# AN ANALYSIS OF SOCIO-ECONOMIC AND DEMOGRAPHIC DETERMINANTS FOR ESTIMATING SOLID WASTE GENERATION IN HOUSEHOLDS IN ESTATES IN KISUMU CITY, KENYA

**BY**

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**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL SCIENCE**

**SCHOOL OF ENVIRONMENT AND EARTH SCIENCES**

**MASENO UNIVERSITY**

## DECLARATION

### Declaration by Student

I certify that this Thesis has not been previously presented for a degree in Maseno University, or in any other University. The work reported herein has been carried out by me and all sources of information have been acknowledged by means of references.

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## ACKNOWLEDGEMENTS

First and foremost, I acknowledge the blessings of the Almighty God in my life. I thank him for granting me good health, wisdom, strength and faith throughout this degree Programme, a journey that was filled with so many ups and downs and without whose guidance and compassion this degree would only be a mirage. Similarly, I extend my gratitude to my colleagues in the School of Environment and Earth Sciences for their support. I also wish to express my deep and endless gratitude to my supervisors Prof. Boniface Oindo and Dr. Esna Bosire both of School of Environment and Earth Sciences, Maseno University, for their constructive criticism, guidance and supervision in the writing of this Thesis.

I would also like to extend my gratitude to my field assistants Mr. Micah Kipleting and Mr. Walter Abwao and Miss. Bernadette Achieng' for assisting me to collect data. I would also like to thank Bramuel, Abraham, Kenneth, Mike, John and Moses who are members of a youth group involved in private waste collection in Obunga and Migosi estates for their assistance in distribution and collection of plastic waste bags to households under study. I would also like to thank Mr. Elvis Otieno, the manager of Migosi solid waste transfer station and all the solid waste collection workers for their invaluable support during the study. My gratitude also goes to Mr. Bernard Otieno, a private waste collector operating within Milimani estate for his assistance in distribution and collection of plastic bags as well as his invaluable support during the study. Similarly, I would like to sincerely thank Ms. Belinda Nyakinya, Environment officer, County Government of Kisumu for providing invaluable information useful in this study. I would like to thank all the household heads in the study area and all other respondents without which I'd have no findings and thus no research Thesis.

I extend my gratitude to my parents, first my father Eng. Vitalis Ouma Leo and my mother Mrs. Winnifred Ouma for believing in my academic potential ever since I started going to school. I would like to thank my father-in-law Mr. Benson Odindo Nyagare for his support and encouragement throughout the study period. I would like to thank my sister Miss. Bernadette Achieng', my brothers Mr. Andrew Ouma, Mr. Bernard Ouma and Mr. George Ouma for every support they have accorded me, I thank God for blessing me with this wonderful family. Finally I would like to thank my very dear husband Mr. Tom Nyagare for his encouragement, support and keeping me going and lively in an incredibly bumpy journey in my life. Every support I received is highly regarded.

# DEDICATION

With gratitude to the Almighty God, I dedicate my work to:

My husband Mr. Tom Nyagare, for his invaluable and unconditional support,

My late grandmother *Mama* Bernadette Mala, for her invaluable life lessons that ensured I remained focused and disciplined,

And to my son Master. Ein Baraka Nyagare, for teaching me that in his own appointed time, the Almighty God makes all things beautiful.

## ABSTRACT

Globally, the amount of solid waste (SW) generated has increased proportionately with urbanization. Estimating SW generation in households is vital for sustainable SW management, however, this has not been easy due to inadequate SW generation data. Inadequate time-series data on SW generation in households in Kenya underscores the need for a study utilizing household socio-economic and demographic characteristics. Hardly any studies have been done on estimation of SW generation in households in Kisumu city. Therefore, the purpose of this study was to analyze socio-economic and demographic determinants for estimating SW generation in households in Kisumu city. The objectives were to: analyze the relationship between household size, household monthly income, household monthly expenditure on food and age of the household head on the amount of SW generated; determine the relationship between education level, employment sector and gender on physical components of SW generated; establish the association between socio-economic group and volume of physical components of SW generated and determine the appropriate socio-economic and demographic determinants for predicting SW generation. A cross-sectional descriptive research design was used. Households were covered as sampling units from a total population of 8651 households. Estates were categorized into high, middle and low socio-economic groups and a minimum sample size of 368 household heads interviewed. Purposive sampling was used to identify the key informants. Primary data were collected through: questionnaires, direct waste analysis, key informant interviews and observation. Pearson product moment correlation was used to establish the relationship between household size, household monthly expenditure on food, household monthly income, age of the household head and amount of SW generated. Chi-square test of independence was used to establish the association between gender, education level, employment sector and physical components of SW generated. One way ANOVA was used to establish the association between socio-economic group and volume of physical components of SW generated while multiple linear regression was used to predict SW generation. The study revealed that the amount of SW generated was strongly and positively associated with household size, monthly expenditure on food, monthly income and age of the household head ($r>0.897$, $p<0.05$) in the three socio economic groups. The Chi-Square results ($p<0.05$) showed that the interaction between gender and physical components of SW generated was significant in the three socio-economic groups. Results of the one way ANOVA showed that there were significant differences between volume of physical components of SW generated across socio-economic groups [$F(2,6)= 6.020285$, $P= 0.036788$] significant at $p<0.05$. Household size, monthly income, expenditure on food and age of the household head explained over 97% ($R^2 =0.97$) of the variations in SW generation. The study concluded that in Kisumu city, socio-economic and demographic determinants can be used to estimate SW generated in households. The study recommended that socio-economic and demographic determinants should be considered in design of integrated SW management programs, solid waste collection and transfer, formal waste recovery and recycling, composting and sanitary landfills.

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## LIST OF ABBREVIATIONS AND ACRONYMS

| | | |
|---|---|---|
| **DWA** | : | Direct Waste Analysis |
| **DWW** | : | Direct Waste Weighing |
| **DWS** | : | Direct Waste Sorting |
| **MSW** | : | Municipal Solid Waste |
| **HSW** | : | Household Solid Waste |
| **HSWG** | : | Household Solid Waste Generation |
| **SW** | : | Solid Waste |
| **HSG** | : | High Socio Economic Group |
| **MSG** | : | Middle Socio Economic Group |
| **LSG** | : | Low Socio Economic Group |
| **KNBS** | : | Kenya National Bureau of Standards |

## DEFINITION OF TERMS

**Direct Waste Analysis** - Is a solid waste characterization methodology that is used for establishing the quantities of solid waste generated its sources and physical components where waste is physically weighed and sorted. It entails a physical and manual analysis of waste collected from the point of generation (homes) by weighing at designated points such as solid waste transfer stations within residential areas or a solid waste disposal point.

**Direct waste weighing** -Refers to physically taking and recording the total weight of solid waste generated in households using a portable weighing machine which is calibrated up to 50 kilograms

**Direct waste sorting** -Refers manually segregating (separating) solid waste components into specific fractions, taking the weights using a portable weighing machine calibrated up to 50kgs and recording the weights.

**Direct waste volume estimation -** Refers to taking pre-determined physical components (waste fractions) of solid waste generated in households and pouring inside a calibrated wooden box having the shape of a cube measuring 50cm by 50cm by 50cm. The solid waste is compacted and the readings of the height of the solid waste taken and recorded. Volume of the physical components of solid waste generated in households is calculated using the formulae; Length X Width X Height in cubic centimeters.

**Household solid waste** -Refers to solid waste generated in either single family or multifamily dwellings. It can also be referred to as domestic solid waste and residential solid waste.

**Socio-economic determinants refer to** - The interaction between social and economic outcomes at household level and how they interact to influence household solid waste characteristics. In this study, socio-economic factors were; household monthly income, education level, sector of employment and household monthly expenditure on food

**Demographic determinants refer to** -The quantitative and qualitative aspects of the households and how they influence household solid waste generation. The demographic factors in this study are; Age of the household head, gender and household size

**Socio-economic group** -Refers to estates or residential areas' position within a hierarchical structure. It depends on a combination of variables. In this study, the variables that were considered in placing residential areas into three socio-economic groups of high, middle and low are; quality of road network, type of housing, water and sanitation facilities, access to quality services for example health, transportation, street lighting and solid waste management services

**Solid waste generation in households** - Refers to production of solid waste as a result of various household activities such as cooking, eating etc. Solid waste generation in households for this study was considered in terms of the total amount of solid waste generated in households in kilograms as well as the physical components (solid waste fractions) of solid waste generated in households in kilograms and cubic centimeters. For the purposes of this study, the physical components of solid waste generated in households were categorized into organic, plastic and miscellaneous solid waste.

**Integrated Solid Waste Management** - Refers to a practice of using several alternative waste management techniques to manage and dispose of specific components of the solid waste stream. Solid waste management alternatives include formal solid waste recovery and recycling, composting, land filling, energy recovery etc

**Recyclables** -Refer to materials that still have useful physical or chemical properties after serving their original purpose and that can, therefore, be reused or remanufactured into additional products.

**Shopping habits of households** -Refer to the frequency of buying or purchasing household goods from shops. Shopping habits in this study was categorized into daily, weekly and monthly shopping.

**Solid waste recovery** -Refers to using solid waste as an input material to create valuable products as new outputs with an aim of reducing the amount of solid waste generated.

**Solid waste reuse** -Refers to the action or practice of utilizing something again for another purpose in its original form without any alteration. Examples of things that can be re-used at the household level include plastic and metallic bottles, containers etc.

**Household** - Refers to a collection of persons who depend on a common store. The persons may not necessarily be members of the same family. They often make common production, marketing and consumption decisions.

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background to the Study

The development of an approach for estimating solid waste generation is typically the first task of any solid waste management study (Rhyner and Green, 1988; Kibwage 1996). In preparing a strategic integrated solid waste management plan for a municipality, such a plan should be drawn taking into account the waste generation sources, quantity, characteristics and the socio-economic structure of the city (Asase et al., 2009). However, lack of reliable studies on solid waste generation is a major limitation for sustainable solid waste management (Davidson, 1972; Richardson and Harvileck, 1978; Medina, 1997). Households account for the largest percentage of solid waste generated in urban cities of the world (Koushki and Al-khaleefi (1998); Emery et al., (2003); Afon, 2007; Ogwueleka, 2009). Recognizing that the quantity and physical components of solid waste are essential in waste management planning, a dozen of researches have been conducted to estimate future waste generation in the cities (Dyson and Chang, 2005; Beigl et al., 2004; Jiang et al., 2009; Chung, 2010).

Previous studies on solid waste generation in households have shown that socio-economic and demographic characteristics of households play a significant role in solid waste generation (Collins and Downes, 1977; Filani, 1983; Adedibu, 1984; Christine, 2001). Previous studies on household solid waste management by Adedibu (1984), Ikuporukpo (1993), Abumere (1993), Rushbook and Pugh (1999), therefore, suggested that in order to have an effective solid waste management strategy, the need to carry out research on socio-economic and demographic characteristics of households was of paramount importance. Solid waste generation in households is a direct consequence of human daily activities and it is closely linked to consumption patterns which are very local and depend on social, economic, and demographic factors (Li et al., 2011). However, previous studies on solid waste generation in households without household socio-economic and demographic characteristics have resulted in an expensive over-capacity for solid waste treatment facilities (Beigl et al., 2003).

Evidence from previous studies on determinants of solid waste generated in households has shown that household socio-economic and demographic characteristics play a significant role in waste generation and are always analyzed together (Ojewale, 2015; Nwachukwu, 2010; Afon, 2007). Evidence from previous studies has also shown than both attributes of the household and the household head can be used to accurately explain the variations of solid waste generation in households (Pham et al., 2015; Bandara et al., 2007). A study by Bandara et al., (2007) established that age, education level and income of the household head significantly contributed to variations in the physical components and generation of solid waste in households.

Beigl et al., (2008) reviewed 45 modelling approaches for solid waste generation and they established that many independent variables have been hypothesized and tested in order to explain the quantity of total or partial streams of municipal solid waste. Similarly, Salhofer (2001), Beigl et al., (2003), Hockett et al., (1995) and Jenkins (1993) summarized the major independent variables that have been hypothesized in order to explain solid waste generation. Furthermore, a number of socio-economic and demographic variables which have further been identified by different authors (Collins and Downes, (1977); Filani, 1983, Adedibu, 1984; Koushki and Al-khaleefi, 1998, Afon, 2007) are family size, employment by sector, education status and age of the household head. Beigl et al., (2003), further noted that in selection of parameters explaining solid waste generation, priority should be given to those parameters with a relatively high accuracy and a long forecasting horizon such as age, household size and household income (Lindh, 2003). A study by Odonez-Ponce (2004) assessing waste generation factors and forecasting waste generation using Artificial Neural Networks in Chile identified household size, education level, population, age, gender, occupation of the head of the family and expenditure on groceries as the main global variables affecting solid waste generation. However, despite the large amount of literature related to solid waste, not many studies have analyzed middle and low income countries (Odonez-Ponce, 2004). Therefore, the selection of independent variables for this study was mainly guided by review of previous studies on the key socio-economic and demographic variables that have been considered as global variables explaining solid waste generation.

Globally, a number of studies on quantification and characterization of solid waste have been done for the purposes of understanding the physical components of municipal solid waste (Gawaikar and Deshpade, 2006; Buenrostro et al., 2001; Forouhar and Hristvoski, 2012). Previous studies on solid waste characterization have majorly focused on municipal solid waste generation trends with the main aim of assessing future municipal solid waste streams using time-series data (Daskolopoulos et al., 1998; Karavezyris et al., 2002; Chang and Lin, 1997; Karavezyris et al., 2002; Navarro et al., 2002; Skovgaard, et al., 2005; Cherian and Jacob, 2012). UNHABITAT (2010) established that one of the main reasons for difficulties in solid waste management is failure to take into account the important differences between geographical regions, nations, cities and even within a city. Most of the research work available in the literature is related to estimation of household solid waste in developed countries and major cities by use of time-series data (Pamnani and Meka, 2014). However, most developing countries lack reliable historic solid waste data, (Beigl et al., 2003). Previous studies on municipal solid waste generation have mainly estimated waste generation using time series data, however, these studies do not give specific information on how solid waste generated in households can be estimated using relevant household socio-economic and demographic characteristics which this study has dealt with. Accurate information on solid waste generation is mandatory for integrated solid waste planning and management (Gomez et al., 2008). Studies on solid waste generation in households are important for decision making in household solid waste management (HSWM) and reliable data is often available in industrialized societies (Mohamed et al., 2012). However, in most developing countries, data is often limited and unreliable (Mohamed et al., 2012). Furthermore, most studies which have been done have often relied on data from disposal and transfer points (Beigl et al., 2003; Buenrostro et al., 2011; Pamnani and Meka, 2014). Weighing and sorting of solid waste generated at source makes identification easy and eliminates any uncertainty as to their origins (Bernache-Perez et al., 2001).

When solid waste generation data is collected at disposal sites which most of these previous studies have done, information is often inaccurate due to interference of the solid waste stream through practices likes solid waste recovery and mixing of solid waste from different sources. This study therefore, estimated Solid waste generation in households using household socio-economic and demographic data and household solid waste generation data was collected at the point of generation.

Previous studies have been done on solid waste characterization focusing on the physical components of solid waste generated in households (Kaseva and Mbuligwe, 2005; Kaseva and Gupta, 1996). Tchobanoglous and Kreith (2002) established that understanding the physical components of the solid waste stream is compulsory in any solid waste management system. Isaac et al., (2013) for instance, studied the characteristics of household solid waste in Wa, Ghana. However, these studies have not addressed the socio-economic and demographic determinants of the physical components of solid waste generated in households (Aisa, 2013). Moreover, studies on solid waste characterization have mainly been done at disposal points and material recovery facilities (Aisa, 2013; Sankoh et al., 2012). Furthermore, studies on solid waste generation in households have provided results on the physical components of solid waste generated in households without giving their socio-economic and demographic determinants. Similarly data for these previous studies has mainly been collected at disposal points and material recovery facilities (MRFs). This study provided results on socio-economic and demographic determinants of the physical components of solid waste generated in households and data was collected at the point of generation which previous studies have not been keen on.

Anomanyo (2009) observed that insufficient information on quantities of solid waste is the major contributing factor to Ghana's solid waste management problems. Studies on solid waste generation in Nigeria show that there is need for further studies on socio-economic determinants of solid waste generated in households for effective management (Olayungbo and Olawale, 2014). Asase et al., (2009) estimated municipal solid waste generation in Kumasi, Ghana. Emphasis on many prior studies has been on municipal solid waste (MSW) generated by a whole community, location or an area with little attention given to socio-economic determinants of solid waste generation at the household level (Alakinde, 1997; Ayotomuno and Gobo, 2004; Afon, 2007; Babayemi and Dauda, 2009; Nwachukwu, 2010; Ukpong and Udofia, 2011). Ajani (2007) studied the effects of educational status, age and amount of money charged for waste collection on solid waste management in Ibadan, Nigeria. Babayemi and Dauda (2009) established that lack of advanced technology, facility for separation at source, strength of solid waste management policy and enforcement, environmental education and awareness affect solid waste generation in Nigeria. Household size and income have widely been acknowledged as important factors influencing solid waste characteristics (Collins and Downes, 1977; Zulien, 2006; Abel, 2007). A clear understanding on the relationship between household socio-economic and demographic characteristics and solid waste generation in households enables policy makers to make more informed decisions about where and when to implement a particular policy (Aisa, 2013). Furthermore, despite the fact that organic and food waste forms the highest bulk of solid waste generated in households (Mohammed et al., 2012), hardly any studies have been done on the relationship between expenditure on food and amount of solid waste generated in households. Previous studies on solid waste management have focused on socio-economic determinants of municipal solid waste and hence they have not provided accurate information on socio-economic determinants of solid waste generation in households. This study focused on socio-economic and demographic determinants of solid waste generation in households where solid waste data was collected at the household level before mixing of the solid waste stream.

Previous studies on solid waste management in Kenya have mainly focused on factors influencing household solid waste management practices (Mulatya, 2011; Yen, 2012; Mukui, 2013). Rotich et al., (2006) examined the current status of solid waste management by municipal councils in major cities in Kenya. A study by Mulatya (2011) on household solid waste management practices in Nairobi established the relationship between socio-economic status and amount of solid waste generated in households in Kilograms. Okalebo et al., (2014) analyzed household solid waste generation patterns and prevailing management practices in Eldoret, Kenya and they established the amounts of solid waste generated in households in Kilograms in different residential areas. A study by Kibwage (1996) on the privatization of household solid waste management services in the city of Nairobi established the amount of solid waste generated in households in the city of Nairobi, however, the study did not establish the socio-economic and demographic determinants of solid waste generated. Furthermore, Kibwage (2002) studied the establishment of informal recycling sector into solid waste management planning in Nairobi city while Kibwage and Momanyi (2002) studied the role of composting groups in Nairobi city. Yen (2012) studied the management of residential solid waste in Mombasa, Kenya and quantified household solid waste characteristics in terms of amount of generated in Kilograms. Mukui (2013) studied the factors influencing household solid waste management in urban Nyeri. These studies have mainly provided information on weight in kilograms of the physical components of solid waste generated in households. None of these studies provided information on the relationship between socio-economic group and the volume in cubic centimeters of the physical components of solid waste generated in households which this study has done.

In Kenya, previous studies on solid waste generation have not provided adequate information on quantification and characterization of solid waste generation in households at the point of generation (Munala and Moirongo, 2011). This is despite the fact that residential areas or households are the major contributors of municipal solid waste followed by markets and commercial areas (Kibwage, 2002). Afullo and Odhiambo (2009) studied the primary waste storage gaps experienced in Nairobi households. Kinyua et al., (2016) studied the socio-cultural factors associated with household solid waste management in a Kenyan informal settlement and only provided information on the relationship between socio-demographic factors and household solid waste management. Oyake-Ombis et al., (2012) studied the household perspectives of innovative plastic waste management in Kenya. These studies have only provided information on solid waste management practices. None of these previous studies have provided information on quantification and characterization of solid waste generation in households which this study has done. Currently, the socio-economic and demographic determinants of the amount and physical components of solid waste generated in households in Kisumu are unknown since previous studies have mainly focused on household solid waste management (Obera and Oyier, 2002; Opande, 2010; Munala and Moirongo, 2011). A study by Obera and Oyier (2002) only focused on sustainable solid waste management for Kisumu and did not provide any information on solid waste generation in households. A study by Gutberlet et al., (2016) on bridging the weak links in solid waste management in informal settlements in Kisumu did not provide any information on the quantities of solid waste generated in households in these informal settlements. Munala (2009) studied the challenges of solid waste management in Kisumu and established that Kisumu generates more than 400 tons of household solid waste per day with 60-65% being organic waste. Opande (2010) studied household solid waste management in low income settlements of Nyalenda and Ondiek estates in Kisumu city and did not give any information on the physical components of solid waste generated in households in these settlements.

In their study on the need for integrated solid waste management in Kisumu, Munala and Moirongo (2011) revealed that the amount and physical components of solid waste generated in Kisumu has been on the increase, however, they did not provide any specific information on the quantities and physical components of solid waste generated in households in Kisumu. These previous studies have only focused on solid waste management in Kisumu. None of these studies have provided reliable information on socio-economic and demographic determinants of solid waste generation in households which is necessary for estimation in the absence of time-series data.

## 1.2 Statement of the Problem

Previous estimates have mainly been done on MSW generation using time-series data which is unavailable in developing countries. Solid waste characterization studies on the amount and physical components of solid waste generated have mainly been done at final disposal sites and material recovery facilities despite the fact that households are the basic unit of solid waste generation. Studies on characterization of solid waste generated in households have mainly provided information on weight in kilograms of solid waste generated in households as opposed to volume in cubic centimeters which is critical in sizing of solid waste disposal facilities. Currently, the amount of solid waste generated in households in Kisumu, volume of the physical components and their socio-economic and demographic determinants are unknown.

Without understanding these critical variables, estimation of solid waste generation in households is impossible. Adequate data on current solid waste generation in households is key in providing information for future estimation of solid waste generation in households. Results from this study is also timely since it can aid in formulation of policies for proper planning of disposal sites, landfills and material recovery facilities. The purpose of this study was therefore to analyze socio-economic and demographic determinants for estimating solid waste generation in households in estates in Kisumu city, Kenya.

## 1.3 Objective of the Study

The general objective of this study was to analyze socio-economic and demographic determinants for estimating solid waste generation in households in estates in Kisumu city, Kenya.

**The specific objectives were;**

(i) To analyze the relationship between household monthly expenditure on food, household size, household monthly income, age of the household head and the amount of solid waste generated in households in estates in Kisumu city.

(ii) To determine the relationship between education level of the household head, employment sector of the household head, gender of the household head and the physical components of solid waste generated in households in estates in Kisumu city.

(iii) To establish the association between socio-economic group and volume of the physical components of solid waste generated in households in estates in Kisumu city.

(iv) To determine the appropriate socio-economic and demographic determinants for predicting the amount of solid waste generated in households in estates in Kisumu city.

## 1.4 Research Hypothesis

(i) $H_o$ Household expenditure on food, household size, household monthly income and age of the household head are not associated with the amount of solid waste generated in households in estates in Kisumu city.

(ii) $H_o$ Education level of the household head, employment sector of the household head and gender of the household head are not associated with the physical components of solid waste generated in households in estates in Kisumu city.

(iii) $H_o$ There are no significant differences in the means of volumes of physical components of solid waste generated in households in estates across socio-economic groups in Kisumu city.

(iv) $H_o$ Household size, household monthly expenditure on food, household monthly income and age of the household head cannot explain the variations in the amount of solid waste generated in households in estates in Kisumu city.

### 1.5 Justification of the Study

The household is the basic unit of solid waste generation in every human settlement and hence the need to study households. Kisumu city was selected for the study since hardly any studies on estimation of solid waste generation have been done there. Due to societal changes, urbanization plays an important role in aggravating environmental problems associated with generation of solid waste. Accurate and detailed estimation of solid waste generation in households can aid authorities and policy makers to plan for capacity requirements of management of solid waste generated in households. The findings of this study have offered insight into the socio-economic and demographic determinants of solid waste generation in households, physical components and how these determinants can be used to estimate solid waste generation in households. These findings can further aid in estimation of the material recovery potential of solid waste generated in households, facilitation and design of equipment for management of solid waste generated in households, compliance with both national and county laws on solid waste management. The findings of this study could be useful to county governments in coming up with sustainable solid waste management programmes. Similarly, the findings of this study have important policy implications for policy and decision makers since appropriate decision making on management of solid waste generated in households requires knowledge on the amount of solid waste generated in households, their physical components as well as their socio-economic and demographic determinants.

### 1.6 Scope and Limitations of the Study

This study analyzed socio-economic and demographic determinants of solid waste generation in households in estates in Kisumu city, Kenya. It covered Milimani, Migosi and Obunga estates within Kisumu city. This study collected data on solid waste generation in households and established the quantities (amount) and physical components (solid waste fractions) of solid waste generated in kilograms and cubic centimeters. Furthermore, the physical components of solid waste generated was divided into three distinct categories namely; organic, plastic and miscellaneous waste. The study collected data on the following socio-economic and demographic determinants; household size, household monthly expenditure on food, household monthly income, age of the household head, education level of the household head, employment sector of the household head and gender of the household head. Seasonal variations were not considered while collecting data on solid waste generated in households since they were out of scope of this study. Furthermore, previous studies, (Asase, 2011; Ketibuah et al., 2004; Fobil and Hogarh, 2006; Dagadu, 2005) have established that within the wet and dry seasons, there was no trend in variation in solid waste generation in households.

The researcher had a limitation due to the fact that some of the physical waste components (solid waste fractions) were available in very small quantities in some households with possibilities of other components not being present at all. This led to the researcher to categorize the small sub-components of solid waste generated as miscellaneous waste. Hence, the study had three major physical components waste namely organic waste, plastic waste and miscellaneous waste.

## 1.7 Assumptions of the Study

The study was based on the assumptions that data on solid waste generation in households as well as the household socio-economic and demographic data collected during the survey reflected the true status of activities as at the time of the study. It was also assumed that the sample population selected for the study was a true replica and was representative of those in high, middle and low socio-economic groups within Kisumu city. The study also assumed that the respondents were knowledgeable on the questions asked and that they answered the survey questions correctly and truthfully.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

This Chapter presents a literature review on socio-economic and demographic determinants for estimating solid waste generation in households in estates in Kisumu city. It presents a review on the relationship between socio-economic and demographic determinants and the amount of solid waste generated in households. It further gives a review on the relationship between socio-economic and demographic determinants and the physical components of solid waste generated in households. Similarly, it provides a review on the relationship between socio-economic group and volume of the physical components of solid waste generated in households. Finally it gives a review on the appropriate of socio-economic and demographic data for modeling solid waste generation in households.

## 2.2 Socio-economic and Demographic Determinants and the Amount of Solid Waste Generated in Households

Given the increasing amount of solid waste being generated as a consequence of rapidly developing economies, sustainable management of solid waste generated in households has become an important concern for local and national authorities worldwide (Barr, 2007; Davies, 2002; UNDP, 1992). In Britain for example, the Department of Environment, Food and Rural Affairs (DEFRA, 2002) estimated that 28.5 million tonnes of municipal solid waste was collected between 2007 -2008, with the majority (88.7%) being solid waste generated in households (DEFRA, 2002). With increases in population and improved living standards, solid waste generation in developing countries has also increased and hence if the current trends continue, the world may witness a five-fold increase in solid waste generation by the year, 2025 (Okalebo et al., 2014). There is a growing demand for availability of reliable information on socio-economic and demographic determinants of solid waste generation in households (Cherian and Jacob, 2012).This information is however, lacking in most developing countries due to the fact that most studies on solid waste management have mainly relied on municipal solid waste generation data collected from disposal points and material recovery facilities.

Proper solid waste management requires accurate information on solid waste generation and factors that contribute to their generation (Aisa, 2013). Studies on solid waste generation in households normally differentiate households by size or income to account for differences in solid waste generation rates (Ojeda-Benítez et al., 2008). Socio-economic and demographic determinants of quantities of solid waste generated in households have been analyzed in a number of studies (Beigl et al., 2003).The results demonstrated the relevance of certain indicators e.g. income (Dennison et al., 1996; Parfitt and Flowerdew, 1997; Salhofer and Graggaber, 1999), household size (Dennison et al., 1996). Family size and monthly income are important determinants in production of solid waste in households ( Ghorbani et al., 2007;Monavari et al., 2012; Phillipe and Clout, 2009; Nilanthi et al., 2006). As study by Ojewale (2015) established that household income, age composition of the household and household size were key determinants of solid waste generation in households. However, the study did not examine monthly expenditure on food and age of household head which this study examined. A study by Afon (2007) established that there was a relationship between household income, household size and occupation and the quantities in kilograms of solid waste generated in households in Oyo state, Nigeria. The work of Afon (2007) however, did not examine monthly expenditure on food and age of the household head.

In a study on the socio-economic factors affecting solid waste composition and generation in Freetown, Sierra Leone, Sankoh et al., (2012) established that solid waste generation and composition was significantly affected by average family size, employment status and monthly income.  A study by Sing et al., (2014) on factors influencing solid waste generation in Malaysia, established that there was a significant positive relationship between household expenditure and solid waste generation in households. Mahees et al., (2011) further established that solid waste generation in households was mainly influenced by weekly food consumption and family size. They however did not study the relationship between monthly expenditure on food and the amount of solid waste generated in households.

Irteza et al., (2013) studied 73 households across five socio-economic groups in Chittagong, Bangladesh and established that there was a positive relationship between the amount of solid waste generated in households and household size and household monthly income. A study of approximately 160 households in Oyo, Nigeria also found a statistically significant correlation between solid waste generation in households, household size and household income (Afon, 2007). However, a study of 47 households in Gaborone, Botswana found no direct relationship between generation of solid waste in households and income (Bolaane and Ali, 2004). It is however important to note that the sample size of the study by (Bolaane and Ali, 2004) was quiet small and this probably could be the reason for the contradicting results. Bruvoll (2001) also established that household monthly income did not influence the amount of solid waste generated in households. Abel (2007) also revealed that with increase in education level of the household head, income and social status the amount of solid waste generated in households decreased. Qu et al., (2009) found a negative correlation between household income and size and the amount of solid waste generated in households.

Socio-economic and demographic determinants may not always have similar relationships with the amount of solid waste generated in households as shown in literature (Bolaane and Ali, 2004); Irteza et al., 2013). Studies by, (Bolaane and Ali, 2004; Irteza et al ., 2013) therefore observed that these differences in findings suggested that caution should be taken in making inferences on the relationship between socio-economic and demographic factors and solid waste generation in households located in different parts of the world or even for households residing in different parts of the same city. In a study on characterization of solid waste generation in households in Kinondoni Municipality, Dar es Salaam, Aisa (2013) established that the relationship between per capita daily waste generation and household size is not clear-cut in low and middle income households. Furthermore, Aisa (2013) established that there was a very weak negative correlation between household income and per capita waste generation. This therefore underscores the need to carry out specific studies on the relationship between socio-economic and demographic determinants and the amount of solid waste generation in households in different socio-economic groups.

A study by World Bank (2012) estimated that Dar es Salaam was generating 4200 tonnes of solid waste per day. The study by (World Bank, 2012), however, did not specify the quantities of solid waste generated from individual solid waste streams. Furthermore, the factors influencing the amounts of MSW generated are not identified in the study by World Bank (2012). Some of the factors affecting solid waste generation in households are demographic factors such as age and education level (Tewodoros, 2009). In Bangladesh, big cities are faced with many problems due to improper management of solid waste generated in households (Mohammed et al., 2012). Indeed, even with the best of intentions, authorities are unable to establish and implement an efficient management plan mainly because of lack of understanding of solid waste generation in households and its characteristics (Mohammed et al., 2012). A good understanding of solid waste stream in households (amount generated, characteristics and the physical components) is therefore critical in enabling local authorities to better plan for solid waste management.

A number of studies have examined the relationship between household socio-economic and demographic determinants and solid waste generation in households (Buenrostro et al., 2001; Banar et al., 2009; Afon, 2007; Hockett et al., 1995; Dyson and Chang, 2005; Daskapoulos et al., 1998; Beigl et al., 2004). The most common factors they studied include the level of income, the overall size of the household, the level of education and employment (Afon, 2007). However, these relationships varied in different locations as well as across countries, cities or zones in a particular city (Cherian and Jacob, 2012). Aisa (2013) noted that, despite many previous studies on socio-economic and demographic determinants of solid waste generation (Hong et al., 1993; Jenkins, 1993; Jenkins et al., 2003; Bandara et al, 2007; Afroz et al., 2010) who established that an increase in lead to an increase in the amount of solid waste generated in households, that was not always the case.

Solid waste generation data is vital for designing a sustainable solid waste management system (RoK, 2005). According to Iboro (2007) the critical steps towards proper solid waste management are; identifying the type, sources and quantities of wastes generated. JICA (1998) established that each Nairobi household generated 253 kilograms of solid waste per year translating to 21 kilograms per household per month. However, they did not provide information on socio-economic and demographic determinants of solid waste generated in households. Previous studies in Kenya have also mainly focused on other aspects of solid waste management in households (Munala and Moirongo, 2011). Afullo and Odhiambo (2009) studied the primary storage gaps experienced by Nairobi households. Mwangi (2011) studied Solid waste management in households in Makina informal settlement in Nairobi and mainly focused on the types of solid waste generated in households and disposal practices adopted at the household level. Mukui (2013) studied factors influencing solid waste management in households in Nyeri municipality and focused only on waste collection and disposal. Previous studies on solid waste management in Kenya have hardly documented the socio-economic and demographic determinants of solid waste generation in households despite the fact that households are the basic unit of solid waste generation.

## 2.3 Socio-economic and Demographic Determinants and the Physical Components of Solid Waste Generated in Households

Knowledge of solid waste characteristics is essential for solid waste disposal facilities planning and solid waste management policy formulation (Chung and Poon, 2001). To plan a solid waste management strategy for a given city or municipality, it is essential to know the physical components of solid waste generated (Aisa, 2013). Differences in the classification of solid waste generated in households exist between geographical regions, nations, cities and even within a city (UNHABITAT, 2010). The physical components (solid waste fractions) of solid waste generated in households vary in time and space and are affected by socio-economic and demographic conditions (Buenrostro et al., 2001). However, the socio-economic and demographic determinants associated with the generation of urban solid waste is often poorly understood, despite the fact that knowledge on solid waste generation is important in planning urban solid waste management programs in developing countries (Buenrostro et al., 2001). In a study on characterization of solid waste generated in households for determination of waste management options in Amassoma, Baylesa state of Nigeria, Igbinomwanhia et al., (2014) categorized solid waste generated in households in Amassoma into three distinct categories namely; garbage (food waste), combustible (paper, plastic, rubber, textile, wood, leather, cardboard) and non-combustible (steel, metal tins, aluminum, glass and ceramics). Ogwueleka (2009) studied the municipal solid waste characteristics and management in Nigeria and classified municipal solid waste generated into seven distinct categories namely; putrescibles, plastics, paper, textile, metal, glass and others. Aisa (2013) characterized solid waste generated in households in Kinondoni municipality, Dar es salaam and classified the physical components of solid waste generated into kitchen/food waste, paper, plastics, glass, metal, aluminum and residual waste. Kasozi and Von Blottnitz (2010) classified the solid waste generated in households in Nairobi into Food waste, paper, plastics, glass, metal and others.

Studies on characterization of solid waste generated in households provide useful information on the physical components of solid waste streams (Newenhouse and Schmit, 2000). Bolaane and Ali (2004) attributed that knowing the solid waste characteristics is important in solid waste management policy and monitoring. Solomon (2011) reported that household level solid waste characterization studies provide more detailed, accurate and crucial information on the physical components of solid waste generated in households. Most studies have however focused on the physical components of municipal solid waste (MSW) and even where the studies are on solid waste generation in households, solid waste data is mainly collected at material recovery facilities and disposal points and hence there is lack of accurate information on the physical components of solid waste generated in households.

A study by Sankoh et al., (2012) on the socio-economic determinants of the physical components of solid waste generated in households in Freetown, Sierra Leone, established that employment sector of the household head was a key determinant of the physical components of solid waste generated in households. Aisa (2013) established that socio-economic and demographic determinants had a significant interaction with the physical components of solid waste generated in households in Kinondoni municipality, Dar-es Salaam. He further went ahead to reveal that households whose heads were female were more likely to generate organic, plastic and miscellaneous solid waste respectively as compared to households whose heads were male.

Jonas et al., (2014) conducted a study on factors influencing solid waste generation and composition in urban areas of Tanzania and established that education level of the household head had a significant interaction with the physical components of solid waste generated in households. Furthermore, Yemadje et al., (2013) revealed that employment sector of the household head had a significant interaction with the physical components of solid waste generated in households in Benin. Bandara et al., (2007) conducted a study to determine the relationship between solid waste generation and composition and socio-economic factors and used variables like population density, average income, level of education, climate, religious and cultural beliefs, living habits and social and public attitudes. However, the study by Bandara et al., (2007) presented a serious setback in literature since the study findings were not presented according to socio-economic group hence there could be issues of accuracy and reliability.

Olayungbo and Olawale (2014) underscored the fact that there was a need for further studies on socio-economic factors affecting solid waste generation in households in Nigeria. Emphasis on many prior studies focused on municipal solid waste generated by a whole community, location or an area with little attention on the socio-economic factors affecting solid waste generation at the household level (Adedibu 1984; Alakinde, 1997; Ayotomuno and Gobo, 2004; Afon, 2007; Babayemi and Dauda, 2009; Nwachukwu, 2010).

## 2.4 Socio-economic Group and the Volume of the Physical Components of Solid Waste Generated in Households

Studies on solid waste generally consider the city as a single entity and fail to take into account variations in solid waste generation from one residential zone to another (Baud, 2002; UNEP, 1999). Societal changes influence the characteristics of given households, socio-economic group, residential location and community status which eventually influence the volume of the physical components (solid waste fractions) of solid waste generated in households (Sujauddin et al., 2008).

The physical components and characteristics of solid waste generated in households is influenced by the socio-economic group (Bichi and Amatobi, 2013). Isaac et al., (2013) conducted a study on the characteristics and management of solid waste generated in households in urban areas in Ghana and classified households into high, middle and low socio-economic groups within the study area to be able to provide a holistic idea on characteristics of solid waste generated in those households. The criteria used by Isaac et al., (2013) to classify the households was based on residents' living standards, housing and access to basic essential services such as water, electricity and toilet facilities among others. According to Jonas et al., (2014), socio-economic group is commonly conceptualized as the social standing or class of an individual or group and it connotes a household's position in the hierarchy, how the hierarchy is structured and very often one's consequent life chances. The socio-economic facilities considered in socio-economic group classification include road network, housing facilities, friendship networks, power, money, material goods, access to quality services for example health, education, communication, security, transportation, commerce etc (Jonas et al., 2014; Kodwo et al., 2015).

According to the Kenya Integrated Household Budget Survey 2015-2016, a set criteria for classification of residential areas into socio-economic groups is non-existent, however, households are classified into poor and non-poor households based on certain welfare indicators like sanitation facilities and assets owned (KNBS, 2015). Previous studies in Kenya indicate that low income settlements are those that have a high incidence of economic poverty, sub-standard quality of housing and basic services are barely provided (Dafe, 2009). High socio-economic groups have low population densities while low income groups have high population densities (K'akumu and Olima, 2007). A solid waste quantification and characterization study done in 2009 in Nairobi classified households into low to middle and high income zones, however, the study didn't give the criteria used for this classification (Kasozi and Blottnitz, 2010).

The volume of the physical components of solid waste generated in households depends on socio-economic groups (Enayetullah et al., 2005). Napoleon et al., (2011) established that the high socio-economic groups produced more inorganic material such as plastic and paper while the low socio-economic groups produced relatively more organic waste. However, Mohammed et al., (2012) revealed that organic waste was highest in all the socio-economic groups. A solid waste characterization study done in three municipalities in Dar es Salaam indicated that solid waste generation is highly dependent on the socio-economic group of the population (Jonas et al., 2014). Anomanyo (2009) observed that apart from lack of funds, insufficient information on the physical components of solid waste generated is a major contributing factor to Ghana's solid waste management problems.

The relationship between income and socio-economic group and the amount of solid waste generated in households has not always returned consistent results (Irteza *et al*., 2013). A study conducted by Jonas *et al.*, (2014) on factors influencing solid waste generation and physical composition in urban areas of Tanzania established that there were significant differences in solid waste generation among three socio-economic groups of high, middle and low. Furthermore, Aisa (2013) established that physical components of solid waste generated in households differed across socio-economic groups with organic waste forming the highest percentage in all the socio-economic groups.

Isaac et al., (2013) revealed that organic materials dominated solid waste produced from households in all socio-economic groups in Wa, Ghana. The study by Isaac et al., (2013) further established that the organic proportion forms approximately half (54%) of solid waste produced in households. The proportion of organic waste in solid waste generated in households is highest in the low socio-economic group and lowest in the high socio-economic group. However all the other physical components of solid waste generated in households reduce from high to low socio-economic group (Isaac et al., 2013). The proportion of plastics/rubber and paper/cardboard, although constitute an insignificant part of solid waste generated in households by weight (5% and 3% respectively) can increase the overall solid waste volumes occupying a significant volume of space during landfilling due to its bulky volume (Hoornweg and Bhada-Tata, 2012). Most of previous studies on solid waste generation in households have, however, mainly focused on the relationship between the weight of the physical components and socio-economic group (Igbinomwanhia et al., 2014). However, it is important that information on the volume of physical components of solid waste generated in households is also made available since it is important in planning for solid waste management, material recovery and disposal facilities.

Studies on solid waste physical components in some Nigerian cities indicate that about 25% of most urban wastes in Nigeria comprise of paper and other non-toxic materials (Bamgboye and Ojolo, 2004). In the recent years, research has shown that there is a high proportion of organic materials in MSW (Igbinomwanhia et al., 2014).  Studies on MSW are, however, too general and the scope too wide, hence they are not able to provide accurate and specific information on solid waste sources.

A study by Mohammed et al., (2012) on solid waste generation and composition in households in Bangladesh, established that organic waste comprised the highest percentage of solid waste component with the low socio-economic group generating the highest proportion of organic waste. The study by Mohammed et al., (2012) further established that in terms weight, 77% of solid waste generated in households was compostable in nature, however, the study did not provide information on the volume of physical components of solid waste generated. According to several researchers, organic waste forms the highest percentage of solid waste generated in households (Moghadam et al., 2009; Abu-Qdais, 2007; Sharholy et al., 2008). There is hardly any information on the physical components solid waste generated in households by volume. Information on the volume of physical components (solid waste fractions) of solid waste generated is key in planning and management of solid waste since it will aid in sizing of material recovery facilities and landfill sites.

## 2.5 Appropriate Socio-economic and Demographic Determinants for Modelling Solid Waste Generated in Households

The main methodologies applied to modelling urban solid waste generation are classified into two groups; qualitative and quantitative models (Iraia et al., 2015). Qualitative models are based on expert knowledge and do not necessarily use quantitative data while quantitative models are more comprehensive and can provide better results when accurate data on solid waste generation is available (Armstrong, 2001). Quantitative models are mainly divided into time series, data-driven and factor models (Iraia et al., 2015). Time series models aim at deducing variation patterns with time and show great ability to determine data repeatedly using historical data on the dependent variable. (Chang and Lin, 1997). Data driven (input-output) models are based on the flow of material to or from waste generators such as production, trade and consumption data (Iraia et al., 2015). Patel et al., (1998) noted that the exclusive use of national aggregates in the data driven (input-output) models is not appropriate for explaining regional dynamics. The selection of solid waste explanatory variables therefore has to prioritize parameters at the city level which can be modelled with relatively high levels of accuracy (Beigl et al., 2003). Factor regression models are statistical models that provide insights to the reasons behind solid waste generation and they focus on analyses of the factors which describe the processes of solid waste generation e.g. income of households, household size and dwelling types (Salhofer, 2001). Similarly, methods that provide easily available, standardized secondary time-series data have previously been favored over elaborate time consuming qualitative approaches (Karavezyris et al., 2002).

A number of studies have focused on the influence of socio-economic and demographic factors in a bid to understand, define and model solid waste generation (Grossman et al., 1974; Dennison et al., 1996; Mazzanti and Zoboli, 2008; Bandara et al., 2007; Emery et al., 2003). Shell and Shupe (1972) developed a multiple regression analysis model as part of a study to estimate present and future municipal solid waste generation rates and analyzed variables such as number of stops for collection, number of families in an area, population and income and they established that the number of stops for collection was the most significant explanatory variable in solid waste generation. Furthermore, Grossman et al., (1974) also used multiple regression analysis model for prediction in Brookline, Massachusetts, USA and they established that this model neither explained nor predicted future generation in a proper manner, therefore, Grossman et al., (1974) concluded that they had made a wrong choice of explanatory variables. Informed by published literature, some of the most common explanatory variables for modelling solid waste generation include household size, age, monthly income, employment, household expenditure, gender and education (Emery et al., 2003; Shan, 2010). Perin (2001) developed models as part of Seattle's solid waste plan which used population, number and size of households, employment by sector, household income, construction activity and employment by sector to estimate future solid waste stream. Cherian and Jacob (2012) reviewed previous models on municipal solid waste generation and identified possible identifiers related to socio-economic and demographic determinants with an aim of arriving at limitations of previous prediction models. The studies by Perin (2001) and Cherian and Jacob (2012), however, focused on modelling municipal solid waste as opposed to narrowing down to solid waste generation in households. Buenrostro et al., (2001) analyzed the relationship between household income, household size, education level, and age in the generation of solid waste in households in Morelia (Mexico) and they established that household income and size were the most useful variables in modelling solid waste generated in households.

In order to understand, describe and model the unit solid waste generation rate of urban solid waste, various researchers have studied the influence of socio-economic and demographic factors (Buenrostro et al., 2001). The variables more commonly analyzed are monthly income/wages, household size, age, gender, population density and ethnicity (Buenrostro et al., 2001). Many predictive modelling studies (Brunner and Ernst, 1986; Jacobs and Everett, 1992; Chang and Lin, 1997; Zaini and Simon, 2012) have been created over the last few decades to assist in developing more efficient solid waste management programs. An effort to develop empirical models for estimation of solid waste generation in a typical residential dwelling is found in a study by Mohd et al., (1993) in a case study of South Johore, Malaysia. Furthermore, Daskapoulos et al., (1998) discussed a modelling methodology for municipal solid waste in the European Union countries and the United States of America. The results in the study by Daskapoulos et al., (1998) established that the model developed could be used to predict future amount of municipal solid waste stream using gross domestic product and population data.

Solid waste models and results from these models are used in the planning of solid waste management systems (Beigl et al., 2008). These solid waste management systems include; the development of solid waste management strategies (Daskapoulos et al., 1998), planning of solid waste collection services (Grossman et al., 1974) and infrastructure (Dennison et al., 1996), or treatment facilities and capacities (Chang and Lin, 1997) and land demand for landfills (Leao et al., 2001). According to Beigl et al., (2008), correlation and regression analyses were the most appropriate modeling methods in testing the relationship between level of affluence and solid waste generation.

### 2.6 Legal Framework on Solid Waste Management

Environmental Management and Coordination (Waste Management) regulations 2006 is the supreme law that addresses solid waste management in Kenya including management of solid waste generated in households.

EMCA (Waste Management) regulations 2006 gives provisions for handling of solid waste right from solid waste generation to final disposal. Regulation two of the Environmental Management and Coordination (Waste Management) Regulations of 2006 states that any person whose activities generate waste shall collect, segregate and dispose or cause to be disposed of such waste in the manner provided for under these Regulations. Furthermore, regulation five on the segregation of waste by a generator states that any person whose activities generate waste, shall segregate such waste by separating hazardous waste from non-hazardous waste and shall dispose of such wastes in such facility as is provided for by the relevant local Authority.

### 2.6.1 Institutional Framework

Solid waste management (SWM) in the city of Kisumu is the responsibility of the County Government of Kisumu, delegated to the City of Kisumu. In the city administration, the services are provided under the Department of Environment (DOE) which has three sections that directly deal with SWM, namely: Street Sweeping Section, refuse collection section and dumpsite section.

Besides the DOE of the City of Kisumu, Community Based Organizations (CBOs), Non-Governmental Organizations (NGOs) and private companies are involved in various aspects of SWM in the city. The activities mainly range from sorting of waste at source, collection and transportation of waste, disposal site, recycling, and creating awareness on solid waste management. Waste disposal is the responsibility of the city administration. It is estimated that about 35 organizations are involved in solid waste management in Kisumu and that between 10 and 20% of the solid waste produced in the city is collected for disposal (County Government of Kisumu, 2015).

## 2.7 Conceptual Framework

Despite the fact that models and theories are available to estimate and predict solid waste generation in developed countries (Daskapoulos et al., 1998), very little research has been done so far to develop models applicable in developing countries (Jasraj, 2013). It is therefore important to develop solid waste generation models and theories for developing countries, Kenya included. Gay et al., (1993) proposed a solid waste modelling theory where they estimated municipal solid waste generation based on economic sales of a region, a theory they termed as economic input/output analysis which is based on the principle that sales of one sector are the inputs to another.

Brunner and Ernst (1986), however concluded that direct waste analysis (DWA) based on the factor models theory was the most appropriate methodology to determine solid waste generation and determining the relationship between socio-economic and demographic characteristics and solid waste generation. Furthermore, direct waste analysis methodology based on factor models theory has been applied by several studies (Buenrostro et al., 2001; Aisa, 2013; Mohammed et al., 2012; Jonas et al., 2014). This study was therefore, conceptualized based on factor models. Factor models use factors to describe processes of solid waste generation (Salhofer, 2001). Factor models aim at unveiling hypothesized causal relationships between factors for modelling solid waste generation.

There are many sources of solid waste but for the purposes of this study, the researcher concentrated on solid waste generated in households. Determining the quantities of solid waste generated in households is the first step in the household solid waste management system (Kibwage, 1996). Household socio-economic and demographic determinants are key in estimating solid waste generation in households. Solid waste generation in households comprises both the amount and physical components of solid waste generated which vary across different socio-economic groups. Socio-economic groups can be categorized into high, middle and low. Socio-economic group is commonly conceptualized as the social standing or class of an individual or group and it connotes a household's position in the social hierarchy, how the hierarchy is structured and very often ones' consequent life chances (Jonas et al., 2014).

According to EPA (1989), solid waste characterization refers to the determination of quantities (amount) and physical components of solid waste generated in households and this can be determined either in terms of weight in kilograms or volume in cubic centimeters. The physical components of solid waste generated in households normally vary from place to place due to several factors like consumption patterns, frequency of shopping by households, environmental awareness, socio-economic group and knowledge of solid waste recovery and recycling. Furthermore, the physical components of solid waste generated in households as well as their quantities can also be determined by several factors such as education level, gender and employment sector. In this study the physical components of solid waste generated in households was categorized into organic waste, plastic waste and miscellaneous waste. Household size, household monthly income, household monthly expenditure on food and age of the household head are highly and positively correlated to the amount of solid waste generated in households and hence they can be used to explain variations in solid waste generation in households across all socio-economic groups. Furthermore, the study was conceptualized on the basis that there were differences in the means of volumes of physical components (solid waste fractions) generated in households in the three socio-economic groups. The conceptual framework is presented in figure 1.

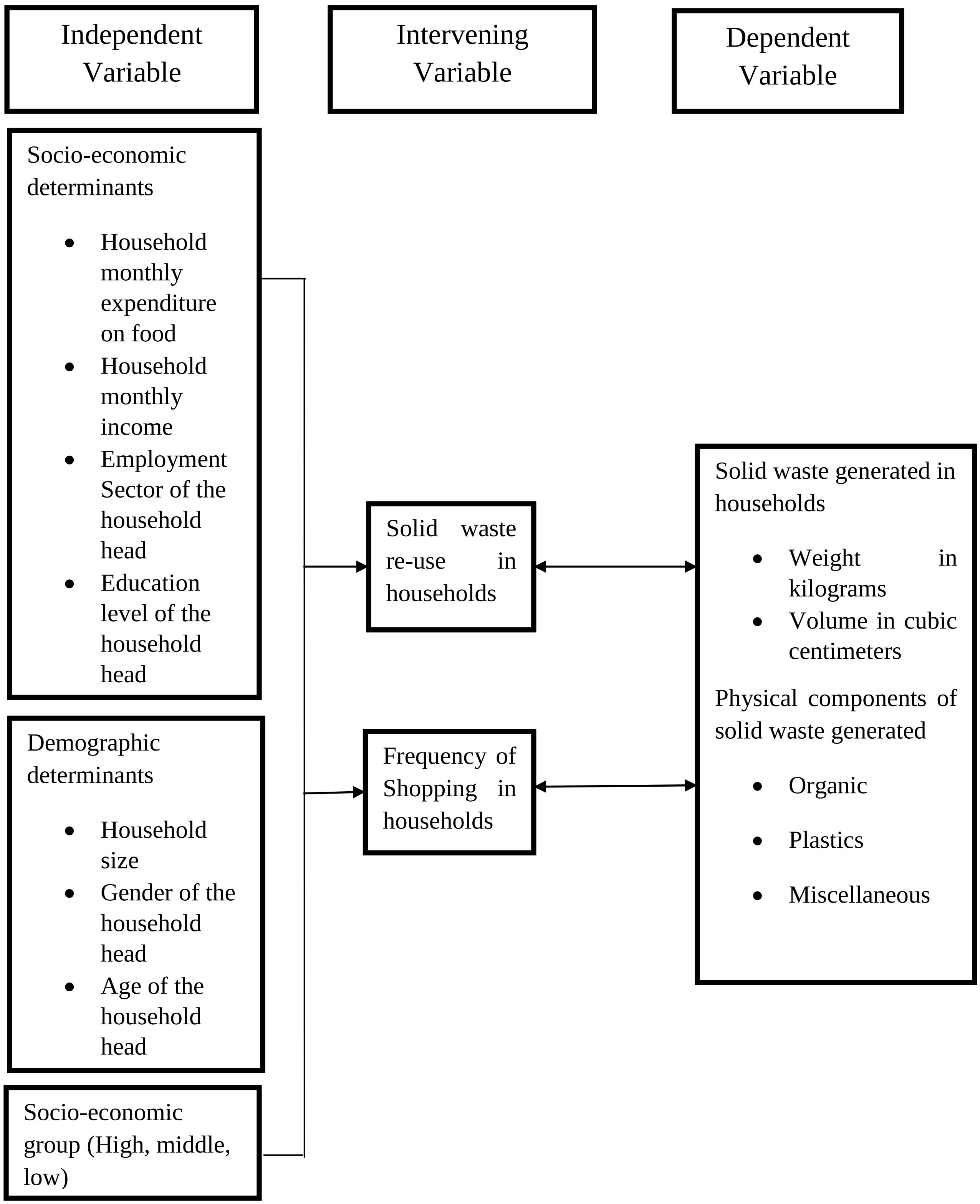


**Figure 1: Conceptual framework of the study**

**Source: Researcher, 2015**

## CHAPTER THREE

## METHODOLOGY

### 3.1 Introduction

This Chapter presents the methodology of the study. The chapter first gives information on the study area highlighting the geographical location and size of Kisumu County and then narrowing down to Kisumu city. Secondly, it highlights the socio-economic and demographic characteristics that are relevant to the study. Similarly, it provides the study design, study population, sampling procedures, data collection, data analysis and presentation, validity and reliability of research instruments as well as the ethical considerations of the study.

### 3.2 Study Area

#### 3.2.1 Geographical Location and Size

Kisumu County covers a total land area of 2085.9 $km^2$ and 567 $km^2$ covered by water (Kisumu county, CIDP, 2103-2017). It borders Homa Bay and Kisii Counties to the south, Nandi County to the north east, Kericho County to the east, Vihiga County to the North West and Siaya County to the west. The County is divided into six sub-counties namely: Kisumu East, Kisumu West, Kisumu North, Nyando, Nyakach and Muhoroni.

Kisumu city is located in Kisumu County and serves as both as the County headquarters and the principal city in the region (NEMA, 2003). It is the third largest city in Kenya and one of the fastest growing cities in the country. It located on the shores of Lake Victoria, the second largest fresh water lake in the world and covers an area of approximately 417 $Km^2$, 35.5% of which is under water (NEMA, 2003). Kisumu city lies between latitude $00^o$ 02'N; $00^o$11'S and longitude $34^0$35'E and $34^0$55'E at an elevation of 1,131 meters above sea level.

Figure 2 shows the map of Kisumu city as well as the map of Kenya showing the location of Kisumu city.

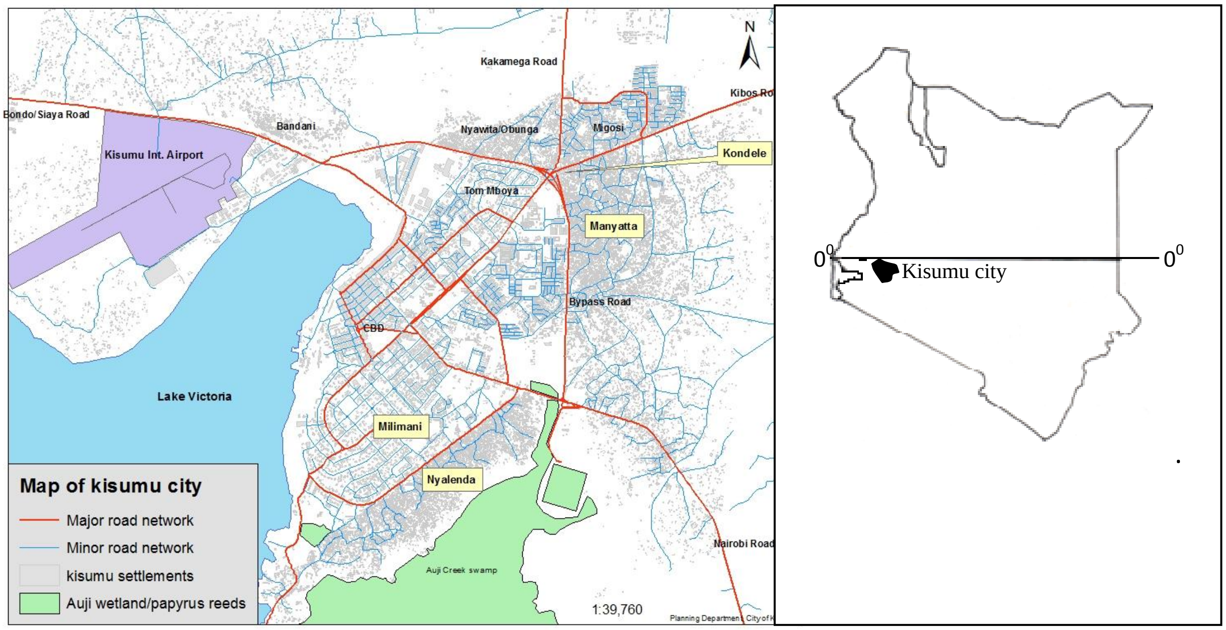


**Figure 2: Map of Kisumu city and a Map of Kenya showing the position of Kisumu city (County Government of Kisumu (GIS Department), 2015).**

### 3.2.2 Demographic Characteristics

The estimated population of Kisumu County according to the 2009 Kenya Population and Housing Census was 968,909 persons (474,687 males and 494,222 females) which was projected to rise to 1,145,747 by 2017. The county has an average population density of 482 persons per square kilometers (Kisumu County Household Baseline Survey Report, 2014). According to the 2009 Kenya Population and Housing Census, Kisumu city had a population of 259,258 persons (131,062 males and 128,196 females) which was projected to rise to 491,893 persons (248,666 males and 243, 228 females) with a population density of 559.2 square kilometers and a total of 115, 502 households by 2017 (Kisumu County Integrated Development Plan 2013-2017).

Rapid population growth in Kisumu County is largely a result of high fertility, which is currently 4.8 children per woman, compared to a national average of 4.6 children per woman. This number has declined from 5.6 children per woman in 1998, mostly because of increasing demand for smaller families and use of modern contraception (Population Action International, 2015). Currently, the county's population is dominated by young people who need to be supported by those in the workforce (Kisumu county household baseline survey report, 2014).

### 3.2.3 Socio-economic Characteristics

The Central Business District of Kisumu is rather small and relatively well planned with government buildings, industries, commercial centers and some residential areas (CCK, 2004). Most of the peri-urban areas are unplanned, densely populated and low income whereas some smaller peri-urban planned residential areas have lower population density with high income (CCK, 2004). Kisumu city is occupied predominantly by low income households, with more than 50% of the population categorized as poor (CCK, 2004). The population who are food poor stands at 61% (Kisumu county household baseline survey report, 2014). The city generates an average of 385 tons of waste per day and only 25% is effectively collected (Munala and Moirongo, 2011). The rest end up in the backstreets, markets, road sides and open spaces more so in the informal settlement since Kisumu city lacks a comprehensive response to solid waste management (Obera and Oyier, 2002). Coupled with this, there is a poor attitude towards waste management and low capacity to offer waste services by Kisumu city management (Kisumu City Development Strategy, MCK, 2014).

### 3.2.4 Estates in Kisumu City

Twenty eight estates were selected purposively and categorized into high, middle and low socio-economic groups (Appendix VI). Classification of estates into different socio-economic groups was done based on a hierarchy classification system borrowed from Isaac et al., (2013), Jonas et al., (2014) and Kodwo et al., (2015). Socio-economic group is commonly conceptualized as the social standing or class of an individual or group (Jonas et al., 2014). It connotes a household's position in the hierarchy, how the hierarchy is structured, and very often individual's consequent life chances (Jonas et al., 2014). Some of the socio-economic facilities considered include quality of road network, housing facilities, water and sanitation facilities, friendship networks, power, money, material goods, access to quality services like health, education, communication, security, transportation, commerce and commerce (Kodwo et al., 2015). This classification system was adopted for the study since decisions on service delivery and supply of solid waste management facilities are based on these proposed classifications.

A summary of the main features of the settlement hierarchy with this system of classification are summarized in Table 1.

**Table 1: Criteria for classification of estates according to socio-economic group using a hierarchy system borrowed from Isaac et al., (2013), Jonas et al., (2014) and Kodwo et al., (2015)**

| Socio-economic group | Features considered in classification |
|---|---|
| **High** | - Good, tarmacked roads<br>- Reliable social amenities e.g. water, electricity supply, security, well planned houses<br>- Houses are often detached single or storey buildings<br>- Large compounds<br>- The compounds are either paved or grassed<br>- Mostly occupied with families with small household sizes<br>- Securely fenced compounds |
| **Middle** | - Mostly characterized by flats, apartments and bungalows<br>- Buildings normally occupied by more than one household<br>- Buildings are either semi-detached or detached with paved compounds<br>- Occasionally with large backyards<br>- Relatively some level of improved social amenities |
| **Low** | - Poor social services and amenities<br>- Mainly located in slum areas and informal settlements of cities<br>- Buildings vary from storey or detached to squatting shacks |

### 3.3 Research Design

The research design was cross-sectional descriptive research and used quantitative tools of data collection and analyses. The design by virtue of being cross-sectional gave a representation of the whole population with minimum bias. Descriptive research is a process of collecting data in order to answer questions concerning the current situation (Mugenda and Mugenda, 2003).

### 3.4 Sampling Procedures

#### 3.4.1 Study Population

The target population of the study was 115, 502 households in Kisumu city. Out of the possible twenty eight estates, three were selected for this study. However, there was no biasness resulting from selection of the three estates since they were selected through multi-stage simple random sampling to represent the three socio-economic groups of high, middle and low. Milimani, Migosi and Obunga estates were selected to represent high, middle and low socio-economic groups respectively. The total number of households in the selected estates was 8651 which made the study population. Selection of estates according to socio-economic groups was done based on a classification system borrowed from Jonas et al., (2014) and Kodwo et al., (2015).

Table 2 shows the number of households under each strata (estate) totaling up to the entire study population of 8651 households.

**Table 2: The number of households in each socio-economic group**

| Socio-economic group | Total number of households |
|---|---|
| High (Milimani) | 1302 |
| Middle (Migosi) | 4795 |
| Low (Obunga) | 2554 |
| **Total (Study Population )** | **8651** |

### 3.4.2 Sample Size Calculation

Fishers et al., (1984) formula for sample size calculation when the study population is less than 10,000 was used at 95% confidence level.

$$N_f = \frac{n}{1 + n / N}$$ Fishers et al., 1984

Where;

$n_f$ = the desired sample size when population is less than 10,000

n = the desired sample size when population is more than 10,000 (usually 384)

N= Estimated population size

$$n_f = \frac{384}{1 + (384/8651)}$$

$n_f$ = 368

The sample size of the study was 368 households. A stratified proportionate random sample of 368 households was selected. The number of households to be interviewed within each sampling unit (strata) was selected proportionally based on the number of households within each sampling unit /strata (socio-economic group). Households within each sampling unit/strata were selected through simple random sampling. The study had two units of analysis i.e. households and household heads. Household heads were selected purposively from each household under study and questionnaires administered. Table 3 gives the sampling frame indicating the number of households studied under each strata and this was calculated proportionately based on the study population.

**Table 3: A sampling frame indicating the number of households sampled under each strata**

| Socio-economic group | Total number of households (Study Population) | Total number of household sampled (Sample size) |
|---|---|---|
| **High (Milimani)** | 1302 | 55 |
| **Middle (Migosi)** | 4795 | 204 |
| **Low (Obunga)** | 2554 | 109 |
| **Total** | 8651 | 368 |

### 3.4.3 Sampling Strategy

The study utilized both multi-stage simple random sampling and stratified proportionate simple random sampling. Estates to be studied were selected through multi-stage simple random sampling while the households to be studied were selected through stratified proportionate simple random sampling. Respondents (household heads) were selected purposively from all the households under study in all the socio-economic groups. Multi-stage simple random sampling refers to a sampling technique which divides large heterogenous populations into clusters with similar characteristics to make sampling more practical and accurate. In this case, estates were clustered into three different socio-economic groups of high, middle and low. Thereafter one estate was selected through simple random sampling from each cluster to form part of the study. Stratified proportionate simple random sampling is a probability sampling technique where a researcher divides the entire population into different sub-groups then randomly selects the final subjects proportionally from the different strata. The sample size of each stratum is proportionate to the population size of the stratum.

## 3.5 Data Collection

The study relied on primary data. Primary data was necessary to establish the amount of solid waste generated in households. Furthermore, primary data was necessary to establish the physical components (solid waste fractions) of solid waste generated in households under study. Primary data was also necessary to establish specific household socio-economic and demographic determinants of solid waste generated in the households under study.

### 3.5.1 Instruments for Data Collection

#### 3.5.1.1 Household Survey Questionnaires

Data was obtained using structured and semi-structured questions. Questionnaires were administered to households across three socio-economic groups. The questions aided in maintaining focus on relevant questions and were useful in obtaining information on specific socio-economic and demographic variables under study. In all cases, questions were administered to obtain precise data on household size, household monetary income, household monthly expenditure on food, age of the household head, education level of the household head, employment sector of the household head ,gender of the household head, frequency of shopping by households and re-use of solid waste generated by households. The questions were administered in households in estates in all the three socio-economic groups and answers captured appropriately. The questionnaire was extensively pre-tested for clarity and comprehensiveness.

#### 3.5.1.2 Direct Waste Analysis Guide

Direct Waste Analysis (DWA) guide was used as a tool to determine solid waste generation in households. DWA guide is a solid waste characterization tool which is used to determine the quantities and physical components of solid waste generated and this is done through direct waste weighing, direct waste volume estimation and direct waste sorting (Jonas et al., 2014).

##### 3.5.1.2.1 Direct Waste Weighing

Direct waste weighing involved each selected household being provided with plastic bags to keep all their waste generated for one week (7 days). Solid waste generated in households was weighed using a capacity portable weighing machine and weights recorded. This enabled the researcher to establish the quantities of solid waste generated in households in Kisumu city and this aided in establishing the relationship between household socio-economic and demographic characteristics and solid waste generation in households in estates in Kisumu city. This also aided in determining the appropriate household socio-economic and demographic determinants for modelling solid waste generation in households in estates in Kisumu city.

##### 3.5.1.2.2 Direct Waste Sorting

Direct waste sorting involved sorting of solid waste generated in households into three pre-determined solid waste fractions namely organic waste, plastic waste and miscellaneous waste. This was done despite the fact that initial separation of solid waste was done at the household level using the colour-coded plastic bags provided by the researcher. Direct waste sorting was necessary for accuracy purposes. Each solid waste sample was weighed separately and its weight recorded. This enabled the researcher to establish the physical components of solid waste generated in households in Kisumu city and this aided in establishing the association between socio-economic and demographic determinants and physical components of solid waste generated in households in Kisumu city. This also aided in determining the appropriate socio-economic and demographic determinants for modelling solid waste generation in households in estates in Kisumu city.

#### 3.5.1.2.3 Direct Waste Volume Estimation

A wooden box in the shape of a cube with calibrated measurements of 50cm by 50cm by 50cm was used to determine the volume of the physical components of solid waste generated in households. Solid waste physical components were poured into the wooden box, compacted and height readings taken and recorded. Volume of the solid waste generated in households was calculated by the following formula;

Volume = Length X Width X Height

Since the length and width were constant, volume of solid waste generated in households was therefore calculated by:

Volume in cubic centimeters ($Cm^3$) = 50 X 50 X Height

#### 3.5.1.3 Observation Guide

An observation guide was used in order to understand the characteristics of solid waste generated in households. Direct observations were mandatory and were used in data collection at all sampling points. Observations and recording data related to physical characteristics of solid waste generated in households in estates in Kisumu city was done.

#### 3.5.1.4 Key Informant Interview Guide

A key informant interview guide was used in order to understand roles and activities of private waste collectors and youth groups in handling of solid waste generated and how these activities influenced solid waste generation in households in the estates sampled. Interview guides were used to obtain specific information on recovery of solid waste generated in households, their involvement in minimization of solid waste generation in households through activities like community participation and education of household members.

### 3.5.2 Procedure for Data Collection

This section describes how data was collected using the instruments of data collection discussed in section 3.5.1.

#### 3.5.2.1 Structured Household Survey Questionnaires

Structured household questionnaires were administered to the household heads. Questionnaires were administered orally and the researcher captured the respondents' answers appropriately. Questionnaire administration was done between 4.00 PM and 7.00 PM on Monday to Friday and between 2.00 PM and 6.00 PM on Saturdays and Sundays. During the reconnaissance study, it was realized that these were the hours that the household heads were most likely to be available to respond to the questionnaires. Research assistants were trained to enable them administer the questionnaires as required.

#### 3.5.2.2 Direct Waste Analysis

Direct waste analysis is a procedure that was accomplished using a direct waste analysis guide. The equipment and materials to be used were methodology driven. A summary of the equipment used for the direct waste analysis has been given in Appendix II of this research thesis. Solid waste generated in households usually doesn’t contain large amounts of microbes and hazardous materials. Microbes found in solid waste generated in households are commonly as a result of rotting and other chemical reactions majorly from organic solid waste. However, since the period between solid waste generation and direct waste analyses was only seven days, the microbial activity that took place was minimal.

The researcher selected households through simple random sampling in the respective estates. Selected households were provided with three plastic solid waste bags to dispose the solid waste generated. Each household was given three separate plastic waste bags to separately put the already pre-determined solid waste fractions. The plastic solid waste bags provided were labelled with stickers from 1-368 (sample size) for household identity. This labelling enabled matching the direct waste analysis data and the questionnaire data. Similarly, the three plastic waste bags provided by the researcher were of three different colors which enabled the household members to segregate solid waste generated into three different physical components as shown in Table 4. The plastic solid waste bags were labelled; Black (Organic waste), Blue (Plastic) and Yellow (Miscellaneous) as shown in Table 4.

**Table 4: Sort categories showing the three pre-determined fractions of the physical components of solid waste generated in households in Kisumu city. Adopted from Jonas *et al* ., 2014; EPA(1989)**

| Sort categories | Physical components of solid waste generated in households | Selected plastic bag colour coding |
|---|---|---|
| 1. Organic Waste | Food waste, garden trimming, wood | Black |
| 2. Plastics | Any type of polymer content including materials such as PETE, HDPE, LDPE, PVC, PP and other plastic bags and plastic bottles; | Blue |
| 3. Miscellaneous | Glass- Any type of glass bottles, containers, sheets and any other type of glass including broken bottles | Yellow |
| | Paper and cardboards- Any type of paper such as newspapers, wrapping materials, paper packaging materials etc | |
| | Metals- Any scrap metals and aluminium cans | |
| | e-waste- anything electronic such as mobile phones, batteries, TV, computer accessories etc | |
| | Textile- Any cloth like material | |
| | Any other materials whose nature could not be immediately determined | |

Distribution of plastic solid waste bags to selected households was done with the help of private solid waste collection companies and youth groups charged with solid waste collection in those estates. Households were advised that apart from the polythene solid waste bag provided, there was need to invest in a container with a tight lid for placing the solid waste generated to prevent spillages, flies and other vermin as well as odour coming from the solid waste. The plastic solid waste bags given to the households were collected after 7 days, for example, households received plastic solid waste bags on a Saturday and they were collected the following Saturday. Collection of plastic solid waste bags was done between 8 and 11.00 AM. During collection of the plastic solid waste bags, new (empty) bags were given to the households to start fresh collection of solid waste and these too were collected after 7 days. This exercise was done four times, hence, the researcher collected solid waste generation data four times from each household. The Household members were provided with gloves to ensure that they did not handle solid waste directly with their bare hands.

Field assistants were engaged and they were utilized in collection of solid waste generated from respective households, sorting, weighing and handling of solid waste generated prior to final disposal. Field assistants were trained on proper handling of solid waste to minimize public health issues such as spillages of solid waste among others. Field assistants were provided with personal protective equipment (PPE) such as gas masks, gloves, gum-boots, overalls and head gear to ensure their safety while handling the solid waste. Solid waste collected from households in Migosi and Obunga was transported using handcarts to solid waste transfer stations within the estates for sorting, weighing and recording of quantities. Solid waste collected from households in Milimani was transported using pick-ups to '*Kachok'* dump site for weighing, sorting and recording since Milimani doesn't have a solid waste transfer station. Extra plastic solid waste bags were provided in case of tears and damage to initially provided bags. This prevented spillages of solid waste during transport from households to solid waste transfer stations. Caution was taken to ensure that solid waste from households is contained within the transfer stations during direct waste analysis.

#### 3.5.2.2.1 Direct Waste Weighing

Solid waste generated in households was transported to various solid waste transfer stations for weighing. Solid waste generated from each household was weighed using a capacity portable weighing machine and weights recorded. Direct waste weighing was done separately for each physical component of solid waste generated since they had been segregated at the point of generation (households). The total amount (weight in kilograms) of solid waste generated per household was calculated as shown below:

Total amount (weight in kilograms) of solid waste generated in households = Amount of organic solid waste generated (weight in kilograms) +Amount of plastic solid waste (weight in kilograms) + Amount of miscellaneous solid waste (weight in kilograms).

**3.5.2.2.2 Direct Waste Sorting**

Direct waste sorting was done at selected solid waste transfer stations for each estate. A large canvas material was spread on the ground surface where solid waste generated from households was poured and spread on during sorting. This was done separately for each and every household. The use of canvas was necessary to prevent solid waste from spilling on the ground. Once the analysis was complete, the solid waste generated from households was collected and put in new plastic solid waste bags and tied tightly to ensure there were no spillages. Solid waste was then placed at designated points within the transfer station awaiting final disposal to *Kachok* dumpsite. Transportation to the final disposal point was done using a hired pick-up.

**3.5.2.2.3 Direct Waste Volume Estimation**

A wooden box in the shape of a cube with calibrated measurements of 50cm by 50cm by 50cm was used to determine the volume of the physical components of solid waste generated in households. Solid waste from households was poured into the wooden box and compacted. Height readings of the compacted solid waste were taken and recorded. Volume of solid waste generated from households was calculated using the following formula;

Volume = Length X Width X Height

Since the length and the width were constant, the volume of solid waste generated from households was therefore calculated by:

Volume in cubic centimeters ($Cm^3$) = 50 X 50 X Height

#### 3.5.2.3 Observations

Observations were done using an observation guide. Directs observations were made during direct waste sorting and this enabled the researcher to establish the physical components of solid waste generated in households. Once observations were made, data on the physical components of solid waste generated were recorded based on the three pre-determined solid waste fractions of organic, plastic and miscellaneous solid waste.

#### 3.5.2.4 Key Informant Interviews

Key informant interviews were done using key informant guides. Three key informants involved in collection of solid waste generated in households in Milimani, Migosi and Obunga were selected and interviews conducted. In-depth interviews were conducted on days when waste collection was being undertaken which were Fridays, Saturdays or Sundays.

## 3.6 Data Analyses and Presentation of Results

Both qualitative and quantitative techniques were used in data analyses. Household survey questionnaires were grouped according to socio-economic group.

The researcher created notes of outstanding points for qualitative data analysis; field notes were edited and cleaned up as the researcher organized the work and later categorized them to themes in line with study objectives and the data were analyzed.

Pearson product moment correlation was used to analyze quantitative data on household size, household monthly expenditure on food, household monthly income and age of the household head and establish their relationship with the amount of solid waste generated in households. Chi-square test of independence was used to analyze quantitative data on gender of the household head, education level of the household head and employment sector of the household head and establish their association with the physical components of solid waste generated in households. Furthermore one way ANOVA (α0.05) was conducted to establish the association between socio-economic group and the volume of the physical components of solid waste generated in households while a multiple linear regression model adapted from Buenrostro et al., (2011) was used to predict the amount of solid waste generated in households.

Equation 1 shows a predictive model on which the multiple linear regression analysis was based.

$S_{wg}= \beta_0+\beta_{Hs} X_{Hs} +\beta_{Hmi} X_{Hmi} + \beta_{Hmef} X_{Hmef}+\beta_{Ahh} X_{Ahh} + \varepsilon$ ………………………………..equation 1

Where;

$S_{wg}$= Dependent variable (Amount of solid waste generated in households in kilograms)

$\beta_{0}$ = Intercept

$\beta_{Hs}$, $\beta_{Hmi}$, $\beta_{Hmef}$ and $\beta_{Ahh}$ = The slope and it indicates the average change in the response variable when the random variable rises

$\varepsilon$ = The term of the average random error

$X_{Hs}$, $X_{Hmi}$, $X_{Hmef}$ and $X_{Ahh}$ = Coefficients of the explanatory variable where;

$X_{Hs}$ = Household size

$X_{Hmi}$ = Household monthly income

$X_{Hmef}$ = Household monthly expenditure on food

$X_{Ahh}$ = Age of the household head

Results obtained from qualitative data analysis were presented inform of narrative and descriptions while those from quantitative data analysis were presented inform of tables and bar graphs.

### 3.7 Validity and Reliability of the Instruments

The validity and reliability of research instruments used for data collection was tested as explained below.

#### 3.7.1 Validity of the Instruments

According to Robson (2011), validity is the ability of a measure to measure what it is supposed to measure. Mohajan (2017) further explains that validity indicates how well the data collection and data analysis of the research captures the reality being studied. Burns (1999) emphasizes that validity is an essential criterion for evaluating the quality and acceptability of research. For this study, content validity was used to ensure all components relevant to the study were included in the instruments of data collection and thus no component was neglected. According to Markus and Smith (2012) content validity refers to the extent to which the items on a test are fairly representative of the entire domain the test seeks to measure. Normally, content validity is ensured by obtaining subjective judgments by experts in the concerned field who judge the survey's appearance, relevance and representativeness of its elements (Bryman and Bell, 2003:

Mugenda and Mugenda, 2003). Therefore, to ensure that all the components relevant to the study were included in the data collection instruments, two supervisors from the School of Environment and Earth Sciences with relevant skills in the field of study as well as the school post-graduate board assessed the content of the instruments and feedback was given. The feedback was incorporated in the final instrument before the actual study.

### 3.7.2 Reliability of the Research Instruments

Reliability is the measure of the degree to which an instrument yields consistent results when the entity being measured hasn't changed (Bless et al., 2006). Reliability deals with the consistency, dependability, and replicability of the results of any research (Neuman 2012). Reliability indicates that the scores of an instrument are stable and consistent (Creswell 2009). Kottner et al., (2011) further defines reliability as the capacity of a test to replicate the same ordering between respondents when measured twice. According to Ary et al., (1996), pre-testing is the best way to minimize ambiguity, enhance clarity and ascertain responses to the style and content of the questions. Test–retest is a term used to describe the properties of measurement tools evaluated twice on different time occasions (Andre, 2016). Test–retest reliability or reproducibility is therefore, a method of estimating a tool's reliability by administering it to the same person or a group of people, in the same way, on two or more different occasions, hours or days apart (Watkins, 2000). The test-retest technique of reliability testing was employed whereby the reconnaissance questionnaires were administered twice to 10% (37) of the respondents then a correlation coefficient of the scores from Time 1 and Time 2 computed. A pearson product correlation coefficient (r) of 0.81 was obtained. According to Colin and Julie (2006), a minimum correlation coefficient (r) of 0.75 is recommended and is a sufficient indicator that the research instrument is reliable. The research instrument was therefore found to be reliable as the computed correlation coefficient (0.81) was found to be within the expected range of the correlation coefficient (0.75). The respondents that were sampled during the reconnaissance were noted to avoid re-sampling during the actual study.

### 3.8 Ethical Considerations

The study was initiated by the researcher and approved by the school of graduate studies (SGS), Maseno University, Kenya.  The study first sought the informed consent of relevant stakeholders on the intention to conduct research. In addition to this, confidentiality or anonymity of respondents was respected by giving them an option not to publish/capture their names in the research tools and assuring them that the information would be used only for purposes of the study. Voluntary participation of the respondents was also be ensured. A copy of the informed consent form is attached in appendix I of this research thesis.

# CHAPTER FOUR

# RESULTS AND DISCUSSIONS

## 4.1 Introduction

This Chapter presents and discusses the main findings of the study. The Chapter is divided into five sections. The first section analyzes the relationship between household monthly expenditure on food, household size, household monthly income and age of the household head on the amount (weight in Kilograms) of solid waste generated in households in estates in Kisumu city. The second section determines the relationship between education level of the household head, employment sector of the household head and gender of the household head and the physical components of solid waste generated in households in estates in Kisumu city. The third section establishes the association between socio-economic group and the quantities of the physical components of solid waste generated in households in estates in Kisumu city while the fourth section determines the appropriate socio-economic and demographic determinants for modelling solid waste generation in households in estates in Kisumu city.

## 4.2 Relationship between Socio-economic and Demographic Determinants and the Amount of Solid Waste Generated by Households

Pearson product moment correlation analysis was conducted to determine the relationship between the amount of solid waste generated in households in kilograms and household socio-economic and demographic determinants namely; household size, household monthly income, household monthly expenditure on food and age of the household head in the high, middle and low socio-economic groups in Kisumu city.

### 4.2.1 Household Size and amount of Solid Waste Generated in Households in Estates in Kisumu City

The relationship between household size and the amount of solid waste generated in households in the high, middle and low socio-economic groups was determined as shown in Table 5. Table 5 further gives the mean household size in the three socio-economic groups.

**Table 5 : Pearson Product-Moment Correlation (r) coefficient between the amount of solid waste generated in households in kilograms and household size in estates in Kisumu city**

| Socio-economic group | Mean household size | Correlation coefficient (r) |
|---|---|---|
| High (*n=55) | 5 | 0.921 |
| Middle (*n=204) | 5 | 0.977 |
| Low (*n=109) | 5 | 0.957 |

*number of households sampled

Statistically significant at 95% confidence level

According to the household survey, the average household size from the sampled population was 5 in all socio-economic groups (Table 5). Household size is measured by the number of family members living under one roof (WHO, 2011). The average national household size for the urban population in Kenya is 4 people (KNBS, 2015) which is closer to the average household size of the study area (Table 5). The average family size of the urban population of Ethiopia is 4.8 (CSA, 2007). Sub-Saharan Africa and Asia have an average household size of 5.1 and 5.3 respectively (John, 2001).

According to results in Table 5 the amount of solid waste generated in households was strongly and positively correlated with household size in the high (r=0.921), middle (r=0.977) and low (r=0.957) socio-economic groups in Kisumu city significant at 95% confidence level. The results imply that an increase in the household size leads to an increase in resource consumption leading to an increase in the household commodities purchased and hence an increase in the amount of solid waste generated in households. This concurs with a study by Singh et al., (2014) who found a strong positive relationship (r= 0.876) between household size and the amount of solid waste generated in households. Comparatively, Sankoh et al., (2012) conducted a study in Freetown Sierra Leone and found a strong positive relationship (r= 0.9914) between household size and the amount of solid waste generated in households. Similarly, Monavari et al., (2012); (Mohd et al., 2010) and Dangi (2009) also found a strong positive relationship between household size and the amount of solid waste generated in households.

However, Aisa (2013) found a weak positive correlation between household size and the amount of solid waste generated in middle income households (r= 0.219) and low income households (r= 0.138). Studies by Jenkins, 1993; Hong, 1999; Hong and Adams, 1999; Jenkins et al., 2003; Ojeda-Benitez et al., (2008) and Qu, et al., (2009) also did not concur with results in Table 5 by establishing that as household size increases, the amount of solid waste generated in households has been found to decrease. According to Ojeda-Benitez et al., (2008), the reason for these contrasting results could be attributed to several factors such as the sample size, knowledge of solid waste re-use and reduction in households as well as the unit of analysis. Nick and Julien (2013) for instance, noted that tendency to conserve on packaging for consumer items such as food and beverages which are purchased in larger quantities for larger family sizes could also be a reason for a negative correlation between household size and the amount of solid waste generated in households. Solid waste reduction activities in households such as solid waste re-use and minimization, knowledge, attitudes and perceptions towards solid waste management are factors that can also lead to contrasting results (Nick and Julien, 2013). Furthermore, (Aisa, 2013) only sampled 75 households out of a study population 4659 which is a relatively small sample in comparison to the study population. Aisa (2013) noted that from a statistical point of view, the accuracy of determining parameters for solid waste generation in households increases with an increase in the number of samples analyzed. Results in Table 5 were obtained from solid waste characterization data collected at the household level and at individual households before the solid waste samples got mixed with other waste samples from the municipal solid waste stream.

### 4.2.2 Household Monthly Income and the Amount of Solid Waste Generated in Households in Estates in Kisumu City

The relationship between household monthly income and the amount of solid waste generated in households in the high, middle and low socio-economic groups was determined as shown in Table 6. Table 6 further tabulates the mean household monthly income in the three socio-economic groups.

**Table 6: Pearson Product-Moment Correlation (r) coefficient between household monthly income and the amount of solid waste generated in households in estates in Kisumu city**

| Socio-economic group | Mean household monthly income in **Kshs | Correlation coefficient (r) |
|---|---|---|
| High (*n=55) | 57555 | 0.939 |
| Middle (*n=204) | 17333 | 0.938 |
| Low (*n=109) | 15130 | 0.981 |

*number of households sampled ** Kenya shillings

Statistically significant at 95% confidence level

According to the household survey, the average household monthly income from the sampled population was Kshs. 57555, 17333 and 15130 in the high, middle and low socio-economic groups respectively (Table 6). Mwangi (2011) established that majority of households in Makina, Kibera which is a low socio-economic group earned between Kshs.5000 to 18,000 per month. According to the Kenya Integrated Household Budget Survey (2015), the mean household monthly income in urban households in Kenya was Kshs. 10, 000. Results (Table 6) revealed that the amount of solid waste generated in households was strongly and positively correlated with household monthly income in the high (r = 0.939), middle (r = 0.938) and low (r = 0.981) socio-economic groups, significant at 95% confidence level. These results imply that an increase in household monthly income increases the purchasing power which in turn leads to an increase in consumption of goods and services leading to an increase in the amount of solid waste generated in households. Increase in household monthly income is therefore expected to lead to an increase in the amount of solid waste generated in households.

Individuals with high income have a high purchasing power therefore they consume more than individuals with low income (Grover and Singh, 2014) making household monthly income one of the most significant factors affecting the quantity of solid wastes generated from household consumption (Richardson and Harvileck, 1978; Sudhir et al., 1997). Results in Table 6 concur with results from a study by Mohamed et al., (2012) which established that there was a strong positive correlation between household monthly income and the amount of solid waste generated in households (r= 0.87). Results in Table 6 implied that as households earned more money per month, they had a tendency to generate larger quantities of solid waste each day. This positive correlation between household monthly income and the amount of solid waste generated by households was also found in a research conducted by Sujauddin et al., (2008). Comparatively, Sankoh et al., (2012) found a strong positive relationship (r= 0.921) between household monthly income and amount of solid waste generated in households in Freetown Sierra Leone. Results from a study by Aisa (2013), however, found a weak negative relationship between household monthly income and the amount of solid waste generated in households in the middle socio-economic group (r=-0.108) and low socio-economic group (-0.096) households in Kinondoni municipality, Dar es Salam. Aisa (2013) attributed these unexpected results partly to difficulties in establishing the actual income of households in Kinondoni municipality.

### 4.2.3 Household monthly expenditure on food and the amount of solid waste generated in households in urban estates in Kisumu city

The relationship between household monthly expenditure on food and the amount of solid waste generated in households in the high, middle and low socio-economic groups was determined as shown in Table 7. Table 7 further tabulates results of the mean household monthly expenditure on food in the three socio-economic groups.

**Table 7: Pearson Product-Moment Correlation (r) coefficient between household monthly expenditure on food and the amount of solid waste generated in households in estates in Kisumu city**

| Socio-economic group | Mean household monthly expenditure on food in *Kshs | Correlation coefficient (r) |
|---|---|---|
| High (*n=55) | 17509 | 0.978 |
| Middle (*n=204) | 15102 | 0.990 |
| Low (*n=109) | 8314 | 0.931 |

*number of households sampled **Kenya shillings

Statistically significant at 95% confidence level

According to the household survey, the mean household monthly expenditure on food of the sampled population was Kshs. 17509, 15102 and 8314 in the high, middle and low socio-economic groups respectively (Table 7). According to Kenya Integrated Household Budget Survey, poor households in urban areas spend 57% of their income on food while the non-poor urban households spend 44% (Kamau et al., 2011). Households in urban areas spend an average of Kshs. 11, 155 on food, however, this increase with household income (Kamau et al., 2011). Based on these results from previous studies, (Kamau et al., and 2011), household monthly expenditure on food takes a huge portion of the monthly expenses.

According to the results in (Table 7), the amount of solid waste generated in households was strongly and positively correlated with household monthly expenditure on food in the high ($r = 0.978$), middle ($r = 0.990$) and low ($r = 0.931$) socio-economic groups, significant at 95% confidence level. Food is a commodity which is consumed on a daily basis. It is therefore expected that as household expenditure on food increases the amount of solid waste generated in households will also increase. Previous studies have shown that food waste make up the largest fraction of solid waste stream in households (Aisa, 2013; Jonas et al., 2014; Mohammed et al., 2012; Yemadje et al., 2013).

There are hardly any studies on the relationship between household expenditure on food and the amount of solid waste generated in households. This raises serious concerns bearing in mind that previous studies have established that food waste make up the largest fraction of solid waste stream in households. Sing et al., (2014) revealed that expenditure on food accounted for the highest (26.9%) in households in Iskandar, Malaysia. Singh et al., (2014) found a significant positive relationship between the amount of solid waste generated in households and household expenditure. Thanh et al., (2010) found a significant positive relationship between the amount of solid waste generated in households and household expenditure. Results in Table 7 therefore, bridge an important gap in knowledge by providing key information which despite its relevance has been ignored by previous studies on the relationship between household socio-economic characteristics and solid waste generation.

### 4.2.4 Age of the Household Head and the Amount of Solid Waste Generated in Households in Estates in Kisumu City

The relationship between age of the household head and the amount of solid waste generated in households in the high, middle and low socio-economic groups was determined and results tabulated in Table 8. Table 8 further presents the mean age of the household head in the three socio-economic groups.

**Table 8: Pearson Product-Moment Correlation (r) coefficient between the age of the household head and the amount of solid waste generated in households in estates Kisumu city**

| Socio-economic group | Mean age of the household head in years | Correlation coefficient (r) |
|---|---|---|
| High (n=*55) | 42 | 0.939 |
| Middle (n*=204) | 36 | 0.876 |
| Low (n*=109) | 35 | 0.920 |

*number of households sampled

Statistically significant at 95% confidence level

According to the household survey, the mean age of household head from the sampled population was 42, 36 and 35 in the high, middle and low socio-economic groups respectively (Table 8). According to the world health organization (WHO), young adults fall between age categories 31-55 years which is the most productive age group in any given scenario (WHO, 2011). It is therefore important  to note that majority of household heads in estates in Kisumu city were within the most productive age group (Table 8) based on the WHO (2011) classification. According to Ojewale (2015), 70.6% of the respondents in a study on socio-economic correlates of solid waste generation in households were young adults between the ages

31-55 years. Ojewale (2015) further revealed that the most dominant age group in Lagos Metropolis in the high, middle and low socio-economic groups were young adults which concurred with results in Table 8. Results in Table 8 revealed that the age of the household head was strongly and positively correlated with the amount of solid waste generated in households in the high (r = 0.939), middle (r = 0.876) and low (r = 0.920) socio-economic groups, significant at 95% confidence level. The results implied that households with older heads were expected to have children and even live with relatives and hence more people living within the household. Similarly, as age of the household head increases, it was expected that one had progressed career wise, business wise or in better paying jobs as compared to households with younger heads who had just started their careers. Increase in the amount of disposable income was in turn expected to lead to an increase in household expenditure and consumption, hence an increase in the amount of solid waste generated in households. Results in Table 8 concur with those from a study by Koushki and Al-Kaleefi (1998) who established that families with older heads generated larger quantities of solid waste each day.

A study by Omole and Alakinde (2013), however, did not concur with results in Table 8 since they established that there was a negative relationship between age of the household head and the amount of solid waste generated in households (r= -0.035). Omole and Alakinde, (2013) explained that this could be attributed to the fact that as the age of the household head increased, there was tendency to re-use some household commodities and also these households tended to purchase in bulk hence, a reduction in the amount of solid waste generated in households. Likewise, Derksen and Gartel (1993) found that as the age of the household head increased, there was a decrease in the amount of solid waste generated in households. The inconsistencies in results arise from the fact that there could be differences in solid waste handling practices in households such as knowledge and awareness on recycling and re-use (Quinn and Nivison-Smith, 2006). Results in Table 8 on the relationship between age of the household head and the amount of solid waste generated in households provide useful information since results have been presented according to three socio-economic groups unlike previous studies where the results were lumped together despite the fact that solid waste generation patterns in households vary across socio-economic groups.

According to the findings in Tables 5, 6, 7 and 8 the amount of solid waste generated in kilograms in households was strongly and positively correlated with household size, household monthly income, household monthly expenditure on food and age of the household head in the high, middle and low socio-economic groups in Kisumu city. This is evidenced by the correlation coefficient (r) of the variables household size, household monthly income, household monthly expenditure on food, age of the household head and the amount of solid waste generated in households which was (>0.87) in all the three socio-economic groups.

## 4.3 Relationship between Socio-economic and Demographic Factors and the Physical Components of Solid Waste Generated in Households in Estates in Kisumu City

A Chi-Square test of independence was done to determine the association between physical components of solid waste generated in households in kilograms and employment sector of the household head, gender of the household head and education level of the household head in the high, middle and low socio-economic groups in Kisumu city.

### 4.3.1 Employment Sector of the Household Head and the Physical Components of Solid Waste Generated in Households

Results of a Chi-Square test of independence between the employment sector of the household head and physical components (organic, plastic and miscellaneous) of solid waste generated in households in the high, middle and low socio-economic groups in Kisumu city are presented in Table 9. Employment sector of the household head was categorized into either formal or informal as presented in Table 9.

**Table 9: Chi-Square test of independence between employment sector of the household head and physical components of solid waste generated in households in Kisumu city**

| Socio-economic group | Employment Sector | | Calculated P - value | Chi-square statistic ($X^2$) |
|---|---|---|---|---|
| | Formal (%) | Informal (%) | | |
| **High** | 89 | 11 | 0.839665 | 0.3495 |
| **Middle** | 87 | 13 | 0.53184 | 5.868 |
| **Low** | 39 | 61 | 0.00001 | 39.8862 |

Significance level = 0.05

Physical components of solid waste generated in households - Organic, plastic and miscellaneous

According to results in Table 9, 89%, 87% and 39% of respondents in the high, middle and low socio-economic groups respectively were employed in the formal sector. Furthermore, 11%, 13% and 61% of respondents in the high, middle and low socio-economic groups were employed in the informal sector. These results revealed that majority of the respondents (61%) in the low socio-economic group were employed in the informal sector while majority of the respondents in the high (89%) and middle (87%) socio-economic group worked in the formal sector. These results imply that household heads in the high and middle socio-economic groups had high levels of education; they were able to acquire professional jobs such as teaching, jobs in the medical field like nursing and doctors which were mostly in the formal sector. On the other hand, in the low socio-economic group, majority of the household heads were unskilled since they had low education levels and hence they worked in the informal sector for example in construction sites, *juakali* sector and hawking of commodities. In a study on municipal solid waste generation in Kumasi, Ghana, Mensah (2010) established that 60% of respondents worked in the informal sector while 30 % worked in the formal sector. Furthermore, over 50 % of residents in Kinondoni municipality in Tanzania relied on informal jobs (Aisa, 2013). Informal jobs include carpentry, mechanics, welding among others (Mwangi, 2011).

In the high socio-economic group, an insignificant interaction was found $\chi^2$ (2) = 0.3495, $p < 0.05$ between employment sector of the household head and physical components of solid waste generated in households. The chi-square statistic was 0.3495 while the calculated p-value was 0.839665. Likewise, in the middle socio-economic group, an insignificant interaction was found $\chi^2$ (2) = 5.868, $p < 0.05$ between employment sector of the household head and physical components of solid waste generated in households. The chi-square statistic was 5.868 while the calculated p-value was 0.53184. However, in the low socio-economic group a significant interaction was found $\chi^2$ (2) = 39.8862, $p < 0.05$ between employment sector of the household head and physical components of solid waste generated in households. The chi-square statistic was 39.8862 while the calculated p-value was 0.00001.

These results revealed that in the high and middle socio-economic groups, the physical components of solid waste generated in households were not dependent on the employment sector of the household head while in the low socio-economic group the physical components of solid waste generated in households depended employment sector. These results imply that in both the high and middle socio-economic groups, consumption patterns were not dependent on the employment sector which was either formal or informal. This meant that the purchasing power, lifestyles and eating habits of these households was not determined by employment sector of the household head. This was attributed to the fact that in both the high and middle socio-economic groups, there were scenarios where the head of the household was in the informal sector like the *juakali* business but then they would be business owners. This meant that they were the decision makers hence; they were still able to have a high income. However, in the low socio-economic group, most of the households who were in the informal sector relied mainly on daily or weekly wages. This therefore, meant that their solid waste generation practices were mainly determined by their earnings for instance, daily wages meant daily purchases in small quantities.

Results in Table 9 concur with results in a study by Afon (2007) who established that employment sector of the household head is one of the socio-economic factors affecting the physical components of solid waste generated in households. Afon (2007) further noted that in essence, the occupation one engages in determined the physical components and the characteristics of solid waste generated in households. Similarly, Sankoh et al., (2012) established that the employment sector had a positive correlation with plastics and paper but a negative correlation with organic waste.

The limitations of these previous studies is that they were not done according to socio-economic group stratification despite the fact that the kind of relationship between the of employment sector and physical components of solid waste generated in households differed according to socio-economic group as evidenced by results from Table 9.

### 4.3.2 Education Level of the Household head and Physical Components of Solid Waste Generated in Households in Kisumu City

The results of a Chi-Square test of independence between education level of the household head and physical components (organic, plastic and miscellaneous) of solid waste generated in households in kilograms in the high, middle and low socio-economic groups in Kisumu city are presented in Table 10. Education level was classified into postgraduate, undergraduate, diploma, secondary and primary as presented in Table 10.

**Table 10: Chi-Square test of independence between education level of the household head and the physical components of solid waste generated in households in Kisumu city**

| Socio-economic group | Education level Post-graduate (%) | Under-graduate (%) | Diploma (%) | Secondary (%) | Primary (%) | Calculated P - value | Chi-square statistic ($X^2$) |
|---|---|---|---|---|---|---|---|
| **High** | 42 | 46 | 12 | - | - | 0.730484 | 2.0287 |
| **Middle** | 9 | 39 | 48 | 4 | - | 0.402499 | 6.1877 |
| **Low** | 6 | 14 | 46 | 32 | 2 | 0.00001 | 46.7924 |

Significance level = 0.05

Physical components of solid waste generated in households- Organic, plastic and miscellaneous

Results in Table 10 revealed that in the high socio-economic group, 42%, 46% and 12% of household heads had postgraduate, undergraduate and college levels of education respectively. Furthermore, in the middle socio-economic group, 9%, 39%, 48% and 4% of household heads had postgraduate, undergraduate, college and secondary levels of education respectively. In the low socio-economic group, 6%, 14%, 46%, 32% and 2% of household heads had postgraduate, undergraduate, college, secondary and primary levels of education respectively. These results showed that education level of the household head varied across socio-economic groups with all the respondents having at least some education. The education level of the household head increased with increasing socio-economic group. In a study on solid waste management in Makina, Kibera, Mwangi (2011) established that 27% of the respondents were educated up to primary level and they were mainly employed in the informal sector, while 51% had secondary level of education. A study by Ojewale (2015) on socio-economic correlates of solid waste generation in Lagos Metropolis, further revealed that the number of years spent in school by household heads differed according to socio-economic group, with those in the high socio-economic group spending more years in school.

According to the results in Table 10, an insignificant interaction was found $\chi^2(4) = 2.0287$, $p < 0.05$ between education level of the household head and physical components of solid waste generated in households in the high socio-economic group. The chi-square statistic was 2.0287 while the calculated p-value was 0.730484. Likewise, in the middle socio-economic group an insignificant interaction was found $\chi^2(4) = 6.1877$, $p < 0.05$. The chi-square statistic was 6.1877 while the calculated p-value was 0.402499. On the contrary, in the low socio-economic group a significant interaction was found $\chi^2(4) = 46.7924$, $p < 0.05$.The chi-square statistic was 46.7924 and the calculated p-value was 0.00001.

Results in Table 10 concur with results from a study by Adedibu (1984) and Afon (2007) who established that education level of the household head significantly affected the physical components of solid waste generated in households in Nigeria. Similarly, Sankoh et al., (2012) established that in Freetown, Sierra Leone, the physical components of solid waste generated in households were significantly affected by education level. Dennison et al., (1996) established that education level is a significant factor in solid waste generation in households. However, this is only true for the low socio-economic group in Kisumu city where a significant interaction was found between education level of the household head and physical components of solid waste generated in households.

It is however important to note that the results in most of these previous studies on solid waste generation in households, (Afon, 2007; Sankoh et al., 2012; Olayungbo and Olawale, 2014) were not presented according to socio-economic groups which posed a serious challenge in decision making since results in Table 10 have revealed that the interactions between education level of the household head and the physical components of solid waste generated in households varied across socio-economic groups.

### 4.3.3 Gender of the Household Head and Physical Components of Solid Waste Generated in Households in Estates in Kisumu City

The results of a Chi-Square test of independence between gender of the household head and physical components (organic, plastic and miscellaneous) of solid waste generated in households in the high, middle and low socio-economic groups in Kisumu city are presented in Table 11. Gender of the household head was either male or female as presented in Table 11.

**Table 11: Chi-Square test of independence between gender of the household head and physical components of solid waste generated in estates within households in Kisumu city**

| Socio-economic group | Gender Male (%) | Female (%) | Calculated P - value | Chi-square statistic ($X^2$) |
|---|---|---|---|---|
| **High** | 30 | 70 | 0.030484 | 2.0287 |
| **Middle** | 35 | 65 | 0.006186 | 10.1711 |
| **Low** | 24 | 76 | 0.000508 | 15.1719 |

Significance level = 0.05

Physical components of solid waste generated in households - Organic, plastic and miscellaneous

According to results in Table 11, 30%, 35% and 24% of household heads in the high, middle and low socio-economic groups respectively were males. On the other hand, 70%, 65% and 76% of household heads in the high, middle and low socio-economic groups respectively were females. These results indicate that majority of the respondents across in all the socio-economic groups were female. This implied that there was a big percentage of female headed households, however, even in cases where the males were available, they preferred that their spouses (wives) to take questions on their behalf since it was presumed that women were more informed about household information. According to Anomanyo (2009), females were the majority of respondents in a study conducted on solid waste generation in households in Kumasi, Ghana. Mwangi (2011) established that 32% of households in Makina, Kibera were female headed while 68% were headed by males. Furthermore, Jasraj (2014) established that 53% of households in urban Guma gewog were female headed while 47% were male headed. Previous studies in developing countries, have established that women played a critical role in solid waste handling at the household level (Scheinberg, 2011; UNEP, 2005; Eugene et al., 2013). According to results in Table 11, a significant interaction was found $\chi^2 (4) = 2.0287$, $p < 0.05$ between gender of the household head and physical components of solid waste generated in households in the high socio-economic group. The chi-square statistic was 2.0287 while the calculated p-value was 0.030484. Furthermore, in the middle socio-economic group a significant interaction was found $\chi^2 (2) = 10.1711$, $p < 0.05$ between gender of the household head and physical components of solid waste generated in households. The chi-square statistic was 10.1711 while the calculated p-value was 0. 006186. Similarly, in the low socio-economic group a significant interaction was found $\chi^2 (2) = 15.1719$, $p < 0.05$ between gender of the household head and physical components of solid waste generated in households. The chi-square statistic was 46.7924 while the calculated p-value was 0.000508. According to these results, the relationship between gender of the household head and the physical components of solid waste generated in households in estates in Kisumu city was significant at $p<0.05$ in all the three socio-economic groups. These results therefore, imply that the physical components of solid waste generated in households in Kisumu city were dependent on the gender of the household head.

Results in Table 11 are comparable to those in a study by Olayungbo and Olawale (2014) who established that gender of the household head had a significant interaction with the physical components of solid waste generated in households. They interpreted this to mean that female headed households were more likely to generate organic and food waste since they were more involved in food preparations and also due to the fact that they were more likely to prepare their food from home. Furthermore, Balogun (2013) also established that there was a significant interaction between the physical components of solid waste generated in households and the gender of household head. Results in Table 11 further concur with results from a study by

Sankoh et al., (2012) who revealed that in Free town, Sierra Leone, male headed households were more likely to have higher percentages of plastic waste in their waste stream as compared to female headed households. The major limitation of these previous studies which results in Table 11 have addressed is the fact that most of these previous studies were not conducted across different socio-economic groups; hence they overlooked the fact that different cities have different social stratification.

The findings in Tables 9, 10 and 11 revealed that the interaction between gender of the household head and the physical components of solid waste generated in households was significant in the high, middle and low socio-economic groups. The study findings further revealed that there was an insignificant interaction between employment sector of the household head and the physical components of solid waste generated in households in the high and middle socio-economic groups. However, the interaction between employment sector of the household head and the physical components of solid waste generated in households was significant in the Low socio-economic group. Furthermore, there was an insignificant interaction between education level of the household head and the physical components of solid waste generated in households in the high and middle socio-economic groups. In the low socio-economic group, however, the interaction between education level of the household head and physical components of solid waste generated in households was significant.

## 4.4 Association between Socio-economic Group and Quantities of Physical Components of Solid Waste Generated by Households in Estates in Kisumu City

### 4.4.1 Quantities of Physical Components of Solid Waste Generated in Households

The percentage average amount of solid waste generated by households in high, middle and low socio-economic groups in Kisumu city is presented in Table 12.

**Table 12: The average amount of solid waste generated by households in high, middle and low socio-economic groups in estates in Kisumu city**

| Socio-economic group | % mean of solid waste generated in households **Kgs/hh | | | % mean of solid waste generated in households *** $Cm^3$/hh | | |
|---|---|---|---|---|---|---|
| | **Organic** | **Plastic** | **Miscellaneous** | **Organic** | **Plastic** | **Miscellaneous** |
| **High (*n=55)** | 64.3 | 16.7 | 19 | 11.0 | 52.2 | 36.8 |
| **Middle (n*=204)** | 70.3 | 11.9 | 7.8 | 19.9 | 47.5 | 32.6 |
| **Low (n*=109)** | 77.6 | 10.2 | 12.2 | 30.3 | 41.7 | 27.9 |

*number of households sampled **Kilograms per household

*** cubic centimeters per household

Results in Table 12 revealed that in terms of weight in kilograms, organic waste component constituted the highest percentage of physical components of solid waste generated by households in Kisumu city across all socio-economic groups. Results in Table 12 revealed that the percentage weight of organic waste generated was 77.6%, 70.3% and 64.3% in the low, middle and high socio-economic groups respectively. These results further revealed that the percentage weight of plastic waste generated was 16.7%, 11.9% and 10.2% in the high, middle and low income groups respectively. Finally the percentage weight of miscellaneous solid waste generated was 19%, 17.8% and 12.2% in the high, middle and low socio-economic groups respectively.

According to results in Table 12, the percentage volume (cubic centimetres) of the physical components of solid waste generated in households varied across socio-economic groups. Results in Table 12 revealed that the percentage (volume) of plastic waste generated was 52.2%, 47.5% and 41.7% in the high, middle and low socio-economic groups respectively. These results further revealed that the percentage volume of organic waste generated was 30.3%, 19.9% and 11.0% in the low, middle and high socio-economic groups respectively. Finally the percentage volume of miscellaneous solid waste generated was 36.8%, 32.6% and 27.9% in the high, middle and low socio-economic groups respectively.

Results in Table 12 imply that when measurements are taken in terms of weight, the percentage of organic waste is highest in all the socio-economic groups while on the other hand, when measurements are taken in terms of volume, the percentage of plastic waste is highest in all socio-economic groups. These results therefore underscore the fact that it is important to quantify solid waste generated in households both in terms of weight in kilograms and volume in cubic centimetres due to the differences observed.

When solid waste generated is quantified in terms of weight in kilograms, the higher percentage of organic waste (Table 12) in all the socio-economic groups can be attributed to the food habits of the households. The population mostly consumed different varieties of fresh vegetables and fruits which are mostly available in the open air markets. This is a feature that has been supported by researches in several cities of developing countries where organic waste was found to form the highest percentage of solid waste generated in households. 80-88% of solid waste generated in households in Iran is organic (Moghadam et al., 2009). Furthermore, (Bolaane and Ali, 2004), (Imam et al., 2008) and (Abu-Qdais, 2007) established that 68%, 52-65%, 54-78% of solid waste generated in households in Botswana, Nigeria and Jordan respectively were organic. It is however important to note that these previous studies on solid waste generation in households mainly quantified solid waste generated by weight (kilograms).

Results in Table 12 further concur with a study by Ogwueleka (2009) who established that 60% of solid waste generated in households in Nigeria are organic waste. Similarly, Hoornmeg et al., (1999) established that in developing countries, over 50% of the waste stream is organic. Hoornweg *et al.,* 1999 established that in Bandung and Indonesia respectively, 78% and 90% of solid waste generated in households is composed of organic material. According to results in Table 12, organic solid waste had the highest percentage in the low socio-economic group because there was less consumption of packaged and processed materials. This can be attributed to the fact that their incomes are low and hence they do not have extra money to spend on packaged and processed food with may be considered as luxuries.

Results in Table 12 further concur with findings by Mohamed et al., (2012) who established that households in the low socio-economic group consumed less of packaged and processed food. According to Mohamed et al., (2012), plastic waste component normally constitute the highest percentage of solid waste generated in the high socio-economic group because they can afford and consume more packaged foods as compared to the other socio-economic groups. During the household-survey in the high socio-economic group, majority of respondents revealed that they burnt some of their yard wastes in their backyards while food waste was used as organic manure for their kitchen gardens.

Jonas et al., (2014) established that the possible explanation for the differences in the quantities of physical components of solid waste generated in households was as a result of differences in consumption patterns derived from a differences in income levels, lifestyles and cultural norms in the different socio-economic groups. They further established that the lower percentage of plastic in the low socio-economic groups may be explained by the fact that there was re-use and recovery of plastic waste. During questionnaire administration, respondents in the middle and low socio-economic groups revealed that they re-used their plastic materials for storage of household items such as salt, sugar, detergents etc. The scenario was however different in the high socio-economic group where the re-usable plastic containers were disposed.

The fact that plastic waste volume is highest in the HSG can be explained by the fact that those in the high socio-economic groups consumed a lot of packaged and processed products. Similarly, results in Table 12 could also imply that there is absence of re-use and recovery of plastic and other miscellaneous waste in the HSG. Furthermore, there was solid waste recovery in solid waste transfer stations in both the middle and low socio-economic groups. Solid waste items that were recovered at solid waste transfer stations mainly included plastics and metals. Waste recovery was completely non-existent in the high socio-economic group. The low socio-economic group generated the highest volume of organic waste since they majorly relied on natural food products like vegetables and fruits. Similarly, respondents in the low socio-economic group revealed that they mainly relied on home cooked meals and therefore did not dine outdoors in restaurants and hotels.

The main limitation of previous studies on quantification of solid waste generated in households which results in Table 12 has addressed is the fact that most of these studies have mainly looked at the physical components of solid waste generated in households in terms of weight

(Enayetullah et al., 2005; Mohammed et al., 2012; Jonas et al., 2014) and hence there is lack of information on the volume of physical components of solid waste generated in households. Accurate information on the quantities of the physical components of solid waste generated in households in terms of volume is key in decision making for solid waste management. Establishing the volume of the physical components of solid waste generated is important in designing landfills and material recovery facilities as well as establishing the resource recovery potential of the waste stream (Ogwueleka, 2009). Results in Table 12 on the percentage volume of physical components of solid waste generated in households in Kisumu city are therefore timely and are key in decision making for proper solid waste management.

### 4.4.2 Socio-economic Group and Volume of Physical Components of Solid Waste Generated in Households

One-way ANOVA was conducted to compare the differences in means of volume of physical components (organic, plastic, miscellaneous) of solid waste generated in households in estates in the high, middle and low socio-economic groups in Kisumu city.

Results of a one-way ANOVA on the association between volume of physical components of solid waste generated in households in Kisumu city are presented is Table 13.

**Table 13: One-way ANOVA on the association between socio-economic group and means of volume (cubic centimetres) of physical components of solid waste generated in households in Kisumu city**

| Source of Variation | *ss* | *df* | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| **Between Groups** | 1.62E+09 | 2 | 8.08E+08 | 6.020285 | 0.036788 | 5.143253 |
| **Within Groups** | 8.06E+08 | 6 | 1.34E+08 | | | |
| **Total** | 2.42E+09 | 8 | | | | |

Socio-economic groups – high, middle and low socio-economic groups

Significant at 95% confidence level

According to results in Table 13, the association between socio-economic group and the volume of physical components of solid waste generated in households is significant at $p<0.05$ for the three conditions [ $F(2,6)= 6.020285$, $P= 0.036788$]. The results imply that as socio-economic group changes, the means of volumes of physical components of solid waste generated in households also differ.

Furthermore, a post hoc comparison using Tukey HSD test was conducted to confirm the differences in means of volumes of physical components of solid waste generated in households in estates in the three socio-economic groups (high, middle and low) and results tabulated in Table14.

**Table 14: Results of Post hoc comparisons using the Tukey HSD test**

| Treatments pair | Tukey HSD Q statistic | Tukey HSD p-value | Tukey HSD inference |
|---|---|---|---|
| Organic vs Plastic | 4.9054 | 0.0306686 | * p<0.05 |
| Organic vs Miscellaneous | 2.3361 | 0.2966607 | insignificant |
| Plastic vs Miscellaneous | 2.5693 | 0.2422690 | insignificant |

Post hoc comparisons using the Tukey HSD test indicated that the mean score for plastic waste (M = 55360.33, SD = 1.47e-04) was significantly different from organic waste (M = 67629, SD = 7893.45). However, the organic waste (M = 38171.67, SD = 1.11+04) did not significantly differ from the Miscellaneous waste as shown in Table 14. Taken together, these results imply that as socio-economic group changes the volumes of physical components of solid waste generated in households differ.

Results in Tables 13 and 14 concur with previous studies which established that there were differences across socio-economic groups in the volume of physical components of solid waste generated in households (Isaac et al., 2013). Furthermore, these results concurred with several other studies (Ojewale, 2015; Beigl et al., 2008) who established that as the socio-economic group of households or individuals change so does the percentage of the different physical components of solid waste generated in households. A study by Pham et al., (2015) revealed that households in the high socio-economic group generated lesser amounts of organic waste while the generation of plastic and miscellaneous waste increased. They attributed this to the fact that households in the low socio-economic groups mainly depended on traditional packaging such as sisal baskets while households in the high socio-economic group depended on industrial packaging. In their study on municipal solid waste characterization and quantification in Ghana, Kodwo et al., (2015) established that there were no significant differences in the quantities of physical components of solid waste generated in households in Kumasi across socio-economic groups. However, it is important to note that the study by Kodwo et al., (2015) only quantified solid waste generated in households in terms of weight in kilograms. Quantification of solid waste in terms of volume (cubic centimeters) is critical in decision making in solid waste management (EPA, 1989). Previous studies have established that, households in the high socio-economic group generated high volumes of plastic and paper since they consumed a lot of packaged and processed products as compared to households in the low socio-economic group who mainly relied on home cooked meals (Mohammed et al., 2012). Furthermore previous studies have also shown that the percentage of organic waste is high in the low socio-economic group as compared to the middle and high socio-economic group (Kodwo et al., 2015)

Research findings in the study revealed that the quantities of physical components of solid waste generated in households in Kisumu city differed in the three socio-economic groups. The study revealed that the organic waste constituted the highest percentage of weight (kilograms) of solid waste generated in households in high (64.3%), middle (70.3%) and low (77.6%) socio-economic groups. However, when measurements were taken in terms of volume (cubic centimetres) , plastic waste constituted the highest percentage of solid waste generated in high (52.2%), middle (47.5%) and low (41.7%) socio-economic groups. The study further established that the association between socio-economic group and volume in cubic centimetres of physical components of solid waste generated in households was significant at $p<0.05$. These study findings therefore underscore the fact that in quantification of solid waste generation in households, it is mandatory to quantify solid waste in terms of volume.

### 4.4.3 Solid waste re-use and recovery at the household level

Results showing the status of solid waste re-use are presented in figure 3.

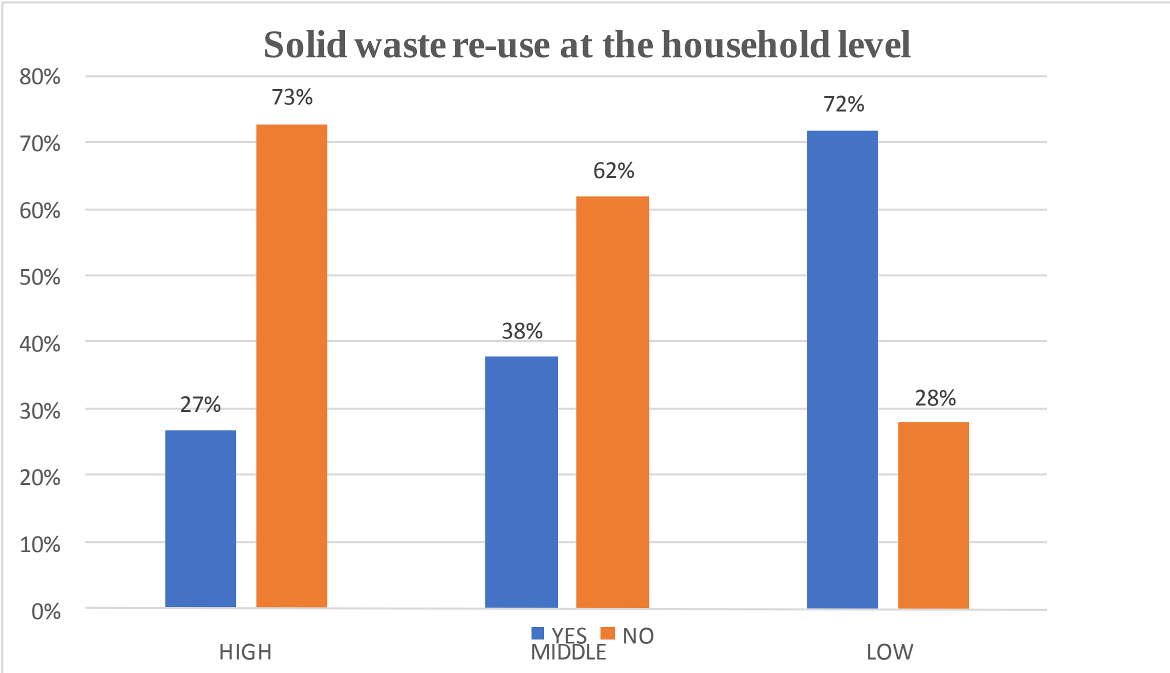


**Figure 3: solid waste re-use in the high, middle and low socio-economic groups in households in estates in Kisumu city**

According to the results in figure 3, 27%, 38% and 72% of households in the high, middle and low socio-economic groups respectively reported that they practiced solid waste recovery at the household level. However, 73%, 62% and 28% of households in the high, middle and low socio-economic groups respectively reported that they did not practice solid waste re-use at the household level. Results in figure 3 imply that solid waste re-use was highest in the low socio-economic group and lowest in the high socio-economic group. Re-usable components of the solid waste stream in households in Kisumu city included plastic bottles, plastic containers, glass bottles and metallic containers among others. Results in figure 3 concur with a study by Ojewale (2015) who established that majority of households (82%) in the low socio-economic group practiced recovery and re-use of solid waste generated at the household level. Ojewale (2015) further went ahead to explain that although households in the high socio-economic group were

Knowledgeable on the environmental benefits of solid waste re-use, majority (87%) did not see the need to re-use and preferred to purchase special containers and bottles for storage of substances. Results in figure 3 also concurred with studies by Ogwueleka (2009) and Jonas et al., (2014) who established that majority of households in the low socio-economic group practiced solid waste re-use as compared to their counterparts in the high and middle socio-economic groups. Furthermore, previous studies on characterization of solid waste at household level have established that high income households preferred dumping their re-usable solid wastes with the knowledge that solid waste scavengers and informal waste scavengers will recover them for sale to recycling companies (Kibwage, 2002; Mohammed et al., 2012).

### 4.4.4 Relationship between Frequency of Shopping by Households and the Volume of Physical Components of Solid Waste Generated

A one-way ANOVA was conducted to compare the differences in means of volume of physical components of solid waste generated in households in estates in the three socio-economic groups. Table 15 presents the results on the association between shopping frequency (Monthly, weekly and daily) of households and the volume of physical components (organic, plastic and miscellaneous) of solid waste generated in households in estates in Kisumu city .

**Table 15: One-way ANOVA on the association between frequency of shopping by households and volume (cubic centimeters) of solid waste generated in households in Kisumu city**

| **Source of Variation** | ***SS*** | ***Df*** | ***MS*** | ***F*** | ***P-value*** | ***F crit*** |
|---|---|---|---|---|---|---|
| **Between Groups** | 3.80068E+13 | 2 | 1.90034E+13 | 5.709814534 | 0.040863639 | 5.14325285 |
| **Within Groups** | 1.99692E+13 | 6 | | 3.3282E+12 | | |
| **Total** | 5.7976E+13 | 8 | | | | |

Significant at 95% confidence level

According to results in Table 15, the association between frequency of shopping by households and volume of physical components of solid waste generated is significant at the $p<0.05$ level for the three conditions [F (2, 6) = 5.709814534, P = 0.040863639]. The results imply that as the frequency of shopping by households changes the volume of the physical components of the solid waste generated in households also differ. Results in Table 15 concur with findings by Mohammed et al., (2012) who established that the association between frequency of shopping and quantities of the physical components of solid waste generated in households in Bangladesh was significant at $p<0.05$. These results further concur with a study by Olayungbo and Olawale (2014) who established that shopping habits of households significantly influenced the volume of physical components of solid waste generated in households in Nigeria.

Table 16 presents results on the frequency of shopping by households in estates in the high, middle and low socio-economic groups in Kisumu city

**Table 16: Frequency of shopping in households in estates in the three socio-economic groups in Kisumu city**

| Socio-economic group | Frequency of shopping (percentage) | | |
|---|---|---|---|
| | Monthly | Weekly | Daily |
| High (*n=55) | 95 | 5 | 0 |
| Middle (*n=204) | 65 | 35 | 0 |
| Low (*n=109) | 0 | 10 | 90 |

*Sample size per socio-economic group

According to results in Table 16, 95% and 65% of households in the high and middle socio-economic groups respectively shopped on a monthly basis. Furthermore, results in figure 4 revealed that 5%, 35% and 10% of households in the high, middle and low socio-economic groups respectively shopped on a weekly basis while 90% of households in the low socio-economic group shopped on a daily basis.

Results in Table 16 imply that shopping habits of households varied according to socio-economic group. Majority of the respondents in the high socio-economic group shopped in bulk and this was occasioned by the fact that most of them were employed in the formal sector or were business owners and hence relied on monthly salaries and therefore they could have monthly budgets. However, majority of households (90%) shopped on a daily basis and this was occasioned by the fact that majority of these households had their household heads working in the informal sector and hence they relied mainly on daily wages. Reliance on daily wages meant that most of them could only shop on a daily basis. Results in Table 16 concur with findings from a study by Ojewale (2015) who established that majority (92%) of the respondents in the low socio-economic group in households in Nigeria shopped (especially food and groceries) on a daily basis and hence they generated higher percentages of food waste as compared to their counterparts in the high socio-economic group. In a study on household solid waste management in Makina informal settlement in Kibera, Mwangi (2011) established that majority of the households relied on daily wages from informal jobs and hence they shopped on a daily basis. Previous studies on solid waste generation have provided empirical data indicating that frequency of shopping greatly influences solid waste generation in households (Mohammed et al., 2012).

#### 4.4.5 Role of Private Waste Collectors in Handling Solid Waste Generated in Households

The three estates surveyed had private waste collectors who had been contracted by residents to collected solid waste generated from households in these three estates. The private waste collectors were registered by the county government as private waste collection companies and hence they charged households a monthly solid waste collection fee which ranged from Kshs. 120 per month in the low socio-economic group to Kshs. 200 per month in the middle socio-economic group and Kshs. 300 per month in the high socio-economic group. The study established that the entire three key informants interviewed (one per socio-economic group) had no training on solid waste management and that they were in business to earn a living. Therefore, apart from collection of solid waste generated in households in the three estates surveyed, the private waste collectors were not involved in any form of community awareness or sensitization on proper solid waste management practices such as minimization of solid waste generated at the household level. However, the private waste collectors revealed that they were involved in solid waste recovery mainly to get items from the waste streams that they could re-use or sell. Some of the items recovered from the solid waste stream by the private waste collectors were plastics, metals, mobile phones, old clothes, plates and cups.

## 4.5 Modelling solid waste generated in households using socio-economic and demographic Determinants

The behavior of solid waste generated in households is difficult to explain by using a single predictor variable (Ojeda-Benitez et al., 2008). Thus, to find the appropriate model that best explained solid waste generated in households, data were analyzed and variables involved identified. A symbol was assigned to each variable and the type of dependence and unit of measure was set. Table 17 shows the possible variables selected for inclusion in the multiple linear regression for modelling solid waste generated in households in estates in Kisumu city in the high, middle and low socio-economic groups.

**Table 17: Variables selected for possible inclusion in the multiple linear regression model, their symbol, type and unit of measure**

| Variable name | Symbol | Type | Unit of measure |
|---|---|---|---|
| Household Size | $X_{Hs}$ | Independent | Persons per household |
| Household monthly Income | $X_{Hmi}$ | Independent | Monthly Income per household |
| Household Monthly Expenditure on Food | $X_{Hmef}$ | Independent | Monthly expenditure on food per household |
| Age of the Household Head | $X_{Ahh}$ | Independent | Total number of years the household head has lived |
| Employment Sector of the household head | $X_{Esec}$ | Independent | Formal; Informal |
| Education level of the household head | $X_{ed}$ | Independent | PG;UG;D;S;P: N |
| Gender of the household head | $X_{Ge}$ | Independent | Male or Female |
| Amount of SW generated in households in Kgs | $Y_{Swgh}$ | Dependent | Kgs/month/household |

PG- Post graduate; UG- Undergraduate; D-Diploma; S-Secondary; P- Primary; N-none

The variables in Table 17 were selected for possible inclusion in the multiple linear regression model since they were easily available at the household level. Moreover, previous studies (Koushki and Al-khaleefi, 1998; Beigl et al., 2003; Afon, 2007) have identified these variables as suitable explanatory variables for solid waste generation in households.

### 4.5.1 Socio-economic and Demographic Variables Analysed

The collected data on socio-economic and demographic determinants ware analyzed to check for multicollinearity problems among the variables. Highly correlated explanatory variables were omitted as their effect on solid waste generated in households was achieved through some other variable(s). Multicollinearity means that explanatory (independent) variables are highly correlated making it difficult to separate their respective effects on the dependent variable. A student-*t* test was therefore used to conduct a test of multicollinearity among pairs of independent variables. Pairs of independent variables with an absolute value of *t* greater than 1.96 ($t>1.96$) and a p value less than 0.05 ($p<0.05$) were considered highly correlated and hence they were unsuitable for the model. Those pairs of independent variables with an absolute value of *t* less than 1.96 ($t<1.96$) and p value greater than 0.05 ($p>0.05$) were the most suited for the model. Table 18 tabulates the results of the student *t*- test among the independent variables.

**Table 18: Values of *t* and p from a test of independence among independent variables in three socio-economic groups (high, middle, low) in estates in households in Kisumu city**

| Compared Independent Variables | Standard Value of Z | Socio-economic group | | | | | |
|---|---|---|---|---|---|---|---|
| | | High | | Middle | | Low | |
| | | Absolute value of *t* | P value | Absolute value of *t* | p value | Absolute value of *t* | P value |
| $X_{Hs}$ Vs $X_{Hmi}$ | 1.96 | -1.39 | 0.17 | -1.88 | 0.06 | 0.37 | 0.71 |
| $X_{Hs}$ VS $X_{Hmef}$ | 1.96 | 1.54 | 0.13 | -1.17 | 0.24 | -0.20 | 0.84 |
| $X_{Hs}$ Vs $X_{Ahh}$ | 1.96 | 0.40 | 0.69 | 0.04 | 0.97 | -1.33 | 0.18 |
| $X_{Hmi}$ Vs $X_{Hmef}$ | 1.96 | 0.15 | 0.88 | -0.95 | 0.34 | -0.33 | 0.74 |
| $X_{Hmi}$ Vs $X_{Ahh}$ | 1.96 | -1.07 | 0.29 | -1.75 | 0.08 | -1.08 | 0.28 |
| $X_{Ahh}$ Vs $X_{Hmef}$ | 1.96 | -0.63 | 0.53 | -0.63 | 0.53 | -0.53 | 0.59 |
| $X_{Hmi}$ Vs $X_{Esec}$ | 1.96 | 46.00 | 0.01 | 9.30 | 0.01 | 14.33 | 0.01 |
| $X_{ed}$ Vs $X_{Ahh}$ | 1.96 | -26.98 | 0.01 | -45.75 | 0.01 | -30.56 | 0.01 |
| $X_{Ge}$ Vs $X_{Hmef}$ | 1.96 | -18.48 | 0.01 | 23.55 | 0.01 | -17.56 | 0.01 |

Significant at 95% confidence level

*1.96 – the standard value of Z on the t- table when the level of significance is 95%

$X_{Hs}$ -Household size; $X_{Hmi}$- Household monthly income; $X_{Ge}$- Gender of the household head

$X_{Hmef}$ –Household monthly expenditure on food; $X_{Ahh}$- Age of the household head

$X_{ed}$- Education level of the household head; $X_{Esec}$- Employment sector of the household head

The calculated p values of the selected socio-economic and demographic variables were greater than 0.05 (p value) indicating poor multi-collinearity and independence among them (Table 18). A student *t*-test was mandatory to ensure that multicollinearity problems which are common in multiple linear regression were taken care of. The test of multicollinearity on the independent variables (Table 18) established that variables household size, household monthly income, household monthly expenditure on food and age of the household head did not exhibit multicollinearity hence they were selected for the multiple linear regression model.

In a study on forecasting solid waste generation in households, Buenrostro et al., (2011) conducted a student *t* test among selected independent variables and established that explanatory variables household monthly income and education level, age and education level, age and household income exhibited multicollinearity. The study therefore concluded that these variables had the effect of decreasing the significance of the regression model when the four variables were included in a multiple linear regression model.

Zaini and Simon (2013) also established that household size, type of housing and age composition of the household were significant factors in modeling solid waste generated in households in Malaysia. They however, did not conduct a test of multi collinearity which this study has done (Table 18). Likewise, Ojeda-Benitez et al., (2008) selected education level of the household head, household size and household income as the most suitable variables for modelling solid waste generated in households. From these previous studies (Ojeda-Benitez et al., 2008; Zaini and Simon, 2013; Buenrostro et al., 2011), it is clear that household socio-economic and demographic characteristics can successfully be used to model solid waste generation in households, however caution must be taken to ensure that only the most suitable explanatory variables are selected for modelling.

### 4.5.2 Socio-economic and Demographic Variables included in the Multiple Linear Regression Model

Multiple linear regression was calculated to model solid waste generation in households in kilograms based on household monthly income ($X_{Hmi}$), household monthly expenditure on food ($X_{Hmef}$), household size ($X_{Hs}$) and age of Household head ($X_{Ahh}$) in selected estates in Kisumu city representing high, middle and low socio-economic groups. Results of the multiple linear regression yielded a significant regression equation with $R^2$ adjusted of 0.973, 0.984 and 0.975 at 95% confidence level in the high, middle and low socio-economic groups respectively as shown in Table 19.

**Table 19: Model summary for MLR analysis results for explanatory variables $X_{Hs}$, $X_{Hmi}$, $X_{Hmef}$ and $X_{Ahh}$ and dependent variable SW generated in households in estates in Kisumu city**

| Socio-economic group | R | R square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| **High** | .987[a] | .975 | .973 | 4.26012 | 2.313 |
| **Middle** | .992[a] | .984 | .984 | 2.863 | .430 |
| **Low** | .988[a] | .976 | .975 | 2.516 | .646 |

Significant at 95% confidence level

$X_{Hs}$ -Household size; $X_{Hmi}$- Household monthly income; $X_{Ahh}$- Age of the household head
$X_{Hmef}$ –Household monthly expenditure on food; MLR – Multiple linear regression
SW -solid waste

Results in Table 19 revealed that the explanatory variables selected (household size, household monthly income, household monthly expenditure on food and age of the household head) accounted for over 97% of solid waste generated in households in estates in high, middle and low socio-economic groups Kisumu city and therefore can be used to model solid waste generation in households. The high values of $R^2$ in all the socio-economic groups (Table 19) was attributed to the fact that solid waste characterization was done at the household level for each household and this allowed for accuracy as it clearly indicated the source of solid waste and number of generators. Furthermore, solid waste characterization was done before any form interference such as solid waste recovery by private waste collectors.

Results in Table 19 concur with a study by Ojeda-Benitez et al., (2008) who established that selected socio-economic and demographic variables (education level, household income and household size) explained 51% ( $R^2$ = 0.51) of the solid waste generated in households in Mexicali, Mexico. Similarly, Zaini and Simon (2012) established that household socio-economic and demographic characteristics explained 63% of the variation in solid waste generated in households in Malaysia. Furthermore, Ojewale (2015) established that household income, education level, age, length of stay and household size explained 54.9% of the variation of solid waste generated in households in Lagos Metropolis.

Results in Table 19, however, differed with those in a study by Buenrostro et al., (2001) who established that socio-economic and demographic variables (household income and household size) selected were of limited value in explaining the total variation in solid waste generated in households since they yielded a low value of $R^2$ (0.075) which meant that they could only be used to explain 7.5% of the amount of solid waste generated. However, Buenrostro et al., (2001) used a small sample size (243 households) with respect to the study population (123, 000 households) and hence this could be a probable reason for the low value of the $R^2$.

The results of the multiple linear regression analysis using the explanatory variables household size, household monthly income, household monthly expenditure on food and age of the household head in households in estates in high, middle and low socio-economic groups by the predictive model in equation 1 (section 3.6) is presented in Table 20.

**Table 20: Results of solid waste (SW) generation in households prediction based on predictive model in equation 1**

| Socio-economic group | Means of independent variables | | | | SW generation based on predictive model in equation 1 | Predicted amount of SW generated in households | Actual amount of SW generated in households |
|---|---|---|---|---|---|---|---|
| | $X_{Hs}$ | $X_{Hmi}$ in Kshs | $X_{Hmef}$ in Kshs | $X_{Ahh}$ in years | $S_{wg}= \beta_0+\beta_{Hs} X_{Hs} +\beta_{Hmi} X_{Hmi} + \beta_{Hmef} X_{Hmef}+\beta_{Ahh} X_{Ahh} + \varepsilon$ | | |
| **High** | 5 | 57555 | 17509 | 42 | $S_{wg} = -54.958 - 2.296X_{Hs}+0.001X_{Hmi} + 0.002 X_{Hmef} +0.597 X_{Ahh}$ | 51.2Kgs | 54Kgs |
| **Middle** | 5 | 17333 | 15102 | 36 | $S_{wg} = -2.924+2.305X_{Hs}+ 0.00002032X_{Hmi} + 0.001 X_{Hmef} +0.090 X_{Ahh}$ | 27.3 Kgs | 36Kgs |
| **Low** | 5 | 15130 | 8314 | 35 | $S_{wg} = 4.17+1.161X_{Hs}+ 0.002X_{Hmi} + 0.001X_{Hmef} +0.091 X_{Ahh}$ | 34.28Kgs | 31.5Kgs |

$X_{Hs}$ – Household size $X_{Hmi}$ – household monthly income $X_{Ahh}$ – Age of the household head
$X_{Hmef}$ – Household monthly expenditure on food Kshs- Kenya shillings Kgs – Kilograms

A paired-samples *t*-test was conducted to compare the differences between the actual and predicted weights (kilograms) of solid waste generated in households in estates in Kisumu city. This was done to establish the predictive accuracy of the multiple linear regression model that yielded the results in Table 20. Results of a paired-samples *t*-test on the differences between the actual and predicted weights in kilograms of solid waste generated in households in Kisumu city are tabulated in Table 21. A paired-samples *t*-test was conducted to compare the differences between the actual and predicted weights (kilograms) of solid waste generated in households in estates in Kisumu city. This was done to establish the predictive accuracy of the multiple linear regression model that yielded the results in Table 20. Results of a paired-samples *t*-test on the differences between the actual and predicted weights in kilograms of solid waste generated in households in Kisumu city are tabulated in Table 21.

**Table 21: Results of a paired samples *t*-test on the differences between the actual and predicted weights in kilograms of solid waste generated in households in Kisumu city**

| | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| | Mean | *SD | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | Lower | Upper | | | |
| **Predicted - Actual** | -3.0067 | 5.8927 | 3.4022 | -17.6450 | 11.6317 | -.884 | 2 | .470 |

*Standard deviation Significant at 95% confidence level

According to the results in Table 21 there were no significant differences between the predicted (M=37.5, SD 12.42) and actual (M=40.5, SD 11.9) weight in kilograms of solid waste generated in households in estates in Kisumu city for the conditions [t (2) = -0.884, p=0.470]. These results imply that the prediction model developed for SW generated in households in estates in Kisumu city was accurate and therefore suitable.

According to results in Tables 20 and 21 , household size, household monthly income, household monthly expenditure on food and age of the household head can be used to predict solid waste generated in households. Results in Table 20 are comparable to those by Buenrostro et al., (2001) who predicted solid waste generated in households using household size and household income and established that the actual and predicted weights were 2.46Kgs and 2.49Kgs respectively per household per day. Similarly, results in Table 21 concur with results in a study by Ojewale (2015) who conducted a one-way ANOVA to assess the overall significance of a multiple regression model explaining 54.9% of solid waste generation in households based on residents socio-economic characteristics and established that the model was significant at $p<0.05$. Ojewale (2015) further confirmed that household size and household income were the most significant factors explaining the variations in solid waste generation in Lagos Metropolis. Furthermore, Afroz et al., (2008) conducted an F-test to test the overall significance of a model explaining 51% of solid waste generation based on household socio-economic characteristics and established that the linear relation of the model was highly significant (the p value for the F-test was less than 0.0001).

The findings of this study have revealed that household size, household monthly income, household monthly expenditure on food and age of the household head are good predictors of solid waste generated in households since they explained over 97% ($R^2$= 0.97) of the variations in solid waste generated in households in estates in the high, middle and low socio-economic groups in Kisumu city. Furthermore, the predictive model in Table 20 was highly significant and therefore accurate and hence it was very suitable for prediction of solid waste generated in households in estates in Kisumu city.

# CHAPTER FIVE

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Introduction

This Chapter provides the summary of findings, conclusions and recommendations of the study. It is divided into four sections; in the first section the main points emerging from the results of the study are summarized. The second section presents the conclusions of the study based on the findings. The third section provides suggestions and recommendations in line with the objectives of the study. Finally, the fourth section provides suggestions on areas for further research.

## 5.2 Summary of Findings

The study revealed that the amount of solid waste generated in households in kilograms is strongly and positively associated with household size, household monthly income, household monthly expenditure on food and age of the household head in the high, middle and low socio-economic groups in households in estates in Kisumu city. Variables household size, household monthly income, household monthly expenditure on food and age of the household head were strongly and positively correlated with the amount (in kilograms) of solid waste generated in households in estates in all the three socio-economic groups.

The findings the study revealed that there was an insignificant interaction between employment sector of the household head and physical components of solid waste generated in households in estates in the HSG and MSG with P-values of 0.839665 and 0.53184 respectively significant at 95% confidence level. However, the association between employment sector of the household head and physical components of solid waste generated in households in estates in the LSG was significant with a P-value of 0.0001 at 95% confidence level. Furthermore, there was an insignificant interaction between education level of the household head and physical components of solid waste generated in households in estates in the HSG and MSG with P-values of 0.730484 and 0.402499 respectively significant at 95% confidence level. In the LSG, however, the interaction between education level of the household head and physical components of solid waste generated in households was significant at 95% confidence level. The interaction between gender of the household head and physical components of solid waste generated in households was significant in the HSG, MSG and LSG with P- values of 0.030484, 0.0006186 and 0.000508 respectively significant at 95% confidence level.

The study findings revealed that the weight in kilograms of organic waste generated formed the highest percentage (>64%) of the physical components of solid waste generated by households in all the three socio-economic groups. However, the study further established the percentage volume (in cubic centimeters) of plastic waste generated was highest in all the socio-economic groups (>41%) across all socio-economic groups. The findings of this study further revealed that there were significant differences in the means of volumes of physical components of solid waste generated in households across socio-economic groups and therefore the association between socio-economic group and volume of physical components of solid waste generated in households was significant at $p<0.05$ for the three conditions [F (2,6)= 6.020285, P= 0.036788].

Finally, the findings of this study revealed that household size, household monthly income, household monthly expenditure on food and age of the household head were good predictors of solid waste generation in households since they could explain over 97% ($R^2$= 0.97) of the variations in solid waste generation in households in the high, middle and low socio-economic groups in Kisumu city.

## 5.3 Conclusions

This study revealed that in the high, middle and low socio-economic group in Kisumu city, the amount of solid waste generated in households in kilograms was strongly and positively correlated with household size, household monthly income, household monthly expenditure on food and age of the household head. As household size, household monthly expenditure on food, age of the household head and household monthly income increases, the amount of solid waste generated in households in kilograms also increases. An increase in the number of people in the household leads to an increase in the amount of commodities (food, detergents) purchased in the due to increased consumption. The amount of solid waste generated in households is a product of household consumption patterns. Furthermore, increase in household monthly income leads to an increase in the purchasing power of the household. Similarly, an increase in the household monthly expenditure on food implies that food is consumed on a daily basis at times even three times a day in most households.

Increased food consumption leads to increase household expenditure on food which in turn leads to an increase in the amount of solid waste generated especially food and organic waste but in some cases packaging materials from processed and packed food items. This is evidenced by the fact that organic and food waste forms the highest bulk of solid waste generated in households in kilograms.  Furthermore, an increase in the age of household head implies that the household head has probably stabilized career or business wise and has moved up the ranks and hence earning a higher income as compared to households with younger heads. Similarly such households would also have more members like children and relatives. This would therefore lead to an increase in the amount of solid waste generated in households since consumption will increase. These study findings therefore imply that there is a linear relationship between the amount of solid waste generated in kilograms and household monthly expenditure on food, household size, household monthly income and age of the household head in households in estates in Kisumu city, Kenya. The study further implies that these socio-economic and demographic determinants should be considered as essential factors in the design of solid waste management programs, location, sizing and design of solid waste management facilities for example transfer stations and solid waste collection vehicles.

The study findings have established that the physical components of solid waste generated in households in kilograms have an insignificant interaction with employment sector and education level in the HSG and MSG. On the other hand, physical components of solid waste generated in households in kilograms have an significant interaction with employment sector and education level in the LSG. Furthermore, the interaction between physical components of solid waste generated in households in kilograms have a significant interaction with gender across in all the socio-economic groups. These study findings imply that there are variations in the interaction between physical components of solid waste generated in households in kilograms and socio-economic and demographic variables (Education level of the household head, gender of the household head and employment sector of the household head) in the three socio-economic groups.

This study findings have established that there are variations in the weight of physical components (solid waste fractions) of solid waste generated in households with organic waste forming highest percentage across all socio-economic groups (>64%). This study has further revealed that the percentage volume (cubic centimeters) of the physical components of solid waste generated in households varies across socio-economic groups with plastic being the highest (>41%) in all the socio-economic groups. Furthermore, the study findings have revealed that there were significant differences in the means of volumes of physical components of solid waste generated in households across socio-economic groups. The differences in volumes of the physical components of solid waste generated in households in the three socio-economic groups could be attributed to differences in consumption patterns as a result of lifestyles, societal and cultural norms. Plastic waste volume is highest in households in the high socio-economic group due to their tendency to consume packaged and processed foods while households in the low socio-economic group may generate more of organic waste due to the fact that they do not dine out of their homes and mainly consume food from the local markets. The study findings therefore imply that there is a potential for formal plastic solid waste recovery and recycling since by volume, plastic waste forms the highest percentage of solid waste generated in households in estates in the three socio-economic groups. Knowledge of quantities of physical components (solid waste fractions) of solid waste generated both by volume and weight is a key factor in determining the size and design of solid waste treatment facilities such as recycling plants and sanitary landfills.

Lastly, the study findings have revealed that household monthly income, household size, household monthly expenditure on food and age of the household head are good predictors of solid waste generation in households since they explained over 97% ($R^2$= 0.97) of the variations in solid waste generation in households in all the socio-economic groups. These findings therefore imply that these socio-economic and demographic variables have a linear relationship with the amount of solid waste generated in households in all the three socio-economic groups. The findings of this study further imply that the analyses of household socio-economic and demographic determinants influencing solid waste generation in households enable prediction of their quantities and are useful in planning for their adequate management. Furthermore, the study findings imply that the model developed on the household socio-economic and demographic characteristics can provide accurate data in predicting the amount of solid waste generated in households in the future in Kisumu city.

## 5.4 Recommendations

Based on the findings and conclusions of the study, the following recommendations were made;

(i) Modern solid waste transfer stations with measurement points are established in residential areas in Kisumu city. The sizing and siting of these transfer stations within the residential areas should be based on household size, household monthly income, age of the household head and household monthly expenditure on food. Establishment of modern solid waste transfer stations within residential areas will ensure availability of data on solid waste generation in households for periodic household solid waste stream assessments which are necessary in identification of successful protocols as well as areas needing improvements. Planning and design of solid waste transfer stations requires data on the amount of solid waste generated in households and factors determining these amounts which this study has provided.

(ii) Development of a centralized yard waste composting facility within Kisumu city based on socio-economic group. Development of a centralized yard waste composting facility will ensure source separation so that organic waste is made available. Compost products from the facility can be used in agriculture, flower and tree nurseries, green houses and individual gardens. These compost products can also be used as fill material in municipal operations (parks and landscaping). Furthermore, composting is a volume reduction activity, therefore, even if the compost material is landfilled, composting conserves landfill space. Evidence from this study has shown that organic waste forms the highest percentage (over 64%) of solid waste generated in households in all the socio-economic groups hence, availability of raw materials necessary for composting.

(iii) Development of a formal solid waste recycling program within Kisumu city which will include material recovery facilities to be established in specific residential areas within the city. The formal solid waste recycling program can be developed according to socio-economic group. The recycling program can begin as small scale or pilot-scale programs in neighborhoods, residential areas or specific areas of the community. This will be made possible since there is availability of information from this study on the physical components solid waste volumes according to socio-economic group.

(iv) Development of an integrated solid waste management strategic plan for Kisumu city. An integrated solid waste management strategic plan is a concept where decision makers plan for long-term solid waste management where the planning process anticipates the changes that are likely to occur in the future waste stream. This will be made possible by availability of data on the current information on solid waste generation in households and a predictive model based on household socio-economic and demographic determinants which will be useful in predicting the future waste stream which this study has provided.

## 5.5 Areas for Further Research

(i) This study focused on estimation of solid waste generation in households using socio-economic and demographic determinants. Thus, it is suggested that another study be done focusing on the effects of seasonal variations on solid waste generation in households.

(ii) This study focused on urban residential areas, the researcher recommends that another study be done focusing on the peri-urban and rural residential areas due to their different lifestyles.

(iii) This study has established that the amount of solid waste generated in households, the physical characteristics of solid waste generated both in kilograms and cubic centimeters, therefore it is recommended that there is need for a study focusing on the chemical characteristics of the physical components solid waste generated in households. This will aid in establishment of the heating values of solid waste which is key in establishment of waste-to-energy facilities.

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# APPENDICES

## APPENDIX I: INFORMED CONSENT FORM

CONSENT TO PARTICIPATE IN RESEARCH

RESEARCH TITLE :
…………………………………………………………………………………………………………
…………………………………………………………………………………………………………
……………………………………………………………………………………

You have been asked to participate in a research study.

You have been informed about the study by..………………… ……………………………of phone number………………You may contact Ms. Jenniffer Vera Atieno (Principal investigator) of cell phone number 0728-77773 any time if you have questions about the research.

This research is purely for academic purposes and effort will be made to keep personal information confidential. The answers given will simply help the researcher to answer the study research questions.

Your participation in this research is voluntary, and you will not be victimized in any way if you refuse to participate or decide to terminate participation.

The research study, including the above information has been verbally described to me. I understand what my involvement in the study means and I voluntarily agree to participate.

____________________ __________________

Signature of Participant Date

____________________ __________________

Signature of Witness Date

## APPENDIX I: QUESTIONNAIRE OUTLINE FOR HOUSEHOLDS

### INTRODUCTION

The purpose of this study is to analyze the Socio-demographic and economic determinants for estimating solid waste generation in households in estates in Kisumu city, Kenya. This research is purely academic and any information given will be treated with utmost confidentiality. In order to achieve this objective, we humbly request you to help us by filling this questionnaire to the best of your ability and knowledge.

**Name and contact of Student**


Jenniffer Vera Atieno

Maseno University

P.O Box 333, Maseno

Email Address; tjnyagare@gmail.com

Cell phone; 0728-777737


**Name and Contact of the interviewer**

Name……………………………………. Phone number……………………………

Date _____/____/_______

**SECTION I: GENERAL INFORMATION**

1. Name of respondent ………………………… Phone number of respondent……………
2. Estate

   [ ] Milimani

   [ ] Migosi

   [ ] Obunga

3. Household ID……………………………

4. Status of the respondent

   [ ] Household head…………………………………………….…………

   [ ] Member…………………………………………………………………

**SECTION II: HOUSEHOLD SIZE, HOUSEHOLD MONETARY INCOME, HOUSEHOLD MONTHLY EXPENDITURE ON FOOD AND AGE OF THE HOUSEHOLD HEAD**

5. How many people live in your household? ......................................................................
6. Approximately, what is your monthly monetary income in Kshs?...................................
7. Does the household have any other source of monthly monetary income?

   (a) If YES, please specify the amount…………………………..

   (b) If NO, skip and go to question 8

8. Approximately, how much do you spend of food every month? ……………………
9. What is the age of the household head? ………………………………………………

**SECTION III: EDUCATION LEVEL, GENDER AND EMPLOYMENT SECTOR**

10. Gender of the household head

[ ] Male……………………………………………………………………………...…(1)

[ ] Female…………………………………………………………………………..(2)

11. What level of formal education have you attained

[ ] University Postgraduate……………………………………………………… ...(1)

[ ] University Undergraduate…………………………………………………… ... (2)

[ ] College (Diploma, certificate, etc.)…………………………………………… (3)

[ ] Secondary…………………………………………………………………..….. (4)

[ ] Primary……………………………………………………………………………(5)

[ ] None……………………………………………………………………….…(6)

12. What is your sector of employment

[ ] Formal…………………………………………………………………………...(1)

[ ] Informal………………………………………………………………….......(2)

**SECTION IV: SOCIAL ATTRIBUTES OF HOUSEHOLDS INFLUENCING SOLID WASTE GENERATION:**

13. Does the household practice re-use of solid waste

[ ] Yes………………………………………………………………………………(1)

[ ] No ……………………………………………………………………………(2)

If the answer to question 13 is Yes, kindly answer question 14; if the answer is no, kindly go to question 15

14. What items are re-used in the household…………………………………………………………………………………

15. How often is shopping for basic household commodities done

    [ ] Monthly

    [ ] Weekly

    [ ] Daily

General comments

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………....Thank you.

## APPENDIX II: DIRECT WASTE ANALYSIS GUIDE

### INTRODUCTION

The purpose of this study is to analyze the socio-demographic and economic determinants for estimating solid waste generation in households in estates in Kisumu city, Kenya. This research is purely academic and any information given will be treated with utmost confidentiality. In order to achieve this objective, we humbly request you to help us obtain data on the quantities and physical components of solid waste generated through a direct waste analysis approach.


Jenniffer Vera Atieno

Maseno University

P.O Box 333, Maseno

Email Address; tjnyagare@gmail.com

Cell phone; 0728-777737


Date _____/____/_______

### I EQUIPMENT AND MATERIALS REQUIRED

1. Trash polythene bags
2. Twenty five kilogram (25 Kg) weighing machine
3. Sorting shed
4. Digital camera
5. Personal Protective Equipment
6. Large plastic canvas

## II GENERAL SAFETY PROCEDURES

1. All weighing personnel must be in good physical condition, not allergic to odours and dust

2. No eating, smoking or drinking will be allowed during weighing activities.  Food and water will be kept away from the weighing area to avoid  contamination

3. Extreme care must taken in the handling of  waste material

4. Spills, dirt and residue on the floor are to be immediately wiped out to prevent slip

5. Replacement of damaged protective gear is to done immediately after such occurrence

**APPENDIX III: DATA SHEET FOR WEEKLY SOLID WASTE GENERATION IN HOUSEHOLDS**

**ESTATE..................................................**

**DATE......................................................**

| **Household ID** | **Weekly solid waste generation in households in Kgs (weight)** | | | **Weekly solid waste generation in households in cubic centimeters (volume)** | | |
|---|---|---|---|---|---|---|
| | **Organic waste** | **Non-organic waste** | | **Organic waste** | **Non-organic waste** | |
| | | Plastic waste | Miscellaneous waste | | Plastic waste | Miscellaneous Waste |
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## APPENDIX IV: OBSERVATION GUIDE

1. Physical components (solid waste fractions) of solid waste generated in households i.e. Organic, plastic and miscellaneous solid waste were observed and recorded as shown in the Table below:

**Estate name** …………………**Socio-economic group**……………………..Date……………

| Household ID | Physical components (sort categories) of solid waste generated | | |
|---|---|---|---|
| | Organic waste | Plastic waste | Miscellaneous waste |
| | | | |
| | | | |
| | | | |
| | | | |
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## APPENDIX V: KEY INFORMANT GUIDE

The interview guide was intended to collect information from private waste collectors who operate in the estates under study. It was subjected to the private waste collectors to understand their roles and activities in handling of solid waste generated and how these activities influenced solid waste generation in households in the estates sampled. Key interview guides were used to obtain information on recovery of solid waste generated in households by the waste collectors, their involvement in minimization of solid waste generation in households through activities like community participation and education of household members.

**Name of Private waste collection company** ………………………………………

**Estate**………………………………………………….. **Date**………………………………...

1. Do you have any training on solid waste management
2. For how long have you been involved in collection of solid waste from households
3. How often do you collect wastes from households i.e. daily, twice a week, weekly etc.
4. Do you recover re-usable and recyclable solid waste components from the solid waste that you collect from households
5. What are the most common fractions of solid waste that is recovered from the solid waste collected
6. Are there any differences in the solid waste fractions generated from households in different seasons
7. Are you involved in education of households in solid waste minimization practices

## APPENDIX VI: ESTATES SELECTED FOR POSSIBLE INCLUSION IN THE STUDY

| S/no | Estate Name | Socio-economic group |
|---|---|---|
| 1. | Kaloleni | Low |
| 2. | Nyawita | Low |
| 3. | Lumumba | Low |
| 4. | Obunga | Low |
| 5. | Arina | Middle |
| 6. | Anderson | Low |
| 7. | Bandani | Low |
| 8. | Nyalenda | Low |
| 9. | Migosi | Middle |
| 10. | Makasembo | Middle |
| 11. | Mosque | Middle |
| 12. | Nubian | Middle |
| 13. | Polyview | Middle |
| 14. | Nyalenda Railways | Middle |
| 15. | Nyamasaria | Middle |
| 16. | Pembe Tatu | Middle |
| 17. | Posta Flats | Middle |
| 18. | Upper Railways | Low |
| 19. | USAID | Middle |
| 20. | Robert Ouko | Middle |
| 21. | Kenya- Re | Middle |
| 22. | Lower Railways | Middle |
| 23. | Mountain View | Middle |
| 24. | Patel Flats | Middle |
| 25. | Tom Mboya | Middle |
| 26. | Milimani | High |
| 27. | Ondiek | Low |
| 28. | Okore | Middle |

**APPENDIX VII: REGRESSION COEFFICIENTS IN THE LOW SOCIO-ECONOMIC GROUP**

**Coefficients**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 4.147 | 1.134 | | 3.657 | .000 |
| | Household Size | 1.161 | .389 | .160 | 2.989 | .003 |
| | Household Monthly Income | .002 | .000 | 1.204 | 13.017 | .000 |
| | Household Monthly Expenditure on food | -.001 | .000 | -.449 | -6.654 | .000 |
| | Age of Household Head | .091 | .057 | .065 | 1.605 | .112 |

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .988[a] | .976 | .975 | 2.516 | .646 |

## APPENDIX VIII: REGRESSION COEFFICIENTS IN THE HIGH SOCIO-ECONOMIC GROUP

**Milimani Coefficients**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -54.958 | 8.251 | | -6.661 | .000 |
| | Household Size | -2.296 | 1.246 | -.142 | -1.843 | .071 |
| | Household Monthly Income | .001 | .000 | .391 | 5.087 | .000 |
| | Household Monthly Expenditure on Food | .002 | .000 | .506 | 5.204 | .000 |
| | Age of Household head | .597 | .159 | .260 | 3.762 | .000 |

| Mode l | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .987[a] | .975 | .973 | 4.26012 | 2.313 |

## APPENDIX IX: REGRESSION COEFFICIENTS IN THE MIDDLE SOCIO-ECONOMIC GROUP

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -2.924 | 1.379 | | -2.121 | .035 |
| | Household Size | 2.305 | .436 | .266 | 5.287 | .000 |
| | Household Monthly Income | 2.032E-005 | .000 | .232 | 10.184 | .000 |
| | Household Monthly Expenditure on food | .001 | .000 | .476 | 8.236 | .000 |
| | Age of Household head | .090 | .064 | .040 | 1.405 | .162 |

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .992[a] | .984 | .984 | 2.856 | .422 |

**APPENDIX X: DESCRIPTIVE STATISTICS**

High socio-economic group

| | Total | Average |
|---|---|---|
| **Households size** | 265 | 5 |
| **Age of the household head** | 2254 | 42 |
| **Monthly income** | 3108000 | 57555 |
| **Monthly expenditure on food** | 945500 | 17509 |

Middle socio-economic group

| | Total | Average |
|---|---|---|
| **Households size** | 993 | 5 |
| **Age of the household head** | 7221 | 36 |
| **Monthly income** | 3535814 | 17333 |
| **Monthly Expenditure on food** | 3065900 | 15102 |

Low socio-economic group

| | Total | Average |
|---|---|---|
| **Household size** | 470 | 5 |
| **Age of the household head** | 3751 | 35 |
| **Monthly income** | 1649200 | 15130 |
| **Monthly expenditure on food** | 906300 | 8314 |

## APPENDIX XI: CORRELATIONS

High socio-economic group

**Correlations**

| | | Household Size | Household Monthly Income | Household Monthly Expenditure on Food | Age of Household head | Monthly Household Domestic solid waste in kilograms |
|---|---|---|---|---|---|---|
| Household Size | Pearson Correlation | 1 | .945** | .926** | .867** | .921** |
| | Sig. (2-tailed) | | .000 | .000 | .000 | .000 |
| | N | 54 | 54 | 54 | 54 | 54 |
| Household Monthly Income | Pearson Correlation | .945** | 1 | .921** | .836** | .939** |
| | Sig. (2-tailed) | .000 | | .000 | .000 | .000 |
| | N | 54 | 54 | 54 | 54 | 54 |
| Household Monthly Expenditure on Food | Pearson Correlation | .926** | .921** | 1 | .941** | .978** |
| | Sig. (2-tailed) | .000 | .000 | | .000 | .000 |
| | N | 54 | 54 | 54 | 54 | 54 |
| Age of Household head | Pearson Correlation | .867** | .836** | .941** | 1 | .939** |
| | Sig. (2-tailed) | .000 | .000 | .000 | | .000 |
| | N | 54 | 54 | 54 | 54 | 54 |
| Monthly Household Domestic solid waste in kilograms | Pearson Correlation | .921** | .939** | .978** | .939** | 1 |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 | |
| | N | 54 | 54 | 54 | 54 | 54 |

Middle socio-economic group

**Correlations**

| | | Household Size | Household Monthly Income | Household Monthly Expenditure on food | Age of Household head | Monthly household domestic solid waste in kilograms** |
|---|---|---|---|---|---|---|
| Household Size | Pearson Correlation | 1 | .883** | .981** | .872** | .977** |
| | Sig. (2-tailed) | | .000 | .000 | .000 | .000 |
| | N | 204 | 204 | 203 | 204 | 204 |
| Household Monthly Income | Pearson Correlation | .883** | 1 | .914** | .794** | .938** |
| | Sig. (2-tailed) | .000 | | .000 | .000 | .000 |
| | N | 204 | 204 | 203 | 204 | 204 |
| Household Monthly Expenditure on food | Pearson Correlation | .981** | .914** | 1 | .945** | .990** |
| | Sig. (2-tailed) | .000 | .000 | | .000 | .000 |
| | N | 203 | 203 | 203 | 203 | 203 |
| Age of Household head | Pearson Correlation | .872** | .794** | .945** | 1 | .876** |
| | Sig. (2-tailed) | .000 | .000 | .000 | | .000 |
| | N | 204 | 204 | 203 | 204 | 204 |
| Monthly household domestic solid waste in kilograms** | Pearson Correlation | .977** | .938** | .990** | .876** | 1 |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 | |
| | N | 204 | 204 | 203 | 204 | 204 |

Low socio-economic group

**Correlations**

| | | Household Size | Household Monthly Income | Household Monthly Expenditure on food | Age of Household Head | Amount of Monthly Household Solid waste (KG) |
|---|---|---|---|---|---|---|
| Household Size | Pearson Correlation | 1 | .958** | .926** | .905** | .957** |
| | Sig. (2-tailed) | | .000 | .000 | .000 | .000 |
| | N | 109 | 109 | 109 | 109 | 109 |
| Household Monthly Income | Pearson Correlation | .958** | 1 | .974** | .926** | .981** |
| | Sig. (2-tailed) | .000 | | .000 | .000 | .000 |
| | N | 109 | 109 | 109 | 109 | 109 |
| Household Monthly Expenditure on food | Pearson Correlation | .926** | .974** | 1 | .903** | .931** |
| | Sig. (2-tailed) | .000 | .000 | | .000 | .000 |
| | N | 109 | 109 | 109 | 109 | 109 |
| Age of Household Head | Pearson Correlation | .905** | .926** | .903** | 1 | .920** |
| | Sig. (2-tailed) | .000 | .000 | .000 | | .000 |
| | N | 109 | 109 | 109 | 109 | 109 |
| Amount of Monthly Household Solid waste (KG) | Pearson Correlation | .957** | .981** | .931** | .920** | 1 |
| | Sig. (2-tailed) | .000 | .000 | .000 | .000 | |
| | N | 109 | 109 | 109 | 109 | 109 |

**. Correlation is significant at the 0.01 level (2-tailed).

# APPENDIX XII: SCHOOL OF GRADUATE STUDIES PROPOSAL APPROVAL

**MASENO UNIVERSITY**

**SCHOOL OF GRADUATE STUDIES**

***Office of the Dean***

**Our Ref:** PG/PHD/00094/2012

Private Bag, MASENO, KENYA
Tel:(057)351 22/351008/351011
FAX: 254-057-351153/351221
Email: sgs@maseno.ac.ke

Date: 01st February, 2016

**TO WHOM IT MAY CONCERN**

**RE: PROPOSAL APPROVAL FOR JENNIFFER ATIENO VERA—PG/PHD/00094/2012**

The above named is registered in the Doctor of Philosophy Programme of the School of Environment & Earth Sciences, Maseno University. This is to confirm that her research proposal titled "An Analysis of Socio-Demographic and Economic Determinants for Estimating Domestic Solid Waste Generation and Composition in Urban Estates in Kisumu City, Kenya" has been approved for conduct of research subject to obtaining all other permissions/clearances that may be required beforehand.

MASENO UNIVERSITY DIRECTOR 02 FEB 2016 SCHOOL OF GRADUATE STUDIES

Prof. P.O. Owuor
**DEAN, SCHOOL OF GRADUATE STUDIES**

*Maseno University* *ISO 9001:2008 Certified*

## APPENDIX XIII: MASENO UNIVERSITY ETHICS REVIEW COMMITTEE APPROVAL

**MASENO UNIVERSITY ETHICS REVIEW COMMITTEE**

Tel: +254 057 351 622 Ext: 3050
Fax: +254 057 351 221

Private Bag – 40105, Maseno, Kenya
Email: muerc-secretariate@maseno.ac.ke

**FROM**: Secretary - MUERC

**DATE**: 6th July, 2017

**TO**: Vera Jenniffer Atieno
PG/PHD/00094/2012
Department of Environmental Science
School of Environment and Earth Sciences
Maseno University
P.O. Private Bag, Maseno, Kenya

**REF**: MSU/DRPI/MUERC/00279/16

**RE: An Analysis of Socio-Demographic and Economic Determinants for Estimating Domestic Solid Waste Generation and Composition in Urban Estates in Kisumu City, Kenya. Proposal Reference Number: MSU/DRPC/MUERC/00279/16**

This is to inform you that the Maseno University Ethics Review Committee (MUERC) determined that the ethics issues raised at the initial review were adequately addressed in the revised proposal. Consequently, the study is granted approval for implementation effective this 6th day of July, 2017 for a period of one (1) year.

Please note that authorization to conduct this study will automatically expire on 5th July, 2018. If you plan to continue with the study beyond this date, please submit an application for continuation approval to the MUERC Secretariat by 6th June, 2018.

Approval for continuation of the study will be subject to successful submission of an annual progress report that is to reach the MUERC Secretariat by 6th June, 2018.

Please note that any unanticipated problems resulting from the conduct of this study must be reported to MUERC. You are required to submit any proposed changes to this study to MUERC for review and approval prior to initiation. Please advice MUERC when the study is completed or discontinued.

Thank you.

DIRECTORATE OF RESEARCH PUBLICATION & CONSULTANCIES
06 JUL 2017
MASENO UNIVERSITY

Dr. Bonuke Anyona,
Secretary,
Maseno University Ethics Review Committee

Cc: Chairman,
Maseno University Ethics Review Committee.

MASENO UNIVERSITY IS ISO 9001:2008 CERTIFIED