KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DEPARTMENT OF ENVIRONMENTAL SCIENCE

INSTITUTE OF DISTANCE LEARNING

STUDIES ON UTILIZATION OF DECOMPOSED SOLID WASTE COMBINED WITH COW DUNG AND POULTRY MANURE FOR URBAN AGRICULTURE IN THE TAMALE METROPOLIS

A Thesis Submitted to the Department of Environmental Science, Kwame Nkrumah University of Science and Technology, Kumasi, in Partial Fulfillment of the Award of Master of Science in Environmental Science

BY

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DECLARATION

I hereby declare that except for works of other authors which served as sources of references and information and which have been duly acknowledged, the work herein submitted as a thesis for the MSc. Environmental Science Degree, is the result of my own effort under supervision, and has not been presented nor is being concurrently submitted for any other degree elsewhere. I am thus responsible for the views expressed and the factual exactness of its contents.

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DEDICATION

This Thesis is dedicated to my father, Rev Masak D. O. Simon, of blessed memory who upheld the zeal to send me to school and paternal care.

My mother, Madam Eunice Samson whose maternal role has been a replica of that of my father and financial contribution has seen me thus far. Mum I will forever be grateful.

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DEFINITION OF TERMS

Bin – Receptacle used for storage of refuse.

BOD – (Biological Oxygen Demand) – The amount of dissolved oxygen used by microbes in the biochemical oxidation of organic matter. It is measured in milligrams per litre over 5 days at 20 oC.

Eutrophication – is an adverse environmental condition that occurs when large quantities of animal sewage are introduced into a waterway, producing an increase in the concentration of available nutrients in that system. The result is the overgrowth of algae (algal blooms), which depletes oxygen sources for other aquatic life and creates a condition of low dissolved oxygen called hypoxia. The end results, such as massive fish kills, can be devastating in the ecosystem.

Garbage – Putrescible wastes resulting from growing, preparation, cooking and consumption of food.

Household – Number of people living in a house.

Leachate – The liquid discharge of dumps and landfills; it is composed of rotted organic waste, infiltrated rainwater and extracts of soluble material.

Pathogenic organisms (Pathogens) – These are disease causing organisms found in waste matter that have originated from human beings who are infected with disease.

Refuse – Rubbish; useless matter.

ABBREVIATIONS / ACRONYMS

BOD	Biological Oxygen Demand
CNPP	Canada's National Packaging Protocol
COD	Chemical Oxygen Demand
ENS	Environmental News Service
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
GLM	General Linear Model
HIV/AIDs	Human Immune Virus/Acquired Immune Deficiency Syndrome
LSD	Least Significance Difference
MSW	Municipal Solid Waste
MRFs	Material Recycling Facilities
NOP	National Organic Programs
SA	Sustainable Agriculture
SAS	Statistical Analysis Software
SCC	Science Council of Canada
SPSS	Statistical Package for the Social Sciences
OECD	Organization for Economic Co-operation and Development
PVC	Polyvinyl Chloride

TDS	Total Dissolved Solids
UA	Urban Agriculture
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USDA	United State Department of Agriculture
WCED	World Commission on Environment and Development

ABSTRACT

The main aim of the research was to explore how disposal and treatment of solid domestic waste impacts urban crop production by urban farmers in the Tamale Metropolis. The research focused on decomposed solid waste soils by urban farmers and on-farm trails with combination of soil amendments, cow dung and poultry manures. A descriptive cross-sectional study was used to gather data on the quantity of solid waste generated, methods used to collect and transport solid domestic waste.

Decomposed solid waste was combined with the various soil amendments in the ratio of 1:1 used for cabbage cultivation. The soils were spread evenly on beds incorporated using hoe by tilling 30 days prior to transplanting cabbage seedlings to beds. A randomized complete block design with 4 replications of 5 treatments was used. Soil amendment treatments consisted of combinations of the following: decomposed solid waste soil with combination of poultry manure and cow dung. The parameters assessed to determine the impact of the various soil amendments on cabbage were weekly plant height for seven weeks and weights of cabbage heads at maturity. However, differences among the soil amendment treatments were not significant, but all soil amendment treatments resulted in significantly greater yields than the No input treatment. Significant differences in plant growth occurred beginning with week 2, and by week 7 plant growth differences among treatments paralleled trends in yield. Decomposed solid waste soils combined with cow dung and poultry manure resulted in depressed yields and plant growth as compared to the other treatments.

Farmers formed the majority constituting sixty seven percent (67%). Respondents who lived in middle income areas formed majority with sixty seven percent (67%). Ninety-two (92) respondents representing twenty-four percent (24%) had availability of municipal cooperation dustbin while two hundred and ninety three (293) respondents representing seventy six percent (76%) had no access to municipal dustbin within 100 metres from their homes. The disposal of waste is done by both adults and children.

One hundred thirty nine (139) respondents representing thirty six percent (36%) called for the provision of municipal cooperation waste bin. Thirty (30) respondents representing eight (8%) also called for residents to contribute by clearing bushes around homes. Seventy eight percent (78%) of respondent do not make financial contribution to the current waste collection systems. The study showed that one hundred and twelve (112) respondents representing forty four percent (44%) of the urban farmers use organic manure while seventy five (75) respondents representing twenty nine percent (29%) use inorganic fertilizers.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Agriculture is the basis for human survival and, therefore the need to ensure the provision of safe food stuffs. Soil is the very resource on which agriculture is based and, therefore needs to be protected so as to enable food production to be continuous and beneficial in order to ensure food security for the ever growing population.

It has been estimated that within the next 20 years, two out of three West Africans will live in urban centers' (Bradford, 2005). Globally, the United Nations expects that between 2000 and 2025 the number of people living in urban areas will increase from 2.8 to 5.3 billion and that 90 % of the growth will occur in developing countries, mostly in Asia and Africa. The corresponding increase in urban food demand not only challenges rural crop production, but also, increasingly, specialized urban and peri-urban farming systems (Bradford, 2005). Due to the increase in the world's population and most of it moving to urban cities, there is increased demand for food, and this has resulted in the production of large amounts of agricultural wastes, both at farmer, municipality and city levels (Sabiiti *et al.* 2005).

According to Cofie *et al*. (2005) presently, it is believed that artificial fertilizers are as unrivalled in their capacity to furnish rich crops as are the organic manures in permanently maintaining the soil and the plants in good condition. This accounts for the ever increasing interest in the use organic waste for fertilization purposes, an interest very much alive on European continent and to a considerable extent in Great Britain.

Recycling of organic waste could in addition reduce its environmental pollution potential, increase the lifetime of landfills, and close the rural-urban nutrient cycle. However, very scanty information on the amounts, quality, and availability of the different organic wastes are available for the recommendation of location-specific technologies that match the requirement and ability to pay of different (Peri-) urban farming systems (Bradford, 2005).

The bulk of the agricultural food in developing countries is transported to cities in its raw form, thus compounding the net effect on large deposits of waste in urban markets, around homes and in slums as well as in various dumping grounds (Westerman and Bikudo, 2005).

Renewed interest in organic farming has resulted in a need for research in sustainable farming practices (Born, 2004; Bull, 2006; Dimitri and Oberholtzer, 2006; Greene and Dimitri, 2003; Granatstein, 2000; Organic Consumer Trends Report (OCTR:, 2007). This interest is in response to environmental and health concerns (Kramer, 2006).

Moreover, price premiums, niche markets, reduced chemical inputs, perceived health benefits, and its position as an environmentally friendly alternative growing system presents further attraction for organic production (Dainello, 2000).

Farmers in poor countries have acquired and continue to access urban organic wastes and to process and use them in various ways. Green wastes obtained from fruits and vegetables markets and used for animal fodder, food wastes form hotels, canteens and food processing industries are fed to pigs and goats.

The importance of such waste matter however is not restricted to its use in agriculture only. It has yet another, no less important aspects: its sanitary significance as a possible means of transmitting infectious disease and parasitic organisms cannot be over emphasized. Both the agricultural and sanitary significance must therefore be discussed in order to be able to make a clear appraisal of its sustainability for agricultural use.

1.2 PROBLEM STATEMENT AND JUSTIFICATION

1.2.1 Problem Statement

Many urban farmers are continuously cultivating on pieces of land year after year which is observed to have lost its nutrients resulting in poor or low yields of crops. It is therefore anticipated that the use of decomposed organic waste will boost crop production. Much of the decomposed solid waste consists of organic matter that can fertilize crops or can be recycled into a profitable input (compost) for urban agriculture (Dainello, 2000).

Urban farmers using decomposed solid waste in the Tamale metropolis have attested to the benefit of better soil structure. However, they complain of the manner in which solid waste disposed from homes affect their ability to efficiently use decomposed solid waste for fertilizing their crops. They cite an example of the way urban dwellers mix all kind of waste without segregating waste especially, those of organic waste from the non organic waste as noted by (Allison *et al*. 1998).

1.2.2 Justification for the Research

Over the last decade the demand for organic products has increased by approximately 20 % per year and the amount of certified land has doubled, making organics the fastest growing sector of agriculture (Baldwin, 2001). Currently the demand for organic products far outweighs the supply, and increasing numbers of small acreage landowners are considering a transition to certified organic production (Baldwin, 2001). Composting the large quantities of organic matter provides a win-win strategy by reducing waste flows, enhancing soil properties, recycling valuable soil nutrients and creating livelihoods, but there remain several constraints that explain why this opportunity is seldom exploited (Asomani-Boateng and Haight, 1999).

It has been observed that, peri-urban farmer's continuous use of low-cost organic matter from garbage dumps has increased in the last decade (Asomani-Boateng and Haight 1999). Therefore research is needed to develop cost-effective soil fertility practices for urban organic farming operations.

1.3 RESEARCH QUESTIONS

The research aims at contributing to the understanding of the following question:

- Which environmentally safe nutrient sources/recycling options would fit best to what kind of farmer/farming system with regard to economic and socio-cultural acceptability in each rural-urban context?

1.4 OBJECTIVES

1.4.1 Main Objective

To assess the generation, disposal and collection of Municipal Solid Waste and also determine the impact of decomposed solid waste for urban crop production in the Tamale Metropolis.

1.4.2 Specific Objectives

1. To assess the impact of generation, disposal and collection of Municipal Solid Waste on urban agriculture in the Tamale Metropolis.
2. To assess the impact of improved decomposed solid waste through the combination of soil amendments such as cow dung and poultry manure on the yield of cabbage
3. To recommend measures to ensure the effective disposal and management of Solid Waste in the Metropolis

1.5 ORGANIZATION OF THE REPORT

Chapter one contains background information of the study, statement of the problem and justification, research question and objectives of the research. Chapter two offers literature review. Chapter three focuses on study methods and analysis. Chapter four presents the results/findings; chapter five contains discussion of results whilst chapter six contains conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 SOLID WASTE

"Waste" is a material discarded and discharged as unnecessary from each stage of daily human life activities, which leads to adverse impacts on human health and the environments (Daskalopoulos and Auschutz, 1998).

The word "waste" refers to useless, unused, unwanted, or discarded materials. The term waste can also be used in reference to the protection of public health and, in particular, of the environments (Bilitewski *et al*. 1994).

Municipal solid waste are the waste from residential, commercial, institutional, construction and demolition, municipal services including the wastes from treatment plant sites (e.g. sludge from waste water treatment plants) and municipal incinerators. Industrial process waste and agricultural waste are excluded from municipal solid waste. Municipal solid waste can be divided into three types: organic wastes (combustible waste, plastic, wood, paper, textile, leather, rubber etc), inorganic wastes (non-combustible wastes, ferrous material, non-ferrous material, glass, stone, ceramic, bones, shells etc) and miscellaneous wastes. Municipal solid waste composition varies based on the location, season, economic condition and social life styles of a particular place.

2.1.1 Sources of Solid Waste

The sources of solid waste can be classified into the following categories:

a. Domestic/Residential solid waste

Garbage consists of results from food marketing, preparation and consumption in relationship to residential units. It contains putrecible organic material that needs special consideration due to its nature of attracting vermin (rats and flies) and of producing very strong odours.

Rubbish/ trash consist of paper and paper products, plastics, cans, bottles, glass, metal, ceramics, dirt, dust, yard trimmings and garden wastes, and the like. Except for the yard trimmings and garden wastes, these materials are non-putrecible.

Ash is a residue from combustion processes resulting from household activities.

Bulking waste include furniture, appliances, mattresses and springs, and similar large items.

b. Commercial and Institutional solid waste

This category consists of waste that originates from offices, retail stores, restaurants, schools, hospitals, and so on. Moreover, there are two additional categories which are construction and demolition wastes, and special waste. The former includes the material associated with the demolition of old buildings and construction of new buildings. The latter is the wastes that are generated by special facilities such as hospitals and research laboratories.

c. **Municipal solid waste**

This category includes the solid residues that results from the municipal functions and services such as street refuse, dead animals, abandoned vehicles, water and sewage plant residues, park and beach refuse and landscape waste.

d. **Industrial solid waste**

There are two sources of waste generated in the industrial sites: (1) the commercial/institutional part of the plant and (2) the manufacturing processes. The quality and characteristics of the wastes from these two are considerably different.

e. **Agricultural waste**

This is wastes that are generated from confined animal feeding and crop residues. This residue is the problem of rural areas because agriculture poses the significant and unique problems.

2.1.2 Types of Solid Waste Management

The four most common methods of municipal solid waste management include land filing, incineration, composting and anaerobic digestion. Incineration, composting and anaerobic digestion are volume reducing technologies; ultimately, residues from these methods must be land filled (Seo, 2004).

Land filling is the only true “disposal” method of managing municipal solid waste. It is also the most economical, especially in developing countries where it typically involves pitching refuse into a depression or closed mining site (Daskalopoulos and Auschutz, 1998)

Generally, the municipality is responsible for the collection and disposal of solid wastes. Open dumping is the basic municipal solid waste disposal practice for many municipalities because there is no need to invest in engineering designs, construction facilities or in technical operations (Daskalopoulos and Auschutz, 1998). Open dumps require a large land area for dumping municipal solid waste and for degradation of solid waste under natural conditions.

2.1.3 Uses of Solid Domestic Waste

Gourlay (1992) reported that environmentalists have joined hands with scientists and the more responsible sectors of industry and agriculture not merely to find better ways for disposing of wastes, but to seek its uses, reduction and eventual elimination. Before the advent of mineral fertilizers, manure and composts were the only source of nutrients for crop plants (F.A.O. and Environment, 1986). Solid domestic waste can be used as organic fertilizer. The amount of organic residues used in developing countries in 1971 was eight times higher than mineral fertilizers and exceed the world supply of mineral fertilizer (F.A.O. and Environment, 1986).

There is a growing awareness of the usefulness of organic fertilizers as a means of maintaining and improving soil productivity when applied alone or in combination with mineral fertilizers. F.A.O. and the United Nations Development Programme (UNDP) are enhancing the long tradition in Asia of recycling. According to Kordyles (1990) vegetable waste and putrescible matter are very useful in the preparation of compost and natural organic fertilizers. A research conducted by Chowder and Salaam (1995) indicated that nearly 2,364 tonnes of solid domestic waste are produced annually in a village with a population of 510 people. About 77% of the wastes were used as domestic fuel, animal fodder and organic fertilizer for crop production. Food residues, cereal straw, legumes, tuber crop peels and others have been generally utilized as animal feed. For instance, waste from plantain, cassava, yam and potatoes are processed into animal feed for which there is a large market.

Domestic wastes (garbage, cassava peels and others) covered with a layer of sand or clay media increase plant height, leaf area, plant dry weight, induce early flowering, enhance early yield and increase total yield (Salaam, 1996).

Gourlay (1992) reported that workers at the United States Department of Agriculture (USDA) conceived the idea of producing true high quality protein by using poultry manure. He further noted that cocoa seed coat is rich in digestible protein and minerals can be milled and incorporated into animal feed in small quantities. Fresh coconuts are used in making a reddish dye and used to dye fishing net. Mantell (1972) also confirmed that cocoa pods are dried and used as fuel. Brewer (1996) has reported that various agricultural wastes provided satisfactory substrates for vegetable growth and increased yield.

2.2 URBAN AGRICULTURE

Smith and Nasr (1992) defined urban agriculture as “food and fuel grown within the daily rhythm of the city or town, produced directly for the market and frequently processed and marketed by farmers or their close associates”. They suggest that urban agriculture is a “large and growing industry” which contributes to more sustainable resource use through using “urban waste water and urban waste as inputs”.

Urban agriculture can also be defined as “any agricultural activity within the administrative boundary of an urban centre” (Foeken and Owuor, 2000). According to Foeken and Owuor (2000), urban agricultural is central and critical to the actualization of sustainable, livable human settlements that more fully invite the full expression of humanity, including the production and purveyance of food.

2.2.1 The Use of Organic Waste in Urban Agriculture

From centuries of experience, farmers know that organic matter improves the workability of the soil, and soils rich in organic matter are likely to give a good harvest.

In Kampala alone, over 1000 mt of waste accumulate in the city and only about 30 % of it is collected by City Council leaving the rest to rot and pollute the environment (Sabiiti *et al.* 2005). Although it is recognized that the accumulation of waste has enormous ill effects on humans and the environment, such wastes if properly managed could be considered a big bio-resource for enhancing food security in the smallholder farming communities that would not afford use of expensive inorganic fertilizers. These organic wastes contain high levels of nitrogen, phosphorus, potassium and organic matter important for improving nutrient status of soils in urban agriculture. Various factors amplify the agricultural waste problem, especially in developing countries where there are limited facilities for recycling waste. In Kampala many small holder farmers have increased nutrient supply in soils by applying organic compost leading to improved crop yields, especially vegetables, maize which fetches high prices for the farmers thus reducing poverty levels and enhancing food security of these farmers. This alternate method of removal of these wastes for agricultural production by farmers has also reduced the rate of accumulation with subsequent reduction on environmental pollution thus improving on environmental health (Sabiiti *et al.* 2004).

2.2.2 Overview of Organic Crop Production

During the 1990's certified organic cropland increased twofold. Lowering cost and reliance on inputs and capturing price premiums are some of the reasons for farmers transitioning to organic production. In 1997 farmers committed 1,346,558 acres of cropland to organic production with California, Florida, North Dakota, Montana, Minnesota, Wisconsin, Iowa, and Idaho as the leading producers (Greene, 2001). Almost half of all certified organic vegetables were grown in California that year. Also that year, over 1 percent of tomatoes, oats and dry peas acreage, around 2 percent of lettuce, apple, grape and carrot, and one-third of the mixed vegetable, buckwheat and herb crops were grown organically. Organic fruits, vegetables, and herbs are grown most frequently.

Crops commonly grown in the US organically include citrus, onions, nuts, lentils, grain crops such as corn, buckwheat, millet, barley, sorghum, rice, spelt, rye, and oilseeds such as flax and sunflower (Greene, 2001; Klonsky and Tourte, 1998). Produce, such as the fruits, nuts, and vegetables mentioned above, dominate the organic market in the U.S., whereas agronomic crops such as corn, wheat, hay, and soybeans dominate the conventional sector (Klonsky and Tourte, 1998).

Research involving organic fertilizers in commercial crop production systems and their efficacy is scarce. What work has been done occurs largely outside of the southeastern United States. Soil quality, conservation, nutrient dynamics, cover cropping, and organic matter and amendment management have been studied in many regions of the country (Bary *et al*., 2000; Glover *et al*., 2000). Farmers have been growing vegetables organically for years, but without proper documentation, record keeping, yield comparison, and replication, the data reported is primarily anecdotal and is not very useful (Pimentel *et al*., 2005). Price premiums remain favorable for organic food due to increasing consumer demand. Even without price premiums however, organic production has been reported to be more than or equally as profitable as conventional agriculture for a variety of crops (Pimentel *et al*., 2005; Welsh, 1999).

In terms of overall vegetable yield, several studies have shown that organic production is comparable to conventional and low-input systems (Delate *et al*., 2003; Gent, 2002; Lang, 2005, Martini *et al*., 2003). Examples include: carrots, lettuce, tomatoes (Eggert and Kahrmann, 1984), cabbage (Warman and Harvard, 1997), and peppers (Roe *et al*., 1997). When conventional growing did come out ahead in terms of yield, organic and low-input systems had enhanced microbial biomass and activity, water-holding capacity, increased mobile humic acids, water infiltration rates, pools of phosphorous and potassium, and increased soil organic matter (Klonsky, 2000; Temple, 2002).

The United States Department of Agriculture (USDA) regulates which substances are allowable in organic crop production. The National Organic Program's (NOP) Final Rule states that organic production must "maintain or improve" the soil and provide "soil fertility through rotations, cover crops, and the application of plant and animal materials" (www.ams.usda.gov/nop). The Final Rule prohibits most synthetic substances commonly used in conventional agricultural operations; therefore organic farmers have limited options in choosing soil amendments to enhance soil fertility. Furthermore, commercially available organic soil amendments may be cost-prohibitive for small, limited resource organic farms.

Over the last 50 years, synthetic fertilizers have become the primary nutrient source for agriculture. However widespread use of fertilizers has had adverse impacts on the environment raising serious public concern. Leaching of nitrates and phosphates from soil is problematic, and fertilizers have been linked to marine eutrophication and groundwater contamination (Crews *et al.*, 2004). In addition, the production of synthetic fertilizers requires an immense amount of energy input and is dependent on the price of natural gas in the United States (www.ams.usda.gov/nop). For these reasons recent research has focused on seeking effective sustainable and organic alternatives to enhance soil fertility and crop yields. Lee *et al.* (2003) evaluated poultry manure compost as a supplement to inorganic sources of nitrogen. Their results indicated that the amount of added nitrogen could be reduced by 40 % with the addition of poultry manure.

In contrast to conventional agriculture organic farmers approach soil fertility in a holistic manner by implementing production practices that improve the physical, chemical, and biological properties of a soil. Physical characteristics of soil include texture and structure. The texture of a given soil is the percent sand, silt, or clay and is generally unchangeable for a given location (Brady *et al.*, 2002). Structure is the aggregation of these sand, silt, or clay particles into secondary clusters, and is readily altered by agricultural practices (Brady *et al*, 2002). Texture and structure are responsible for the porosity, drainage, water-holding capacity, compaction and tilth of a soil (Brady *et al*, 2002). Soil physical characteristics influence the ability of roots to grow and proliferate, extracting water and nutrients and stabilizing the plant. Wong *et al.* (1999) found that livestock manure compost applied to soils of organic farms in Hong Kong improved soil physical properties with a significant decrease in bulk density and increase in soil porosity and hydraulic conductivity.

Soil chemical properties determine the availability of plant nutrients (Brady *et al*, 2002). Due to constraints on chemical inputs, organic farmers focus less on this component of soil fertility. Where conventional farmers place great emphasis on inputs of synthetic chemical fertilizers, organic farmers manage soil chemical properties with addition of organic matter thereby increasing cation exchange capacity of the soil (Baldwin, 2001).
The biological component of soil is perhaps the most important for organic farmers. Organisms living in a healthy soil include earthworms, arthropods, bacteria, fungi, algae, protozoa, and nematodes. These organisms break down plant material, feed on each other, and excrete nutrient-rich wastes, amino acids, sugars, antibiotics, gums, and waxes (Sullivan, 2004). Much of these excreta are beneficial to soil structure and plant health. The balance in which these organisms reside in the soil is a delicate one, highly sensitive to chemical inputs and dependent on organic matter for food.

It is generally recognized that the foundation of good soil quality is organic matter. Sullivan (2004) describes a few of the benefits of a topsoil rich in organic matter, including rapid decomposition of crop residues, granulation of soil into aggregates, decreased crusting, better water infiltration and drainage, increased water and nutrient holding capacity, easier tillage, reduced erosion, better formation of root crops, and more prolific plant root systems. Addition of organic matter to agricultural soil can most easily be accomplished with incorporation of cover crops, manure, and/or compost (Sullivan, 2004).

2.2.3 Organic Production

Over fertilization in agriculture has led to surface water and ground water contamination. Nitrogen fertilizer pollution is responsible for eutrophication, hypoxia, and algal blooms in rivers, marshes, ground water, and runoff, and may be a public health risk (Kramer *et al*. 2006).

Decomposition of soil organic matter, as well as water and wind erosion, is accelerated by ploughing, tillage, and crop burning. Good agricultural practices are performed in most organic production systems, such as minimum tillage, crop rotations, addition of organic materials, and cover cropping to improve overall soil health, fertility, tilth, soil aggregate stability, earthworm number, potential denitrification rates, denitrification efficiency, water holding capacity, soil respiration, nutrient cycling, enzyme activity, and microbial life, biomass, and activity, as well as minimize runoff and erosion (Bot and Benites, 2005; Gaskell, *et al*. 2000; Hochmuth, *et al*. 2000; Kramer, *et. al*. 2006; Mader, *et al*. 2002; Sanchez, *et al*. 2003). Increased microbial diversity in the soil leads to efficient production of soil biomass and nutrient utilization (Mader, *et al*. 2002).

Often organic fertilizers are bulky or are necessary in large quantities. This can make shipping expensive and is one of the reasons organic farming is more viable for small-scale farms and on farm inputs are preferred (Adediran, *et al*. 2004; Hochmuth, *et al*. 2000). Reduced reliance on external inputs may be achieved in an organic system due to increased soil fertility and biodiversity (Mader, *et al*. 2002). As cities are looking for ways to reduce their municipal wastes, agriculture may be an option. Compost from waste facilities can be applied to soils to add nutrients and improve soil, but compost should be mature and the nutrient content known. Immature compost may take nitrogen from the soil in order to complete the composting process, causing nitrogen deficiencies in plants (Hochmuth, *et al*. 2000). The nutritional condition of the compost may also aid in suppression of soil-borne plant pathogens (Fertilization Systems in Organic Farming, 1997). The decomposition and formation of organic matter releases nutrients into the soil. To adequately determine the amount of nutrients the soil contains, various tests can be used for different nutrients. Calcium, magnesium, and sulfur are usually present in enough quantities in an organic system due to irrigation water, addition of compost, and the use of sulfur fungicide (Gaskell, *et al.* 2000). Compost and organic matter contain nutrients that are not readily available for plant uptake, unlike inorganic fertilizers. Thus, soil microorganisms must break down the organic nitrogen into inorganic nitrogen through the biological process of mineralization (Zublena, *et al*. 1991). The amount of nitrogen a soil contains and needs can be estimated by the amount likely to mineralize over a given period of time, but studies have shown that crop rotations, green manures, cover cropping, compost application and allowable fertilizers can keep soil fertility at optimum levels (Adediran, *et al.* 2004; El-Tarabily, *et al*. 2003; Mader, *et al*. 2002; Sanchez, *et al.* 2003; Zublena, *et al*. 1991). Soils under an organic management system can retain nitrogen in the soil longer and uptake of nitrogen is more efficient. In times of drought or flooding, organic soils retained optimum nutrient status allowing crops to survive through harsh conditions (Hepperly, 2005). Studies have shown that an integrated nutrient system is also a viable alternative to conventional growing practices.

Inorganic fertilizers combined with compost or other organic amendments provide successful yield rates (Adediran *et al*. 2004). Increased soil organic matter leads to increased soil quality, and a system that uses organic amendments is promoting the formation of soil biomass (Saleque *et al*. 2003). The combination of organic matter with mineral fertilizers has shown benefits over mineral nutrient use alone (Berecz, 2005). In addition, integrated systems reduce polluting nitrate losses to the environment and promote more efficient nutrient usage (Kramer *et al*. 2006). The overuse of mineral fertilizers has been discussed, but growers must also be aware of overuse of organic amendments. Nitrogen leaching may be a problem in organic systems due to the usually heavy use of animal and green (cover crops) manures. Growers should take care to investigate the nutrient status and requirement of the crops being grown before application of animal or green manures; contamination of waterways could possibly be a result from an organic growing system that uses excessive nitrogen (Beckwith, *et al*. 1998; Bergstrom, *et al*. 2004; Havlin, *et al*. 1999). In addition, contamination of vegetables from uncomposted manure can be a problem if not handled properly (Ingham, *et al*. 2005). Slurries, broiler litter, biosolids, animal manures, Milorganite (a commercially available refined biosolid manure) and green manures, are common organic fertilizers (Munoz, *et al*. 2005). Animal manures as well as cover cropping have been shown to be successful organic fertilizers (Gareau, 2004; Munoz, *et al*. 2005). On farm inputs via a combined animal and crop production scheme do not have the additional transport and purchase costs and can therefore be substantially more profitable (Gareau, 2004). Additional fertilizers are also commonly used, such as fish emulsion or seaweed extracts.

2.2.4 Urban Organic Waste

Urban organic waste is the biodegradable part of households refuse, market waste, yard waste and animal and human waste. Waste water is not included. The emphasis is laid mainly on household waste. When waste is not managed properly it may cause serious health and environmental risks. The overall goal of municipal refuse management is to improve and safeguard the public health and welfare, reduce waste generation and increase resource recovery and re-use, and protect environmental qualities (Cointreau, 1982).

Table 1 shows that the nature of municipal refuse is related to the relative consumption and production activities within countries, according to their stage of economic development.

Table 2.1 Composition of municipal refuse for low, middle and upper income countries

Waste generation	**Low-income countries**	**Middle-income countries**	**Industrialized-countries**
(kg/cap/day)	0.4 - 0.6	0.5 - 0.9	0.7 - 1.8
Composition			
(% wet weight)	1 – 10	15 – 40	15 - 40
Paper	1 – 5	1 – 5	3 - 13
Metals	1 – 5	2 – 6	2 - 10
Plastics	40 – 85	20 – 65	20 - 50
Vegetables/	1 – 5	2 – 10	-

wood/bones/straw

Source: Cointreau, 1982

The scale of resource recovery is much wider in economically less developed countries than in the industrialized countries. In economically less developed countries, poverty is the major reason why thousands of people are involved in the (informal) collection, sorting and processing of solid waste.

2.3 COMPOST PROCESSES

Compost is the end product of a number of biological degradation processes (composting, co-composting or anaerobic digestion). It is the stable end product from the biological degradation of organic material, which can vary from dead leaves and rots to kitchen waste and vegetable remains. Composting is an aerobic decomposition process in which some of the organic material is decomposed to carbon dioxide (CO_2) and water, while stabilized products, principally humic substances, are synthesized. The composting process is carried out by micro organisms which spontaneously grow in any mixed natural organic waste if it is kept moist and aerated. The growth of these organisms liberates heat, CO_2 and water vapour.

The principal variables which must be controlled to make good compost are:

- Oxygen
- Moisture
- The fraction of nitrogen in the organic matter, usually expressed as the C/N ratio

- The temperature, and

- The acidity (pH) (Brunt *et al*. 1985).

Composting systems can be categorized as open (non-reactor) and closed (reactor system). Closed systems are popular in industrialized countries. In an open system the organic waste material can be arranged in piles or in windrows. Anaerobic decomposition can take place in uncontrolled systems (for example waste dumps) and in controlled systems (for example reactors). Anaerobic decomposition in a waste heap occurs when the oxygen supply is restricted or absent. Besides compost biogas is produced. Due to the formation of biogas less compost is produced. If the organic waste material is well decomposed (aerobically or an aerobically), the odourless and pathogen-free black brown mixture can be used as a soil conditioner.

2.3.1 Characteristics of Compost

Compost has been used as: a) fertilizer, b) soil conditioner, c) feed for fish in aquaculture, d) landfill material and e) soil medium for horticultural purposes (Polprasert, 1989).

According to the degree of biochemical degradation and final processing, compost may be classified in four types:

1. Raw compost - not decomposed or disinfected
2. Fresh compost - composting material in the early stages of biological degradation and fully disinfected

3. Mature compost - fully composted and disinfected product of a composting process
4. Special compost - compost which has been given further processing by screening, ballistic separation or air classifying, the addition of mineral substances, or both (Brunt *et al*. 1985).

All of these forms can be used in urban agriculture. Type 3 and 4 are preferred, because the waste material is fully disinfected and has a settled composition. General properties of mature compost are listed in table 2 below.

Table 2.2 General properties of finished compost

Property	**Normal range**
Moisture (g/100 g)	30 - 50
Inert matter (g/100 g)	30 - 70
Organic content (g/100 g)	10 - 30
pH (1 : 10 slurry in distilled water)	6 - 9
Maximum particle size (mm)	2 - 10

Source: Brunt et al., 1985

Both the major and the minor nutrients are important for the growth of plants. The major essential plant nutrients are N (nitrogen), P (phosphorus) and K (potassium) (Brunt *et al*.1985). They are called major, because a relative high amount of these nutrients is needed. The higher the content of these nutrients, the greater the fertilizer value of the compost. Most of the N in the compost is in an organic form and must be mineralized to inorganic ammonium or nitrate before it is available to the plant. The N, P and K values for compost depend on the type and the initial C/N ratio of the material. The ranges of concentrations of the major nutrient in finished compost are shown in table 3 below. Minor elements are also important for plant growth, but only in a small amount. Too high amounts will negatively influence crop growth.

Table 2.3 Concentrations of the major elements in finished compost

Element	**Normal range (in g/100 g dry basis)**
N	0.1 - 1.8
P (P2O5)	0.1 - 1.7 (0.2 - 3.8)
K (K2O)	0.1 - 2.3 (0.1 - 2.8)
S	0.5 - 3.0
Alkalinity (as CaO)	(1 - 20)
Total Salts (as KCl)	(0.5 - 2.0)

Source: Brunt et al., 1985

Maung (1982) stated that the generally high organic matter content and low heavy metal content of municipal solid waste found in developing countries mean high quality compost which is safe for application to the soil. Due to the increased `modernization', the composition of the waste is changing. Organic chemicals such as pesticides and polychlorinated bi-phenyls (PCBs), and heavy metals may be present in wastes in such high concentrations that will make compost undesirable for land application.

Compost can be considered as a fertilizer rich in organic matter. The organic matter is an excellent soil conditioner because it has been stabilized, decomposes slowly, and thus remains effective over a longer period of time (slow release N-fertilizer). With synthetic fertilizers the nutrients are mainly directly available for plant uptake. Besides acting as organic fertilizer, compost plays a role in soil physical properties.

Compost maintains the humus balance in the soil, which improves the structure of the soil, helps to bind nutrients, ensures the proper circulation of air and water, and is thus indispensable for the growth of healthy crops. When compost is applied around the plant it has a mulching effect which includes moisture holding capacity, prevention of weeds and reduction of soil erosion. The greatest improvement in soil physical properties occurs in sandy and clay soils (Polprasert, 1989).

2.4 THE USE OF ORGANIC WASTE AS FERTILIZER

There are various ways of using urban organic waste materials for urban agriculture practices:

- Using garbage: directly on the garbage heap or in the back yard
- Using compost, self-produced or bought
- Using manure from cattle (raised near the house)
- Using human waste (treated or untreated)

The use of manure and human waste are only discussed when they are used in combination with garbage or compost. Combining different types of organic materials may have a positive result, because these materials complement each other very well. Compost has a high carbon (C) content and is a good bulking material, while human and animal wastes are high in nitrogen (N) content and moisture contains (Cross and Strauss, 1985). Table 4 below shows an overview of the nutrient values of various natural fertilizers.

Table 2.4 Nutrient value of various natural fertilizers

Nutrient content (% dry matter)	**Ntot**	**P2O5**	**K2O**
Pig manure	4 – 6	3 – 4	2.5 - 3
Plant residues	1 – 11	0.5 - 2.8	1.1 - 11
Composted material	0.4 - 3.5	0.3 - 3.5	0.5 - 1.8

Source: Cross and Strauss, 1985

There is not always a clear distinction between fresh garbage and compost. Garbage which has been disposed can already be in a far-reaching phase of decomposition, e.g. when it has been lying for some time on the street or at a transfer station.

2.4.1 The Use of Garbage

Two ways of using garbage in urban agriculture: gardening on garbage heaps, and using garbage on the farmer's `own' plot of land.

Gardening on (former) waste disposal sites is common in many Southern countries (Drescher, 1994). Such sites offer fertile land not used for other purposes. In general, these sites have high organic matter content. Serious disadvantages are the possible heavy metal content and types of wastes, such as broken glass and tins, which may cause injuries. Heavy metals can be absorbed by the cultivated crops and may cause health problems to the consumer. Whilst in case of the use of garbage on the farmer's 'own' plot, it should be done mindful of eliminating all foreign materials and knowledge of the nutrient requirements of the crops to be grown.

2.5 SOIL FERTILITY

Soil fertility is the quality that enables a soil to provide the proper nutrients, in the proper amounts and in the proper balance, for the growth of specified plants when other growth factors such as light, temperature, moisture and the physical condition of the soil are favourable. It is also said to be the ability of the soil to provide the plant with all its needs during the growing season. These definitions mean that depending on the specific growth requirements of a crop, a fertile soil for one crop may not necessarily be fertile for another. However, no matter the meaning attached to "soil fertility" the objective of increasing or conserving fertility is to obtain as large a yield as is economic, or as is possible, of the crops to be grown.

High fertility further implies an increase in the range of crops that can be grown. Strictly, a soil can only be fertile if it is favourable environment for root growth; and a soil can only be a suitable environment for plant roots if: (i) it is adequately drained and aerated; perhaps rice is the only exception of crops whose roots need only very little oxygen in the soil, as it appears to be supplied with oxygen through special tissues on the stem and root. (ii) if it's salt content and content of exchangeable sodium ions are low; and (iii) if its pH falls in a suitable range.

2.5.1 Rationale for Soil Fertility Concerns

The increased awareness of soil as a critically important component of the earth's biogeosphere has stimulated interest in the concept of and assessment of soil quality (Karen, 2000). Demand on soil resources for enhancing food security, improving water quality, disposing wastes and mitigating climate changes has raised in response to growing population. This increased demand has intensified anthropogenic activities and amplified pressure of degradation. Although the threats of land degradation are wide spread, it is more intensive in the poorer regions, where the land users entirely depend on the inherent capacity of the land for their basic needs.

A soil fertility test evaluates the nutrient-supplying power of a soil. The results of the test are used to predict if, or how much fertilizer is required for optimum plant growth. Soil fertility test becomes necessary when human activities on the soil renders the soil infertile resulting in low yields due to the poor growth and development of crop plants (Karen, 2000).

A major focus of environmental science is solving environmental problems. Even though there seems to be unlimited number of environmental problems, almost all of them fall into one of three categories: Resource depletion, Pollution and Extinction. A resource is depleted when a large part of it has been used up (Karen, 2000). Loss of soil nutrients (decrease in soil fertility) is a form of resource depletion.

Roar (1997) indicated that soil depletion occurs when the components which contribute to fertility are removed and not replaced; and the conditions which support soil fertility are not maintained. This leads to poor yields. In agriculture, depletion can be due to excessively intense cultivation and inadequate soil management. One of the most wide spread occurrences of soil depletion as at 2008 in the tropical zone is where nutrient content of soil is low. The combined effects of growing population densities, large scale industrial logging, slash-and-burn agriculture, land clearing practices and other factors have in some places depleted soil through rapid and almost total nutrients removal. He added that topsoil depletion is when the nutrient rich organic topsoil that takes hundreds to thousands of years to build up under natural conditions is eroded or depleted of its original organic matter.

2.5.2 Human Impact on Soil Fertility and Environment

Historically, many past civilizations collapsed can be attributed to the depletion of the topsoil. Since the beginning of agricultural production in Great plain of North America in 1880s about one half of its topsoil has disappeared. Depletion may occur through a variety of other effects, including over tillage which damages soil structure, over use of inputs such as synthetic fertilizers and herbicides, which leave residues build up that inhabit micro-organisms, and salinisation of soil (Koetke and William, 1993).

Human activities have exposed many parts of the natural environment to considerable risk. The first human impact on the environment is on vegetation, which is still prevalent, is the use and misuse of fires. Deliberate burning is use to clear the land for agricultural purposes. Fires cause a reduction in natural vegetation; they threaten wildlife, humans and property. Fire produces secondary problems associated with the clearance of vegetation such as soil erosion, flooding and wind erosion. Deforestation involves the deliberate removal of forest to create new agricultural lands. Deforestation and degradation of other vegetation, particularly near the margins of deserts, have caused once fertile/vegetated lands to become barren in a process called desertification. Factors that contribute to the expansion of desert regions also include bad land management and poor farming techniques (Kevin and Owen, 1995).

The earth has a limited amount of arable land-fertile land that can be ploughed to grow crops. This amount is decreasing every year. It is estimated that the arable land in the world will have decreased by one-fifth from 1985-2000 (United Nation Environmental Programme Study, 1990) About 135 million hectares (about 334 acres) will become unusable for farming because the soil will be damaged. The shortage of fertile agricultural land threatens our ability to feed the human population (Karen, 2000). The soil that has taken so long to form is being lost to erosion at an alarming rate. Erosion is the wearing away of the topsoil by wind and water. In the United States, about half of the topsoil has been lost to erosion in the past 200years. Worldwide, it is estimated that about 11 percent of the soil has been eroded in the last 45years. Topsoil erosion is ranked as one of the most serious ecological problem we face. Without the valuable topsoil, crops cannot be grown to feed the world's people.

2.5.3 Fertility Management

Soil health is imperative to obtain high yielding, quality vegetables. Both the chemical and physical conditions of the soil can be changed to benefit vegetable production. Mineral soils - the sandy, loamy and clayey soils, along with organic soils - the muck or peat soils high in organic matter, are best suited for vegetable production and is where plants obtain their nutrients (Bot and Benites, 2005).

The environment also has an effect on successful vegetable production. These environmental factors can be broken down into three groups: climate; temperature, water, wind, radiation, CO_2 concentration, and air pollution, soil; nutrients, soil water, structure, textures, chemical components and air content, and bios; pests, beneficial organisms, and microorganisms. Such features, along with economic aspects such as market influences and input costs, greatly affect crop production (Krug, 1997). The availability and uptake of nutrients from soil is also affected by environmental conditions (Gent, 2002).

2.6 SUSTAINABLE AGRICULTURE

How can we continue to feed the world's population without continuing to deplete the world's resources? One answer is low-input farming, otherwise known as sustainable agriculture. Low –input farming is farming without using a lot of energy, pesticide, fertilizer and water. One kind of low-input farming is organic farming that is growing plants without any synthetic pesticide or inorganic fertilizers. Organic farming keep the soil moist and fertile by adding manure, compost and other organic matter, by keeping the soil planted at all times to avoid erosion, and by alternating different crops to reduce pest populations. In addition to protecting the environment, organic farming reduces the need for water, pesticides and fertilizers (Karen, 2000).

Papendick and Parr (1990) stated that for a farm to be sustainable, it must produce adequate amount of high quality food, protect its resources and be both environmentally safe and profitable instead of depending on purchased materials such as fertilizers and that a sustainable farm relies as much as possible on the beneficial natural processes and renewable resources drawn from the farm itself. Papendick and Parr (1990) defined sustainable agriculture as one that equitably balances concerns of environmental soundness, economic viability and social justice among all the sectors of the society. The Science Council of Canada (1991) explains sustainable agriculture to mean food production systems that are economically viable and meet society needs for safe and nutritious food whiles considering or enhancing the natural resources and the quality of the environment. Yet (Fresco and Kroonenberg, 1992) referred sustainable agriculture to be the use of agricultural land in such a way to ensure that over time no net quantitative or qualitative loss of natural resources occurs. Sustainable agriculture consist of agricultural processes involving biological activities of growth or reproduction intended to produce crops which do not undermine our future capacity to successfully practice agriculture. Sustainable agriculture simply means farming with wisdom or farming without causing any serious damage to the soil, environment, plant, water bodies, humans and animals. In fact Ainworth (1989) defined sustainable agriculture as profitable agriculture, nothing more, and nothing less. In all sustainable agricultural activities, the activities must be economically viable, environmentally safety (sound), and socially justice.

2.7 SUSTAINABLE AND INTEGRATED WASTE MANAGEMENT TECHNIQUES

2.7.1 Definition of Sustainable and Integrated Waste Management

Sustainability: "existing and solving today's problems in a responsible environmentally-friendly manner thereby not prejudicing the ability of future generations to exist to solve their own problems".

Integrated waste management: "the consideration of all components which make up the waste management hierarchy and the selection of the appropriate components in consideration with each other cradle to grave approach" (Novella, 2001).

Solid waste management is the integration of suitable techniques, technologies, and management programs to achieve waste management objectives. Of the many components of solid waste management, solid waste collection is one of the most complex and costly to plan and implement. Thus, it is one of the most beneficial to modernize. Though the many aspects of modernization are case specific, the use of conventional solid waste containers and collection trucks is a general practice that can greatly increase the efficiency of solid waste collection by decreasing the time required at individual collection sites. In addition, modernization of solid waste collection practices improves the aesthetics and reduces the number of vectors attracted to the collection locations.

Solid waste management planning includes all aspects of solid waste collection, transport, processing and disposal. Solid waste collection is perhaps the most important of these components. A solid waste collection system must be convenient, efficient, economical, and dependable and must protect human health and the environment. Solid waste collection systems vary between countries. Political considerations, public acceptance, public health, economics, and environmental and historical conditions are a few of the many factors affecting solid waste collection plans.

2.7.2 Frequency of Collection

The frequency of collection is an important factor in the solid waste management program due to the cost involved in personnel and equipment requirements. The optimal collection frequency is decided by the quantity of solid waste generated, the climate, the cost involved in collection, and public demand or consumer service expectations. The following summarizes some of the factors involved in determining the frequency of solid waste collection:

- Costs, where a lower collection frequency corresponds to fewer trucks, employees, and mileage put onto the collection vehicles.

- Storage space, where more storage space is needed at the collection point having less frequent collection (the frequency of collection should be less than the time in which the amount of solid waste that is generated no longer fits into the storage container); and
- Sanitation, where more frequent collection reduces health, safety, and nuisance concerns associated with stored solid waste (the frequency of collection should be less than the time it takes for vectors, e.g. flies, to complete a breeding cycle, and less than the time it takes for solid waste to develop an odour problem) (Wallace *et al*. 2001).

2.7.3 Producing Less Waste/Source Reduction

In general, waste prevention has a high priority in integrated waste management concepts. European Waste laws clearly define, that waste prevention is the first option to solve waste problems. This hierarchy is also found in the European community strategy, where prevention represents the first priority, followed by recovery in the forms of recycling and energy recover, and in the last instance by waste disposal (Salhofer *et al*. 2001).

Source reduction, is the reduction in the amount and/or toxicity of materials entering the waste stream prior to recycling, treatment or disposal. Source reduction applies to municipal solid waste and to waste resulting from a products life’s cycle, including raw materials extraction, processing and distribution (Saphire, 1998). For many companies, this involves eliminating waste that would go into their own dumpsters, as well as materials that would become waste for their customers. The Brundtland report of the United Nations "Our Common Future" (WCED, 1987) clearly spelled out that sustainable development would only be achieved if society in general, and industry in particular, learned to produce "more with less"; more goods and services with less use of the world's resources (including energy) and less pollution and waste. What is even better than reusing materials? Generating less waste in the first place industry can play an important role in reducing the quantity of waste from source.

Excess packaging of food and consumer products is one of our greatest sources of unnecessary waste. Paper, plastic, glass, and metal packaging material make up 50% of our domestic trash by volume. Much of that packaging is primarily for marketing and has very little to do with product protection. Manufacturers and retailers might be persuaded to reduce these wasteful practices. Canada's National Packaging Protocol (CNPP) recommends that packaging minimize depletion of virgin resources and production of toxins in manufacturing. The preferred hierarchy is

- No packaging.
- Minimal packaging.
- Reusable packaging and
- Recyclable packaging.

Where disposable packaging is necessary, we still can reduce the volume of waste in our landfills by using biodegradable materials. Usually this means no plastics. Recently, however, plastics have become available that they do breakdown in the environment under ideal circumstances. Photodegradable plastics breakdown in the environment when they are exposed to ultra violet radiation. Biodegradable plastics incorporate such materials as cornstarch that can be decomposed by microorganisms. Each individual can contribute towards waste minimization by:

- Buying foods that come with less packaging; shop at farmers' market using your own container.
- When you have a choice at a grocery store between plastic, glass, or metal containers for the same food, buy the reusable or easier-to-recycle glass or metal.
- When buying plastics, pay a bit extra for environmentally degradable varieties.
- Separate your cans, bottles, papers and plastics for recycling.
- Wash and reuse bottles, aluminium foils, plastic bags, etc. for personal use.
- Compost grass and garden waste, leaves and grass clippings (Cunningham, 1997).

Source reduction differs from recycling, which diverts materials that have entered the waste stream and uses them in place of virgin materials to make other products. Source reduction instead prevents materials from becoming part of the waste stream. Materials that are discarded, whether recycled or not, require costly and time consuming collection, handling, and processing. Source reduction reduces or eliminates the need for this effort. Besides preventing waste, source reduction conserves resources, reduces the use of raw materials, avoids the need for energy to manufacture or recycle containers, and reduces pollution arising from the manufacture or recycling of containers.

2.7.4 Reuse of solid waste

Even better than recycling or composting is cleaning and reusing materials in their present form, thus saving the cost and energy of remaking them into something else. In most cities, glass and plastic bottles are routinely returned to beverage producers for washing and refilling. The reusable, refillable bottle is the most efficient beverage container we have. To encourage use of refillable glass bottles, Ecuador has a refundable beverage container deposit fee that is 50 % of the cost of the drink. In Finland, 95 % of the soft drink, beer, wine, and spirits containers are refillable, and in Germany, 73 % are refillable (Miller, 2002).

In less affluent nations, reuse of all sorts of manufactured goods is an established tradition. Where most manufactured products are expensive and labour is cheap, it pays to salvage, clean, and repair products. Cairo, Manila and Mexico City, and many other cities have large populations of poor people who make a living by scavenging, sorting, and reprocessing scraps from city dumps (Cunningham, 1997).

Advantages of reuse e.g. refillable containers

Reuse is a form of waste reduction that

- Extends resource supplies.
- Keeps high-quality matter resources from being reduced to low-matter-quality waste.
- Reduces energy use.

Unlike throwaway and recyclable cans and bottles, refillable beverage bottles create local jobs related to their collection and refilling. Moreover, studies by Coca- Cola and Pepsi companies of Canada show that their soft drinks in 0.5litre throwaway bottles cost one-third less in refillable containers (Miller, 2002).

2.7.5 Recycling

This is the recovering of waste from one process and reusing it in the same process or in another process in an environmentally safe manner. Recycling involves collecting and processing a resource into new products. Such valuables are sorted or selected from the refuse and are later crushed or melted to produce new ones. For example, glass bottles can be crushed and melted to make new bottles or other glass items. Large scale recycling can be accomplished by collecting mixed urban waste and transporting them to centralized material recycling facilities (MRFs). There, machines shred and automatically separate the mixed waste to recover valuable materials for sale to manufacturers as raw materials. The remaining paper, plastics and other combustible wastes are recycled or burnt to produce steam or electricity to run the recovery plant or to sell to nearby industries or home (Miller, 2002).

Recycling is a three-step process. First, materials are collected. Secondly, the collected materials are purchased by manufacturers for use in making new products. And thirdly, the new products are sold to consumers for re-use. Each step needs to happen for true recycling to occur.

2.7.6 Types of Recycling

There are two types of recycling for materials such as glass, metals, paper, and plastics: Primary, or closed loop, recycling, in which waste discarded by consumers are recycled to produce new products of the same type. (Such as newspaper into newspaper and aluminium cans into aluminum cans).

Secondary, or open loop, recycling, in which waste materials are converted into different and usually low-quality products. Primary recycling reduces the amount of virgin materials in a product by 20-90 %, whereas secondary recycling reduces virgin material by 25 % at most.

Studies show that one of the best ways to encourage recycling is a pay- as- you throw program that bases garbage collection charges on the amount of waste a household generates for disposal; materials sorted out for recycling are hauled away free (Miller, 2002). Segregating organic matter from garbage can be handled in several ways. Separate collection of organic and non-organic garbage is one option for city governments, with the city assuming responsibility for composting the organic waste.

A more innovative and decentralized approach is city sponsorship of educational programs that equip residents to compost their own food and garden wastes (Brown *et al*, 1998).

Many Solid waste experts argue that it makes more sense economically and environmentally for household and business to separate trash into recyclable and reusable categories (such as glass, paper, metals, certain types of plastics, and materials that can be composted). Then compartmentalized city collection truck, private haulers or volunteer recycling organizations pick up the segregated waste and sell them to scrap dealers, compost plants and manufacturers.

Another alternative (especially in less populated areas) is to establish a network of drop-off centres, buyback centres, and deposit refund programs in which people deliver and either sell or donate their separated recyclable material (Cunningham, 1997). Industries can save money by collecting different categories of waste separately and local communities can install bottle banks and waste paper collection system (Thomas and Croft, 1990). Japan has the most successful recycling program in the world. Half of all household and commercial waste in Japan are recycled while the rest is incinerated or landfilled. Japanese families diligently separate waste into as many as seven categories, each picked up on a different day (Cunningham, 1997). Germany Sweden, Holland, Belgium and Austria also have a well-developed household waste collection and recycling program (Bramryd, 1997).

2.7.7 Benefits of Recycling

Recycling is usually a better alternative to either dumping or burning waste. It saves money, energy, raw materials, and land space, while also reducing pollution. Recycling also encourages individual awareness and responsibility for the refuse produced. Many recycling programs cover their own expenses with materials sales and may even bring revenue to the community.

Another benefit of recycling is that it could cut our waste volumes drastically and reduce the pressure on disposal systems. Recycling lowers our demand for raw resources. In the United States, two million trees are cut down daily to produce newspaper prints and paper products. Recycling the print run of a single Sunday issue of the New York Times would spare 75,000 trees. Recycling one tonne of aluminium saves four tonnes of beauxite (Al_2O_3) (Bramryd, 1997).

Recycling also reduces energy consumption and air pollution. Plastic bottles recycling could save 50-60 % of the energy needed to make new ones. Producing aluminium from scrap instead of the bauxite ore cuts energy use by 95 %, yet we still throw more than a million tonnes of aluminium every year. If aluminium recovery were doubled worldwide, more than a million tonnes of air pollutants would be eliminated every year.

Reducing litter is an important benefit of recycling. Ever since disposable paper, glass, metal, foam, and plastic packaging began to accompany nearly everything we buy, these discarded wrappings have collected on our roadside, in our rivers and oceans. Without incentives to properly dispose of beverage cans, bottles, and papers, it often seems easier to just toss them aside when we have finished using them. Bottle bills or deposits on cans and bottles have reduced littering in many countries.

2.7.8 Creating Incentives for Recycling

In many communities, citizens have done such a good job of collecting recyclables that a glut has developed. Mountains of waste materials accumulate in warehouses because there are no markets for them. Too often waste that we carefully separate for recycling end up being mixed together and end up in a landfill or incinerator (Cunningham, 1997).

2.7.9 Incineration

In natural ecosystems, waste incineration corresponds to forest fires and natural burning of savannahs or grasslands. In these rather limited numbers of ecosystems, fire is used naturally to mineralise nutrients from litter and other debris and thus promotes regeneration and activation of the ecosystem. The ashes contain easily available nutrients and at the same time they produce an increase in the soil pH. In a system controlled by man, incineration should only be used for by-products that will leave ash with such low concentrations of heavy metals and other pollutants that a recirculation of the ashes to, for example, forests is possible.

If mixed and polluted waste is burnt, the total amount of nutrients is lost in contaminated ash, which must be landfilled, in sealed and carefully controlled monofills. Thus, in a city with mass incineration as the main route for waste disposal, almost the whole stream of nutrients that has been transported into the society from agriculture or forestry will be lost in toxic ash. The other main problem with incineration of waste mixed with polluted material is the risk of polluted gas emissions and heavy metals (Bramryd, 1997).

Despite what industry and governments would like people to believe, incineration is not a solution to the world’s waste problems, but part of the problem. Incineration of waste is a major contributor to air pollution. Other human activities such as power generation, industrial combustion or emission from traffic are other important sources of air pollution. Incinerators may reduce the volume of solid waste, but they do not dispose of the toxic substances contained in the waste. Incinerators emit a wide range of pollutants in their stack gases, ashes and other residues. The filters used to clean incinerator stack gases produce solid and liquid toxic wastes, which also need to be disposed.

Municipal and biomedical waste incinerators are the largest dioxin sources in industrialized countries, according to the US environmental protection agency. An important contaminant in incinerators is PVC. Although it only accounts for approximately 0.5% of municipal waste by weight, PVC provides over 50% of available chlorine-the element essential to dioxin formation. According to the majority of incineration studies, when all other factors are held constant, there is a correlation between input of PVC and output of dioxin. For this reason, the Danish government policy is to avoid the presence of PVC in incinerators. If all PVC and chlorinated waste were eliminated from the waste stream, incineration will still be a poor solution due to high costs, loss of jobs in the recycling industry, loss of profits from secondary resale and ongoing contamination from heavy metals, hydrocarbons and other air emissions (Greenpeace, 1993).

The only way to improve the situation is to avoid toxic waste production by improving our products and processes. Public opposition to incineration is growing worldwide. People are recognising that there is no place for the incineration of waste in a sustainable society. Strategies to prevent generating incineratable waste streams currently exist by: Waste reduction and alternative forms of sterilization in hospitals, and efficient reduction, recycling and compost actions at community level for household waste. Processes to stop the generation of hazardous waste in the first place are needed.

There following are important quality issues in relation to incineration of wastes:

- Incineration is one of the important generating sources for the emission of organic micro pollutants like dioxins and furans.
- Incineration is an important source for the release of volatile metals like mercury and lead, which can be transported over long distances.
- Trace metals, including heavy metals are not destroyed during incineration. The minor part remains in the slag that can be considered as biologically inert materials.

However, the slag is not chemically inert .The major part is transferred to the fly ashes. Thus fly ashes cannot be landfilled without pre-treatment. In Europe, the fly ashes are considered as hazardous waste.

2.8 AEROBIC TECHNIQES

From an ecological point of view, composting can be compared to the natural degradation of organic matter in most aerobic ecosystems. Most of the organic matter is degraded over a longer or shorter time, while, at the same time, the nutrients are mineralised to fractions available for plant uptake (Bramryd, 1996). Composting is a several month long process in which bacteria, worms, or other organism feast on piles of carbon rich matter and digest it, leaving behind humus-a rich, stable medium in which roots thrive. Because it is riddled with pores, humus shelters nutrients and provides extensive surface area to which nutrients can bond; indeed, humus traps three to five times more nutrients, water, and air than other soil matter does (Brown *et al*., 1998). At home, compost pile is an easy and inexpensive way to dispose of organic waste in an interesting and environmentally friendly way. Home composting is easy, beneficial and educational. It takes very little effort or attention because millions of tiny microorganisms do the work (Cunningham, 1997).

Farmers, homeowners, and communities produce compost by pilling up alternating layers of (1) nitrogen rich waste such as grass clippings, weeds, animal manure, and vegetable kitchen scraps, (2) Carbon rich plant wastes (dead leaves, hay, sawdust) and (3) topsoil (Miller, 2002). Too much nitrogen will produce an odour like urine or ammonia gas; it also will make the pile slimy and putrid. To function well, a compost pile shouldn't either be too large or too small. A pile that is too small doesn't retain enough heat for the microorganisms to grow optimally. One to two metres wide and a metre high is about right. Given a good nutrient supply and plenty of air, bacteria and fungi growing in the compost pile will produce a temperature of about 70°C, enough to kill most pathogens and weed seeds. Turning the pile frequently (every week or two) will mix the components and provide enough fresh air to keep the pile working well and to prevent the sour smell of anaerobic (oxygen starved) fermentation.

The other essential ingredient for microorganisms in a compost pile is water. If you leave a rainy climate or put lots of vegetables and grass clippings in your compost pile, you won't need supplemental moisture, but if you use lots of dry leaves or live in a very dry place, you may need to add some water from time to time. The compost should be moist but not saturated (Cunningham, 1997). Decomposition ideally requires a humidity of around 60% in the compost heap. If much lower, the process comes to a standstill because the organisms involved in the process are deprived of water (Esrey *et al*. 1998). Too much water blocks oxygen penetration. The rate of decomposition depends on the surrounding temperature. In the summer, a few weeks should produce a dark, soft, crumbly material that smells earthy. Composting will even work in winter-but slowly if you live in a cold climate. Branches and large chunks of material decay very slowly. Shredding, chipping, or chopping the starting material into small pieces will speed up the process.

2.9 ANAEROBIC TECHNIQUES

The anaerobic techniques include both reactor fermentation and fermentation in bioreactor cells constructed in landfills. Controlled steel-reactor fermentation is normally faster than landfill bioreactor fermentation. On the other hand, the total yield of energy is normally lower with the faster techniques. In the slower landfill bioreactor cell there is enough time for processes such as the hydrolysation of cellulose, which can significantly increase the yield of methane gas. If non-polluted waste is used for the fermentation process, the bio-residue can be used for soil improvement. Because of the content of organic matter, the bio residue has a value as both fertilizer and soil conditioner.

Mixed residual municipal and light industrial wastes, remaining after source separation for recyclable material and/ or fractions for the production of soil improvers, can be fermented in the landfill bioreactor cells (Bramryd, 1996). Fermentation in landfill bioreactor cells is an ecologically based technique, which opens possibility for both bio-energy and nutrient extraction. The reactor cell functions like an anaerobic filter, where energy is extracted through the collected biogas, while nutrients are recovered through the leachates. Pollutants, such as the heavy metals, are captured in the fermentation residue and are left in the landfill (Bramryd, 1996).

2.10 SITTING OF OPEN DUMPSITES

Sitting a sanitary landfill requires an extensive evaluation process in order to identify the best available disposal location. This location must comply with the requirements of government regulations, and at the same time must minimize economic, environmental, health, and social costs (Siddiqui *et al*. 1996). In assessing a site as a possible location for solid waste land filling many factors need to be considered, and these are categorized as topography and geology, socio-economic effects, economy and safety, and natural resources (Savage *et al*. 1998). Most of the open dumpsites in Africa were arbitrarily located. Very little or no consideration of environmental impacts were paid in the selection of the dumpsites.

Under normal circumstances, an environmental impact assessment is a prerequisite when sitting a new dumpsite. However, in most cases convenience takes priority. There has been a tendency by local authorities to locate dumpsites near collection areas. The dump must not be located too far away from residential areas as this would deter people from carrying their wastes to these sites. It turns out that borrow pits and quarries are often selected as a reclamation strategy. Love *et al*. (2006) assert that the Golden Quarry landfill site in Harare, Zimbabwe, is an abandoned gold mine which started operating as a landfill in 1985 to reclaim the land by filling the shafts and pits. Rotich *et al*. (2006) contend that in Eldoret, Kenya, an abandoned sand quarry at Mwendeni was used for the disposal of municipal solid waste, yet it was clear that the site was a water catchment area for small streams that drain into the Sosiani River. The Dandora municipal dumping site in Nairobi, Kenya, is an old quarry which had to be refilled using garbage. It has turned out to be a health hazard to the people living close to its environs (Environmental News Service, 2007).

2.10.1 Practices at the Dumpsites

Generally, the practices at municipal dumpsites are not effective. Dumping is unrestricted and industrial, agricultural, domestic, and medical wastes end up in one site. Dumpsites are not always fenced off as in some cases the perimeter fence has been stolen or vandalized. This allows easy access to the site at any time of the day.

Mangizvo (2008) observed that the perimeter fence at Mucheke Municipal dumpsite had been removed and the place was not guarded, enabling the dumping of restricted materials, such as car batteries and metals. Scavengers had free access to the dump, and they mixed up the waste as they dug into it to salvage any valuable material. As a result of poor control, medical and hazardous wastes end up at municipal dumpsites even though they have their own special dumping areas. In Dares Salaam City, industrialists and hospital owners take their waste to the Vingunguti dumpsite (Mato and Kaseva, 1999). In Ibadan, Nigeria, pathological wastes and sharps from the city's hospitals are dumped in an unregulated and haphazard manner in open dumpsites at Aba-Eku, Aperin-Oniyere, and Ajakanga. Maintenance of the open dumps is also an issue; there is no compaction and covering of waste (Agunwamba, 1998). As a result waste is easily blown away by the wind, making it an eyesore as plastics litter the area around the dump. Most local authorities resort to burning the waste to curb the nuisance produced by flying litter. Scavengers and workers at the dump run the risk of contracting respiratory diseases as they inhale the smoke. The lack of soil cover enables rainwater to infiltrate refuse and produce leachate that contaminates ground water reserves.

2.10.2 Threats Posed by Solid Waste Dumpsites

The uncontrolled manner in which solid waste is disposed of at most open dumpsites creates serious health problems to humans, animals, and environmental degradation. This inadequate waste disposal translates into economic and other welfare losses (Wilson *et al*. 2005). The environment is degraded in a number of ways. Soil is contaminated by being in contact with solid waste and leachate. In a study on a dumpsite in Kariba in Zimbabwe, trace metal concentrations were determined in soil samples collected from the area during 1996 and 1997. Accumulation of copper (Cu), lead (Pb), iron (Fe), and zinc (Zn) were found within the disposal site (Chifamba, 2007). Concentration of Zn, Pb, and Cu were in surface soil samples up to 75 meters away from the disposal site. Leachates collected from Ibadan and Lagos dumpsites had appreciable levels of dissolved solids, chloride, ammonia, chemical oxygen demand (COD), lead, iron, copper, and manganese. This was most likely a result of rampant dumping of lead acid car batteries and metal scraps (Ikem *et al*. 2002). In a study carried out at Dandora dumpsite, 42% of soil samples had ten times higher lead levels than normal (Oyaro, 2003). Leachates also contaminate both ground and surface water. During floods, water mixed with leachate may flow out of the dumpsites and get into nearby ponds, streams, and rivers. The Nairobi River for example, passes through the Dandora Municipal Dumping site, and some of the waste from the site finds its way into the river (Environmental News Service, 2007). This is a health risk to the communities near the dump and those downstream who may be using the water for various purposes. In Eldoret town, the operation of an open dumpsite near the Mwenderi River has greatly polluted the Sosiani River, because the dumpsite, formerly a sand quarry, has small streams draining into the Sosiani River (Rotich *et al*. 2006). The study at Kariba showed that water samples taken from the vicinity of the dumpsite had a high level of concentration of mercury (Hg) and Pb (Chifamba, 2007). Okonkwo and Mothiba (2004) found a high concentration of lead in the Madanzhe and Mvudi Rivers in Thohoyandou, South Africa, which was attributed to the effluent from a nearby sewage treatment plant and a waste dumping site, which leachate had contaminated with lead flowing into the rivers. The Golden Quarry landfill in Harare pollutes ground water in the area close to it. Levels of coliforms, cadmium, iron, lead, and nitrates were above the water quality guidelines throughout the nearby suburb of Westlea (Love *et al.*, 2006). Water in the suburb is not suitable for domestic use. Mangizvo (2008) identified in a study of the Mucheke Municipal dumpsite in Masvingo, Zimbabwe, that soils within a 50 meter radius had been contaminated by trace metals of lead, iron, copper, zinc, and phosphorus.

Rapid urbanization has resulted in existing dumping sites originally located at a safe distance outside the municipal boundaries are now being increasingly encircled by settlements and housing estates (Schertenleib and Meyer, 1992). This has caused the public to oppose their existence as they cause odor, dust, and other nuisances. People living close to dumpsites are in danger of contracting diseases associated with dumps. Oyaro (2003) notes that tests conducted on 328 children living near the Dandora dumpsite found that half of them had excess concentrations of lead in their blood. They were also disproportionately affected by anemia, skin infections, asthma, and other respiratory diseases. These conditions are associated with high levels of toxins at the dumpsite, which receives plastics, rubber, wood, metals, chemicals, and hospital waste (Environmental News Services, 2007; Oyaro, 2003).

Thousands of poverty stricken Africans make a living through salvaging recoverable materials from waste sites. Daily, women, the elderly, and children spend long hours at the open solid waste dumps sifting through the rubbish for valuable items. Wilson *et al.*, (2005) say these people use bare their hands and wear no protective clothing. This lack of protective clothing and equipment puts them in direct contact with hazardous waste such as broken glass, human and animal faecal matter, paper that may have become saturated with toxic materials, as well as containers with residues of chemical, pesticides, and solvents. They are also exposed to needles, bandages, and other refuse from hospitals, exposing them to diseases, such as HIV and AIDS, and hepatitis (Oyaro, 2003). This state of affairs was observed at the Dandora dumpsite in Nairobi, Kenya. Informal waste pickers are at high risk as basic principles of occupational health and safety are disregarded. As such scavenging in open dumps is considered one of the most detrimental activities to health. Some people come to the dumps looking for food. They are not spared from the inhalation of bio-aerosols, and of smoke and fumes produced by open burning of waste, which can also cause health problems. Respiratory and dermatological problems, eye infections, and low life expectancy are common among these people.

2.11 LAND FILLING FOR WASTE TREATMENT

Land filling stands alone as the only waste disposal method that can deal with all materials in the solid waste stream. Other options such as biological treatment themselves produce waste residues that subsequently need to be land filled. Consequently, there will always be need for landfilling in any solid waste management system. Landfilling is also considered as the simplest, and in many areas the cheapest, of disposal methods, so has historically been relied on for the majority of solid waste disposal. Not all cases of “landfill” actually involve filling of land.

The concept of landfilling as a final disposal method for solid waste can also be challenged. A landfill is not a “black hole” into which material is deposited and from which it can never leave. Like all other waste options, landfilling is a waste treatment process, rather than a method for final disposal. Solid wastes of various compositions form the majority of the inputs, along with some energy to run the process. The process itself involves the decomposition of part of the landfilled waste. The outputs from the process are the final stabilised solid waste, plus the gaseous and aqueous products of decomposition, which emerge as landfill gas and leachate. As in all processes, process effectiveness and the amounts and quality of the products depends on the process inputs and the way that the process is run and controlled. The same applies to landfilling: what comes out of a landfill depends on the quantity and composition of the waste deposited, and the way the landfill is operated (White *et al*. 1999).

2.11.1 Land Filling Process

In a sanitary landfill, trash and garbage are crushed and covered each day with fresh layer of clay or plastic foam to prevent accumulation of vermin and spread of disease (Cunningham, 1997). Modern landfills on geologically suitable sites are lined with clay band plastic before being filled with garbage. The bottom is covered with a second impermeable liner, usually made of several layers of clay, thick plastic, and sand. The liner collects leachate and is intended to prevent its leakage into groundwater (Stegmann, 2001).

The purpose of a sealing system in the landfill is to protect nature from pollution by the hazardous materials produced by landfill processes. A typical final cover for a landfill is from 0.6-2m thick (Tammamagi, 1999). A new advancement in landfill sealing is to smear the surface cover with methane bacteria of the genus pseudomonas. These bacteria break down any methane that leaks from the landfill into carbon dioxide and water. This has been done in Switzerland (Bramryd, 1997). Collected leachate is pumped from the bottom of the landfill, stored in tanks, and sent to a regular sewage treatment plant or an on-site treatment plant. When full, the landfill is covered with clay, sand, gravel, and topsoil to prevent water from seeping in. Several wells are drilled around the landfill to monitor any leakage of leachate into nearby ground water. Modern landfills are equipped with connected network of vent pipes to collect landfill gas (consisting mostly of two green house gases, methane and carbondioxide), released by underground (anaerobic) decomposition of wastes. The methane is filtered out and burned in small gas turbines to produce steam or electricity for nearby facilities or sold to utilities. However, thousands of older and abandoned landfills do not have such systems and will emit methane and carbondioxide, both potent greenhouse gases, for decades (Miller, 2002). Therefore, the operation of closed landfills has to continue in other to seize remaining emissions and to reduce them to an acceptable minimum. This so-called aftercare phase of closed landfills should, however, be kept as short as possible. The landfill should then remain mainly self-regulatory and only very few measures of control should be necessary. The aftercare phase will last, however for a few decades (Stegmann, 2001).

2.12 WASTE COMPOSITION AND LOADING

The composition and volume of disposed wastes vary nationally and regionally in relation to the local human activities, and the quantity and type of products that communities consume (Attahi, 1999). Discarded waste in lower income areas is typically rich in food-related waste, i.e. organic (carbon-rich) substances (Onibokun and Kumuyi, 1999). Although such waste is not in itself toxic, decomposition of organic matter can alter the physicochemical quality of groundwater and enhance the mobility of hazardous chemicals including metals and solvents. The proportion of manufactured (e.g. paper) and potentially hazardous (e.g. textiles, metals, plastics) wastes increases in relation to income and degree of industrialization, and waste disposal leachate from highly industrialized settings may contain a wide range of anthropogenic contaminants (OECD, 1993).

Table 2.5 Solid-waste generation and composition from selected regions in the world (OECD, 1993, 1997; Attahi, 1999; Lusugga Kironde 1999; Onibokun and Kumuyi, 1999)

Location	Rate (kg/per/year)	Composition (%)						
		Paper	Food	Plastics	Glass	Metals	Textiles	Other
China	285	3	60	4	1	0	2	-
Denmark	520	30	37	7	6	3	17	-
France	560	30	25	10	12	6	17	-
Mexico	320	14	52	4	6	3	20	-
Poland	290	10	38	10	12	8	23	-
USA	730	38	23	9	7	8	16	-
Côte d'Ivoire	211	4	63	5	1	1	1	25

CHAPTER THREE

METHODOLOGY

3.1 BACKGROUND OF STUDY AREA

Tamale Metropolis is the regional capital of the Northern Region and is predominantly a farming community with about 60 per cent of the population being farmers (Tamale Metropolitan Assembly Document, 2009). The soils of this area are Savanna Ochrosols. These are similar to the Forest Ochrosols except that they occur in the savanna areas with semi-arid climatic conditions. Though the soils are moderately deep to deep, the soil is relatively thinner than their forest counterparts. Decomposing rock or hard rock may be encountered within 150 cm depth. The topsoils are generally thin (<20cm), grayish brown sandy loam, weak granular and friable. The subsoil range from red in summits to brownish yellow middle slope soils (especially on some sandstone soils). Ironstone concretions and sandstone brashes of about 10-40 per cent commonly occur in some of these soils. Further differentiation into Red and Yellow Savanna Ochrosols is made at the great soil subgroup level. Several soil series have also been identified in this group of soil. The bulk of the country's food crops are grown on these soils. The soils support crops such as yams, maize, cowpea, soybean, millet, groundnuts, sorghum and cassava. Farmers in the metropolis are involved in the cultivation of these crops using various land tillage practices. The soils are rather impoverished through continuous cropping/short fallows without nutrient amendments. Erosion hazard is also a serious problem on steep slopes though most parts of the savanna are generally low lying (Brammer, 1962).

3.1.1 Demographic Characteristics of the study

Male respondents were more than female respondents in the study. The average age was forty six (46) years. Respondents consisted of varied occupations made of bankers, contractors, teachers, public servants, nurses and farmers. Farmers formed the majority with a few unemployed consisted the least. A few of them had primary education, middle school, senior high school, no formal schooling at all, tertiary education and with majority of them having attended junior high school.

Household with members ranging from 6-10 persons formed the highest membership with household with less than 6 members formed the least. The study also revealed that most of the respondents lived in compound houses with a few respondents living in independent houses. Respondents who lived in middle income areas formed majority with few respondents in residential and slump areas. Below is a map of the study area.


Tamale
Location in Ghana
Coordinates: 9°24′27″N 0°51′12″W


TAMALE
METROPOLITAN

3.2 STUDY DESIGN AND TYPE

Phase One

A descriptive cross-sectional study was used to gather data on the quantity of solid waste generated, methods used to collect and transport solid domestic waste, solid domestic waste management and solid domestic waste disposal methods. Focus Group Discussions was also organized to elicit information on consequences of improper solid domestic waste management and suggestions offered to improve solid domestic waste management. The study population involved households in the Tamale Metropolis with specific reference to household heads or substitutes who usually supervise or direct the daily handling of sanitation in the home.

Phase Two

Cultivation of cabbage using different soil amendments for improved decomposed solid waste to assess impact on crop yields was also carried out. Field trials were conducted at the Water Works Vegetable Farms in the Tamale Metropolis. Cabbage vegetable was grown with treatment plots of 1metres x 5metres. A randomized complete block design with 4 replications of 5 treatments was used. Soil amendment treatments consisted of combinations of the following: decomposed solid waste soil with combination of poultry manure and cow dung.

Table 3.1 Field Experimental lay out for cabbage cultivation

Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
DSW only	DSW + CD	DSW + PM	DSW + CD + PM	No Input

Treatment 1=Decomposed Solid Waste only, Treatment 2=Decomposed Solid Waste + Cow Dung, Treatment 3=Decomposed Solid Waste + Poultry Manure, Treatment4=Decomposed Solid Waste + Cow Dung + Poultry Manure, Treatment 5=No Input

Plot size was 1m X 5m with a ration of 1:1 of soil amendments to decomposed solid waste was used with 5kg each of soil amendments.

3.3 SAMPLING TECHNIQUE AND SAMPLE SIZE

SAMPLING TECHNIQUE

Phase One

Purposive sampling techniques were used for data collection on questionnaires. Purposive sampling technique is chosen because it is believed that the study subjects will have in-depth information which gave optimal insight into the issue under investigation. Questionnaires was carefully designed and used to secondarily collect information from the population or the sampling universe on waste generated and disposal methods. Five (5) suburbs in the Metropolis were randomly selected and seventy seven (77) questionnaires administered in each suburb giving a total of three hundred and eighty five (385) questionnaires. Selection of suburbs was based on population size, accessibility and prevalence of urban farmers. Farmers were the sampling universe. Sampling frame used was list of suburbs which will enable the sample size of the population to be determined. Non-randomized sampling procedure was used with judgmental or purposive sampling technique.

Phase Two

Cultivation of cabbage was conducted to execute the second phase of the research. The decomposed soiled waste was first collected from the refuse dump. It was prepared by sieving with wire mesh to eliminate the presence of inorganic or foreign materials that will be present in the soil. The collection of soil amendments that was used were also done along side. The various soil amendments were also sieved to eliminate inorganic or foreign materials that will be present in them. The decomposed soil was combined with the various soil amendments in the ratio of 1:1 to be used for cabbage cultivation and spread evenly on beds incorporated through hoe by tilling 30 days prior to transplanting cabbage seedlings to beds. The acquisition of cabbage seeds, nursed and the preparation of the research plots were carried out for the cabbage planting. The plots were watered regularly morning and evening and monitored throughout the research to the time of maturity of the cabbage. The parameters assessed to determine the impact of the various soil amendments on cabbage were weekly plant height for seven weeks and weights of cabbage heads at maturity. Height was measured as the distance between the intersection of the petiole of the lowest leaf (or scar) with the main stem and the top of newest growth with a ruler and yield weights with a digital scale.

3.4 DATA COLLECTION TECHNIQUES AND TOOLS

Phase One

Data collection tool was a structured questionnaire backed by interview. The main issues that were addressed in the design of the questionnaire included the respondents' educational background, socioeconomic and cultural backgrounds, knowledge level on solid waste management, attitude and behavior towards sanitation programmes, frequency of emptying storage receptacles, methods of transport of solid waste, method of refuse disposal, proximity to dump site and availability of community storage receptacles.

Phase Two

Results of cabbage yields was determined by weighing cabbage to assess the impact of decomposed solid waste soil combined with cow dung and poultry manure on cabbage yields. Weekly plant height for seven weeks and was also measured.

3.5 DATA HANDLING / ANALYSIS

Phase One

After the data for each community had been checked for accuracy and completeness, data was entered into a computer and analyzed with Statistical Package for the Social Sciences (SPSS) version 14 and Microsoft Excel 2007. The relevant information was retrieved in a standard form using tables, figures, frequencies and percentages for analysis and interpretation of the information.

Phase Two

Results from cabbage yields were analyzed with SAS software version 9.1 (SAS Institute Inc., Cary, NC, 2002-2003). The GLM procedure was used for simple analysis of variance among treatments. LSD values were used to determine differences in means at 0.05 alpha level.

3.6 PRE-TESTING

Pre-testing of the questionnaire was conducted in a similar area with similar characteristics to enable the instruments to be redesigned. The pre-testing was therefore carried out in a suburb with similar features. After the pre-testing some of the questions were modified as the need be.

3.7 ETHICAL CONSIDERATION

The nature, purpose and procedure of the study were explained to each participant and they were made aware that they were free to refuse to answer any questions or drop out of the study at any time and this will not affect them. Consent was then obtained from each participant in the study. Participants were assured of the confidentiality of personal information and written materials. Participants will rather benefit from the study since they have an opportunity to express their views and experiences with regards to solid domestic waste management.

3.8 LIMITATIONS OF STUDY

The study did not cover the entire suburbs in the Metropolis due to lack of resources such as financial support, time and personnel. These limitations could impact the depth the study could have reached to address the research questions.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 INTRODUCTION

This chapter presents details of the findings of three hundred eighty five (385) household heads or substitutes, key informants. The presentations are made in the form of tables with frequencies and percentages for ease of comprehension.

4.2 SOCIAL CHARACTERISTICS OF RESPONDENTS

4.2.1 Sex of Respondents

The male respondents were made of three hundred and nine (309) respondents consisting of eighty percent (80%) while female respondents were made of seventy six (76) respondents representing twenty percent (20%).

Table 4.1 Sex of respondents

Variables	Frequency	Percentages (%)
Male	309	80
Female	76	20
Total	**385**	**100**

Source: Field survey, 2012

4.2.2 Age of Respondents

Respondents above sixty (60) years consisted of two percent (2%) while those in the age between forty (40) to forty-nine (49) years were made of fifty eight percent (58%) representing the highest respondents.

Table 4.2 Age of respondents

Variables	Frequency	Percentages (%)
20-29 years	7	2
30-39 years	78	20
40-49 years	224	58
50-59 years	70	18
60+ years	6	2
Total	**385**	**100**

Source: Field survey, 2012

4.2.3 Occupation of Respondents

Farmers formed the majority of respondents with sixty seven percent (67%). Teachers also formed fifteen percent (15%) with public servants constituting four percent (4%) of respondents.

Table 4.3 Occupation of Respondents

Types of occupation	Frequency N=385	Percentages (%)
Bankers	30	8
Contractors	8	2

Farmers	257	67
Nurses	11	3
Public servants	15	4
Teachers	59	15
Unemployed	5	1

Source: Field survey, 2012

4.2.4 Educational Level

Thirty percent (30%) of the respondents had no formal schooling at all and fifteen percent (15%) had Primary education. Middle School had seven percent (7%) and Junior High School had the highest percentage of thirty four percent (34%). Four percent (4%) went through Senior High school with thirty percent (30%) having had tertiary education.

Table 4.4 Educational level

Educational level	Frequency N=385	Percentages (%)
No Formal Education	37	10
Middle School (MSLC)	28	7
Primary	58	15
JHS	130	34
SHS	15	4
Tertiary	117	30

Source: Field survey, 2012

4.2.5 Household Membership Information

One hundred and eighty six (186) respondents representing forty eight percent (48%) with membership ranging from 6-10 had the highest percentage with household with members between 16-20 forming nineteen percent (19%) with respondents of seventy four (74). Household with less than 6 memberships formed three percent (3%) with ten (10) respondents. Forty one (41) respondents representing eleven percent (11%)

constituted household membership of 21-25 with those above 25 memberships being five percent (5%).

Table 4.5 Total household size

Variables	Frequency	Percentages (%)
0-5	10	3
6-10	186	48
11-15	53	14
16-20	74	19
21-25	41	11
Above 25	21	5
Total	**385**	**100**

Source: Field survey, 2012

4.2.6 Type of Housing

It was realized that most of the respondents lived in compound houses with a percentage of sixty one percent (61%) while those of independent houses was thirty nine percent (39%).

Table 4.6 Type of housing

Variables	Frequency	Percentages (%)
Compound House	233	61
Independent House	152	39
Total	**385**	**100**

Source: Field survey, 2012

4.2.7 Description of vicinity

Respondents who lived in middle income areas formed majority with sixty seven percent (67%) with respondents in residential area is made of twenty four (24%). While those who lived in slump area had a percentage of nine percent (9%).

Table 4.7 Description of vicinity

Vicinity	Frequency	Percentages (%)
Residential area	93	24
Slump area	33	9
Middle income area	259	67
Total	**385**	**100**

Source: Field survey, 2012

4.3 AVAILABILITY OF MUNICIPAL COOPERATION WASTE BIN

4.3.1 Availability of Municipal Corporation waste bin within 100 metres.

Ninety-two (92) respondents representing twenty-four percent (24%) had availability of municipal cooperation dustbin while two hundred and ninety three (293) respondents representing seventy six percent (76%) had no access to municipal dustbin within 100 metres from their homes. Of the two hundred and ninety three (293) respondents who did not have municipal cooperation dustbin within 100m of their homes, nine percent (9%) used private waste bins while ninety one percent (91%) disposed waste at refuse heaps.

Table 4.8 Availability of Municipal Corporation waste bin within 100 metres

Response	Frequency N=293	Percentages (%)
Yes	92	24
No	293	76
Total	**385**	**100**
Waste disposal sites		

Private Waste Bin	25	9
Refuse heaps	268	91

Source: Field survey, 2012

4.4 WASTE DISPOSAL APPROACHES

4.4.1 Waste segregation at home

On waste segregation at home, it was observed that three fifty nine (359) respondents representing ninety three percent (93%) do not segregate solid waste. Six (6) respondents representing two percent (2%) segregate waste at home.

Table 4.9 Waste segregation at home

Variables	Frequency	Percentages (%)
Yes	6	2
No	379	98
Total	**385**	**100**

Source: Field survey, 2012

4.4.2 Who in household usually throws out waste?

The disposal of waste is done by both adults and children alike. It was observed that, three hundred and eight (308) respondents of children representing eighty percent (80%) formed the majority who dispose or throws out waste in the household.

Table 4.10 Persons in household who usually throws out waste

Persons	Frequency	Percentages (%)
Adult	77	20
Children	308	80
Total	**385**	**100**

Source: Field survey, 2012

4.4.3 Average number of carrier bags (about 1kg) of waste disposed

One hundred and ninety eight (198) respondents representing fifty one percent (51%) throws a maximum of 1 carrier bags of waste of approximately 1kgs per week. Fifty seven (57) respondents making fifteen percent (15%) are those who throw 3 carrier bags of waste per week.

Table 4.11 Average number of carrier bags (about 1kg) of waste disposed per week

Carrier bags	Frequency	Percentages (%)
1 bag	198	51
2 bags	130	34
3 bags	57	15
Total	**385**	**100**

Source: Field survey, 2012

4.5 REUSE OF WASTE

Items which are reused by households in the study are forty seven percent (47%) representing plastic bottles with the highest. One hundred sixty one (161) respondents representing forty two percent (42%s) reused plastic bags and bottles.

Table 4.12 Reuse of waste

Variables	Frequency	Percentages (%)
Plastic bags	39	10
Plastic bottles	181	47
Plastic bags and bottles	161	42
Plastic bottles and paper bags	4	1
Total	**385**	**100**

Source: Field survey, 2012

4.6 KNOWLEDGE ON MUNICIPAL SOLID WASTE DISPOSAL AND IMPACT ON ENVIRONMENT

4.6.1 Knowledge on final destination of waste

Three hundred and twenty seven (327) respondents representing eighty five (85%) lacked adequate knowledge on final destination of waste with fifty eight (58) respondents representing fifteen percent (15%) having knowledge on final destination of waste.

Table 4.13 Knowledge on final destination of waste

Response	Frequency N=385	Percentages (%)
Yes	58	15
No	327	85

Source: Field survey, 2012

4.6.2 Problems of improper waste disposal

The study showed that one hundred and five (105) respondents mentioned the problems of bad odour from rubbish heaps representing twenty seven percent (27%) while dirty surroundings represented twenty six percent (26%). The problem of outbreak of malaria was also recorded with one hundred (100) respondents representing seventeen percent (17%). Thirty three (33) respondents representing nine percent (9%) mentioned the issue smelling surroundings. Twenty nine (29) respondents representing eight percent (8%) smoke pollution from rubbish fires in their vicinities.

Table 4.14 Problems of improper waste disposal

Problems	Frequency	Percentages (%)
Bad odour from rubbish heaps	105	27
Choked open drains	53	13
Dirty surroundings	100	26
Malaria outbreak	65	17
Pollution from rubbish fires	29	8
Smelling surroundings	33	9
Total	**385**	**100**

Source: Field survey, 2012

4.7 MEASURES TO IMPROVE MUNICIPAL SOLID WASTE DISPOSAL

4.7.1 Methods of improving waste disposal problems

One hundred five eight (158) respondents representing forty one percent (41%) called for rubbish heaps to be collected as major way of improving environments. One hundred thirty nine (139) respondents representing thirty six percent (36%) called for the provision of municipal cooperation waste bin. Thirty (30) respondents representing eight (8%) also called for residents to contribute by clearing bushes around homes. Twenty (20) respondents representing five percent (5%) called for spraying of mosquitoes to help in reducing the prevalence of malaria. Twelve (12) respondents representing three percent (3%) mentioned the closure of open drains to prevent them from choking of rubbish to allow free flow of water

Table 4.15 Methods of improving waste disposal problems

Methods	Frequency N=385	Percentages (%)
Clearance of bushes	30	8
Open drains should be covered	12	3

Cleaning of dirty surroundings	26	7
Mosquitoes should be sprayed	20	5
Municipal cooperation waste bin provided	139	36
Rubbish heaps be collected	158	41

Source: Field survey, 2012

4.7.2 Contribution in improving neighbourhood environment

The study also revealed that three hundred and fifty seven (357) respondents representing ninety three percent (93%) expressed their desire to participate in clean up exercises to improve their neighbourhood environments. Twenty eight (28) respondents representing seven percent (7%) of respondents wished to contribute by way of educating residents on good sanitation practices.

Table 4.16 Desire to participate in improving neighbourhood environment

Contribution	Frequency N=385	Percentages (%)
Educate residents on good sanitation practices	28	7
Participate in clean up exercise	357	93

Source: Field survey, 2012

4.8 LEVEL OF CONTRIBUTION TO MUNICIPAL SOLID WASTE MANAGEMENT

4.8.1 Financial contribution to the current waste collection system

The study revealed that two hundred and ninety nine (299) respondents making seventy eight percent (78%) do not make financial contribution to the current waste collection systems. Eighty six (86) respondents representing twenty two percent (22%) made financial contribution to the current waste systems. It was further observed that, of the twenty two percent (22%) made an average payment of GHC 12.3 per month.

Table 4.17 Financial contribution to the current waste collection system

Variables	Frequency	Percentages (%)
Yes	86	22
No	299	78
Total	**385**	**100**
Amount/month		
GH¢10	8	9
GH¢12	34	40
GH¢15	44	51
Total	**86**	**100**

Source: Field survey, 2012

4.9 THE USE OF FERTILIZER TO IMPROVE CROP YIELDS

4.9.1 Fertilizer used to fertilize farm/crops.

The study showed that one hundred and twelve (112) respondents representing forty four percent (44%) of the urban farmers use organic manure while seventy five (75) respondents representing twenty nine percent (29%) use inorganic fertilizers. The study also showed that forty four (44) respondents representing seventeen percent (17%) of farmers use decomposed refuse soils while twenty six (26) respondents representing ten percent (10%) use compost manures for fertilizing their crops.

Table 4.18 Fertilizer used to fertilize farm/crops

Types	Frequency	Percentages (%)
Organic	112	44
Inorganic	75	29
Compost	26	10
Decomposed refuse soils	44	17
Total	**257**	**100**

Source: Field survey, 2012

4.9.2 Knowledge on fertilizer type which improves and maintains good soil condition

One hundred and forty one (141) of respondents making fifty five percent (55%) of farmers indicated organic manures has the highest benefits in terms of improving and maintaining good soil condition while inorganic was three percent (3%).

Table 4.19 Knowledge on fertilizer type which improves and maintains good soil condition

Types	Frequency	Percentages (%)
Organic	141	55
Inorganic	9	3
Compost	79	31
Decomposed refuse soils	28	11
Total	**257**	**100**

Source: Field survey, 2012

Table 4.20 Cabbage yield

Treatment	Mean yield (kg)
DSW only	2.83 +/- 0.52 a
DSW+ CD	2.79 +/- 0.46 a
DSW+ PM	3.34 +/- 0.36 a
DSW+CD+PM	2.32 +/- 0.33 a
NONE	1.04 +/- 0.21 b

Source: Field trails, 2012

DCS=Decomposed Solid Waste only; DSW+CD=Decomposed Solid Waste + Cow Dung; DSW+PM=Decomposed Solid Waste + Poultry Manure; DSW+CD+PM=Decomposed Solid Waste+ Cow Dung + Poultry Manure; None=No Input

Mean +/- standard error

Means with the same letter are not significantly different at α=0.05

The decomposed solid waste soils combined with poultry manure treatment resulted in the greatest yields, followed by the DSW only, DSW+CD, DSW+CD+PM, and No input treatments, respectively.

Table 4.21 Cabbage plant growth

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
DSW only	324.32 +/- 32.01 a	414.20 +/- 57.88 bc	906.82 +/- 127.06 b	1213.16+/- 190.10 ab	1373.56+/- 168.85 b	1352.60+/- 168.85 b	1377.10+/- 166.25 ab
DSW+ CD	330.99 +/- 34.21 a	473.55 +/- 50.50 ab	855.19 +/- 121.96 b	1092.66+/- 144.76 b	1266.66+/- 148.93 b	1192.80+/- 148.93 b	1220.48+/- 164.02 b
DSW+ PM	344.58 +/- 43.41 a	559.53 +/- 91.47 a	1216.64+/- 153.29 a	1473.62+/- 206.50 a	1711.98+/- 204.45 a	1717.26+/- 204.45 a	1610.46+/- 196.41 a
DSW+CD+ PM	344.31 +/- 43.27 a	500.67 +/- 67.08 ab	862.28 +/- 121.63 b	1067.67+/- 158.23 b	1262.55+/- 137.45 b	1181.32 +/ 137.45 b	1161.10+/- 164.22 bc
NONE	309.98 +/- 46.38 a	327.79 +/- 41.55 bc	494.16 +/- 75.07 c	633.71 +/- 100.51 c	696.38 +/- 127.48 c	752.28 +/- 127.48 c	879.50 +/- 146.53 c

Source: Field trail, 2012

DCS=Decomposed Solid Waste only; DSW+CD=Decomposed Solid Waste + Cow Dung;

DSW+PM=Decomposed Solid Waste + Poultry Manure; DSW+CD+PM=Decomposed Solid Waste+ Cow Dung + Poultry Manure; None=No Input

Mean plant area (cm^2) +/- standard error

Means with the same letter are not significantly different at $\alpha=0.05$

Decomposed solid waste soils combined with poultry manure resulted in the greatest yield and plant growth in all trials. Decomposed solid waste soils combined with cow dung and poultry manure resulted in depressed yields and plant growth as compared to the other treatments.

CHAPTER FIVE

DISCUSSION

5.1 INTRODUCTION

This chapter considers the findings gathered on the sample from the study population from field survey, vegetable growth and discusses it in line with the objectives, literature review, and the key variables of the research.

5.2 SOLID WASTE COLLECTION METHODS AND DISPOSAL

Twenty-four percent (24%) disposed solid waste at municipal cooperation dustbin while seventy six percent (76%) had no access to municipal cooperation dustbin within 100 metres from their homes. Of the seventy six percent (76%) who did not have municipal cooperation dustbin within 100m of their homes, nine percent (9%) of respondents used private waste bins while as high as ninety one percent (91%) disposed waste at refuse heaps. The disposal of solid waste at refuse heaps is not recommended as far as public health is concerned. Basically, solid waste collection is the process of transferring solid wastes from storage receptacles into vehicles and then transporting it to the disposal sites (Nyang'echi, 1992). In this study, no vehicles were involved in waste collection but rather people carried waste from the storage sites to the refuse heaps. Some of the receptacles leaked and dropped some of the waste on the ground and may spread pathogens. The presence or otherwise of municipal cooperation dustbin may influence the kind of solid domestic waste management practiced. Gourlay (1992) stated that, " Environmentalists should not only join scientists and other responsible sectors of industry and agriculture to find better ways for disposing of wastes, but to locate convenient places for their disposal.

5.2.1 Waste generation and segregation

One hundred and ninety eight (198) respondents representing fifty one percent (51) generates and throws a maximum of 1 carrier bags of waste of approximately 1kgs per week. Fifty seven (57) respondents making fifteen percent (15%) were those who throw 3 carrier bags of waste per week. The disposal of waste is done by both adults and children alike. But, children representing eighty percent (80%) from the study formed the majority of persons who dispose or throw out waste in the household. Considering the fact that, children who are assigned to carry wastes to the dumps may find it inconvenient to walk long distances and out of frustration may dump them anyhow and anywhere. Fasida (1996) also stressed that the paramount consideration in the management decisions involving waste disposal is site location. To eliminate the problem involved in indiscriminate disposal of waste, sites located for waste disposal be "paramount" as quoted by Fasida. The results therefore suggest that the communities have not taken the pains to identify suitable sites to enable them manage wastes well.

The study showed that, ninety eight percent (98%) of respondents do not segregate waste solid waste at home, with a very few representing two percent (2%) attempting to segregate solid waste. Rosario (1999) noted that, the recyclable portion dry waste collected by the local waste collection agency is separated either at the source, in front of the household after collection, or at the waste collection site. In this study, informal waste collectors form an informal recycling network with local recyclable traders. The rapid economic growth of the market for recyclable portions has contributed to the numbers of informal waste collectors operating in the community (Sudhir *et al*. 1997). Informal waste collectors are street children and migrants who are transitioning recyclable portions trade into more permanent employment. In the case of street children recyclable traders can act as a type of surrogate parent. However, the relationship is often exploiting the children to collect more materials than the recyclable trader helping them (Rosario 1999). The individuals involved are susceptible to discrimination and harassment because of their low social status.

5.3 RECOVERY AND REUSE OF SOLID WASTE

Items which were mostly reused by household's respondents in the study are plastic bottles at forty seven percent (47%) representing the highest. One hundred and sixty one (161) respondents representing forty two percent (42%) reused plastic bags and bottles. Diaz and Golueke (1985) noted, for several reasons, resource recovery is a major element in solid waste management in developing nations. Reclaimable inorganic components (metals, glass, plastic, textiles, and others) traditionally have been recovered mostly by way of unregulated manual scavenging by private individuals (typically known as the "informal" sector). In recent years, the trend is to formalize and mechanize scavenging through the establishment of material recovery facilities. Reuse and recovery of the inorganic components of the waste stream is an important aspect of waste management.

Special attention is given to organic (biodegradable) residues since, in the majority of developing countries, these residues constitute at least 50% of the waste (by weight). The resource recovery aspect regarding the organic component is threefold:

1. The component can be used in agriculture as a soil amendment through composting.
2. Its energy content can be recovered either biologically or thermally. Biological energy recovery is by way of methane production through anaerobic digestion. Thermal recovery is by way of combustion to produce heat.
3. The organic content can be hydrolysed either chemically or enzymatically to produce a sugar. The sugar can be used as a substrate for ethanol fermentation or for single-cell protein production.

5.4 KNOWLEDGE ON MUNICIPAL SOLID WASTE DISPOSAL AND IMPACT ON ENVIRONMENT

5.4.1 Knowledge on final destination of waste and problem of improper waste disposal

Three hundred and twenty seven (327) respondents representing eighty five percent (85%) lacked adequate knowledge on final destination of waste with fifty eight (58) respondents representing fifteen percent (15%) had knowledge on final destination of waste. The study showed that twenty-seven percent (27%) of respondents mentioned the problem of bad odour from rubbish heaps while dirty surroundings represented twenty six percent (26%). The problem of outbreak of malaria was also recorded representing seventeen percent (17%). Thirty three (33) respondents representing nine percent (9%) mentioned the issue smelling surroundings. Goldsmith (1988) emphasized that improper refuse dump site, apart from ruining an area's appearance, also provide a comfortable breeding place for animals and other organisms that spread diseases. These wastes, according to him, drain into water bodies to contaminate the water sources, the result of which is the rampant outbreak of typhoid fever in the area. Since mosquitoes also breed at unhygienic places, the improper dump in the area gives the mosquitoes an opportunity to lay their eggs which are hatched and increase the quantum of mosquitoes and hence a high incidence of malaria. The virus which causes cholera arrests the opportunity of the unhygienic environment to cause infection. Open dumps are poor methods of disposing of waste because of the environmental problems they cause. Refuse dumps are located on the edges of cities, towns, and villages, sometimes in ecologically sensitive areas, or areas where groundwater supplies are threatened. They serve as breeding grounds for rats, flies, birds and other organisms that function as disease vectors. In poorer areas, uncollected wastes accumulated at roadsides, are burnt by residents, or are disposed of in illegal or inappropriate dumps which blight neighbourhoods and harm public health (Medina, 1997). Bad odour is also released polluting the air. Water bodies get polluted giving rise to water-borne diseases such as cholera and diarrhoea. Tsiboe (2004) add weight to this fact by stating that in Accra disposal sites are located near the sea and are polluting the Korle lagoon creating an unhealthy environment. The sheer volume of domestic solid wastes is already causing serious disposal problems because most of the methods used to dispose them result in some kind of damage to the environment. When these solid domestic wastes are placed into open dumps, they ruin the attractiveness of the surrounding area. Dumps also provide habitats for disease carrying organisms (Barrow, 1995).

5.5 MEASURES TO IMPROVE MUNICIPAL SOLID WASTE DISPOSAL

Forty one percent (41%) of respondents called for rubbish heaps to be collected as major way of improving environments with thirty six percent (36%) mentioned the provision of municipal cooperation waste bin.

The study also revealed that ninety three percent (93%) of respondents expressed their desire to participate in clean up exercises to improve neighbourhood environments while seven percent (7%) wish to contribute by way of educating residents on good sanitation practices. Goldsmith (1988) emphasized that communities therefore must be taught and sensitized to live in a clean environment. But this would be possible if people would change their negative attitude about waste disposal to help reduce the outbreak of diseases. Agenda 21, Chapter 36 states, "Education, including formal education, public awareness and training, should be recognized as a process by which human beings and societies can reach their fullest potential. Education is critical for promoting sustainable development and improving the capacity of people to address environment and development issues." Education aims to contribute to the public's knowledge of inappropriate SWM as a problem for the community in order to start working towards solving the waste problem. The education program builds on the knowledge, values, skills, experiences, and determination of human capacity needed to work on solving waste management issues at an individual and community level (Salequzzaman and Stocker 2001).

The research also revealed that a majority of the respondents representing ninety three percent (93%) are prepared to participate in clean up exercise to tidy their communities. This will go a long way to ensure that the sanitation in the suburbs is improved. If this is sustained and promoted then communities in the Metropolis will become clean devoid of filth and refuse heaps.

5.6 FINANCIAL CONTRIBUTION TO MUNICIPAL SOLID WASTE MANAGEMENT

The study showed that, majority of the respondents representing seventy eight percent (78%) did not make financial contribution to the current waste collection systems. Only eighty six (86) respondents representing twenty two percent (22%) made contribution to the current waste systems. It was further observed that an average payment of GH¢ 12.3 per month to private waste collectors (Zoom Lion Ltd.). Tsiboe (2004) stated in their study that "a combination of poverty, population pressure, and economic hardships is placing a considerable strain on household environments in Accra. Majority of the people in Ghana live below the internationally recognized poverty line of one dollar a day. Satterthwaite (1998) virtually agrees in principle that the waste problem emanates from poverty and lack of funding as a result of low level of economic growth. Financial constraints undoubtedly are a factor that contributes to improper solid domestic waste management.

5.7 THE USE OF FERTILIZER TO IMPROVE CROP YIELDS

5.7.1 Fertilizer used to fertilize farm/crops.

Forty four percent (44%) of urban farmers use organic manure while seventy five (75) respondents representing twenty two percent (29%) use inorganic fertilizers. Seventeen percent (17%) of farmers use decomposed refuse soils and ten percent (10%) use compost manures. Fifty five percent (55%) of farmers indicated organic manures has the highest benefits in terms of improving and maintaining good soil condition with inorganic being the least of three percent (3%). In contrast to conventional agriculture organic farmers approach soil fertility in a holistic manner by implementing production practices that improve the physical, chemical, and biological properties of a soil. Physical characteristics of soil include texture and structure. The texture of a given soil is the percent sand, silt, or clay and is generally unchangeable for a given location (Brady *et al.*, 2002). Structure is the aggregation of these sand, silt, or clay particles into secondary clusters, and is readily altered by agricultural practices (Brady *et al.*, 2002). Texture and structure are responsible for the porosity, drainage, water-holding capacity, compaction and tilth of a soil (Brady *et al.*, 2002). Soil physical characteristics influence the ability of roots to grow and proliferate, extracting water and nutrients and stabilizing the plant. Wong *et al.* (1999) found that livestock manure compost applied to soils of organic farms in Hong Kong improved soil physical properties with a significant decrease in bulk density and increase in soil porosity and hydraulic conductivity.

Soil chemical properties determine the availability of plant nutrients (Brady *et al.*, 2002). Due to constraints on chemical inputs, organic farmers focus less on this component of soil fertility. Where conventional farmers place great emphasis on inputs of synthetic chemical fertilizers, organic farmers manage soil chemical properties with addition of organic matter thereby increasing cation exchange capacity of the soil (Baldwin, 2001).

It is generally recognized that the foundation of good soil quality is organic matter. Sullivan (2004) describes a few of the benefits of a topsoil rich in organic matter, including rapid decomposition of crop residues, granulation of soil into aggregates, decreased crusting, better water infiltration and drainage, increased water and nutrient holding capacity, easier tillage, reduced erosion, better formation of root crops, and more prolific plant root systems. Addition of organic matter to agricultural soil can most easily be accomplished with incorporation of cover crops, manure, and/or compost (Sullivan 2004).

5.8 YIELD FROM FIELD TRAILS OF CABBAGE

The decomposed solid waste soils combined with poultry manure treatment resulted in the greatest yields, followed by the DSW only, DSW+CD, DSW+CD+PM, and No input treatments, respectively. However, differences among the soil amendment treatments were not significant, but all soil amendment treatments resulted in significantly greater yields than the No input treatment. Significant differences in plant growth occurred beginning with week 2, and by week 7 plant growth differences among treatments paralleled trends in yield. DCS+PM resulted in significantly larger plants than the DSW only, DSW+CD, DSW+CD+PM, and No input treatments, although differences in plant size between the DSW + PM and DSW only treatments were not significant. No significant differences in plant size occurred among the DSW only, DSW+CD, and DSW+CD+PM treatments. Surprisingly, plant growth did not differ significantly between the DSW+CD+PM and No input treatments.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Three hundred and eighty five (385) respondents were interviewed on the assessment of the methods solid domestic waste management in the Tamale Metropolis through multistage, purposive and simple random sampling. Majority of the respondents representing sixty percent (60%) had average education. Twenty-four percent (24%) had availability of municipal cooperation dustbin while seventy six percent (76%) had no access to municipal dustbin within 100 metres from their homes. Waste was mainly carried on the head to the refuse heap site by both adults and children with the children forming majority of eighty percent (80%). These refuse heaps were found around houses in most cases. Nine percent (9%) disposed solid waste through private waste bins with lids as the type of receptacle. Ninety-one percent (91%) had no municipal collection waste bin serving as receptacles and fifty one percent (51%) throws a maximum of 1 carrier bags of waste of approximately 1kgs per week with fifteen percent (15%) those who throw 3 carrier bags of waste per week. Respondents stated bad odour from refuse heaps, breeding of vectors of disease and malaria outbreak as the major consequence of improper solid waste management. Seventy eight percent (78%) do not make financial contribution to the current waste collection systems with twenty two percent (22%) making financial contribution to the current waste collection systems. The supply of municipal cooperation waste bins making thirty six percent (36%) and refuse heaps collected representing forty one percent (41%) was the most popular suggestion by respondents for improving solid waste management with participation in clean up exercise at ninety three percent (93%) with intensification of sanitation education at seven percent (7%).

6.2 RECOMMENDATIONS

This study has revealed that solid domestic waste management is not proper and healthy in the Tamale Metropolis and the following measures are recommended for action by all stakeholders.

The Metropolitan Assembly

In collaboration with the people, the Metropolitan Assembly should supply hygienic bins or storage receptacles to community members as most suburbs lacked hygienic bins. The Metropolitan Assembly should provide waste collection vehicles and come out with a programme that should completely involve the communities (community participation) in managing solid domestic waste in the metropolis.

The Assembly should ensure that recommended dump sites are properly located and regulations governing environmental health are enforced in the communities.

Educational Institutions

More students of public health are to undertake further research into solid domestic waste management as the study was not in-depth enough due to certain limitations. Solid domestic waste management with more emphasis on recycling of domestic waste and transforming domestic waste into manure and compost should be included in the school curriculum right from the basic to the tertiary levels.

The Metropolitan Health Management Team

The MHMT should organize periodic environmental health education at social gatherings, on market days and in places of worship on the need to live in a healthy environment and proper methods of waste disposal.

Government, Non-Governmental Organizations and Research Institutions

Government, non-governmental organizations (NGOs) and research establishments should encourage research into problems concerned with solid domestic management such as bulkiness, offensive odour and financial constraints among others. An integrated approach to urban waste management, currently absent, is needed to improve the use of urban waste. Such an approach should recognize the roles of farmers and livestock keepers, incorporate approaches to segregate waste materials, manage the waste in an environmentally sustainable way and also consider effective ways to market waste.

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APPENDICES

APPENDIX 1

Sample size

A sample size of three hundred and eighty five (385) will be used in the study. The following statistical formula will be used based on the fact that the study population was more than 25,000:

$$n = \frac{z^2 \, p \, q}{d^2}$$

Where n = the desired sample size (when population is greater than 25,000)

z = the reliability coefficient for 95% confidence level usually set at 1.96

p = the proportion in the target population estimated to have a particular characteristic. 50% will be used because there was no reasonable estimate. (i.e. 0.50)

q = 1.0 – p

d = degree of accuracy desired, usually set at 0.05

$$n = \frac{(1.96)^2 (0.5)\,(0.5)}{(0.05)^2}$$

n = 385.

The total sample size came up to three hundred and eighty five (385).

APPENDIX 2

Questionnaire on studies on utilization of decomposed solid waste combined with cow dung and poultry manure for urban agriculture in the tamale metropolis.

A. Respondent Background information

Sex____ Age_____

Occupation_______

Educational level:

None__MidleSchool___Primary______JHS_____SHS___Tertiary___

B. Household Information

1. How many members do you have in your house?

Adults: __________ Children: ___________ Senior Citizens: ___________

2. How many working members live in the household?

Number: _________ Occupations: ___________

Type of housing

3. Please choose the type of housing that you live in:

Independent House:____ Compound House:____ Others (please specify):___________

4. How would you describe the vicinity that you live?

Residential area:___________ Slump area:___________Middle income area:___________

C. Availability of Municipal cooperation dustbin

5. Do you have a Municipal Corporation dustbin within 100 metres of your home?

If yes please specify what

kind:____

If no, where do you dump your waste:

____

D. Waste Disposal approaches

6. Do you segregate your waste at home?

Yes:____ No:____ If yes please choose: Dry__ Organic__ Biomedical__

Others:___________________

7. Who in your household usually throws out the waste?

____

8. On an average, how many carrier bags of waste ________& how often _______ do you throw out per week?

E. Reuse of waste

9. Do you reuse any of the following items:

Plastic bags:____ Plastic bottles:____ Paper bags:____

Others:______________________

F. Knowledge on Municipal solid waste disposal and impact on environment

10. After you put out your waste, do you know where the waste goes?

Yes:____ No:____ If yes, please specify

where:_________________________________

11. Do you think that waste disposal method is a problem in your neighborhood?

Yes:____ No:____ If yes please specify

why:_____________________________________

12. Do you see any of these environmental problems in your neighborhood?

Rubbish heap:____ Dirty streets:____ Open drains:____ Rubbish fires:____

Flies and Mosquitoes:____

Others:____

13. Do you think that the above mentioned problems can be improved?

If yes, how?

____

If no, why not?

____

G. Measures to improve Municipal solid waste disposal

14. What one thing do you think would improve your neighbourhood environment?

____

15. Would you like to have an opportunity to participate in improving your neighbourhood environment?

____

H. Level of contribution to Municipal solid waste management

16. Do you make a financial contribution to the current waste collection system?

Yes:____ No:____ If yes please specify how much:________________________________

I. The use of fertilizer to improve crop yields

17. What type of fertilizer do you use to fertilize your farm/crops.

Organic____ Inorganic____ Compost____ Decomposed refuse soils____

18. Why do you use the fertilizer type for fertilization of your farm/crops

____

19. Which of the fertilizer types do you think improves soil and maintains good soil condition?

Organic____ Inorganic____ Compost____ Decomposed refuse soils___

APPENDIX 3

Figure 1 Map of Ghana showing the study area

APPENDIX 4

Figure 2 The use of private domestic solid waste collection bin

APPENDIX 5

Figure 3 The use of municipal cooperation waste bin for domestic solid waste collection

APPENDIX 6

Figure 4 The disposal of solid waste on refuse heap around homes

This presents unsightly scene, stench for residents and the possibility of disease out-break in the area.

APPENDIX 7

Figure 5 The cultivation of cabbage at the field

APPENDIX 8

Figure 6 The cultivation of cabbage at the field with each treatments


DECOMPOSED
SOLID WASTE
ONLY


DECOMPOSED
SOLID WASTE +
COW DUNG


DECOMPOSED
SOLID WASTE +
POULTRY MANURE


DECOMPOSED
SOLID WASTE +
COW DUNG +
POULTRY MANURE


NO INPUT