Study on Bio-Fertilizer Extraction and Management of Municipal Solid Waste of Khulna City

by

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A project submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering in the Department of Mechanical Engineering

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Declaration

This is to certify that the project work entitled "*Study on Bio-Fertilizer Extraction and Management of Municipal Solid Waste of Khulna City*" has been carried out by *Debasish Adhikary* in the Department of *Mechanical Engineering*, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above project work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Approval

This is to certify that the project work submitted by *Debasish Adhikary* entitled "*Study on Bio-Fertilizer Extraction and Management of Municipal Solid Waste of Khulna City*" has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of *Master of science in Engineering* in the Department of *Mechanical Engineering*, Khulna University of Engineering & Technology, Khulna, Bangladesh in December 2016.

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Abstract

The increasing population of Bangladesh leads to the growth of urban areas and slums which in turn, generating a huge volume of wastes. Thus disposal of waste has become a serious issue. In this project, generation and characteristics of municipal solid waste in Khulna city has been analyzed along with the associated environmental impacts and existing municipal waste management practices. Main focus is given on bio-fertilizer extraction from municipal solid waste comparing with a few solid waste management projects. The main objective of the study is to achieve the knowledge of solid waste management procedure in Khulna city and find out the best possible way of bio-fertilizer extraction from the study of those projects. Major portion of municipal solid waste of Khulna City is organic which are rapidly biodegradable. Because of unsatisfactory solid waste management system in Khulna city, some common problems usually occurs such as diseases, fire hazards, odor for nuisance atmosphere, water pollution and consequently economic losses. At the same time, those wastes have a potential value of producing organic bio-fertilizer. This potential factor makes interest to study the composting procedure from municipal solid waste and find out efficient way to do it. The total daily household wastes generated in Khulna City areas is about 500 tons and from this total waste daily 200 tons for compost production is possible. But only 1.5 tons of compost is producing per day in Rajbandh by RUSTIC and generating 10,000 taka profits. Again the waste produces in Khulna University of Engineering & Technology at the rate of 3898 kg/month of which 65.09% are compostable. Current compost generation in KUET is only 50 kg/month because of small area and limited waste production. The finished product in Rajbandh and KUET is also different because of waste composition, separation process and production process. However waste in KUET is well managed and the whole process is closely monitored but in the other hand solid waste management process in Khulna City Corporation is very poor. In this context, to meet up the growing demand of bio-fertilizer, it is the best way to use renewable resources like municipal solid waste. It can help to create a modern waste well managed beautiful city and will make an example. With better management plan and realistic approach, compost generation from municipal solid waste could be economically profitable and save the environment.

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CHAPTER I

Introduction

1.1 General

Municipal solid waste comprises of all the wastes arising from human and animal activities those are normally solid and are discarded as useless or unwanted things. It may be heterogeneous mass of throw-away from the urban community as well as the more homogenous accumulation of agricultural, industrial and mineral wastes. It includes durable goods, non-durable goods, containers and packaging, food wastes, yard wastes, and miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources. Examples from these categories include appliances, newspapers, clothing, food scrapes, boxes, disposable cable ware, office and classroom paper, wood pallets, rubber tires, and cafeteria wastes.

Municipal Solid Waste is considered as one of the most immediate and serious environmental problems confronting municipal authorities in developing countries like Bangladesh. The rapid growth of urbanization and uncontrolled urban sprawl, severely degrades environment, natural resources and consequently undetermined equitable and sustainable development. Now it is a major global concern which is increasing day by day. Municipal government in the entire world is struggling today to find the best method to manage their residents' wastes; particularly Municipal wastes; presently, this Municipal Waste Management is a burning issue in the urban centers particularly in the rapid growing cities in Least Developed Asian Countries (LDAC). But LDAC like Bangladesh is not too much concerned and anxious about her environmental problems on Municipal Waste Management. Now it is the time to motivate our policy makers, politicians, environmentalists, economists and also the government about the proper utilization of urban waste to save our city dwellers. However, effective management of wastes requires sound setting of human resources and technical support. Waste disposing is an important part of waste utilization system, which requires much attention to avoid environmental pollution. In context of Bangladesh, waste disposal and utilization is in a bad shape in urban areas since urban inhabitants generate huge quantity of

municipal waste daily and in such areas population density is high. Only major cities have some sort of garbage disposal system. In the major cities of Bangladesh, per capita production of waste is 0.5 kg/day but only 0.2 kg of waste per capita is carried to the final disposal site [1]. The rest is disposed locally. This scenario of waste disposal of the major cities of any country obviously expresses the poor waste management situation of that country.

Management of vast quantities of Municipal waste generated by urban communities is a very much complex process. Due to several financial constraints, lack of motivation and the absence of effective legislation to protect the environment and to handle the waste, the whole system becomes as a threat for city dwellers, planners and other concerned stakeholders. Municipal waste management is carried out by the City Corporation for which conservancy fee is also charged on to the urban inhabitants. But waste management system of Khulna City Corporation (KCC) of Bangladesh is not satisfactory. The most common problems associated with improper management of Municipal waste include diseases transmission, fire hazards, odor for nuisance atmosphere and water pollution, aesthetic nuisance and economic losses [1].

The developing cities like Khulna have now begun to acknowledge the environmental and public health risks associated with uncontrolled dumping of wastes. That has occurred mainly due to the active participation of private sector in municipal waste management. The present scenario of Khulna city is given to highlight the management and technical issues. The management issues encompass waste generation, composition and characterization, collection, transport, processing and disposal of waste while the technical aspects comprise implementation of legal provisions, economic and financial issues.

The increasing population of Bangladesh leads to the growth of urban areas and slums which in turn, generating a huge volume of wastes. Thus, disposal of solid waste has become a serious issue in the modern society. Different study showed that the major portion of municipal waste of Khulna City is organic which are rapidly biodegradable and creating various environmental and health risks [1]. At the same time, the total daily household solid wastes generated in Khulna City areas is about 490 to 510 tons. Around 40% of total household wastes are managed by different organizations [2]. Because of unsatisfying solid waste management system in Khulna city, some common problems are occurring such as diseases, fire hazards, odor for nuisance atmosphere, water pollution and consequently

economic losses [3]. To prevent those problems, it becomes necessary to manage properly the municipal solid waste rather than dumping outside the main city. These municipal solid wastes can be used to produce bio-gas by anaerobic digestion process and generate electricity and it can also be used to produce bio-fertilizer [4]. So it could be beneficial to the environment as well as economically profitable. Depending on a few variables, producing organic bio-fertilizer from municipal solid waste could be one of the best ways to turn these wastes into resources [5].

An integral management approach for household municipal waste has to address the overall flow of material through various waste management activities, such as - collection, transport, separation, reuse, recycling, composting, treatment, and final disposal. Municipal solid waste recycling and composting has been found to be acceptable as a sustainable approach towards the municipal waste management in environmental, economic and social points of view. If municipal solid wastes are not recycled, the land will be filling up very fast and as a result, dumping site could be exhausted and that necessitates the search for a new one. Recycling, reuse of solid waste reduces environmental damage, enhances income generation activity, saves energy, conserves resources, and saves waste collection, transportation and disposal cost.

This study will help to minimize supply demand gap of bio-fertilizer and create a modern well waste managed beautiful city effectively. In this project, generation and characterization of bio-fertilizer from municipal solid waste in Khulna city and KUET are analyzed along with the associated environmental impacts and existing solid waste management practices.

1.2 Objectives of the Study

The specific objectives of the research work are:

- To study the recent potential of municipal solid waste in KCC area.
- To study existing bio-fertilizer extraction process from Municipal Solid Waste (MSW).
- To disclose the existing Municipal solid waste management practice.
- To find out the efficient way to extract bio-fertilizer from municipal waste among a few alternatives by comparative study.
- To suggest the best suited waste management policy.

1.3 Technical Terms Used in this Study

Municipal solid waste (MSW): Municipal solid waste are all the waste arising from human and animal activities that are normally solid discarded as useless or unwanted.

Open dumping: Disposing of wastes in open dumps is the most common methods used in developing countries. The term dump means the uncontrolled deposit of waste. In open dumps waste is exposed to flies and rodents and a source of nuisance from the smell and unsightly appearance. It can also cause water and air pollution if the selection is not proper.

Primary disposal point: The household carry their waste to bins or similar facilities situated at specific location and deposit waste there. This area is known as primary disposal point.

Secondary disposal point: It is a place where waste are deposited from primary disposal point and thus carried out it by van or truck to the final disposal point.

Final disposal point: It is a place where waste finally deposited and it may be associated with various activities of waste processing plants that are no further use. Final disposal may include open dumping, sanitary land filling, incineration, composting etc.

Landfill: A land waste disposal site that is designed to minimize water pollution from run-off and leaching.

Reuse: Reuse is the process of taking idle goods and materials such as cloths, kitchen waste, computers, and re-employing them in a manner that does not require altering their original form. Reuse can also mean just using something over and over again, such as cloth shopping bags or plastic insulated coffee mugs.

Recycling: It is the process of transforming materials into raw materials for manufacturing new products, which may or may not be similar to the original product.

Resource recovery: The extraction and utilization of materials and energy from wastes.

NGO: NGO refers to Non-Government Organization which carries out various projects for the socio-economic development of the country.

CBO: These are the organizations that usually run by self-finance and involved in various social activities. Basically it is a self-motivated organization.

Composting: Biological decomposition of solid organic materials by bacteria, fungi and other organisms into a soil like products.

1.4 Limitations of the Study

KCC is a large study area. Due to the limitation of resources this study only focus on the basic problems associated with waste utilization and thus analyzes its prospects in city area. In analyzing Prospects of municipal waste utilization in Khulna City, following limitations are faced:

- **Lack of supporting information:** This study depends on huge and vast information. For supporting as well as enriching it, more documents and necessary information are lacking in few cases (fund, awareness, co-operation of the relevant officials etc.).
- **Lack of literature materials:** There is no extensive literature support on the topic of this study. Even less literature material available on Khulna city. Only a number of thesis papers from some renowned organizations and library of the University, few books, reports of concerned authority etc. were available. Thus in case of literature support, the materials regarding the topic were rare.
- **Lack of accurate information:** Exact information could not be collected from many government offices as they did not sort or keep data.
- **Poor secondary information:** Secondary information is not updated; therefore the interpretation sometimes becomes difficult.

CHAPTER II

Literature Review

2.1 General

Regarding the study entitled "Study on Bio-fertilizer extraction and management of Municipal Solid Waste of Khulna city" there is not sufficient work in Bangladesh. Some research works conducted on specific entitled topic. To grow concept, early ideas about the selected topic without the help of literature review is not possible. Various data, necessary materials can be collected from literature review. So the books and other related materials which were reviewed to prepare this paper are given below.

2.2 Literature

(According to the Khulna City Corporation Ordinance, 1984) Khulna City Corporation (KCC) is responsible for collection, transportation, and treatment of solid waste in Khulna City but KCC does not collect any waste in 7 wards out of 31 wards because these wards are situated remote area and waste are locally managed there. Sometimes causes few regional affect for constructive factors but in the rest of 24 wards only 20% wastes where collect by KCC and 80% wastes are not managed properly (Conservancy Department of Khulna and RUSTIC).

Sumon [6] stated in his report that municipal waste utilization system as an alternative option for Khulna city. Here the author emphasized on the city's waste utilization system that is performed by thy City Corporation, NGOs and other management bodies as a whole basis. He also emphasized on community based municipal waste utilization system, which is better than the KCC, and also provides the recommendation how to manage community awareness. He also consider on collection, transportation, and dumping of the waste.

H. K. Richard [7] reported that in the rapidly growing cities of developing countries, urban solid waste management is currently been regarded as one of the most immediate and serious issues for city authorities. Due to inadequate and often inefficient solid waste management and visible environmental degradation, solid waste generated at an increasing rate has also

become an important environmental issue for the residents of the major cities of Least Developed Asian Countries (LDACs) like Bangladesh.

Hoque, M. A. [8] reported that the location of disposal (secondary) sites of KCC represent the unconsciousness about the environmental and public health hazards arising from disposing of waste in improper location. A suitable site must have environmental safety criteria's. Criteria for site selection include natural physical characteristics as well as socioeconomic, ecological, and land use factors. The Geographical Information System (GIS) can provide an opportunity to integrate field parameters with population and other relevant data or other associated feathers, which help in selection of suitable disposal sites.

Salequzzaman [4] stated that, Khulna city is reported to generate some 200-370 tones of wastes daily, per capita per day generation variously quoted lying between 0.22 kg and 0.75 kg. The city has a population of about 1.5 million. In Dhaka, per capita waste generation per day is 0.52 kg. Assuming the same value for Khulna, daily waste generation should be more than 750 tones which are sufficient for setting up a power plant about 3 MW (Mega watt). To the knowledge of the consultant of this report, there has been no study on the quality assessment of Khulna city waste.

Alamgir and Ahsan [9] said that management of this steeply increasing vast quantity of solid wastes is a very complex process indeed. Due to severe financial constraints, absence of appropriate technology, lack of people's awareness, motivation and participation, ineffective legislation and law enforcement to protect the environment and to handle the waste, the whole system is becoming a threat to city dwellers, planners and other stakeholders including these factors, resource and other constraints and limitations, KCC has not been able to manage well entirely the whole task of solid waste disposal.

Sultana, T. [1] stated the existing Municipal Waste Utilization of Khulna City Corporation and determined the ecological footprint of waste generation of KCC area. She also recommended the way by which the ecological footprint of waste generation can be very effective tool for sustainable waste utilization in KCC area.

Alamgir and Ahsan [3] stated most of the wastes of landfill are wagered to our soil nutrition and to ensure our food security, intensive cultivation and applied commercial fertilizer are also degrading air soil health. This is why, to ensure a clean, hygiene, environmental-friendly city and to protect soil health and to develop agro-ecological soil based country, the City

Authority and Agricultural Ministry of Bangladesh are looking for a safe and sustainable solution for the appropriate management of solid wastes.

Kashem [10] stated in his research that, if the municipal waste which is generated in Khulna city is managed properly, it can be a potential resource. By using waste, biogas can be produced and the residue of biogas can be used as compost fertilizer and the produced biogas can be used as a means of producing electricity. In this way, potential resource can be recovered through waste utilization which is highlighted in his research.

Khulna Development Authority [11] this report stated that the daily collection efficiency of MW (Municipal Waste) is only 23 percent of the generated volume in KDA master plan area. The reason for low collection efficiency as stated in this report are; insufficient funds to run the activities for collection and transportation of solid waste, insufficient number of equipment and carriers, insufficient number of road side rubbish bins, practice of improper use of bins and drains for waste disposal, insufficient maintenance staff and lack of public awareness on waste disposal system etc.

CHAPTER III

Strategic Aspects and Disposal Alternatives of Municipal Solid Waste

3.1 General

Municipal Solid Waste Management (MSWM) is major responsibility of local government. It is a complex task which requires appropriate organizational capacity and cooperation between numerous stakeholders in the private and public sectors. Although it is essential to public health and environmental protection, solid waste management in most cities of developing countries is highly unsatisfactory. This Conceptual Framework provides brief definitions of the main concepts of MSWM and identifies the goals and principles that normally guide MSWM system development. It discusses key objectives and issues which should be addressed by MSWM strategies with regard to political, institutional, social, financial, economic and technical aspects.

3.2 Strategic Aspects of Solid Waste Management

To achieve sustainable and effective waste management, development strategies must go beyond purely technical considerations to formulate specific objectives and implement appropriate measures with regard to political, institutional, social, financial, economic and technical aspects of MSWM.

3.2.1 Political Aspects

Political aspects concern the formulation of goals and priorities, determination of roles and jurisdiction, and the legal and regulatory framework. Society's goals and priorities regarding environmental protection and equitable service access must be clearly articulated in order to mobilize popular support and resources required for their realization. A clear definition of jurisdiction and roles is essential to the political sustainability of MSWM systems. The strategic plan for MSWM provides a basis for putting the defined roles of government authorities and other actors into effect. By laws, ordinances and regulations for MSWM should be few in number, transparent, unambiguous and equitable [12].

3.2.2 Institutional Aspects

Institutional aspects concern the distribution of functions and responsibilities and correspond to organizational structures, procedures, methods, institutional capacities and private sector involvement. Effective MSWM depends upon an appropriate distribution of responsibilities, authority and revenues between national, provincial and local governments. In metropolitan areas, where MSWM tasks extend across several local government units, inter-municipal cooperation is essential. Decentralization of responsibility for MSWM requires a corresponding distribution of powers and capacities. It normally calls for revised organizational structures, staffing plans and job descriptions of the local agencies concerned. Capacity-building measures for MSWM should give primary attention to strategic planning and financial management. Discrepancies often exist between MSWM job requirements and the actual staff qualifications, training and human resource development are thus important components. Private sector involvement in MSWM implies a shift in the role of government institutions from service provision to regulation. Essential conditions for successful private sector involvement include competitive bidding, technical and organizational capacity, regulatory instruments and monitoring and control systems. The contribution of informal waste collection workers may be significantly improved through appropriate organizational measures [12].

3.2.3 Social Aspects

Social aspects of MSWM include the patterns of waste generation and handling of households and other users, community-based waste management and the social conditions of waste workers. Waste generation patterns are determined by people’s attitudes as well as their socio-economic characteristics. Attitudes towards waste may be positively influenced by awareness-building campaigns and educational measures. In many low-income residential areas, community-based solid waste management is the only feasible solution. Functional links between community-based activities and the municipal system are very important, however. Even where municipal waste collection services are provided, user cooperation is essential to efficient MSWM operations. Cooperation may be promoted through general awareness-building programmers as well as focused MSWM information campaigns. Waste workers especially those in the informal private sector live and work under socially precarious conditions and are subject to serious health risks. Support should aim to improve their working conditions, earnings, and access to social services [12].

3.2.4 Financial Aspects

Financial aspects of MSWM concern budgeting and cost accounting, capital investment, cost recovery and cost reduction. Although they are essential to effective MSWM, available practical methods of budgeting, cost accounting, financial monitoring and financial evaluation are too seldom employed. Their application should be actively promoted within institutional development programs. The main options for financing capital investment for MSWM include local budget resources, loans from financial intermediaries and special central government loans or grants. While central financing is often needed, investment authority should be devolved to local governments. The main options for financing recurrent MSWM costs are user charges, local taxes and intergovernmental transfers; clear preference should be given to user charges. To achieve equitable service access, some degree of cross-subsidization and/or financing out of general revenues is often needed, however. MSWM fee collection performance is often poor. Improvement can often be achieved by attaching solid waste fees to the billing for another service, such as water supply. Solid waste service revenues normally flow into a general municipal account, where they tend to be absorbed by overall expenditures. Clear political decisions and autonomous accounting procedures are required to ensure that MSWM revenues are employed for the intended purpose. The potential for increasing MSWM revenues is usually limited; cost reduction - “doing more with less” is almost always the best way to improve financial sustainability [12].

3.2.5 Economic Aspects

Economic aspects of MSWM are concerned with the impact of services on economic activities cost-effectiveness of MSWM systems, macro-economic dimensions of resource use and conservation, and income generation. Solid waste generation and the demand for waste collection services generally increase with economic development. A trade-off is normally required between the objectives of low-cost collection service and environmental protection. The economic effectiveness of MSWM systems depends upon the life-cycle costs of facilities and equipment and the long-term economic impact of services provided. Economic evaluation constitutes an important input to strategic planning and investment programming for MSWM. Measures should be introduced which discourage wasteful use of materials and encourage waste minimization. The best way to promote efficient use and conservation of materials is to internalize the costs of waste management as far as possible in the production, distribution and consumption phases. Private sector involvement in waste management may

actually reduce the number of jobs in the sector. Economic strategies should seek, firstly, to increase effectiveness and labor productivity of MSWM and, secondly, to generate employment by expanding service coverage [12].

3.2.6 Technical Aspects

Technical aspects of MSWM are concerned with the planning and implementation and maintenance of collection and transfer systems, waste recovery, final disposal and hazardous waste management. Technical facilities and equipment must be designed and selected with careful regard to their operating characteristics, performance, and maintenance requirements and expected life-cycle costs. Close attention should be paid to preventive maintenance, repair and spare parts availability. Design of transfer facilities and equipment must match the characteristics of local collection systems and the capacity of existing disposal facilities. Local collection systems should be designed with active participation of the communities concerned. Informal waste recovery and scavenging may be rendered more productive through support measures and appropriate technical design of the waste management systems. Public sector involvement in waste recovery and/or leasing of waste recovery rights to private sector enterprises may be considered. The most appropriate method of final disposal in developing countries is nearly always the sanitary landfill. To minimize their environmental impact, landfills must be carefully sited, correctly designed and well operated. Sources of hazardous waste materials must be identified, registered and targeted for appropriate management; special attention needs to be paid to infectious healthcare wastes [12].

3.3 Eco-Friendly Waste Management Approaches and Disposal Alternatives

Waste management and disposal treatment is an appropriate management technique based on prevailing socio-economic settings, technological capabilities and waste separation into the organic, inorganic, depositional, thermal, recycling, reduce and reuse treatment [13]. Sustainability of the selected management options provides the energy safe and ecological development goal. In Bangladesh, the Solution for MSW management handled separately as the situation varies city by city, within different regions of the city and within different parts of the region [14]. Although different activities for different region occurred city by city, but there is common waste-safe activity and disposal role played an important role to manage the

waste and provide us an eco-living nature. Those management activities are describes as follows.

3.3.1 Reduce, Reuse and Recycle of Wastes

Methods of waste reduction, waste reuse and recycling are the preferred options when managing waste. There are many environmental benefits that can be derived from the use of these methods. They reduce or prevent green house gas emissions, reduce the release of pollutants, conserve resources, save energy and reduce the demand for waste treatment technology and landfill space [12]. Therefore it is advisable that these methods will be adopted and incorporated as part of the waste management plan.

3.3.2 Waste Reduction and Reuse

Waste reduction and reuse of products are both methods of waste prevention. They eliminate the production of waste at the source of usual generation and reduce the demands for large scale treatment and disposal facilities [15]. Methods of waste reduction include manufacturing products with less packaging, encouraging customers to bring their own reusable bags for packaging, encouraging the public to choose reusable products such as cloth napkins and reusable plastic and glass containers, backyard composting and sharing and donating any unwanted items rather than discarding them. All of the methods of waste prevention mentioned require public participation. In order to get the public onboard, training and educational programs need to be undertaken to educate the public about their role in the process. Also the government may need to regulate the types and amount of packaging used by manufacturers and make the reuse of shopping bags mandatory.

3.3.3 Incineration

Incineration is the most common thermal treatment process. Figure 3.1 shows the schematic diagram of waste incineration plants. This is the combustion of waste in the presence of oxygen. After incineration, the wastes are converted to carbon dioxide, water vapor and ash. This method may be used as a means of recovering energy to be used in heating or the supply of electricity [16]. In addition to supplying energy incineration technologies have the advantage of reducing the volume of the waste, rendering it harmless, reducing transportation costs and reducing the production of the green house gas methane.

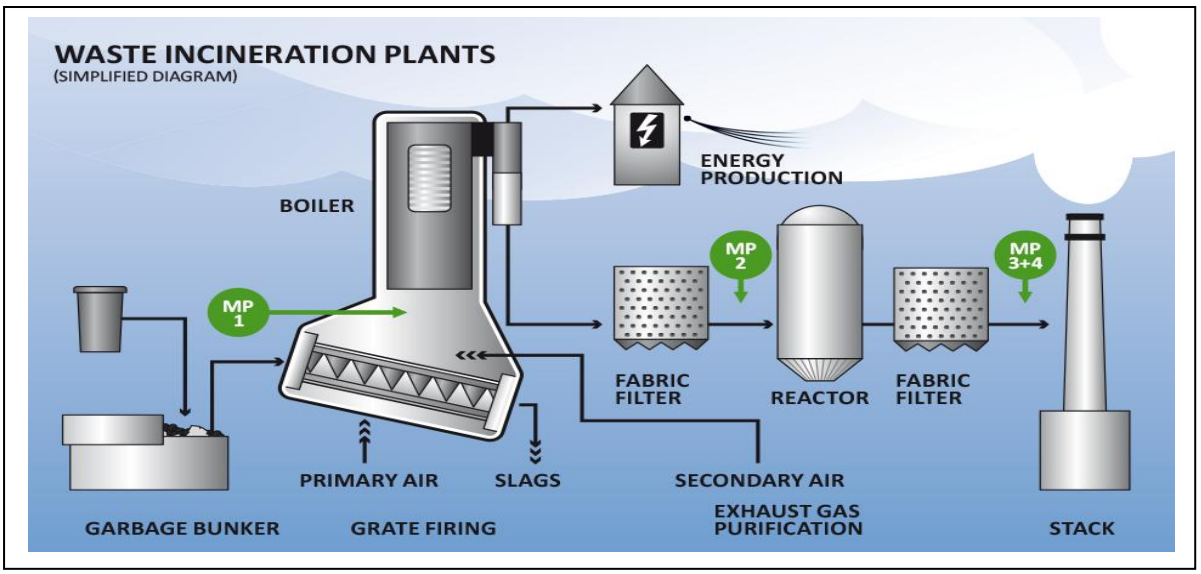

Figure 3.1: Schematic diagram of waste incineration plants

3.3.4 Pyrolysis and Gasification

Pyrolysis and gasification are similar processes they both decompose organic waste by exposing it to high temperatures and low amounts of oxygen [17]. Gasification uses a low oxygen environment while pyrolysis allows no oxygen. These techniques use heat and an oxygen starved environment to convert biomass into other forms [18]. A mixture of combustible and non-combustible gases as well as pyroligenous liquid is produced by these processes. All of these products have a high heat value and can be utilized. Gasification is advantageous since it allows for the incineration of waste with energy recovery and without the air pollution that is characteristic of other incineration methods. Figure 3.2 represents the Schematic diagram of gasification process.

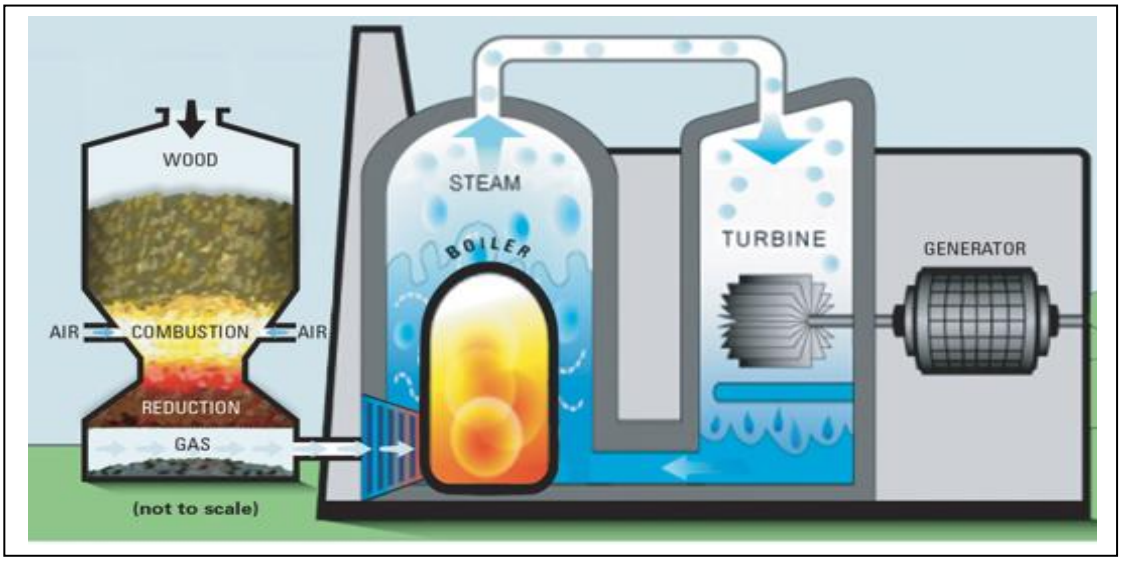

Figure 3.2: Schematic diagram of gasification process

3.3.5 Open Burning

Open burning is the burning of unwanted materials in a manner that causes smoke and other emissions to be released directly into the air without passing through a chimney or stack. This includes the burning of outdoor piles, burning in a burn barrel and the use of incinerators which have no pollution control devices and as such release the gaseous by products directly into the atmosphere (Department of Environmental Quality, 2004). Open burning has been practiced by a number of urban centers because it reduces the volume of refuse received at the dump and therefore extends the life of their dumpsite. Garbage may be burnt because of the ease and convenience of the method or because of the cheapness of the method. In countries where house holders are required to pay for garbage disposal, burning of waste in the backyard allows the householder to avoid paying the costs associated with collecting, hauling and dumping the waste. Open burning has many negative effects on both human health and the environment. This uncontrolled burning of garbage releases many pollutants into the atmosphere. These include dioxins, particulate matter, polycyclic aromatic compounds, volatile organic compounds, carbon monoxide, hexachlorobenzene and ash. All of these chemicals pose serious risks to human health. The Dioxins are capable of producing a multitude of health problems; they can have adverse effects on reproduction, development, disrupt the hormonal systems or even cause cancer. The polycyclic aromatic compounds and the hexachlorobenzene are considered to be carcinogenic. Figure 3.3 represents the photographic view of solid waste open burning process.

Figure 3.3: Photographic view of solid waste open burning

The particulate matter can be harmful to persons with respiratory problems such as asthma or bronchitis and carbon monoxide can cause neurological symptoms. The harmful effects of open burning are also felt by the environment. This process releases acidic gases such as the halo-hydrides; it also may release the oxides of nitrogen and carbon. Nitrogen oxides contribute to acid rain, ozone depletion, smog and global warming. In addition to being a green house gas carbon monoxide reacts with sunlight to produce ozone which can be harmful. The particulate matter creates smoke and haze which contribute to air pollution.

3.3.6 Controlled Dumps

Controlled dumps are disposal sites which comply with most of the requirements for a sanitary landfill but usually have one deficiency. They may have a planned capacity but no cell planning, there may be partial leachate management, partial or no gas management, regular cover, compaction in some cases, basic record keeping and they are fenced or enclosed. These dumps have a reduced risk of environmental contamination, the initial costs are low and the operational costs are moderate. While there is controlled access and use, they are still accessible by scavengers and so there is some recovery of materials through this practice.

3.3.7 Biological Waste Treatment as Composting

According to figure 3.4, composting is the controlled aerobic decomposition of organic matter by the action of micro organisms and small invertebrates. There are a number of composting techniques being used today. These include: in vessel composting, windrow composting, vermin-composting and static pile composting. The process is controlled by making the environmental conditions optimum for the waste decomposers to thrive [19]. According to Mehnaz [20] the rate of compost formation is controlled by the composition and constituents of the materials i.e. their Carbon/Nitrogen (C/N) ratio, the temperature, the moisture content and the amount of air [15]. The C/N ratio is very important for the process to be efficient. The micro organisms require carbon as an energy source and nitrogen for the synthesis of some proteins. If the correct C/N ration is not achieved, then application of the compost with either a high or Low C/N ratio can have adverse effects on both the soil and the plants. A high C/N ratio can be corrected by dehydrated mud and a low ratio corrected by adding cellulose. Moisture content greatly influences the composting process. The microbes need the moisture to perform their metabolic functions.

Figure 3.4: Composting of solid waste

If the waste becomes too dry the composting is not favored. If however there is too much moisture then it is possible that it may displace the air in the compost heap depriving the organisms of oxygen and drowning them. A high temperature is desirable for the elimination of pathogenic organisms. However, if temperatures are too high, above 75°C then the organisms necessary to complete the composting process are destroyed. Optimum temperatures for the process is the range of 50-60°C with the ideal being 60°C. Aeration is a very important and the quantity of air needs to be properly controlled when composting. If there is insufficient oxygen the aerobes will begin to die and will be replaced by anaerobes. The anaerobes are undesirable since they will slow the process, produce odors and also produce the highly flammable methane gas. Air can be incorporated by churning the compost [21].

3.3.8 Anaerobic Digestion

Anaerobic digestion like composting uses biological processes to decompose organic waste. However, where composting can use a variety of microbes and must have air, anaerobic digestion uses bacteria and an oxygen free environment to decompose the waste. Aerobic respiration, typical of composting, results in the formation of Carbon dioxide and water. While the anaerobic respiration results in the formation of Carbon Dioxide and methane. In addition to generating the humus which is used as a soil enhancer, Anaerobic Digestion is also used as a method of producing biogas which can be used to generate electricity. Optimal conditions for the process require nutrients such as nitrogen, phosphorous and potassium, it

requires that the P^H be maintained around 7 and the alkalinity be appropriate to buffer P^H changes, temperature should also be controlled. Figure 3.5 shows the flow chart of Anaerobic Digestion.

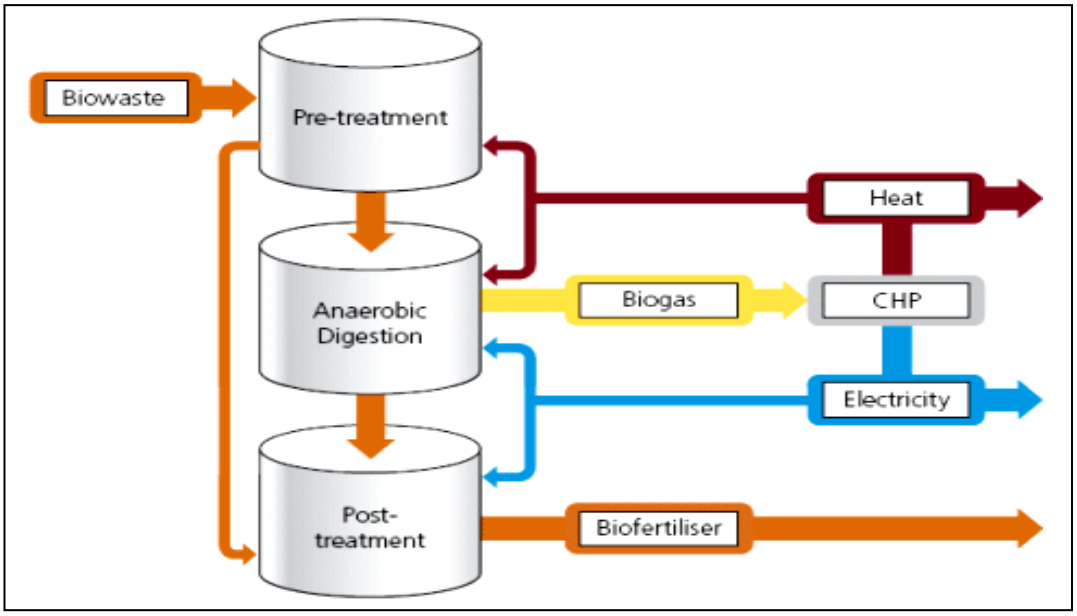

Figure 3.5: Flow chart of Anaerobic Digestion

3.3.9 Integrated Solid Waste Management

According to figure 3.6, Integrated Solid Waste Management (ISWM) takes an overall approach to creating sustainable systems that are economically affordable, socially acceptable and environmentally effective. An integrated solid waste management system involves the use of a range of different treatment methods, and key to the functioning of such a system is the collection and sorting of the waste [9]. It is important to note that no single treatment method can manage all the waste materials in an environmentally effective way [4]. Thus all of the available treatment and disposal options must be evaluated equally and the best combination of the available options suited to the particular community chosen [22]. Effective management schemes therefore need to operate in the ways which best meet current social, economic, and environmental conditions of the municipality. Any disposal waste of landfill treated with the different treatment methods according to their recycling, landfill, thermal and biological treatment waste materials [23].

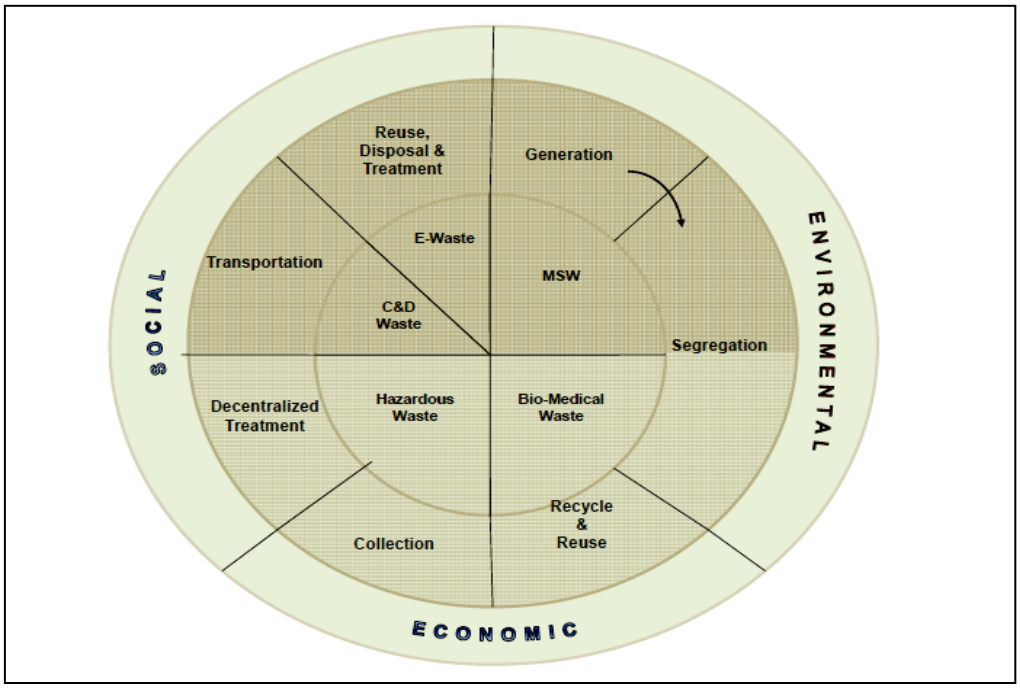

Figure 3.6: Integrated Solid Waste Management (ISWM) diagram

Alamgir [20] reported thermal treatment, biological treatment and also materials recycling were an Integrated Solid Waste Management practice to cover waste generation.

3.4 Composting in Khulna

Waste generated in Khulna city is suitable for composting as its physical composition analysis shows that the bulk (65-70%) is compostable. It has been found that informal sector extracts most of the readily recyclable materials which is about 6% of the total generated waste from Khulna's waste stream comprising of paper, plastic, polythene, glass, iron, bone, tin etc. However, still considerable amount remains in the bulk compostable portion of the waste, that may be further recycled through composting.

3.4.1 Preconditions for Composting in Khulna City

Major preconditions which are necessary for successful operation of composting are: suitability of waste, market for end product near the source, support from government authorities, particularly those responsible for agriculture, local government and environmental protection, affordable price of compost for the farmers and availability of labor.

3.4.2 Potentials of Composting in Khulna City

It is said earlier that factors favor composting as a resource recovery option for Khulna city. The factors which favor for composting are: waste generated in Khulna is suitable for composting as around 78% of it is compostable. Moisture content of 50 to 60 percent is optimum for aerobic composting. The typical moisture content of Khulna city is 55 percent, which is within the acceptable range for composting. Source separated organic waste, free from toxic and clinical wastes, which are essential for good quality compost, can easily be obtained in Khulna. House to house collection of waste and separate collection of clinical and hospital waste are being introduced in Khulna with community participation by NGOs/ CBOs and active support of KCC [24].

There is a good potential market for compost around Khulna city as majority of land use in greater Khulna and adjoining areas is agricultural. 21.2 percent of KCC area is under agricultural use while 59.4 percent of the area of Khulna Division is under agricultural use. There is also a big market for compost in Godkhali, Jessore with an annual demand of 5550 metric tons of compost [15]. At present the farmers are not getting compost in Godkhali.

Recently adopted environmental policy of the Government of Bangladesh favors to restrict the use of chemical fertilizer as far as possible and encourages use of organic manure. Moreover, recently adopted National Policy for Safe Water & Sanitation, 1998 of the Government of Bangladesh, has also recommended for recycling of organic waste and use of compost in agriculture.

The production cost of compost using manual aerobic method in the Waste Concern project at Dhaka is Tk. 1.65 per kg, excluding the land rent/cost. Due to the effectiveness of compost, farmers of the KCC area are interested to buy compost. Most of the farmers are willing to pay for the compost if the price is between Tk. 4 to Tk. 6 per kg that is the price less than market price of chemical fertilizer. A large number of unemployed labor forces are already available in Khulna city. Compost plants can be initiated in Khulna city in an organized way, involving this unemployed and neglected labor force. In Khulna city, 46 percent of the labor force will gainfully employed through establishment of necessary compost plants [15].

3.4.3 Composting Strategy for Khulna City

It has shown that in developing countries, large centralized and highly mechanized composting plants have often failed to reach their target and had to be abandoned due to high operational, transport and maintenance costs. In many cases, small-scale decentralized communal composting plants may be considered as a suitable option for treating municipal solid waste as they reduce transport costs, make use of low-cost technologies, based mainly on manual labor, and minimize problems and difficulties encountered with backyard composting.

Small scale manually operated decentralized compost plants can be used in Khulna city strategically in different wards rather than one single large mechanical plant. Such decentralized approach will have some benefits. These benefits are: Khulna being a medium sized city has many potential consumers of compost- farmers, shrimp farms and fish farms etc. who are mainly located outside the city boundary near its peripheries; low transportation cost both for carrying of wastes from collection centers to the compost plant and transportation of compost from plant to potential consumer and low production cost due to manual composting method. Because of smaller size, it is feasible to use manual method for process.

3.4.4 Possibilities of Using Composts in Agriculture in Khulna City

An enormous amount of commercial fertilizer has been spilled over to improve our agricultural production and now a day our agriculture is going to depend as an artificial fertilizer day by day. But it is a threat to our soil health, crop yield and natural habitat because use of commercial fertilizer and pesticides to land again and again causes many affect to soil nutrition's, soil water and plant resistant to pathogen. As a result, breakdown our natural habitat, increased our farmer cost and we losses our eco-sustainability. In this condition, the compost fertilizer may cause a great revolution in our agricultural activity and also can remove this unexpected risk of our environmental goal and national economy. In fact, wastes are common in our living society and to live in, waste must be generated by human and other natural sources. So the management practice can save energy and provide sustained to form of end product of these waste and also while brings a most and foremost Change in our nature. Composting and compost manure is one of the activities of them. This is a biological process and there no need a higher technology support. Although this report shown the solid

waste management of KCC by compost production but also our farmers can produce it easily by their agricultural waste, domestic waste and other villagers' sources. So in future, the compost manure of waste management can played an important role to our agriculture in Bangladesh.

3.5 Benefits of Compost

Some benefits of using compost as a soil conditioner is given below:

- This finished product offers numerous benefits to our garden soil.
- Compost will improve the quality of almost any soil, and for this reason it is most often considered a soil conditioner.
- Compost improves the structure and texture of the soil enabling it to better retain nutrients, moisture, and air for the betterment of plants.
- Incorporating compost into soil dramatically improves soil structure. Soil structure refers to how inorganic particles (sand, silt, clay) combine with decayed organic particles (compost, humus).
- A well-structured soil with lots of small aggregates stays loose and is easy to cultivate. Compost helps improve all soil types, especially sandy and heavy clay soils.
- Sandy soil compost helps to bind these particles together and increase the soil's ability to retain moisture and nutrients. Plant roots penetrate easily, finding moisture where there was none before.
- When compost is mixed with clay soils, it binds to the clay particles forming larger particles that now have larger air spaces between them. These spaces allow better surface water drainage and air penetration.
- Compost contains a variety of the basic nutrients that plants require for healthy growth. In addition to the main three: nitrogen, phosphorous, and potassium, of special importance are the micronutrients found in compost such as manganese, copper, iron, and zinc. Compost is basically a free nutrient boost for your plants.
- Compost is made up of different ingredients, some of which rot more rapidly than others. As a result, nutrients are released over a long period of time. Call it a slow-release fertilizer.
- Adding compost to your soil breaks down over time and provides Nitrogen to your garden and landscape plants. Sufficiently aged compost releases organic nitrogen after soils warm in the spring.

- Compost attracts earthworms and provides them with a healthy diet. The presence of earthworms, red worms, centipedes, sow bugs, and other soil critters shows that compost is a healthy living material.
- Research is showing us that soil treated with compost tends to produce plants with fewer pest problems. Compost helps to control diseases and insects that might otherwise overrun a more sterile soil lacking natural checks against their spread.
- Soil P^H also benefits with the addition of compost. This is a measure of soil acidity or alkalinity. Finished compost has a neutral P^H.

3.6 Side-effects of Waste Disposal and Composting

Manufacturing process of compost is directly carried out manually. So, the manufacturing process by human causes some disease to the field workers and surroundings people and the application of Compost to soil also can be effective at controlling some soil-borne diseases, particularly root-rot diseases. Another disadvantage is described as follows:

- Sharp material cause injury and infection.
- Frequent headache, diarrhea.
- Skin diseases to workers and allergenic norms.
- Apparently pickers are found to be suffering from malnutrition.
- No hand gloves and masks are used, which exposes them directly to the polluted environment.
- Some problems encountered in a composting operation may include odors, temperature abnormalities, and fly or mosquito problems.
- Lack of adequate and trained man-power for composting.
- Dustbins are not adequate and properly located.
- People involved in collection and disposal of solid waste don't follow hygienic practices.
- Negligence of duties responsible for road sweeping.
- Absence of effective accountability of the activities.
- Inadequate contextual legal support to address the solid waste
- Lack of regular supervision of activities.
- Delay in obtaining decisions.
- Irregular payment of service charges by the households.

- Lack of facilities for wearing gloves, masks, etc by persons involved in waste collection and transportation.
- Involvement of children in collection of waste.
- Lack of financial resources.

CHAPTER IV

Existing Municipal Solid Waste Management in Khulna City

4.1 General

Khulna City Corporation (KCC) is responsible for overall management of municipal solid waste (MSW) in the city corporation areas. Generally, it consists of two functional departments: conservancy and engineering. Conservancy department is responsible for waste management including other utility services. This section supervises the waste intensive workers for collection and transfer, while the engineering section doing operation and maintenance of vehicles, checking community bins, secondary disposal site and ultimate disposal sites (UDS). But waste management method and technologies are not developed and public awareness yet not grown perfectly about this. So, there are some major problems about waste management that creates troubles to the inhabitants. Some NGOs like Prism Bangladesh, Prodipon, Rastic, Sabolombi, Commitment, Goti, Samag Progoti Sangsta (SPS), Muktir Alo, Prosanti, Protisroti etc. are also working on MSWM in Khulna City. Basic information of six city corporations of Bangladesh including Khulna city are given in Table 4.1.

Table 4.1: Basic information of six city corporations of Bangladesh

City corporation	City area (sq. km)	Population (million)	Number of Wards	Wastes generation rate (kg/cap/day)	Total generation (tons/day)	Ultimate disposal site
Dhaka	360	11.00	90	0.40–0.55	5000–5500	2
Chittagong	156	3.65	45	0.30–0.45	1200–1400	2
Khulna	47	1.50	31	0.30–0.50	490–520	1
Rajshahi	48	0.45	30	0.25–0.35	160–210	1
Barisal	45	0.40	30	0.20–0.25	100–140	1
Sylhet	26.5	0.50	27	0.35–0.45	200–240	1

4.2 KCC Initiatives for Solid Waste Management

In connection with solid waste collection, Article 75 of the Khulna City Corporation Ordinate 1984 states that -

"Removal, collection and disposal of refuse:

1. The Corporation shall make adequate arrangements for the removal of refuge from all public streets, public latrines, urinals, drains and all public buildings and land vested in the Corporation and for the collection and proper disposal of such refuge.
2. The occupiers of all other buildings and lands within the Corporation shall be responsible for the removal of refuge from buildings and latrines subject to their general; control and supervision of the Corporation.
3. The Corporation may cause public dustbins or other suitable receptacles to be provided at suitable places and where such dustbins receptacles are provided, the Corporation may by notice, require that all refuge accumulating in any premises or land shall be deposited by the owners or occupiers of such premises or land in such dustbins or receptacles.
4. All refuse removed and collected by the staff of the Corporation or under their supervision and all refuse deposited in the dustbins and other receptacles provided by the Corporation shall be the property of the Corporation"

KCC, the only public sector organization responsible for collection, transportation and disposal of solid waste in Khulna City, is not providing satisfactorily level of conservancy services [21]. It collects 40 to 50 percent of the total waste and the rest is used for land reclamation. Very insignificant portion is also collected by the scavengers. This results in odor and obnoxious conditions in Khulna City according to Sabikunnahar [25]. Table 4.2 shows, KCC have 462 conservancy and 40 supervisory staff for the solid waste management. The solid waste management support facilities of KCC are presented in the table.

Table 4.2: Facilities of manpower, infrastructure and transport in KCC

Manpower	Supervisory	40
	Sweepers etc	104
	Drain cleaners	358
	Drivers	37
	Spray men	31
	Fogger Operators	5
	Truck Helpers/Labors	79/54
Physical Infrastructure	Secondary collection Points	60
	Dustbins	1200
	Metal waste containers	45
Transport and Vehicles	Covered Trucks	5
	Normal Trucks	10
	Container Carries Truck	11
	Rickshaw Vans	200
	Tractors	4
	Damp Truck	8
	Paur-tetar	2
	Vacutac	4
	Night soil carrier	6

Source: Conservancy Department, Khulna City Corporation, December 2014

KCC cleaners sweep the roads and clean the drains. They accumulate the waste at the road and drain sides. Once the streets sweeping and drain cleaning have been done, the cleaners collect the wastes in cane baskets and load them into trucks to dump them at the disposal places or dustbins. The city dwellers also dump their household wastes at the nearby KCC dustbins. KCC trucks collect these wastes for final disposal at Rajbandh landfill area located at a distance of 9 kilometers away from the city centre. The solid waste is dumped at this location without any pollution control measures or treatment options. The leachate from open waste dumps produced in rainy season has extremely high pollution potential and causes surface water pollution around the dumping sites. This causes serious pollution to the surrounding environment, ground water, and soil and is very hazardous to. With 50 garbage trucks, 462 cleaners, and an annual budget of Taka 175.00 lakes, according to vehicles support facilities of KCC. KCC is not well equipped to cater satisfactorily the need of conservancy services of the city dwellers of Khulna. Over the years, KCC has increased its staff size and equipment, but these are insufficient in terms of quality and quantity according to the need [26]. However, it is true that even having these constraints the overall situation of management of solid waste in Khulna City could be improved through introducing a good management system.

4.3 Source and Types of Municipal Solid Waste

KCC of Khulna division, like most of the developing cities, is facing serious environmental problems due to huge amount of MSW generation and its mismanagement. The study reveals that generation rate is very close in each major city. Overall, the per capita generation varies from house to house depending on the economic status, food habit, age and gender of household members and seasons [27].

Table 4.3: Sources and Types of Municipal Solid Wastes of KCC

Sources	**Typical waste generators**	**Types of solid waste**
Domestics	Single houses and apartments	Food scraps, paper, corrugated boxes, plastics, clothing, glass, metals, ashes, and domestic hazardous wastes
Shopping and commercial areas	Shopping centers, hotels, restaurants, markets, offices	Paper, corrugated boxes, plastics, wood, food scraps, glass, metals, special wastes, hazardous wastes
Institutional	Schools, Government offices, Medical-care center, Prisons	As mentioned above in shopping and commercial areas
Public facilities	Street cleaning, landscaping, parks, beaches, recreational areas	Street cleanings, landscape and yard trimmings, general wastes from recreational areas

Table 4.3 reveals, the major sources of solid wastes in Khulna cities are residences, whole and retail sale market places including shopping places, streets, hotels and restaurants, hospitals and private clinics, educational Institutions, cinemas, bus, railway and launch/steamer Ghats, slaughters etc. At the same time, figure 4.1 shows the distribution of different wastes in percentage generated from KCC.

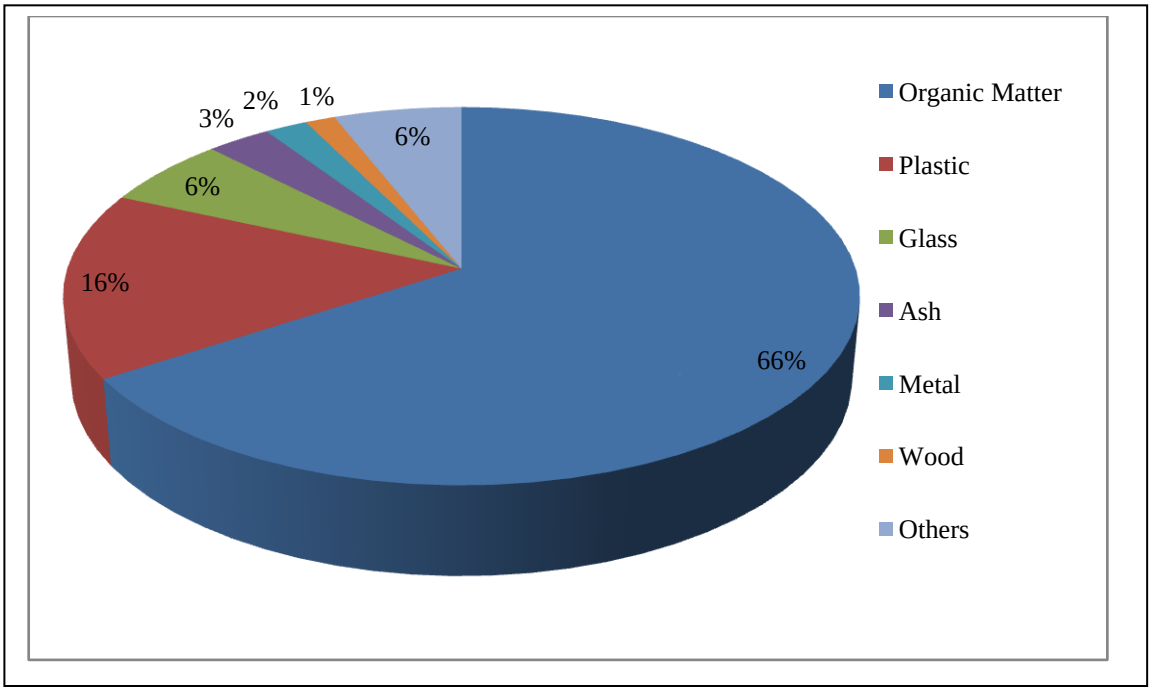

Figure 4.1: Distribution of different wastes in percentage generated from KCC

4.4 Current Situation of Wastes Generated from KCC

Khulna City Corporation consists of 31 wards and the wastes of 24 wards out of 31 were collected by Conservancy Department Activity of City Corporation. Seven wards (No 1 to 7) are situated in the remote area and manage their wastes locally. Sometime the wastes of above seven wards cause few regional effect for constructive factors. Only 40-50% wastes are collected by KCC and 60-50% wastes are not collected and managed (Conservancy Department of KCC). At present the major sources of solid wastes in Khulna cities are residences, whole and retail sale market places Including shopping places, streets, hotels and restaurants, hospitals and private clinics, educational Institutions, cinemas, bus, railway and steamer Ghats, slaughter houses, etc. In general, there is a dearth of information regarding sources, volume, composition, characteristics, etc. concerning the solid waste in Khulna City [3]. This table indicates the some major sources and characteristics of solid waste in Khulna city. It has been observed that 70% to 80% of the generated waste is organic in nature and these are easily bio-degradable. And the rest 30% to 20% of the total waste generated are inorganic and non-biodegradable.

Table 4.4: Source and Characteristics of Solid Waste in Khulna City

Source/Type	Unit	Quantity Produced
Domestic	Kg/day/household	1.0-5.0
Retail sale market	Kg/day	50-200
Slaughter house	Tones/day	2-3.5
Hotels and restaurants	Kg/day	50-150

Source: Environmental Risk Management Action Plan for Khulna City, 2010

Table 4.4 represents the Source and Characteristics of Solid Waste in Khulna City. Further, it has been estimated that at present Khulna city generates 490 to 510 metric tons of solid wastes per day with a per capita of about 0.3 to 0.5 Kg/day [28]. The composition of solid waste varies according to location, level of income and standard of living of the people, energy sources and season. The quantity of waste generation increases during the rainy season, when many people eat vegetables and fruits such as mangoes and jackfruits. Figure shows the rationality of involvement of NGOs and CBOs and partners involved in solid water management system in Khulna City.

Conservancy Department of KCC is responsible for the collection, transportation and disposal of solid waste in Khulna city. Apart from this, a number of government and semi-government organizations are giving emphasis to manage solid wastes that is being generated in their own premises and compounds [29]. Figure 4.2 reveals current distribution of KCC Wastes.

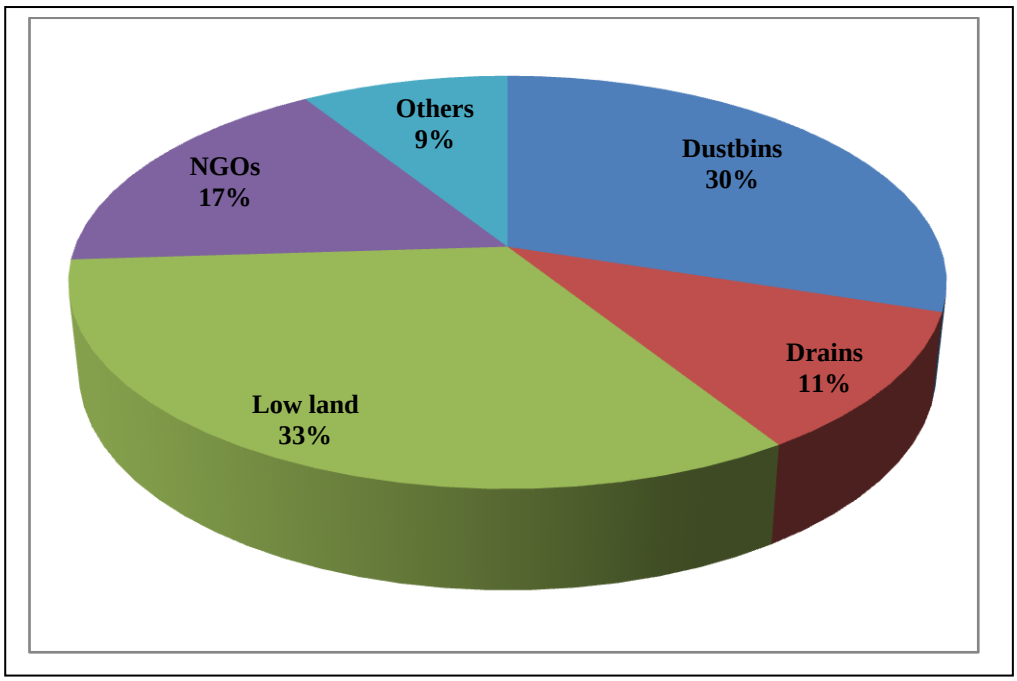

Figure 4.2: Current Distribution of KCC Wastes

Some of these organizations are: Navy Campus, Khulna Newsprint Mills, Khulna Power Plants, Khulna Hardboard Mills, Bangladesh Institute of Technology, Khulna Shipyard Ltd. etc. In recent years, a number of NGOs and CBOs have come forward to managing solid waste such as collecting, transporting, and disposing in Khulna city [26]. According to the results of a household level survey, it shows that 30 percent of the city dwellers of Khulna dispose their solid wastes in the dustbins of KCC, 11 percent in the drains, 33 percent in the nearby low land, 17 percent are taken away by NGOs and the rest 9 percent by other means (Conservancy department of Khulna, September 2014).

4.5 Role of NGOs and CBOs in solid waste management in Khulna City

- Door to door collection.
- Increasing the awareness of the urbanites on municipal waste utilization by publicity, campaign, arranging rally etc.
- Ensuring peoples participation in municipal waste management.
- Developing appropriate model on community based municipal waste management.
- Developing the paying tendency of households for proper municipal waste management.
- Helping Conservancy Department of KCC.

4.6 Solid waste collection system

The KCC is considered as the most important organization involved in waste collection. The collection services in urban centers concentrate only in the removal of wastes from communal bins. Wastes removal services involve manual collection from the bins and manual loading of the collection vehicles. Typical waste collection vehicle being loaded from communal storage bins. The equipment used for waste collection typically includes brooms, shovels, baskets, and trolleys. The system of waste collection is closely related to the stationary container system of collection. The timing and frequency of waste collection, however, is not well defined. The frequency of collection generally varies from more than once per day to once every two weeks depending on the type of urban centers served.

4.6.1 Collection order of wastes

In Bangladesh, the city authorities generally manage MSW. However, recently, some NG0s, CBOs and private organization work with city authorities. But the situation remains

unchanged. The strengths and drawbacks at all levels of the existing wastes management system are identified by Waste-safe [17]. Sabikunnahar [25] Source storage and separation are done in an informal and uncontrolled means; hardly 30-40% of city dwellers practiced it. NGOs, CBOs and city Authorities collect wastes from generation sources by door to door collection. Door to door collection systems are introduced recently for wastes collection from generation sources; mainly from households and dispose the major portion of it to the nearest secondary disposal sites (SDS) and table 4.5 shows the involvement and area coverage by different NGOs to collect municipal solid waste.

Table 4.5: Involvement and area coverage by different NGOs

Name of NGO/CBO	**Area Coverage(Ward)**	**Type of Involvement**
Prodipan	Ward number 6.12.17,18 and 24	House to house waste collection, transportation of waste from the households to the secondary points, construction of secondary collection point s, removal waste to the final disposal site, motivational work at the community level, formation of SWMC's at the community levels.
	119 Health Care Center	Collect all kind of hospital waste
Prasanti	Ward no. 30	House to house waste collection, disposal at the secondary points.
Amadar Paribartan	Ward no. 24(part)	Do
ASODE	Ward no. 25 and 26(part)	Do
Shabolambi	Ward no. 11	Do
Muktir Alo	Ward no. 23	Do
Niharika	Ward no. 30(part)	Do
RUSTIC	Ward no. 18(part)	Do
Centre of Human Development	Ward no. 15 and l6(part)	Do
Unnayan	Ward no. 25(part)	Do

Despite very positive impact of primary collection of wastes from source by door to door system, the coverage of this system is very slim. City authorities collect these wastes from SDS and transfer it to the ultimate disposal site (UDS). The efficiency of the city authority is very disappointing. There is no special department to handle the situation of MSW. Conservancy section, in general is conducting this job along with its other responsibilities such as street sweeping, drain cleaning, street lighting etc. As a result, required attention and efficient management could not be obtained from the responsible department of city authority

of Nagarbhaban. The management practice of KCC wastes by the NGOs, CBOs and other private organization work with city authorities and their activity covered area are given in the table before.

4.6.2 Primary and Secondary Collection

The primary collection means, the wastes generated in the home is stored and collected everyday by a primary collector who transports the waste to the nearby transfer point, normally in a rickshaw van, and transport points are placed where waste is unloaded from primary collection vehicles to be taken away by secondary transport. KCC has a collection area of 47 sq. km. with total number of conservancy staff about 462 and 1200 dustbins. There are minimum 10 to 20 dustbins in each ward. Some of the dustbins are open at the top and some are covered. On realizing the present situation, it handed over some responsibilities of taking wastes from house to house collection of some wards to the several NGOs. KCC allowed them to carry out primary waste collection and to receive payment for these services as the City Corporation fails to provide a sufficient number of roadside bins or does not position them in convenient locations or fails to ensure that they are of an appropriate design. Functional departments of the City Corporation (conservancy, engineering etc.) provided technical and logistical supports. In June 1998 these agreements between KCC and NGOs were formalized by the signing of a Memorandum of Understanding.

Figure 4.3: Photographic view of primary waste collection site

Figure 4.3 shows the photographic view of primary waste collection site and Figure 4.4 shows the photographic view of secondary waste disposal site. The secondary collection means, after primary collection, the primary collection blocks are served by transport points and taken to the final disposal point by a large truck. This is known as secondary collection and is the responsibility of the City Corporation. KCC estimates about 510 ton of wastes are generated daily in the city area and only 300 to 320 ton are collected by it workers and the remaining are dumped irregularly. KCC has 60 secondary disposal sites and some disposal sites are placed with demountable container, from where workers collect wastes with recommended KCC vehicles to the final disposal site in a regulated timetable. It has regular 22 to 25 trips to the final disposal site daily. Rajbandh is the main dumping station of the KCC. It is at the western side of Khulna City and of about 25 acres. The waste truck of the KCC is reported to dump their wastes in many illegal places. This is due to lack of skilled manpower and knowledge and also the lack of sufficient places.

Figure 4.4: Photographic view of secondary waste disposal site

4.6.3 Collection from Secondary disposal Site and Collection Frequency

The functional element of collection includes not only the gathering of wastes and recycle able materials but also the transportation of these materials, after collection to the location where the collection vehicle is emptied. Only City Corporation authorities collect waste from secondary point and transport it by trucks and finally dump it in ultimate disposal site (UDS) at Rajbandh. KCC vehicles collect transfer and dump every day wastes regularly. But due to lack of proper maintenance, wastes are seen sonic places in unmanaged condition. KCC

vehicles cannot collect from narrow road regularly. In KCC areas solid wastes are also thrown in roadside low and marshy land. So these wastes cannot be collected and thus environment pollution takes place in different ways.

Figure 4.5: Photographic view of collecting waste from secondary disposal site

Figure 4.5 shows the Photographic view of collecting waste from secondary disposal site. Collections of MSW from Secondary Disposal Site (SDS) to be transported through vehicles are manually practiced in Khulna city except demountable container shipment. So every vehicle has some labors who conduct the shipment of the waste from secondary site to KCC vehicle. Demountable containers are only hauled by tipping truck. So no workers are required for tipping truck.

City authorities provide total 250 vehicles for collection of Municipal Waste to SDS and shifting to UDS. It is found that each day 320 tons of wastes are collected and transported for open dumping by City authorities. Besides, generated clinical/hospital waste is only 700 kg/day which is collected by NGO called Prodipan. So, total collected waste is 490 - 510 tons per day.

4.7 Existing waste disposal system

In case of localities where NGOs/CBOs are involved in waste management, it is found that in 64% cases wastes are collected from individual households. In 24% cases wastes are disposed of in the KCC provided dustbins. However, where this service is absent, 60% of the

generated wastes are dumped in the KCC provided bins. Roadside dumping and dumping in open fields constitute 12% and 20% respectively.

Crude dumping is the only option practiced so far by the KCC for the final disposal of generated waste in city. Though Rajbandh, a 25-acre site is the only officially designated dumping site, wastes are often seen dumped off in many of the low land of the city.

4.8 Resource recovery from inorganic Waste

Papers, beverage cans and bottles, shopping bags, liquid containers and jars, food containers and packets etc. are most common types of recyclable waste that are normally generated in our everyday life. In Khulna city about 20 percent of the total wastes are recyclable. At present it is estimated that informal sector is responsible for recycling 5% of the total 490 to 510 tons/day of waste generated in Khulna. Informal sector deals only with the inorganic waste and it is responsible for removing around 25 ton of waste per day in Khulna city [1].

4.9 Existing recycling process in KCC

The KCC does not perform any kind of resource recovery activities. Wastes of some market value are being reclaimed or salvaged informally in three stages. In first stage, the housewives separate the refuse of higher market value such as papers, bottles, fresh containers, old cloths, and shoes and sell them to street hawkers (locally called feriwallas). The second stage of salvaging is carried out by wastes pickers (mostly the children of slum dwellers). They collect the refuse and domestic waste of low market value from bins and sweeping accumulation centers. The items include broken glass, can, card board, waste paper, rag, plastics, metals and miscellaneous wastes discarded by households. The third stage of salvaging is done by the refuse pickers when fresh refuse is unloaded by municipal collection vehicles at the final disposal sites which are shown in figure 4.6. The reclaimed material goes to the waste and old material shops through the street hawkers who purchase the old material directly from the homesteads and through refuse collectors who reclaim materials from bins and final disposal sites. The refuse dealers separate the materials in proper form and sell them to consumers as well as supply them to appropriate processing or remolding mills and factories. The processed material recycled through market finally goes to users again.

Figure 4.6: Photographic view of resource recovering by scavengers

The cycle goes on as long as the waste has no economic or market value. Although recycling of waste is not included in the national environmental policy of Bangladesh, yet it has become a main source of income for several groups of the informal sector. The estimated number of scavenger of Khulna city is nearly 600, who are annually earning BDT 4,500,000 by removing solid waste [15].

CHAPTER V

Bio-Fertilizer Extraction from Municipal Solid Waste

5.1 Methodology

Research Design: This research is mainly descriptive in nature. This type of research has helped me to know about the present status of municipal solid waste management system and its prospects in social, economic life as well as in environmental development.

Sources and Collection of Data: Both primary and secondary data is used to prepare this research. The primary data is collected from various sources such as interview, talking with experts and people directly or indirectly related to waste management. Secondary information such as statistical data, reports, MSWM (Municipal Solid Waste Management), transportation related data etc. is collected from various Government offices and Non-Government Organizations (NGOs), CBOs such as:

- Khulna Development Authority (KDA).
- Khulna City Corporation (KCC).
- Demographic information from Bangladesh Bureau of Statistics (BBS).
- Journals and papers relevant to the study from NGOs, seminar library of Environmental Science Discipline of Khulna University and various web sites.
- Waste-Safe bio-fertilizer production project in Khulna University of Engineering and Technology

Information is also collected from informal talking with the personalities who are directly or indirectly related with this matter. At the same time, to find out efficient way to extract bio-fertilizer from municipal solid waste, the collection of MSW, process and marketing cost of bio-fertilizer is analyzed. As a sample, Rajbandh Landfill and Waste-Safe bio-fertilizer production project are taken. Necessary data is collected from them to analyze the best way to produce bio-fertilizer from municipal solid waste.

5.2 Bio-Fertilizer Extraction from MSW in Rajbandh

Khulna is the third largest city in Bangladesh and densely populated with mostly multi-storied residential and commercial buildings. There are several low-income housing areas and slums located throughout the city. So their diversity living and population community are the main source of waste form in Khulna city. Khulna City Corporation (KCC) is responsible for the operation and maintenance of municipal services, including solid waste management (Anisur Rahman, Conservancy Officer of KCC). KCC trucks collect these wastes and through these for final disposal at Rajbandh landfill area which is located at a distance of 9 kilometers from the city centre. Dumping points of KCC are: Rajbandh-1, Rajbandh-2, Shalua, Mathavanga. But Rajbandh-1 is the only current dumping field by KCC and its total area is 25 acres. A few meetings are arranged with the conservancy department of the city corporation office to collect the data and information on MSW management. The ultimate disposal site of MSW at Rajbandha, Khulna was visited several times which is one of my study areas. The burning unit (small incinerator) and concrete chamber for needle and sharp wastes at Rajbandha, Khulna are visited to observe the present scenario of treatment. In Rajbandha, there is no constructive boundary to protect the environmental pollution. Crude open dumping sites are always incompatible with the surroundings. Wastes spreads all over the site are unsightly as no proper system is maintained for filling the area. Wind blows litter and indiscriminate the dumping waste outside the site and on the surrounding surface water. In Rajbandha, RUSTIC (NGO) is responsible for bio-fertilizer extraction from municipal solid waste but do not have enough manpower to handle such a huge amount of waste.

5.2.1 Survey

A survey was conducted in Rajbandh Landfill located in Botiaghata Thana in Khulna city. Questionnaires were prepared and interview of the persons related with the administration and management of the wastes was taken. Around 20 questions were asked to Md. Anisur Rahman (Conservancy Officer of KCC), Md. Abdur Sattar (Conservancy Officer RTD of KCC), Anowar (Supervisor of Conservancy Transport Support Authority), Md. Liton (Driver), Md. Amjad Hossain (Driver), Md. Abul Basahar (Driver), Moral Noor Mohammad (Executive Director, RUSTIC), Md. Sohel (Store and Delivery manager), Hozrat Ali (Senior Compost field maker), Md. Rashed (Senior Compost field maker), Nasima and Asma (Compost field worker), Sagor and Raja (Farmer), Nurul Islam (Field Supervisor in Rajbandh), Ilias (Field Co-supervisor in Rajbandh) and they answered gently. The above

dumping site was selected because maximum wastes of KCC are dumped there and the compost production plant is located there which is shown in figure 5.2.

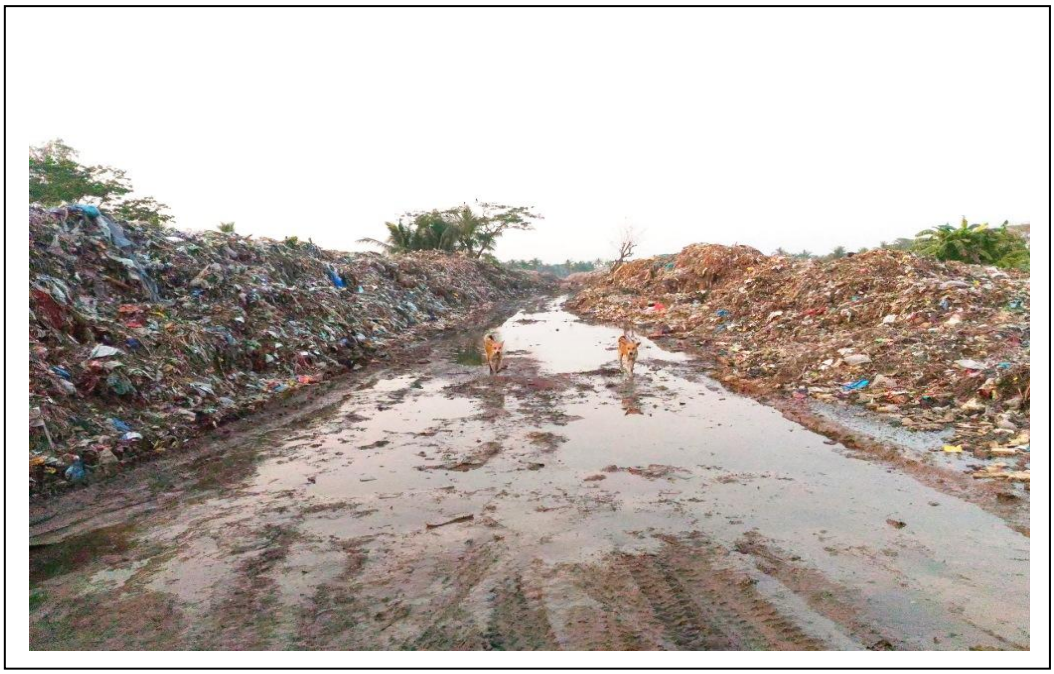

Figure 5.1: Photographic view of municipal solid waste piled up at Rajbandh-1

The questions were as follows:

1. How much wastes are produced daily in KCC?
2. What is the composition of wastes?
3. How wastes are transported?
4. How many vehicles are used for wastes transportation?
5. Which categories of vehicles are used for transportation?
6. How many labors are engaged for transportation and what is their salary?
7. What percentage of biodegradable wastes among total wastes?
8. How wastes are disposed?
9. What percentage of wastes is used for compost productions?
10. What are the processes of composting?
11. What machinery and chemicals used for composting?
12. What additional materials are used for composting?
13. What time is required for completion of composting?
14. How can we confirm the completion of composting?
15. What are the benefits of using compost especially in agriculture?
16. What are the problems of using compost in agriculture?

17. How much compost is produced per day?
18. What is the cost of per kg compost production?
19. What is the selling price of per kg compost?
20. What is the labor cost per day?

5.2.2 Amount of Wastes Produced Per Day in KCC

Heaps of waste remains uncollected in many parts of the city. KCC trucks only pick up waste from the roadside bins while waste is frequently disposed in open drains, free land and around the waste bin sites. It is 490 to 510 tons of waste generated daily. Uncollected waste blocks drains, causes water logging and spills over on to roads, often resulting in increased traffic congestion. These problems are acute during the rainy season especially in poor neighborhoods which are frequently located in relatively low lying areas and have narrow alleys through which municipal trucks cannot pass.

The major sources of solid wastes in Khulna city are from residences and retail sale market places including shopping places, streets, hotels, restaurants, hospitals, private clinics, educational Institutions, cinema halls, bus, railway station, launch/steamer Ghats, slaughter houses etc. [9]. In general, there are some issues regarding sources, volume, composition, characteristics, etc. concerning the solid waste in Khulna City. So, the compositions of the waste also are different. Most of the wastes found in Khulna city are: paper, plastic, kitchen wastes, cow-dung, vegetable waste, ash, glass, metal, straw and others and the waste composition vary season to season and place to place.

Various classes of waste are collected from different sources of city area. But usable and degradable waste is two third that is 335 tons per day [30]. It includes kitchen waste, straw, cow dung, paper, fruits waste and other garbage waste.

5.2.3 Transportation and Separation of Wastes

The quantity of waste which generates in City Corporation area, are not fully controlled or collected by the Conservancy Department because of lack of vehicles, maintenance, manpower and uncontrolled population diversity living. So, the uncollected and system loss waste although considerable at the respect of multidimensional issues but at the same time, the transported waste per day is about 320 tons by their own control activities of KCC according to Conservancy Department of KCC.

According to MSW vehicles support facilities of KCC, there are 50 engine vehicles and 200 rickshaw vans used for waste collection per day in City Corporation. 50 engine vehicles are manly covered trucks, normal trucks, container carrier trucks, DAMP trucks, metal waste container, Night soil carrier, Power tractors. These are used for secondary collection point and rickshaw vans are used for primary collection sources areas. Figure 5.2 represents the photographic view of transportation of municipal solid wastes by KCC.

Figure 5.2: Photographic view of transportation of municipal solid wastes by KCC

The transport of wastes of KCC to the Rajbandh landfill by the City Corporation trucks as a final disposal site. The total waste of Rajbandh is not useable or compostable [30]. Some of this is non degradable, so these wastes are selected by the field workers and separated manually.

Source separation is the second step to composting. The separation process is mostly done manually and by the labors on the field. These are divided into the following parts:

- Higher market value materials
- Recycling materials
- Plastic materials
- Organic materials
- Non-decomposing part
- Others

Higher market value materials are selected and sell it to street hawkers. The raw materials for composting must be separated, collected and shredded by mechanical means before the biological decomposition process. In some cases, the decomposition process itself is aided by mechanical agitation or aeration of the materials. After decomposition, the finished compost is mechanically screened and bagged for distribution and selling.

5.2.4 Composting of MSW

The primary collection and final deposition of the waste to landfill are separated for the purpose of different ecological goal and differ to socio economic importance. For example, composting is a biological process to form manure and try to control our dailies waste.

Composting is the process of decomposing organic matter, whether manure, crop residue or municipal wastes, by a mixed microbial population in a warm, moist aerobic environment. On the other hand, Composting is certainly one of the most natural types of recycling processes there are. It happens in the open air (in a ditch or a heap) or an enclosure (silo, etc) and consists simply of organic waste transforming in the presence of oxygen in the air. Over a total of six months (generally spring and summer), it happens in two stages: Decomposition during which any still-intact organic material is attacked by high temperature bacteria (50-70°C). Maturation during which the fresh compost transforms little by little into compost rich humus thanks to the action of low-temperature yeast (35-45°C).

Compost is a decomposed organic material. Compost is made with material such as leaves, shredded twigs and kitchen scraps from plants. On the other hand, Compost is a finely divided, loose material consisting of decomposed organic matter. It is primarily used as a plant nutrient and soil conditioner to stimulate crop growth. Although many people associate compost production with small garden compost piles that are tended with a shovel, most compost is produced in large municipal, industrial, or agricultural facilities using mechanized equipment.

Materials and chemicals required for composting are

- Bamboo
- Leader
- Boding a windrow
- Thermometer

- Turning the pile
- Mineral addition

The following things are avoided for composting

- Meat and meat byproducts
- Oil
- Dairy products
- Diseased plants
- Invasive plants gone to seed
- Yard waste treated with pesticides and conventional fertilizers.

Every source of compost is separated according their physical/chemical/biological impotency with ecological and socio-economical value.

5.2.5 Steps of Making Compost

Making good compost depends on having the proper sources of nutrients with a balance of carbon and nitrogen, keeping the pile of compost moist and making sure that there is adequate aeration. Different levels of processing are required for achieving the decomposition. It is simply the method of breaking down organic materials into a simple particle size. The decomposition occurs because of the action of naturally occurring micro-organisms such as bacteria and fungi. Small invertebrates, such as earthworms and millipedes help to complete the process. Composting can convert organic waste into rich, dark colored compost or humus, in a matter of a few weeks or months. Natural composting or decomposition occurs all the time in the natural world. So there is nothing mysterious or complicated about composting. At the simplest level, the process of composting simply requires making a heap of wetted organic matter known as green waste (leaves, food waste) and regular mixing of the material will facilitate aerobic conditions and ensure that all feedstock material is exposed to high temperatures. Then the materials will break down into humus after a period of weeks or months. This decomposition process is aided by shredding the degradable solid waste, plant matter, adding water and ensuring proper aeration by regularly turning the mixture. Worms and fungi further break up the materials. Aerobic bacteria and fungi manage the chemical process by converting the inputs into heat, carbon dioxide and ammonium.

Under controlled conditions, however, the process can be speeded up. The compost pile can heat up to 60-70°C due to the microbial activity. However, high temperatures will result in substantial losses of nitrogen in the form of ammonia gas. Farmers with many years experience at compost-making recommend that temperatures are kept below 55°C to avoid overheating and nutrient losses. The most commonly used materials for the compost pile are manure mixed with livestock bedding. When the bedding (which is predominantly carbon) is mixed with the raw manure (which is an excellent source of nitrogen), the balance of carbon to nitrogen (25-35:1) will be achieved which is needed to begin the composting process. Figure 5.3 shows the steps of making compost.

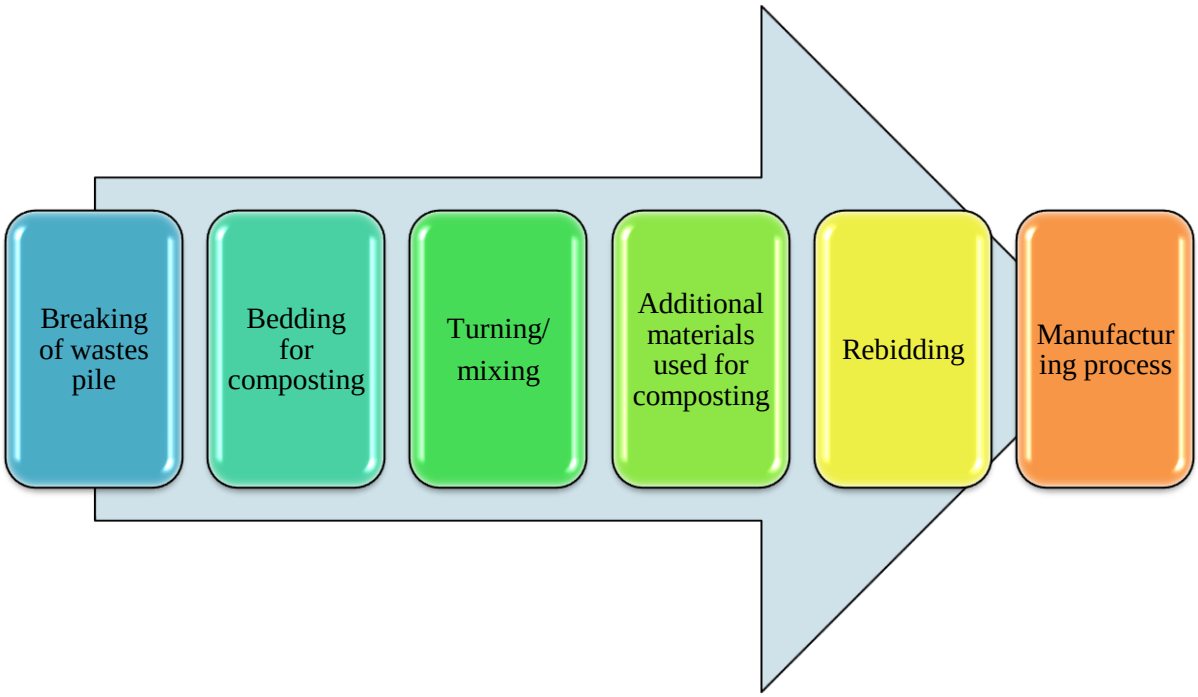

Figure 5.3: Steps of making compost

Breaking of wastes pile: Separated raw materials which are used for composting are not always found in exact size, sometimes there need to treat with hammering, breaking, rotating, pre-composting and other extra physical forces into smaller pieces and thoroughly mixed.

Bedding for composting: The frame shape which made of bamboo local named Forma, played an important role to aerobic digestion. Then the degradable waste materials are ready to decompose with bedding process. It is a pilling or re-deposits process where the mixing wastes are placed on forma step by step for controlling decomposition. During composting of first bedding, at the initial stage the temperature rises at 50°C to 55°C within 12 to 15 days.

Turning/mixing: After deposition or first bedding to control the temperature, there are few raw materials which are more sensible to temperature, moisture, aeration and other physical behaviors, further composting of them, needs to laddering, spread-out and turning or mixing under sun and favorable environmental conditions.

Additional materials used for composting: Ideally, new materials should be added to the composting system during turning or mixing. Generally, the addition of moist materials accelerates the composting process while the addition of dry materials slows the process. Other additional factors influence the process are Cow dung, Water, Ash, Sun light etc. For favorable composting, the physical, chemical, biological and degradable changes occurred under the extra component are used to influence the composting activity like watering, soil, cow-dung, fire-ashes, light sources etc. These remixing of middle waste are kept fallow for few days. In this period, one third of composting is completed.

Rebidding: After the first bedding, turning, mixing spreader-out or extra auditioning and other physiological treatment of fallow waste is rebidded. Rebidded is the final stage to complete the decomposition. In this time the temperature regain at 50°C to 55°C and this treatment are runs under 15 to 20 days.

Manufacturing process: After the last bedded treatment and within 15 to 17 days to complete all microbial activity, the temperature is come down from 15 to 18°C. Then the pile is breakdown and this raw compost is spreader-up to everywhere around the bed and it rests for 1 to 3 days for normal temperature. Then the raw compost is sieved by shaking net with diesel machine sometimes it is done manually. The skilled field workers (4 to 5 persons) are needed to complete this finish product packing. Everyday 1000-1500 kg compost is produced and stored them for marketing.

5.2.6 Finished Compost product

RUSTIC regularly have their finished compost tested to ensure that it is free of harmful materials and contains the proper amounts of plant nutrients. The tests measure the size of the particles, moisture level, mineral content, carbon-to-nitrogen ratio, acidity, nutrient content, free of harmful materials, weed seed germination rate, contains the proper amounts of plant nutrients and many other factors which is shown in the table 5.1.

Table 5.1: Composition of finished compost [30]

Parameter	**Result**
	Present Composition
Color	Grey
Physical conditions	Non-granular
Odor	Absence of foul odor
Moisture	17.0%
pH	7.0
Organic Carbon	10.65%
Total Nitrogen(N)	0.95%
C:N	11.2:1
Phosphorus (P)	0.70%
Potassium (K)	1.25%
Sulfur (S)	0.29%
Zinc(Zn)	0.04%
Copper (Cu)	0.016%
Chromium (Cr)	18.28ppm
Cadmium(Cd)	0.18ppm
Lead (Pb)	22.57 ppm
Nickel(Ni)	24.44 ppm
Inert material	<1%

Sign of the completion of composting: After the readily decomposable material is depleted, the compost pile will no longer heat upon remixing. The temperature will continue to drop to ambient. Only very slow decomposition will continue. Sumon [6] found, the material should have a pleasant "woodsy" odor and a friable texture similar to a good potting soil. The material will likely feel moist and cool and have a dark brown color. Several tests can be used to determine completion of the compost, including incubation to test for generation of metabolism by-products and respire-meter testing to measure oxygen use. Often it is recommended that compost "cure" for several months to allow for continued slow decomposition of more resistant constituents.

Time required for completion of composting: The time required to produce compost depends on several factors, including the size of the compost pile, the types of materials, the surface area of the materials, and the number of turning of piles. For most efficient composting, heat up sufficiently the pile to break down materials. Smaller piles can be made but will take longer time to produce finished compost. Larger piles can be made by increasing the length of the pile but limiting the height to 5 feet and width to 5 feet. If the pile has more brown organic materials, it may take long time to prepare compost. It can be avoided by adding more green materials or a fertilizer with nitrogen. By breaking materials down into

smaller parts (chipping, shredding, mulching leaves), the surface area of the materials will increase. This helps the bacteria to more quickly break down materials into compost.

Finally, increasing turning the pile influences the speed of composting. By turning more frequently (about every 2-4 weeks), compost production is rapid. Waiting at least two weeks allows the center of the pile to heat up and promotes maximum bacterial activity. In winter, the activity of the bacteria slows and it is recommended that you stop turning the pile after November to keep heat from escaping the piles center. In summer, warm temperature encourages bacterial activity and the composting process is quicker.

Action shooting in decomposition: Composting is a natural process and in the case of controlled aerobic decomposition of organic matter by the action of micro organisms and small invertebrates and other physical/chemical/biological and microbial activity played an important role in composting. Physical parameters are organic matter, moisture, oxygen, particle size and temperature. Chemical parameters are C/N ratio and P^H value. The composting process is carried out by three classes of microbes:

- Psychrophiles - low temperature microbes
- Mesophiles -medium temperature microbes
- Thermophiles - high temperature microbes

Generally, composting begins at mesophilic temperature and progresses into the thermophilic range. In later stages other organisms including Actinomycetes, Centipedes, Millipedes, Fungi, Sow bugs, Spiders and Earthworms assist in the process. With the proper mixture of water, oxygen, carbon, and nitrogen, micro-organisms are allowed to break down organic matter to produce compost. There are many types of microorganisms found in active compost of which the most common are Bacteria, Fungi, Protozoa, Earthworms, and Rotifers etc.

5.2.7 Cost and Profit Analysis of RUSTIC in Rajbandh

Calculation of finished compost per day: According to KCC, daily waste generation in Khulna city is 490-510 tons. RUSTIC says that after an initial screening they collect 3.75 to 4.00 tons of waste and from that they collect 2.50 tons of compostable waste. Finally they produce 1.5 tons of bio-fertilizer and figure 5.4 shows the generation of wastes to compost production.

Column 1 = Daily waste production

Column 2 = Daily waste transfer to final disposal site

Column 3 = Daily used compostable waste

Column 4 = Daily finished product

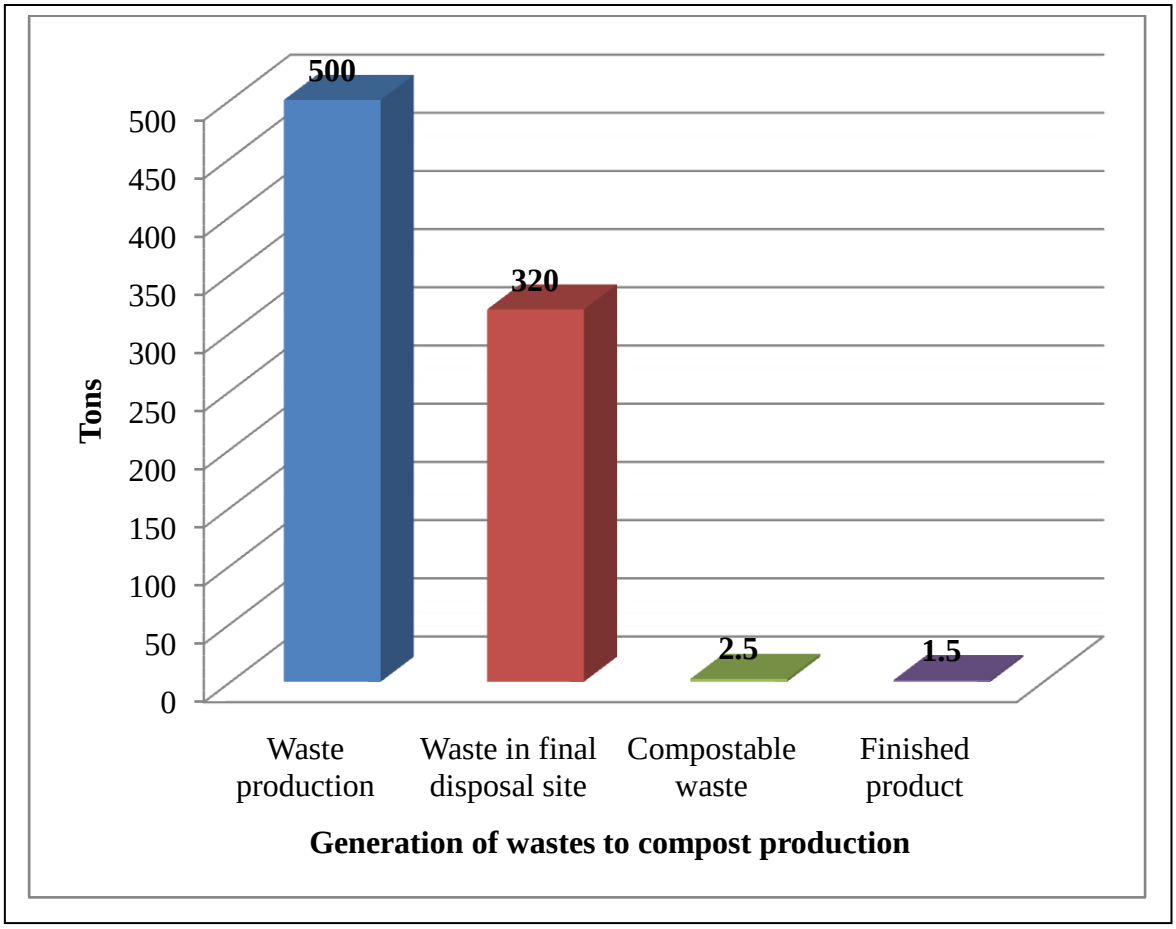

Figure 5.4: Generation of wastes to compost production

Calculation of extra material cost in composting: The materials required for composting are cow dung, saw dust, water, fire ash etc. Cow dung is the most useable part which is collected from different domestic sources and its cost is 2.00Tk per kg. Every bed needs 40 kg everyday 10 beds are placed so; 400 kg cow-dung is used. Its total cost is 800.00 Tk. Useable sawdust and shred wood per bed 10 kg and for 10 bed needs 100 kg which cost is 166.70Tk, Others cost (tools) for every day 310.00Tk. Detail information about daily extra material cost for composting is shown in figure 5.5.

Column 1 = Daily cost of cow dung

Column 2 = Daily cost of sawdust and shreds wood

Column 3 = Daily oil cost

Column 4 = Daily others cost

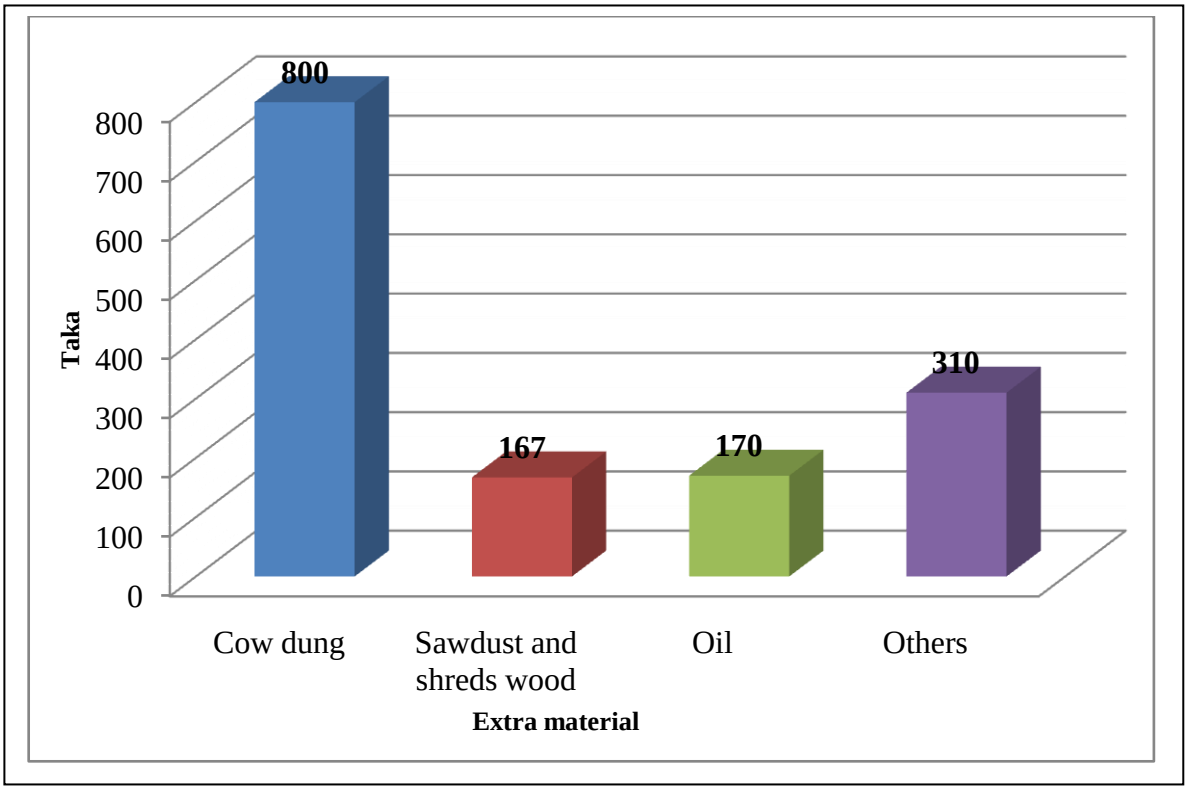

Figure 5.5: Daily extra material cost for composting

Employee salary (per day and monthly): All management activities of composting are carried out manually by RUSTIC where waste collectors are generally women and child. Manufacturing workers are men and all the field activities are supervised under a coordinator. The total expenditure for workers and employees by RUSTIC is shown in the table 5.2.

Table 5.2: Expenditure for workers and employees

Employees	Man power (per day)	Per day bill (Tk)
Female workers	10	2000
Male workers	5	1250
Coordinator	1	666.67
Total	16	3916.67

Net Income (per day):

Municipal Solid Waste = 3750 kg

Compostable solid waste = 2500 kg

Finished product per day = 1500 kg

Selling price per kg = 11Tk

Material Cost per day = 800Tk + 166.70Tk + 170Tk + 310Tk = 1446.70Tk

Labors cost per day = 3916.67Tk

Total cost per day = Material 1446.70Tk + Labors 3916.67Tk = 6640.07Tk

Cost per kg for finished product = $\frac{Total\ cost\ per\ day}{\text{Finished product per day}} = \frac{6640.07\ Tk}{1500\ kg}$ = 4.42Tk

Net income per bag = Market value of finished product per kg - Cost per kg

= 11Tk – 4.42k = 6.58Tk

Net profit per day = Net profit per kg * finished product per day

= 4.58Tk * 1500 kg = **9,870Tk**

From the results of RUSTIC, it is clear that the compost production by Solid waste management in Khulna city is profitable. These profit may depend on local position, construction, equipments, manpower, transportation, manufacturing, social activities, market value and also other different sources. Including all the essential argument and issues, but it is reported that, the KCC waste are beneficial for the local people and society under the management of composting process. So regarding this point from the result and statistics, the future goal to our society may be provided that if all the KCC wastes are properly managed then the maximum benefit of our KCC waste is obtainable. Now in current situation 1.50 tons of finished products can be produced from 2.50 tons/day of degradable wastes.

Now, present profit is 9,870.00Tk per day. But if it is possible to use half of the total waste that is 250 tons then usable and degradable waste is two third which approximately 168 tons

and the finished products will be approximately 100 tons/day. In that case, per day income could be 6, 58,000.00Tk.

Finally if it is possible to use of all waste from Rajbandh landfill which is 500 tons then the compostable waste will be two third that is approximately 334 tons and the finished products will be approximately 200 tons/day. In this case, per day income could be 13,16,000.00 Tk. The figure 5.6 is showing the current profit and expected profit from municipal solid waste per day.

Column 1 = Current profit per day

Column 2 = Expected profit per day by using half of the total waste

Column 3 = Expected profit per day by using total waste

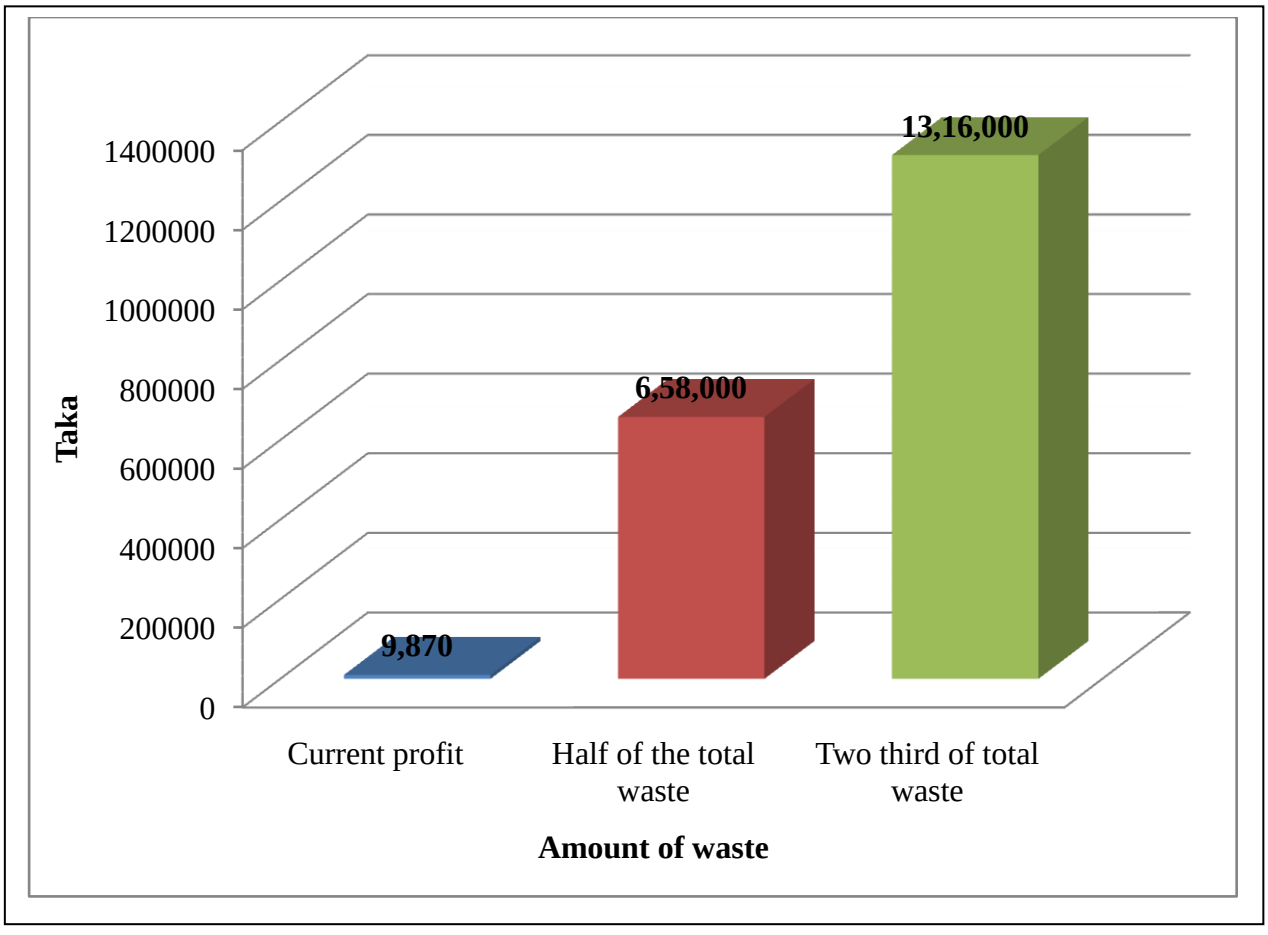

Figure 5.6: Current profit and expected profit

5.3 Bio-Fertilizer Extraction in KUET

This study work was done at Khulna University of Engineering & Technology (KUET) campus, which is one of the leading public universities of Bangladesh giving special emphasis in the Engineering and Technological Education and research. KUET is situated in Khulna district, the third largest city in the southern area of Bangladesh. It is in the northwest part of Khulna city. The campus is about 15 kilometers from the zero point of Khulna City. Khulna is humid during summer and pleasant in winter. Khulna has an annual average temperature of 26.3 °C (79.3 °F) and monthly means varying between 12.4 °C (54.3 °F) in January and 34.3 °C (93.7 °F) in May. The KUET campus covers 101 acres , in the midst of an impressive natural beauty having around 3222 students, 16 Academic Department under 3 Faculty and having total number of population is around 4185 nos. including all stuff. With the increasing rate of students, academic officers the solid waste generation rate is increasing day by day. To control the increasing waste generation rate, after investigating all the possible sites a Solid Waste Management Plant (SWMP) was built. The location of SWMP is beside the employee building number 19 in KUET. A 10 feet boundary wall is to the north of the location, waste treatment plant is to the west, a residential building is to the south and a blank space is to the east. The location of the study area is presented in figure 5.7.

Figure 5.7: Solid Waste Management Plant in KUET

5.3.1 Sources of Solid Waste in KUET

Recent few years the waste management system at this campus is dramatically upgrading and till now the authority trying to level up the SWM system to reaches at meridian level to becoming an aesthetically healthy and environment friendly campus. Generally wastes are generated at KUET campus from human activities and the major components of solid waste are food waste, paper, plastic and some special wastes (sanitary wastes). Due to the dramatic development of infrastructure of KUET, some construction wastes are also generated. To proper management of solid wastes, several facilities such as: waste storage, transportation, treatment and disposal systems are adopted by KUET authorities.

From previous study at KUET campus the solid waste generation rate is 0.074 kg/capita/day and compostable and non compostable waste are 66.67% and 33.33% respectively [20]. Proper solid waste management plan provides a complete way and sets a path to achieve new waste minimization, diversion and disposal targets. The solid waste management plant at KUET mainly consists of six sections

1. Receiving and sorting section
2. Recycling section
3. Composting section
4. Burning unit
5. Inert waste dumping site
6. Aerators and soak well

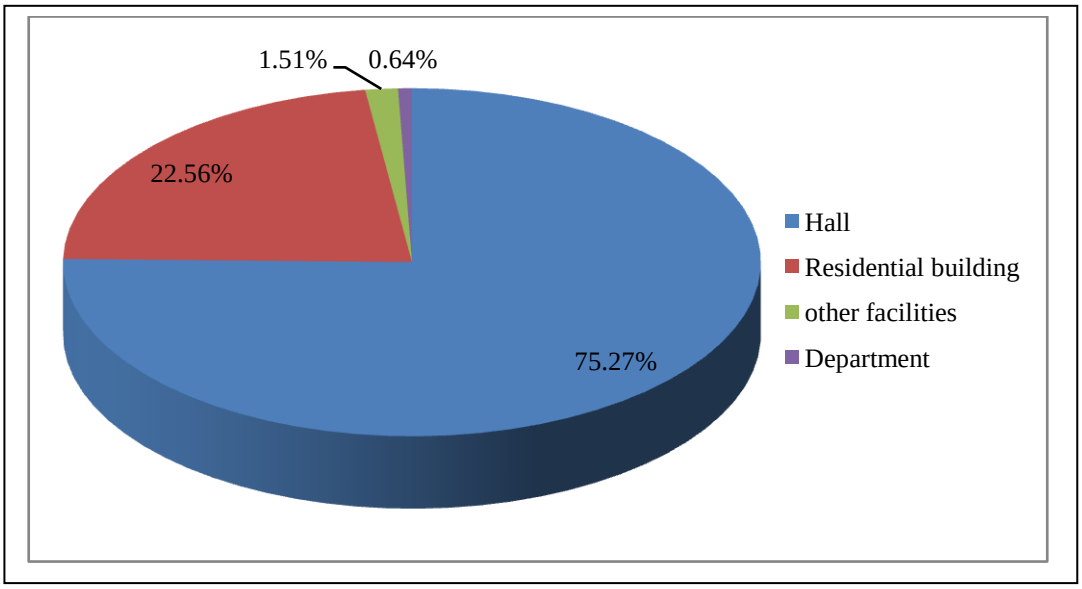

Figure 5.8: Percentage compostable waste sources

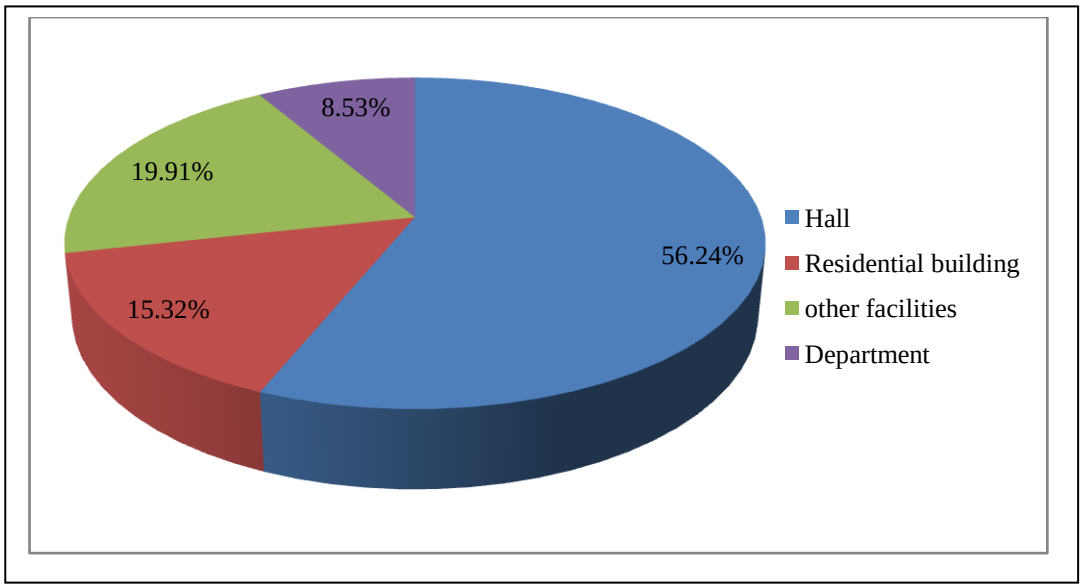

Figure 5.9: Percentage non-compostable waste sources

Special types of dustbins have been integrated with biodegradable hygienic bags for the collection of special wastes (gauge, bandage, sanitary napkin, baby's diaper, condom etc.) provided at some specified points i.e. source such as female students' dormitory, residential buildings and medical center. These special bags were transported every day to the SWMP and directly put into the burning unit. SWMP consists of waste receiving, sorting, composting, recycling and burning unit sections. Wastes are sorted into different categories at SWMP [31]. Figure 5.8 shows the percentage compostable waste sources and figure 5.9 shows percentage non-compostable waste sources.

5.3.2 Process of Composting in KUET

The biodegradable and non-biodegradable waste has been collected separately from student halls and residential area. The wastes come from academic premises and common places are mainly inorganic and have been collected from specified location. These wastes have been transported to the SWMP for ultimate treatment. In purpose of composting process there are 6 nos. of composting pile at SWMP which are made from bamboo and wood. Among them a pile is large and trapezoidal in shape (Figure 5.10) and others are small and triangular in shape. Piles are designed in such a way that the oxygen can enter freely into the wastes through piles.

Oxygen is provided to the composting materials via aeration by soak well. The aerator of SWMP is made of bamboo. After sorting, only biodegradable waste containing 50 to 60% initial moisture has been imposed on trapezoidal pile.

Figure 5.10: Process of composting in KUET

After 20 to 25 days the waste has been shifted to the triangular piles and temperature has been measured. It has been observed that the temperature has been rises at 60 to 65°C up to 45 to 50 days and then temperature began to decrease. After another 10 day temperature reaches at stable condition (about 30 to 35°C) and wastes has been converted into finished compost having dark grey color [31]. Figure 5.11 shows the flow chart of composting.

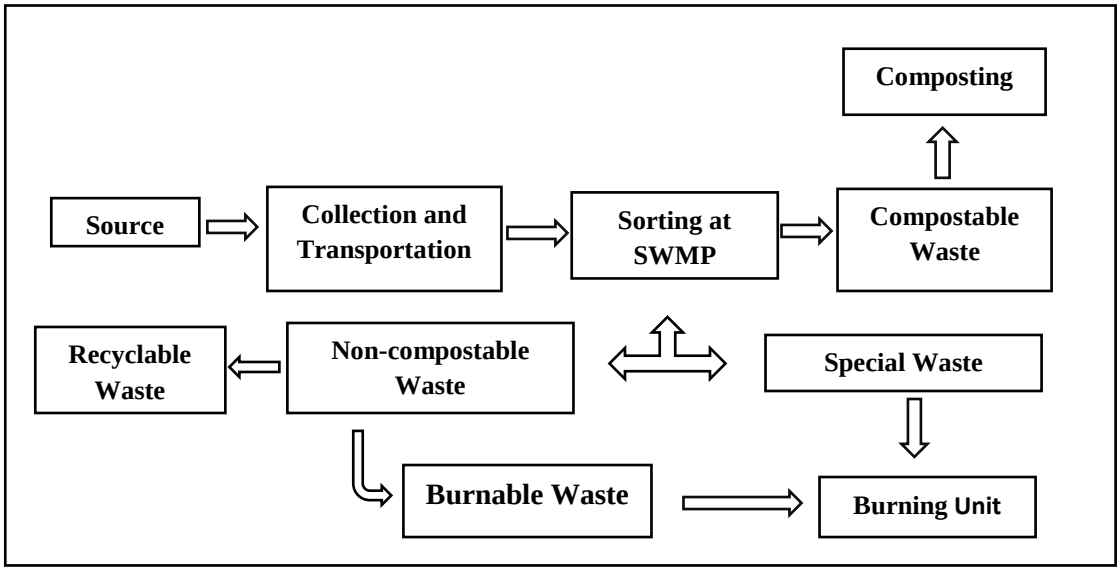

Figure 5.11: Flow chart of composting

5.3.3 Data Collection and Analysis

Both primary and secondary data have been used in conducting the study. Primary data collection includes the field observation and collection of sample as well as exhaustive interviews of respondents groups like corresponding employees and garbage collectors. Solid waste collection was performed from a number of waste generation sources such as halls, residential areas, departments and open areas. Data of compostable and non-compostable waste has been recorded. Secondary data is collected from few previous research conducted on SWMP in KUET.

Composition of waste: Figure 5.12 shows the composition of solid wastes at KUET campus where compostable part of wastes have been found suitable for composting and the amount of compostable waste has been observed as 65.09% of total solid wastes and the amount of no compostable waste has been observed as 29.74% and 5.16% of the total waste has been observed as special waste. It has been observed that about two third of total waste are compostable and compostable waste mainly food waste that are collected from halls and residential areas. So, huge amount of compostable waste are generated everyday which create the opportunity to make compost.

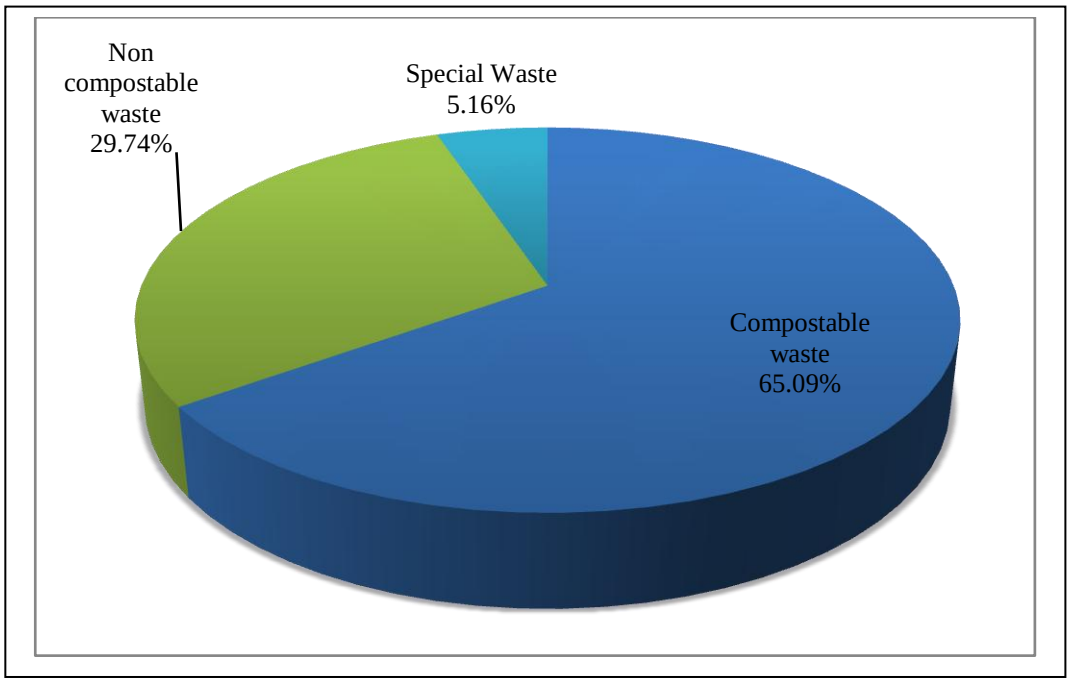

Figure 5.12: Composition of Solid waste

Waste generation rate: The waste generation rate is increasing day by day and Figure 5.13 describes the solid waste generation rate at different month and average solid waste

generation rate has been found as 0.0474 kg/capita/day. The maximum waste generated on august, 2015 and the waste generation rate has been found as 0.0508 kg/capita/day.

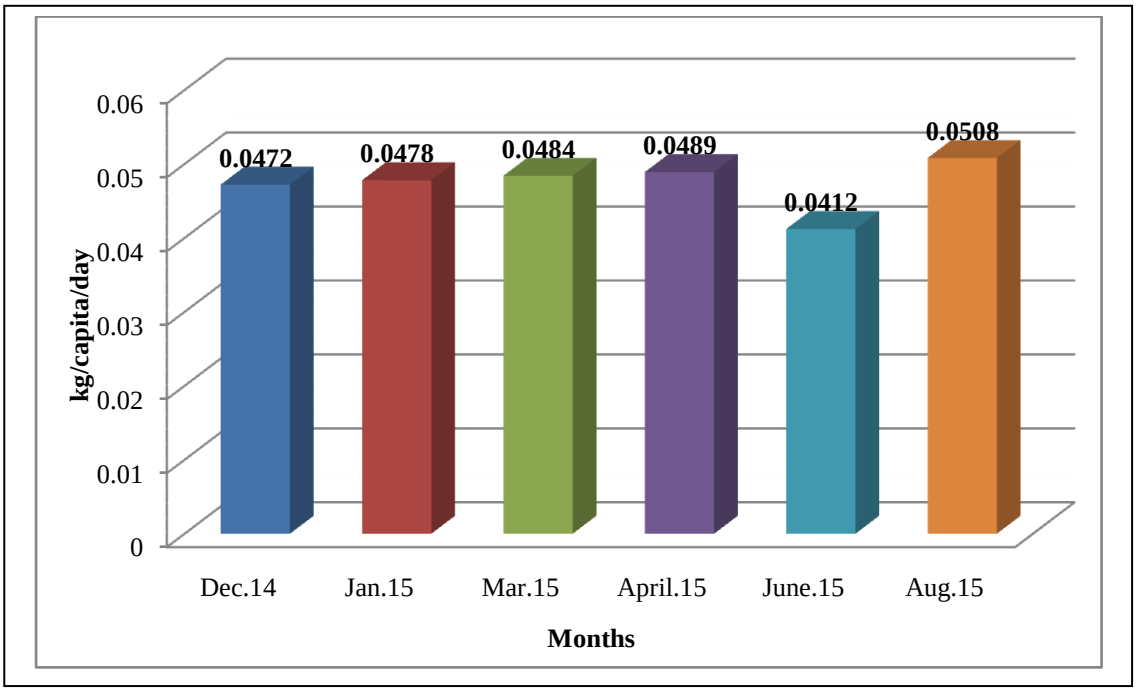

Figure 5.13: Solid Waste Generation Rate

It is noticed that SW generation is increased slowly at every month. However waste generation rate is not constant and varies with different parameters such as season, weather and number of habitants. In KUET campus waste generation varies with number of habitants, vacation and so others. On vacation period, the waste generation rate is decreased because waste only produces from the residential area on that period.

Monthly compostable waste: After collection the waste, it is sorted at SWMP and the compostable wastes are separated for composting. Figure 5.14 presents the amount of compostable wastes at different months and average compostable waste has been found as 3898 kg/month. The maximum amount of compostable waste has been found as 5106 kg on April 2015. It is represented that the amount of compostable waste are increased day by day at every month. The sources of compostable waste are halls, residential areas and cafeteria. Mainly food waste and shell of fruits are used to make compost.

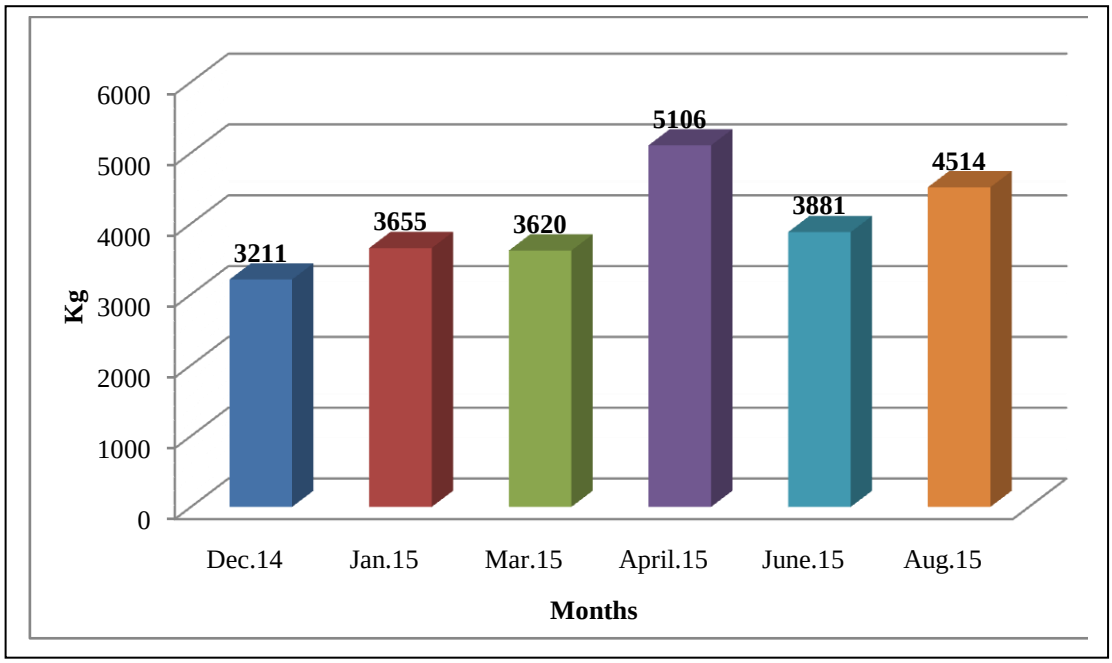

Figure 5.14: Monthly compostable waste

Monthly compost production: The duration of preparation of final compost have no ranges. About 110 days need to complete the process. Then the compost is useable product. Figure 5.15 describes the generation of compost at different months and the average compost generation has been obtained as 48.57 kg/month. The compost is stored at a corner of SWMP. The compostable product is efficient for agricultural and horticultural purposes. This compost mainly use in tree plantation in the campus as a good source of humus. The compost is also sold in local market as 12Tk/kg. So it is also a source of income.

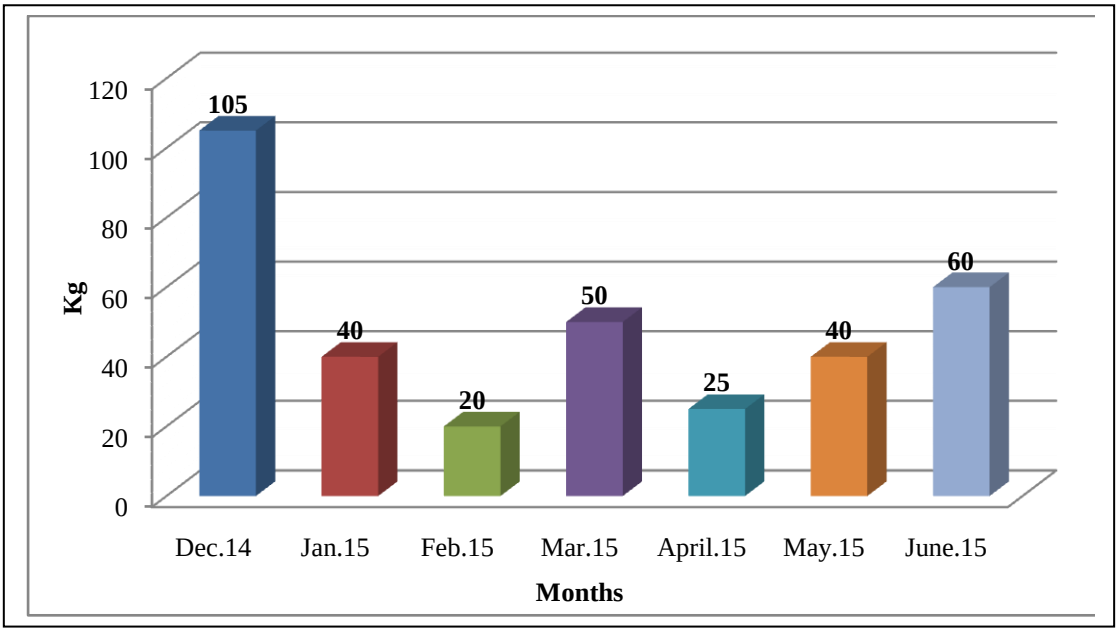

Figure 5.15: Amount of Compost production (Kg)

Table 5.3 shows six months compostable waste generation and compost production. The average compostable waste generation per month is 4006 kg and the average compost production is 50 kg per month.

Table 5.3: Compost production from compostable waste

Month	Compostable waste (Kg/month)	Compost (Kg/month)
December, 2014	3211	105
January, 2015	3655	40
March, 2015	3620	50
April, 2015	5160	25
June, 2015	3881	60
August, 2015	4514	20
Total	**24041**	**300**
Average	**4006**	**50**

Laboratory results of composting parameters: To know the quality of compost some test such as moisture content, P^H, Phosphorus, Potassium, C/N ratio and etc. have been determined from laboratory. The results of laboratory tests are shown in Table 5.4.

Table 5.4: Experimental results of the samples

Parameter	Sample-1	Sample-2
Color	Dark grey	Dark grey
Physical conditions	Non-granular	Non-granular
Odor	Absence of foul odor	Absence of foul odor
Moisture Content (%)	22.60%	21.94%
P^H	8.32	8.54
Carbon (C) (%)	12.01%	13.18%
Nitrogen (N)(%)	0.43%	0.45%
C/N ratio	28:1	29:1
Phosphorus (P)	1.54%	1.65%
Potassium (K)	0.62%	0.59%
Sulfur (S)	0.50%	0.53%
Zinc(Zn)	0.05%	0.05%
Copper (Cu)	0.022%	0.021%
Inert material	<1%	<1%

Composition of burnable waste: Mainly dry paper, plastics, bags and clothes are burnt at burning unit. Figure 5.16 shows the composition of burnable waste where the percentage of paper has been found as 54% and the percentage of plastics has been found as 29% and the others like bags, ropes, cloths has been found as 7%.

From figure it has been observed that there have few amount of dust in the burnable waste. It is hard to remove the dust from the waste. So it affects the temperature of burning unit. Also there has been seen little amount of waste content in the waste and it also affects the process of burning.

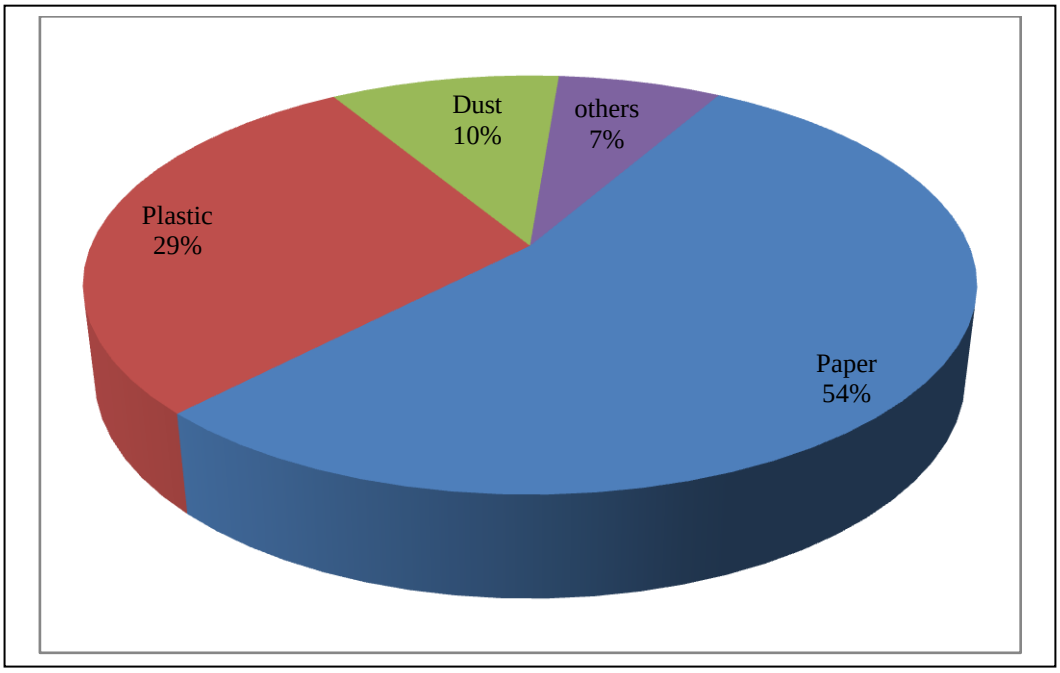

Figure 5.16: Composition of Burnable Waste

Burning unit and procedure: Burning unit is an important sector of SWMP at KUET. The total height of the burning unit is 30ft including 25ft chimney. The lower surface dimension of the chimney is 5ft and the reinforcement place above 15 inches from the floor. The capacity of burning waste is about 730 ft^3 in each time. There is a rectangular hole in the back of the structure to collect the ash after the burning of waste. Also there are some small rectangular holes in both side walls to remove the ash. Normal bricks are used to construct the burning unit. The burnable wastes are burnt every day at noon in the burning unit.

The paper, plastics and other burnable waste are placed into burning unit and the workers are used kerosene as fuel for easy burning. There have no safety measure of the workers. There is no guideline or system to protect air pollution by the burning unit. Even it is not constructed

following the standard manual. Moreover, some hazardous wastes including sanitary napkins and infectious wastes are still not collected for the treatment process. The temperature has been recorded by Infrared Thermometer. The average temperature at burning unit when waste burn, has been found as 383^0C. The maximum temperature has been found as 563^0C at five minutes after the starting of burning of waste [31].

5.3.4 Cost Analysis

Employee salary (per day and monthly): All management activities of composting are carried out manually where waste separators are generally women. Manufacturing workers are men and all the field activities are supervised under a coordinator. The total involved man power cost is shown in table 5.5.

Table 5.5: Expenditure for workers and employers

Employees	Man power (per day)	Monthly salary (Tk)
Female workers	1	11250
Male workers	4	45000
Coordinator	1	11250
Supervisor	1	28000
Total	7	**95500**

Income and Cost (per month):

Finished product per month = 50 kg

Market value of finished product per kg = 12Tk

Total income per month by selling product = (50*12)Tk

= 600Tk

Table 5.6 shows the income sources from Solid Waste Management Plant from selling compost, plastic waste, metal waste, paper bag and carton. Then table 5.6 shows the total cost of SWMP including Employee salary, Waste transport to Rajbandh by KCC vehicle, Soap, Mask, Van repairing, Phenyl, Detergent.

Table 5.6: Income sources from SWMP

Sources of income	**Taka (per month)**
Finished product	600
Plastic waste	420
Metal waste	280
Paper bag and carton	90
Total	**1390**

Table 5.7: Total cost of SWMP

Sources of cost	**Taka (per month)**
Employee salary	95500
Waste transport to Rajbandh by KCC vehicle	9000(1500*6)
Soap	150
Mask	60
Detergent	50
Phenyl	100
Van repairing	500
Total	**105360**

5.4 Comparative Analysis of Chemical Compositions of Compost

From table 5.8, it is definite that the quality of finished product from two different sites is not the same. It depends on the composition of the solid waste, the procedure to generate compost, available supporting equipments and few other factors. Firstly, solid waste composition is different in both sites. In KCC there are huge amounts of household waste and vegetable waste which come from nearby vegetable market. But this is not the case for KUET, grass and green leaf are added for producing good quality compost. The analysis shows higher C:N ratio than expected and the reason behind it is low nitrogen content in

finished product. To increase the amount Nitrogen, some other nutrient could be added like Urea which will increase the quality of compost.

Table 5.8: Comparison of Chemical Compositions of Compost

Parameters	**Govt. suggested parameters**	**Result**	
		Rajbandh	**KUET**
Color	Dark grey to black	Grey	Dark grey
Physical conditions	Non-granular form	Non-granular	Non-granular
Odor	Absence of foul odor	Absence of foul odor	Absence of foul odor
Moisture	10-20%	17.0%	21.94%
pH	6.0-8.5	7.0	8.54
Organic Carbon	10-25%	10.65%	13.18%
Total Nitrogen(N)	0.5-4.0%	0.95%	0.45%
C:N	<20:1	11.2:1	29:1
Phosphorus (P)	0.5-3.0%	0.70%	1.65%
Potassium (K)	0.5-3.0%	1.25%	0.59%
Sulfur (S)	0.1-0.5%	0.29%	0.53%
Zinc(Zn)	<0.1%	0.04%	0.05%
Copper (Cu)	<0.05%	0.016%	0.021%
Chromium (Cr)	<50 ppm	18.28 ppm	-
Cadmium(Cd)	<5 ppm	0.18 ppm	-
Lead (Pb)	<30 ppm	22.57 ppm	-
Nickel(Ni)	<30 ppm	24.44 ppm	-
Inert material	<1%	<1%	<1%

Secondly, for producing compost, in Rajbandh it takes 70 to 90 days for a batch of compost but in KUET it takes 90 to 110 days. Last of all, the whole environment makes a huge difference. In Rajbandh, it is relatively open place, less managed process and also have some leachate problem. But in KUET, the whole process is well managed inside a building and nicely controlled as well. Because of those reasons, the finished product is little different as well as their color and chemical composition.

5.5 Several Waste Management Projects

PRISM Bangladesh Foundation used to manage Municipal Solid Waste from the year of 2000 with the funding of World Bank. After running their operation for five years when World Bank withdrawn their funding in 2005 then PRISM Bangladesh Foundation stopped their operation in Khulna. Now they are running Medical waste Management Program in Dhaka city only. There is no valid and useable data available about their Municipal solid waste management program.

On the other hand, Prodipan (NGO) used to run Municipal Solid Waste Management program at the same time as PRISM Bangladesh Foundation by the funding of World Bank. After 2005, they are only working on Medical waste Management in Khulna and Barisal city. In Khulna, they collect medical waste from 119 health care centers and process it in Rajbandh.

CHAPTER VI

Discussion and Conclusions

6.1 Discussion

The Main goal of the project is to find out the recent potential of municipal solid waste in KCC area and disclose the existing Municipal solid waste management practice. Firstly, existing waste generation is a burden for its dumping due to lack of dumping sites of Khulna city. But Khulna City Corporation's waste is increasing with the increasing of population. Thus it is crucial issue for Khulna City Corporation (KCC) authority and this is the time for making strategic plan on how growing burden of municipal waste is to manage significantly with innovating technologies. Decentralizing ultimate dumping site could be a better option for transportation of waste and composting. In this situation, Municipal Solid Waste has a great significance to produce ecologically sustainable organic bio-fertilizer from the biodegradable waste by using the composting. More than 500 tons of wastes are generated per day in KCC and most of the wastes are dumped as traditional landfill. In addition, most of the residents of KCC throw their waste outside of the dustbin, on the road into the drainage system. It is a huge deal to collect all of the waste from Khulna city and transport it to ultimate dumping site. At the same time, producing compost from all the waste could take lots of manpower, management, strategic depth and initial fund. Public awareness and responsibility could play a big role in this project.

Solid Waste management plant in KUET is an example for any waste management project. The whole process and organizing data is crystal clear and employees are very helpful. But the costing of this project may seem little high comparing other project because of low waste production. Khulna University of Engineering and Technology is a small place to produce huge quantity of waste. The analysis shows higher C:N ratio than expected and the reason behind it is low nitrogen content in finished product. To increase the amount Nitrogen, some other nutrient could be added like Urea which will increase the quality of compost. However this project is essential part of KUET to ensure its public health and beatification. As the bio-fertilizer plant from waste do not produce high profit and very often these plants produces

very low profit or sometimes no profit. So, to make profitable sectors of making bio-fertilizer from waste, government should give subsidy in these sectors considering the social benefit as well as environmental benefit so that these plants can be run smoothly.

During preparation of this research paper, communication with different officials of KCC and officials of different NGOs was needed and at that time the following problems were noticed:

Waste collection problem: All the roads of KCC are not equally wide. So, KCC vehicles cannot collect from narrow road regularly. In KCC areas waste are also thrown in roadside low land and marshy land. So, these wastes are not collected regularly and thus these pollute environment in different ways.

Transportation problem: According to KCC there are 250 vehicles for waste collection. NGOs also complain for insufficient vehicles. Due to improper scheduling and poor operation of vehicles in addition to an inadequate number of vehicles, the transport of the required quantity of waste is never achieved.

Lack of financial support: In 1997-98 KCC budget allocated for conservancy service 27,00,000.00 Tk. and conservancy department got 1,78,23,225.00 Tk. However, the present demand for conservancy department is 25,30,00,000.00 Tk. to provide management system at satisfactory level (Source: Department of Conservancy, KCC 2014).

Lack of public awareness towards MSWM: In Khulna city most of the people are not conscious about MSWM. They are not aware about the benefit of waste management.

Lack of worker and infrastructure: Number of workers for this purpose is 502 in KCC, where 40 are stuffs and 462 labors. For waste management system, required worker is 620. That means extra 120 manpower is needed to run the system properly (Source: Department of Conservancy, KCC 2014).

Insufficient tax collection: Generally, conservancy cost depends on the tax collection by KCC for holding tax. However, the collection of holding and other related tax is very poor. In fact, 4% of tax is included for conservancy service purpose (Source: Department of Conservancy, KCC 2014).

6.2 Conclusions

Due to increasing wastes generation and limited resources of its proper handling, the management of wastes has become an important health and environmental issues not only for Khulna city but also other cities of Bangladesh. The main constraints are weak organization and limited budget allocation for wastes management. From the discussion of this report the following conclusions can be drawn.

- Municipal waste contains various compositions with specific merit of each. So waste need to be separated with its merit to compost, reuse or recycle.
- Only 1.5 tons of finished compost is produced from 2.5 ton degradable waste which is very impressive ratio.
- More than 200 tons of organic compost can be produced in Khulna city if the total generated organic waste is recycled every day. The decentralized community based composting plants can generate employment for the poor, especially the women, and offers new prospects for small entrepreneurs to take part in recycling business.
- By selling 11.00 Tk per kg of compost, approximately 10,000.00 Tk profit is possible per day. By utilizing the total solid waste the profit could be 13,16,000.00 Tk per day.
- Improvement in overall environment of the neighborhood is possible by checking illegal disposal of waste on roads, drains. At the same time waste is directly collected from household recently which is very much appreciated.
- Public awareness about waste disposal is very important and they need to be responsible enough to dump their daily waste in selective places.
- Awareness about using compost as a replacement of chemical fertilizer should be increased to sell more compost to farmers.
- The compostable wastes generated at KUET campus is found as 65.09% amounting 3898 kg/month and the average amount of compost production is found as 48.57 kg/month.
- There are very little amount of compostable waste generated in the academic buildings so this amounts are neglected to record.

- The average moisture content, pH and C/N ratio of final compost are measured as 22.27%, 8.43 and 28.5:1 respectively.
- The quality of finished compost is fairly good.
- The maximum temperature has been found as 563°C at burning unit during waste burning.
- Hygienic bags are used for collection of special waste from predefined locations.
- Air pollution occurs due to emergence of smoke from burn unit.
- However, at present KUET campus seems very neat and clean due to solid waste management by composting process and burning unit at SWMP.

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APPENDICES

Data collection of December 2014 in KUET							
	Hall		Department and campus		Residential area		
Date	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Special waste (kg)**
1	96	57	5	10	44	11	12
2	70		3	12	8	3	15
3	60		6	15	9	3	18
4	100	50	3	20	20	5	11
5	50	40	5	16	15	10	17
6	60	100	2	11	15	10	20
7	50	40	1	13	13	8	10
8	80	60	3	15	16	10	15
9	50	50	5	17	25	15	16
10	80	100	6	18	20	10	11
11	90	50	6	10	15	8	10
12	50	30	4	13	10	8	12
13	70	40	3	14	16	5	14
14	50	50	2	15	8	5	16
15	70	25	6	11	20	5	17
16	80	60	3	13	12	7	11
17	70	40	6	22	10	5	12
18	80	70	8	26	20	10	13
19	90	80	5	27	25	12	14
20	100	100	3	11	35	15	15
21	50	60	4	15	40	15	14
22	100	63	5	17	35	5	10
23	100	100	6	18	20	5	15
24	60	50	7	19	30	10	16
25	70	40	6	20	15	5	17
26	90	40	6	12	25	8	11
27	100	50	7	13	35	5	10
28	100	100	2	14	40	10	12
29	70	100	6	15	30	8	16
30	100	60	2	14	25	10	14
31	100	50	3	15	35	6	11
Total	**2386**	**1755**	**139**	**481**	**686**	**252**	**425**

Total compostable waste = 3211
Total non compostable waste = 2488
Total special waste = 425
Total waste in December = 6124

Data collection of January 2015 in KUET							
	Hall		Department and campus		Residential area		
Date	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Special waste (kg)**
1	150	60	40	40	40	15	15
2	100	70	30	30	35	10	10
3	140	70	50	50	40	8	8
4	150	80		30	30	15	7
5	105	100		20	40	10	6
6	100	80		110	50	12	4
7	150	100		10	25	20	12
8	100	80		25	40	10	15
9	150	100		20	50	15	14
10	70	50		5	40	5	8
11	50	20		10	10	5	6
12	40	20		10	15	5	7
13	150	25		15	12	6	4
14	70	35		5	70	5	3
15	50	20		10	20	5	4
16	60	25		8	11	4	9
17	60	30		7	20	5	8
18	40	20		15	15	5	6
19	70	50		10	20	6	5
20	50	20		5	15	7	11
21	70	30			18	4	12
22	60	25		15	10	5	14
23	70	35		18	20	4	15
24	80	20		10	15	5	13
25	100	30		20	14	5	12
26	82	20		10	30	4	14
27	80	18		16	25	4	15
28	70	25		15	18	8	16
29	80	70		10	25	3	17
30	70	60		7	20	5	3
31	100	70		5	25	11	4
Total	**2717**	**1458**	**120**	**561**	**818**	**231**	**297**

Total compostable waste = 3655
Total non compostable waste = 2250
Total special waste = 297
Total waste in December = 6202

Data collection of March 2015 in KUET							
	Hall		Department and campus		Residential area		
Date	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Special waste (kg)**
1	100	30	2	30	20	5	10
2	90	25	3	33	15	8	6
3	100	20	6	37	20	4	8
4	40	25	7	40	25	3	12
5	50	40	8	41	17	2	5
6	60	10	5	43	15	2	11
7	40	25	4	28	5	2	3
8	50	20	3	32	10	5	9
9	70	30	4	34	15	4	8
10	60	18	5	35	20	5	6
11	35	10	7	40	19	2	9
12	40	15	9	100	10	2	10
13	100	30	2	115	12	3	4
14	100	25		125	15	5	11
15	100	30		35	18	3	13
16	90	45	3	8	20	2	5
17	100	40	1	33	25	3	4
18	150	35	2	35	20	5	9
19	90	40	5	36	18	5	13
20	100	40		40	18	3	11
21	85	44	6	50	16	2	15
22	100	38		22	15	3	8
23	120	38	6	11	15	3	6
24	150	40	9	34	20	5	7
25	110	35	1	38	18	3	6
26	150	35	2	44	20	3	7
27	120	40	4	45	15	5	6
28	150	60	6	32	25	2	4
29	104	25	4	40	25	12	7
30	140	20	5	25	30	15	9
31	130	35	6	30	35	25	10
Total	**2924**	**963**	**125**	**1291**	**571**	**151**	**252**

Total compostable waste = 3620
Total non compostable waste = 2405
Total special waste = 252
Total waste in December = 6277

Data collection of April 2015 in KUET							
	Hall		Department and campus		Residential area		
Date	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Special waste (kg)**
1	200	20		10	40	10	10
2	210	23	15	95	25	5	12
3	220	25		15	35	8	6
4	150	18		10	30	8	8
5	140	15		8	20	5	9
6	120	14	2	5	20	5	11
7	100	18		7	40	10	13
8	110	15		5	40	5	14
9	110	15	5	3	25	5	5
10	150	20		3	30	5	6
11	130	10		2	35	8	7
12	200	10	3	5	20	5	15
13	200	8	2	18	20	3	7
14	130	7	1	7	35	3	4
15	120		2	10	35	5	5
16	150	15			25	8	7
17	200	30	3	5	40	7	2
18	120	30	2	7	30	5	1
19	100	25	3	5	20	4	5
20	90	20	5	8	20	8	6
21	80	20	6	10	35	7	10
22	100	18	5	5	18	5	3
23	130	22	3	4	21	3	6
24	110	20		3	20	2	5
25	100	25	3	7	20	5	6
26	150	18		5	16	5	7
27	100	16	4	8	20	3	8
28	150	15		5	22	5	4
29	95	20		4	15	7	2
30	110	20		5	60	15	3
Total	**4155**	**557**	**64**	**289**	**887**	**179**	**207**

Total compostable waste = 5106
Total non compostable waste = 1025
Total special waste = 207
Total waste in December = 6338

Data collection of June 2015 in KUET							
	Hall		Department and campus		Residential area		
Date	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Special waste (kg)**
1	100	25		13	16	4	13
2	95	20		15	14	7	12
3	70	20		12	18	4	15
4	60	22		13	20	7	14
5	32	10		14	22	5	11
6	30	8		12	25	3	14
7	100	20		15	29	8	5
8	90	18		13	35	5	11
9	80	20		12	22	3	12
10	65	20		22	25	4	5
11	110	25		8	20	7	18
12	95	20		10	25	5	11
13	120	20			21	7	11
14	110	22		5	20	5	13
15	120	25		4	30	7	12
16	111	20		5	25	5	15
17	150	24		5	27	8	14
18	120	30		5	25	5	16
19	150	21		8	35	7	17
20	160	22		7	38	8	18
21	155	20		6	40	9	5
22	150	22		5	20	10	6
23	110	20		20	35	14	7
24	170	15		12	35	10	8
25	150	35			28	8	9
26	100	30			22	7	10
27	95	20			20	10	11
28	80	22			21	12	14
29	80	20		8	30	11	15
30	60	33			20	11	16
Total	**3118**	**649**	**0**	**249**	**763**	**216**	**358**

Total compostable waste = 3881
Total non compostable waste = 1114
Total special waste = 358
Total waste in December = 5353

Data collection of August 2015 in KUET							
	Hall		Department and campus		Residential area		
Date	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Compostable (kg)**	**Recyclable (kg)**	**Special waste (kg)**
1	90	45		13	40	20	15
2	120	40		14	50	30	14
3	85	35		12	55	25	17
4	62	30		15	60	20	16
5	85	20		16	60	20	5
6	80	25		17	55	20	11
7	90	30	2	18	72	18	12
8	90	20		20	60	22	13
9	80	15	4	16	40	15	14
10	99	30	6	14	50	7	15
11	100	30		15	55	5	6
12	65	25		27	60	12	7
13	75	20		32	55	15	11
14	80	25	3	14	65	10	8
15	110	19		14	71	11	9
16	70	30		27	55	10	10
17	76	20		15	45	15	8
18	95	25		13	55	10	6
19	100	30		11	45	14	5
20	90	22		8	50	10	6
21	80	25	5	5	66	16	7
22	75	10		9	48	10	8
23	85	18	6	3	45	12	9
24	80	20			60	15	10
25	90	35			55	10	15
26	95	20	3	4	65	15	16
27	100	30		15	64	15	17
28	90	35		14	50	20	18
29	115	32		2	60	20	14
30	90	50			65	35	13
31	90	45			77	14	12
Total	**2732**	**856**	**29**	**383**	**1753**	**491**	**347**

Total compostable waste = 4514
Total non compostable waste = 1730
Total special waste = 347
Total waste in December = 6591