research work to my close friend Mr. Omran Hamed who taught me the value of continue my study. Also Thanks to Azza Bashir who support me throughout the entire Diploma program.

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I would like to take this opportunity to thank my moderators in Strategia Netherlands, for the sound advice, support and encouragement. They always replied to all my requests and questions. Strategia Netherlands are very helpful for me. I would like to appreciate all their efforts, help and support during the period of my Diploma.

Abstract

Solid wastes are becoming one of the urgent problems in urban and rural areas in the recent years, particularly in places where displaced people are located. The reason behind increasing the volume of wastes in many places is reflected to the issue of overpopulation and overcrowded. The increase of wastes which was generated from large number of industries and households put more stress on the environment. Several policies and strategies were developed in developed countries in order to reduce the level of wastes and maximizing the level of diversion and quality enhancement while low-income countries are still suffering from mismanagement of solid wastes and rely on open areas for the disposal of wastes.

Several issues and challenges are encountered the development of a sustainable Solid Wastes Management (SWM): the first challenge is relating to the substantial arise of human activities and livelihood in urban and rural areas which results in generating an enormous amount of solid wastes. The large quantities of wastes in developing countries go beyond the capacity of the governments, agencies and local councils. Beside this, the issue of deposition and waste burning results in a profound contamination of ground water system and a potential air pollution. Therefore, for an effective and valuable solid waste management, there is need to understand the situation at present and determine the critical issues that can affect the ecology system and finally develop a comprehensive and ideal strategic plans in order to manage solid wastes in urban areas more effectively and enhance the quality of the environment.

In order to develop a sustainable approach for solid waste management. Several analysis will be conducted in this study. The first step is to obtain an extensive and sufficient data from a real-life case study. Afterwards, Different analysis and techniques will be established such as SWOT analysis, Gap analysis, stakeholder analysis and risk assessment.

Eventually, the study will develop strategies for solid waste management in a friendly framework to be as aguidance for developing countries. This guidance will be fruitfull for all decision makkers in low-income countries. It will remaind and support them for all necessay methods and tools that needed for SWM.

**Keywords:** Solid Waste Management. Wastes. Developing countries. Framework. Strategies

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Abbreviations and Acronyms

|  |  |
| --- | --- |
| SWM | Solid Waste Management |
| SW | Solid Waste |
| MSW | Municipal Solid Waste |
| US | United state |
| SA | South Africa |
| UN | United Nation |
| GHE | Green House Emission |
|  |  |

# Introduction

## Background

The entire world is facing an urgent problem in the issue of overpopulation and enormous development of human activities. In 2015 the total population in the world was estimated at 7.5 billion people. A significant number of the population is concentrated in urban areas. The top10 highest populated cities are located in low-income countries. Sudan for example has the highest population growth in Africa with an average growth rate of 2% per year. The substantial number of people living in urbanized area lead to several issues including insufficient water supply, inadequate sanitation system, air pollution and enormous quantities of solid wastes(Hoornweg, 2012)

No doubt, Wastes are becoming a severe problem in urban cities in the recent years, particularly in developing countries due to the issue of urbanization and overcrowded. The increase of wastes which was generated from large industries and households put more stress on the environment. Therefore, researches should be conducted in order to tackle these issues and scientists should working on discovering new strategies for solid waste management (Guerrero, 2013).

Waste can be defined as any object, material or substances that have been discarded or to be discarded. In fact, waste can be classified into two main classifications as follows: hazardous waste and non hazardous wastes. An example of hazardous wastes is the chemical wastes while non hazardous waste could be packaging waste. Mismanagement of waste can threaten valuable natural resources and energy. Besides, biodegradable waste in landfill can emit methane and deteriorate the environment (Sharholy, 2008).

Waste management is the process of collection, transport, treatment, recycling, monitoring and control of wastes that has been generated by human. Waste management has become an important business in the recent years. In developed countries, several policies and strategies were developed in order to reduce the level of wastes and maximizing the level of diversion and quality enhancement while developing countries are still suffering from mismanagement of solid wastes and rely on open areas for the disposal of wastes. However, today decision makers in low-income countries are more aware to give their attention to the issue of solid waste management. They intend to understand properly how to critically manage solid wastes in urban cities. Henceforth, scientists are aiming to develop a sustainable approach for solid waste management and working in reducing the quantities of solid wastes using ideal strategies and techniques in order to enhance the quality of the environment in urban cities more efficiently and effectively (Reed, 1995).

## Problem Statement

In order to build optimum strategic plans for a sustainable solid waste management considering the ecological manner, solid wastes should be treated as a resources and asset not treated as a nuisance. There is demand to develop a comprehensive strategic plans for solid waste management considering several issues including: urbanization, the environment, public health, economical perspective at current and future.

Several issues and challenges are encountered the development of a sustainable solid wastes management: the first challenge is relating to the substantial arise of human activities and livelihood in urban cities which results in generating an enormous amount of solid wastes. The large quantities of wastes in developing countries go beyond the capacity of the governments, agencies and local councils. Beside this, the issue of deposition and waste burning results in a profound contamination of ground water system and a potential air pollution. Also, the absence of policies and legalization in developing countries for realistic strategic plans lead to increase the volume of wastes in open areas and the accumulation of solid wastes in restricted area lead to contamination of soil and severe air pollution. Addition to this is the lack of proper disposal including unscientific and poor waste transportation. Furthermore, urban cities in developing countries suffer from inadequate storages and illegal disposal waste in ponds, rivers and drainage which put more stress on the quality of the surface water. Also, low-income countries have insufficient financial resources which limit the use of advance technology and equipments. The ineffective use of technology lead to irregular collection services and low collection coverage additionally, there is lack of awareness regarding the basic principles in solid waste management among communities. Moreover, many studies were developed in solid waste management in developing countries, but most of these studies do not offer economical feasible strategies that could be implemented in practice due to its high cost and also most of these studies suffer from low data on how waste is produced. Finally, the traditional approach in solid waste management was not considered the ecological manner, the long-term degradation of water resources and the environmental aspect (Zhang, 2010).

Therefore, for an effective and valuable solid waste management, there is need to understand the situation at present and determine the critical issues that can affect the ecology system and finally develop a comprehensive and ideal strategic plans in order to manage solid wastes in urban areas more effectively and enhance the quality of the environment.

## Goal and specific objectives

### Hypothesis

* Mismanagement of solid waste in low-income countries results in several problems including:
* Deterioration in water quality including surface water, ground water system and channels.
* Severe soil contamination due to the accumulation of the solid wastes in landfill and open areas
* Massive air pollution.
* For an effective and practical solid waste management, its important to involve local communities and all effective stakeholders through the different processes in solid waste management.
* Determination the potential resources of the wastes can results in saving about 40% of wastes from recycling and recovery. Also it will save the cost.

### Goal

The overall objective of this research project is to develop a sustainable and practical approach for low-income countries that results in optimizing all the processes in solid waste management including: collection, transportation, recycling process, different kinds of treatment and monitoring solid waste taking into account four main aspects to be minimized which related to environmental impact, sanitary landfill disposal, unrecycled waste and economic costs.

### Specific objectives

The specific objectives for this study can be classified into two main objectives:

**Objective1:** To evaluate and assess the current situation for the solid waste management using specific case study.

**Objective2:** To develop integrated strategic plans for solid waste management considering four main aspects to be minimized which related to environmental impact, sanitary landfill disposal, unrecycled waste and economic costs.

## Rationale and Justification

Developed countries achieved a respected success in managing their wastes. However, still developing countries suffer from poor management of their wastes. Mismanagement of solid wastes can lead to several problems including: deterioration the quality of water resources, air pollution and soil contamination. These issues lead to several public health concerns such as spread of diseases to the entire community particularly the vulnerable people.

In comparison between SWM and other basic human needs, it is clear to notice a considerable attention for decision makers in providing basic human needs such as delivering enough food, providing safe drinking water and providing basic sanitation facilities with less focus on solving the issue of waste management. Today, decision makers in developing countries should put their attention to the issue of solid waste management. This is because, providing proper management of solid waste can indeed improve the quality of the environment significantly such as reducing air pollution and improving the quality of drinking water resources.

## Significance of the study

In developing countries SWM treated as a social responsibility or treated as one of the minor services to be provided by the municipality. However, SWM is not community responsibility only or municipality responsibility only. It is the responsibility of all public health and environmental enhancement bodies. Mismanagement of solid wastes is a public health and environmental crisis. Improper waste management means economic loss, operational inefficiency and public awareness failure. For all this, there is demand to find and deliver sustainable solution for solid wastes in developing country context which span across such wide range of issues.

## Scope of the Study

This section elaborates the scope into two main scales. The first scale is focused on the targeted study area. The second scale is break down of each specified objectives.

**For the first scale:** the selected study area is Khartoum city. Khartoum is the capital city in Sudan with number of population reach around 5,274,321 people. It is the sixth largest urban city in Africa. The following map shows the targeted area in the research paper.



Figure ‑: Map of Khartoum City

**For the second scale:** the breakdown of the specified objectives which are presented as follows:

* To study the existing methods used in solid waste management including: collection, recycling, treatment and disposal.
* To assess the amount of wastes and determine the composition of wastes in the specific case study taking into account the uncertainties.
* To identify the environmental impacts and analyze the public health risks from the accumulation of solid wastes.
* To study the situation of all institutions, agencies and workers that engaged in solid waste management.
* To examine the level of general public involvement in solid waste management.
* To build a comprehensive strategic plan that addresses all elements that influence solid waste management including collection, transportation, treatment and disposal.
* To improve the role of general public in solid waste management planning and implementation.
* To develop an emergency plan for solid waste management in case of disasters.
* To develop performance indicators for SWM suitable for low-income countries.
* To develop a comprehensive and friendly framework for solid waste management as a guidance for low-income countries.

# Literature Review

## Overview

This chapter provides the overall concepts, theories and tools that have been developed by international agencies regarding solid waste management. The literature has been collected from different type of resources such as books, conference papers, dissertations, journals, reports and international organizations websites. This literature highlights and covers wide aspects of solid waste management concept. The chapter starts with defining the standard terminology of solid wastes, afterwards, explains the environmental impacts from mismanagement of solid wastes. Afterwards, it illustrates the regulations of solid wastes in developed and developing countries.

## Waste Definition and Categorizations

### Waste Definitions

The term waste can be defined as all refused material that has been generated from households (residential), industries, public institutions, commercials, constructions, water and wastewater treatment plants, agricultural activities, mining and manufacturing activities(Hoornweg, 2012).

Municipal Solid Waste (MSW) referrers to any object or materials that are discarded by households and general public. It is the waste that is been generated from houses, schools, shops, offices and hospitals. it is called municipal solid waste because it is usually managed by municipalities and public authorities. Also, its commonly named rubbish or garbage (Ekvall, 2007).

### Wastes Types and Categorizations

**2.2.2.1. Waste Types:**

There is no one agreed method to categorise waste in specific form. Surely, there are several kinds of wastes but the main types of wastes can be determined as follows:

1. **Municipal waste:**

Includes any items used in daily basis such as paper, clothes. Municipal waste can be divided into three kinds of waste as follows:

**A.1. Household waste:** such as refused food or materials from houses.

**A.2. Commercial waste:** such as refused food or material from shops or schools.

**A.3. Demolishing waste:** such as refused material generated from the destruction of any sort of structure including bricks, concrete, steel and wood.

1. **Hazardous waste:**

Includes wastes comes from industries and carry one of these properties: toxicity, corrosiveness, reactivity and ignitability.

1. **Biomedical waste:**

Includes any wastes generated from medical services such as hospitals.

**2.2.2.2. Waste Categorization**

Waste can be categorising as follows:

1. **Solid waste:**

It contains any items that coming from houses, offices, schools, commercials places, large or small industries and agricultural. Solid wastes include the following:

**A.1. Wet waste:** Dissolved liquid based comes from domestic residential or sludge generated from wastewater treatment plants.

**A.2. Dry waste:** It is not coming in form of liquid such as papers.

**A.3. Biodegradable waste:** Any kind of organic waste which can break the waste to carbon dioxide, water and methane or organic molecules by specific organism.

**A.4. Non biodegradable waste:** Any kind of waste that cannot break the wastes down into carbon dioxide, water and methane.

1. **Liquid waste:**

This kind of wastes comes in form of liquid only and it can be treated through wastewater treatment plants.

## The Environment Impacts from Solid Waste

### General overview

Mismanagement of MSW can cause different kind of pollution on air, soil and water bodies. In urban places, MSW can clog main drains in rainy season which can results in flooding and development of good environment for insects breeding and growth. The issue of mismanagement of solid waste in open areas can lead to air pollution, the process of burning solid wastes and inadequate incineration process can contribute hugely in air pollution. Green House Emissions (GHE) are generated from the process of burning solid wastes and decomposition of organic wastes from open areas. Around 300,000 tons of different gases per year were emitted due to the issue of improper incineration of MSW in open landfill. Methane only emits about 15 million tons per year(Ramachandra, 2018).

The impact of MSW on surface and ground water is vital. Still there is no exact number regarding the affect of MSW on surface water and ground water bodies. However, plastic materials and papers on surface water have a significant impact on human health and livelihood. Different sort of leaks from wastes can lead to sever health issue in case the waste contaminate the surface water or the soil and ground water(Gupta, 2015).

Open disposal areas for MSW lead to degrade natural habitats. These open areas are not hospitals for plants or wildlife.

In developing countries, several environmental and social issues developed from improper solid waste management which can be determined as follows:

* **MSW open dumping:** the practice of leaving solid wastes accumulated in open areas, open burning sites and lack of managing the leachate produced in final disposal sites are major problems in solid waste management in developing countries. The main noticeable environmental impacts from open dumping in populated are: spread of vectors diseases, surface water and ground water pollution, air pollution, GHE with odours and visual impacts. An example of open dump problem can be found in Cambodia, in the capital city Phnom Penh, where the municipality has poor management process and depend on open dumped. Around 361,000 tons of MSW was recorded in 2008, while in 2015 the volume reaches 635,000 tons in 2015. Also in Thailand, greater than 60% of the solid waste final disposal was carried out by open dumping.
* **Marine litter:** Marine litter is related to plastic waste that entering the marine environment such as ocean and river system. The main consequences from marine litter are blockage of pipes and filters, failure to obtain fishes, risks for swimmers and high cost for cleaning. In Mediterranean sea, ta study performed to identify the number of plastics in the sea and the study revealed that, the number of micro plastic was reached 94.6% while the total weight of all the plastics reach 55%.
* **MSW open burning:** The process of burning wastes in open area creates several health issues. In Philippines for instance, the process of burning wastes generates methane and Polychlorinated dibenzo-p-dioxins (PCDDs). The amount of PCDDs can reach from 200 to 4000 Ton/day.

From all this it is clear to notice the impacts of improper solid waste management in various countries**.**

## The Public health concerns from solid waste

### General overview

No doubt that any unscientific approach for solid waste management will lead to increase the chances of infection diseases. Large numbers of population who live in area closed to waste dump have higher percentage to receive infectious disease than other people. Wastes can attract insects and vectors which can spread different kinds of infectious diseases such as cholera. Exposure to solid wastes particularly chemical waste or medical waste can affect directly on human health. Waste from industries or agricultural activities can cause several health issues. People who exposed to chemical, toxicity and radioactive hazards are more likely to live short life(Cimino, 1975).

## Solid Wastes in Developed and developing countries

### General overview

For more sustainable approach for solid waste management it is important to understand the different perspective between developed and developing countries.

### Solid wastes in Developed countries

The principles of MSW in developed countries are based on three main factors: the first one is to reuses the waste, then recycles and finally recovery. Developed countries developed regulations and rules for MSW. Therefore, the management of solid waste is controlled to some extent (Manaf, 2009).

### Solid wastes in Developing countries

In developing countries, the issue of uncontrolled MSW and improper incineration process of MSW can lead to severe health issues. In India for instance, around 90% of solid wastes are disposed directly to open areas. The collection of solid waste in India is reported to be lower than 60%. (Marshall, 2013)

## Regulations for solid wastes in developed and developing countries

In 1965, the United State (US) developed legislation for solid waste disposal. The legalisation was concerned with promoting better process of MSW. Also it is recommended to support resources recovery. In 1970, the US issued a respected report regarding the process of hazardous wastes. In 1984, the US developed the Hazardous and Solid Waste Amendment (HSWA). This regulation includes the minimum standards including monitoring the ground water system in order to insure that no contamination in ground water bodies(Van der Sloot, 1991).

## Solid waste management and sustainable development goal

In 2002 in South Africa (SA), the world discussed the important of MSW. They were more aware about the important of MSW and they asked to give more attention to waste reduction and recovery. One of the main agenda for United Nation (UN) by 2030 is to make cities and human settlement inclusive safe, resilient and sustainable. The UN has number of sustainable development goals and goal 11 is concerned with the issue of solid waste management, in target 11.6 member states agreed to reduce the amount of wastes by paying more attention to the issue of environment and air pollution. Also, goal 12 describes the guidance to ensure sustainable consumption and production pattern. The member states also agreed to reduce food losses and supply chains including post harvesting losses (Vera, 2007).

Finally, this literature presented a constructive review regarding the environmental risks that associated with SWM. Also it showed the link between SWM and public health risks. The literature also showed that SWM in developing countries is treated as a single problem not treated as a complex issue. Therefore, in order to develop sustainable approach for SWM in low income countries, it is important to consider SWM as a complex and a global issue considering all aspect associated with it. The research paper will focus on improving the life cycle of solid wastes in low income countries considering the economical, social and environmental aspects. It will also focus on the issue of stakeholder engagement particularly informal sectors. This research paper will be as guidance for developing countries aiming to obtain sustainable SWM and improve the quality of the environment..

# Research Methodology

## Overview

This section provide the research paradigm and methodology including all the necessary tools and techniques that will be used in order to reach the overall and specific objectives of this study, based on objective-oriented method. These will include identify specific case study, data collection. The study eventually will develop potential strategies which will be presented in a friendly framework.

## Research paradigm:

The present research report is informed by Mixed Methods Approach (MMR). MMR can be defined as research methodologies that use combination of quantitative and qualitative approach in order to gain broad purpose of breadth and depth of understanding and corroboration (Creswell JW, 2004)**.**

In order to evaluate and assess the current situation of SWM in Khartoum city, there is demand to estimate the current amount of the solid wastes in the city. The estimates of the quantities of SW in Khartoum city required conducting the quantitative approach. However, to deeply understand the main factors that impact the implementation of solid waste management such as policies and regulations, it is important to use qualitative approach such as making interviews with formal and informal sectors in SWM. This is because SWM is abroad field that need to be solved by applying technical solutions and non-technical solutions including managerial aspects.

## Study design

This research aimed to describe specific phenomena accurately. Thus, the study obtained quantitative data in order to estimate the amount of solid wastes in Khartoum city. Also it obtained qualitative data in order to understand the relationship between the formal stakeholders and informal sectors. The study also obtained numerical data in order to estimate the number of population and the weather data. The qualitative and quantitative data was obtained from research projects in Khartoum. Sudan.

The following diagram illustrates the overall framework of this study.

Figure 1.1 shows the general methods and procedures and the different level of the research.

Desk study

Identify specific geographic region. Example: Khartoum state

Data Preparation

-**Qualitative data** (Interviews, specific group discussion with stakeholders, Household survey questionnaire, management staff questionnaire, field survey questionare)

-**Numerical data** (Population growth, weather data)

-**Quantitative data** (quantities of SW)

Creation of database

SWOT and gap analysis

Risk assessment

Uncertainty analysis

Stakeholder analysis

Build strategies for the policies & capacity building

Development of Strategies to optimize the processes of solid waste management

Develop Strategies for stakeholder engagement

Development of practical frameworks for an effective SWM

Figure 3‑‑: Overall research plan

### Study site

The study site is Khartoum city in Sudan. Khartoum is the most populated area in Sudan. The gross area of the city is 20,000Km2. This city is flat with around 400 meter higher than sea level. The weather in the city is hot most of the year. The city generates the highest rate of wastes in Sudan due to large number of households and industries in the city (Walkley, 1935)

### Research approach

From philosophical perspective this research will be conducted by mixed method approach. MMR approach address the research objectives and research questions

### Research method

The research is based on specific case study. The study depends on obtaining data from interviews with stakeholder with formal and informal sectors, focused group discussion with public administration and municipalities in the city, household survey questionnaire and staff management questionnaire. The research also will gather field survey data to understand the level of waste generation in the landfill. Also, the study will obtained data to quantify and categorize the types of wastes and amount of wastes in the city. The study also obtained some geographical, meteorological and population data to evaluate the current situation. After obtaining sufficient data, the research project established different analysis and techniques in order to develop a constructive understanding for the current situation in solid waste management. Each analysis is illustrated as follows:

* **Stakeholder analysis**

In this part, the study developed a stakeholder register and identifies their level of effectiveness (power). Also, this analysis analyzed the desired situation for each stakeholder taking into account their main interest, additionally, the study developed a stakeholder relation diagram in order to understand their level of independencies.

* **Risk assessment**

In this part, the study determined the environmental impacts including the level of contamination in water bodies (surface water, ground water, channels) also the air pollution and soil contamination. Besides, the study analyzed the composition of the wastes and identifies the health concerns from each composition.

* **Uncertainty analysis**

As the measurement of the solid wastes is uncertain issue, there is need to conduct uncertainty analysis using propagation error theory in order to improve the level of accuracy in the assessment.

* **SWOT and gap analysis**

This evaluation technique identifies the strengths points in solid waste management in the specific case study and the weaknesses. Also it examined the opportunities and threats for a sustainable solid waste management. For the gap analysis it was accomplished by presenting the gaps into two main scales:

the first scale is related to the missing rules, policies and regulations for solid waste management and the second scale is related to the missing of tools, methods, technologies and equipments for each individual processes in solid waste management.

### Data needs, types and source

In order to develop a comprehensive plan for solid waste management, it is required to obtain sufficient data from a real-life case study. The primary data is mainly the qualitative data including: questionnaire and interviews while the secondary data is mainly the quantitative data. The meteorological data was obtained from Sudan Meteorological Cooperation (SMC).

### Data source and Analysis

The primary data obtained from previous research papers and textbooks while the secondary data was obtained from the sectarian classification surveys conducted by Industrial Research and Consultancy Centre (IRCC).

### Data presentation

The data presented in the research in tables and statistical analysis.

## Validity and Reliability

Solid waste management data is complex issue and its data can never be certain. Therefore, this research adopted the propagation error theory in order to achieve more reliable and valid data. According to the uncertainty analysis described in last section, the uncertainties for small, random and independent error can be calculated from Equation 3.1. For addition and subtraction, the uncertainty can be estimated using Equation 3.2, while for multiplication and division the uncertainty can be estimated by Equation 3.3 (JR, 1997)

Eq. 3.1

Eq. 3.2

Eq. 3.3

Where: A, B and C are independent variables quantities; U is function in A, B, C; ∆U is the uncertainty of U; ∆A, ∆B and ∆C are uncertainties of variable A, B and C.

## Ethics

This section aims to prove how this research report conducting ethic in solid waste management topic. All obtained data was collected and gathered from open source database. Thus, this research report consider some pracitcal tips for accomplishing ethical research in SWM.

# Presentations of Findings, Analysis and Interpretation

## Main finding

This chapter presents the main outcomes from each objectives of this study.

* In order to meet the first objective, the study categorized the wastes in Khartoum city based on its type and assessed the quantities of the wastes for each specific waste. Table xx shows the wastes classification and its weight in ton per day.

Table ‑: Waste classification and quantities in Khartoum city

|  |  |  |  |
| --- | --- | --- | --- |
| Number | Waste Classification | Weight(Ton per day) | Percentage |
| 1 | Steel | 75.35 | 1.69 |
| 2 | Wood | 17.73 | 0.39 |
| 3 | Skin | 48.76 | 1.1 |
| 4 | Glass | 296.98 | 6.7 |
| 5 | Hair | 0.89 | 0.02 |
| 6 | paper | 921.98 | 20.74 |
| 7 | ceramic | 57.62 | 1.29 |
| 8 | Animal manure | 576.24 | 12.96 |
| 9 | Dust | 119.68 | 2.69 |
| 10 | Plastic | 775.7 | 17.45 |
| 11 | Marble | 1.33 | 0.03 |
| 12 | Plant leaves | 70.92 | 1.59 |
| 13 | Unused Tires | 17.73 | 0.4 |
| 14 | Melamine | 1.33 | 0.03 |
| 15 | Cotton | 22.16 | 0.5 |
| 16 | Jute material | 4.43 | 0.09 |
| 17 | Organic compounds | 1396.27 | 31.44 |
| 18 | Other | 39.89 | 0.89 |
| 19 | Total | 4444.99 | 100% |

The study also evaluates the amount of solid wastes per each sector in Khartoum city. The study includes nine different sectors including: commercial, market places, industrial, wastes generated from wastewater, gardens, hotels, streets, farms and hospitals. The following figure illustrates the percentage of solid waste for each individual sector in Khartoum city.

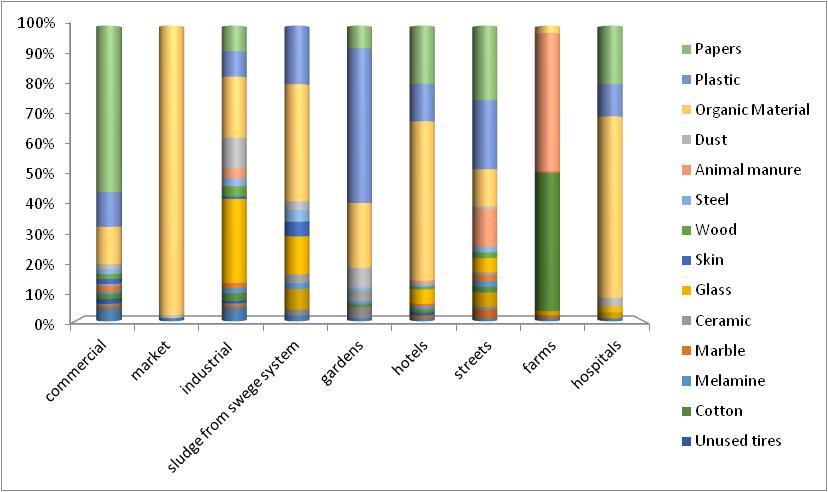


Figure ‑: Percentage of SW per sector

* The study also analyzed the medical wastes which were generated from hospitals in Khartoum. The study considered only 20 hospitals in Khartoum city. The following table shows the amount of wastes generated from 20 hospitals.

Table ‑: Total medical wastes generated from 20 hospitals in Khartoum city

|  |  |  |
| --- | --- | --- |
| Total wastes in hospitals | Quantity in Kg/day | Uncertainty (+/-) |
| Total general wastes | 6253.8 | 34% |
| Total medical wastes | 1250.8 | 22% |

* To conduct risk Assessment analysis, the study reviewed some observations, interviews and questionnaire from previous researches in Khartoum city and revealed the following:

Table ‑: Risk assessment analysis for solid wastes

|  |  |  |
| --- | --- | --- |
| Number | Results from qualitative assessment | Risk assessment |
| 1 | No any kind of treatment of solid wastes in many open dumped areas | Leads to accumulation of wastes in open areas and spread of diseases |
| 2 | Some landfills very close to residential areas |
| 3 | No gas and leachate management | Can lead to contamination of ground water source which is one of the main source of drinking water |
| 4 | Most sites are unfenced | No control over scavengers |
| 5 | Frequent occur of food wastes | Methane will produce to fermentation process and increase the chance of fires in open areas |
| 6 | Organic waste occur frequently |
| 7 | Wastes are not covered with soil | Waste is nuisance and increased the risk of spread of flies. |

* Stakeholder analysis: the study reviewed the current stakeholder in Khartoum city and determines their level of interest and power. The following table elaborates the stakeholders with their level of interests.

Table ‑: Stakeholders analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Stakeholder | Perspective of stakeholder desired situation | dependency | Interest | Power |
| Khartoum government | Clean city | High | Low | High |
| Ministry of health | Reduce health risk | High | Medium | High |
| Ministry of environment affair agency | Improve the environment | High | High | High |
| Khartoum local agency | Improve the environment | Medium | Medium | Medium |
| Non-governmental organization | Improve the process of solid waste management | High | High | Medium |
| Neighborhood health committee | Reduce the volume of wastes | High | Medium | Medium |
| Local markets, restaurant | Reduce the volume of wastes | low | Low | Low |

* SWOT and Gap analysis: the study developed SWOT and gap analysis in form of table as it can be seen as follows:

Table ‑: SWOT and gap analysis for SWM in Khartoum city

|  |  |  |
| --- | --- | --- |
| Institutional aspect matrix | | |
|  | **Strengths** | **Gap** |
| Internal characteristic | There are existing environmental laws. | Insufficient application of the laws |
|  |  |
|  | **Opportunities** | **Threats** |
| External characteristic | There is possibility to engage private sectors | Poor collaboration between the main stakeholders |
|  |  |
| Environmental aspects matrix | | |
|  | **Strength** | **Gap** |
| Internal characteristic | Large number of activeNGO in the field of SWM which lead to improve the awareness and research in Khartoum city | Insufficient environmental data, information and government staff experience |
|  |  |
|  | **Opportunities** | **Gap** |
| External characteristic | Possibilities of funding and support active projects from international organization due to the high attention for this issue. | Risks from high production of methane from open areas and lack of capacities of the landfill in the city |
|  |  |
| Socioeconomic aspect matrix | | |
| Internal characteristic | **Strength** | **Gap** |
| Existence of market forces for recyclable material due to the amount of waste collected at Khartoum State. | Poor investment from private sector due to inflation problem and unstable government |
|  |  |
| External characteristic | **Opportunities** | **Threats** |
| Legalizing employment with economic incentives for the active participant | Current political situation under American sanction |
|  |  |

* The study suggested a framework that will lead to more sustainable SWM in Khartoum city. The framework is suitable for public governments and municipalities. This framework should be guidance for low income countries to follow in order to achieve sustainable SWM.

Monitoring using Performance indicators

Scheduling & Dispatching

Data analysis & planning

Centralized data collection

Collection

Disposal

Transportation

Processing

Figure ‑: Recommended framework for SWM in Khartoum city

# Discussion

## Discussion

Main Outcomes are described as follows:

* Table 4-1 in the previous chapter reveals that the largest amount of wastes was generated from organic compounds with 1396.27 ton per day. The organic materials were appeared in all sectors in Khartoum city as elaborated from figure 4-1
* Hazardous wastes are generated hugely in Khartoum city according to analysis for only 20 hospitals. The total medical wastes in 20 hospitals only reach 1250 kg per day.
* The qualitative results from observations of different sites in Khartoum city revealed poor management of wastes and large scale of uncontrolled wastes in open areas. These results showed the public health concern from mismanagement of solid waste in Khartoum city.
* The study reviewed the available stakeholders in waste management sector and determined their level of interests and power. From table4-4 shows 7 actors in solid waste management field. All these actors play significant role in waste management.
* The SWOT analysis revealed that Khartoum city has powerful rules in solid waste management. However, the application of these rules is very limited.
* The framework is realistic and will be as guidance for low-income countries to support decision makers to implement the strategic plans for solid waste management

## Limitations of the study

* Solid waste management is complex issue and requires an accurate and sufficient data to be obtained frequently. This study needs more data to be obtained in order to achieve constructive SWM.
* The uncertainty analysis is necessary for data improvement but it is not considered in the obtained data.
* The suggested framework is an attempt to guide low income countries to follow the most recognized method for SWM. The method is indeed useful for low income places. However, still the framework needs to be applicable for the cases of developing countries and in particular Sudan.

# Conclusion and Recommendations

## Introduction

Evaluation of solid wastes in developing countries is important. This chapter provides the summary of this research with recommendations to suite the cases of Sudan.

## Conclusion

* The study reviewed the amount of solid waste in Khartoum city and It was found that large quantities of solid wastes were found in Khartoum city. Also this city generated a significant amount of medical and hazardous wastes from big hospitals.
* The outcomes from the public health assessment and the environmental impacts revealed a respected amount of air pollution, soil contamination and water pollutant sources and high rate of pollution in drainage channels and rivers.
* A development of an integrated solid waste management in a friendly framework which can be useful for decision makers in public and private sectors in Khartoum.

## Recommendations

* The assessment of solid wastes in developing countries is uncertain issue. Therefore, the new approach should shift from subjective guess estimation to more accurate and objective estimation. This can be achieved by adopting uncertainly assessment and data validation approach during data collection and evaluation,
* The last years in SWM was focused on improving wastes recycles and disposal process. However, today the focus should be in developing an integrated approach for SWM.
* Developing countries should use performance indicators parameters in order to monitor and control the process of SW.
* Today the world trend is to use technologies in managing complex issues. Therefore, it is recommend using software and advancing tools for monitoring, planning and intervention of SW.
* As solid waste is complex issue, using routine data will result in inaccurate results while collecting detailed data is costly for developing countries. However, it is recommended to make balance between them.

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Appendix

Appendix A-1: An example of wastes in open areas

