STUDY ON SOLID WASTE MANAGEMENT PRACTICES AT SHER-E-BANGLA AGRICULTURAL UNIVERSITY CAMPUS

A THESIS

BY

ABDUL HALIM

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENTAL SCIENCE

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BY

ABDUL HALIM

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Approved by:

Dr. Nuzmun Naher **Supervisor** Professor Department of Agroforestry and Environmental Science SAU, Dhaka-1207	**Dr. Md. Khabir Uddin** **Co-supervisor** Professor Department of Environmental Sciences JU, Dhaka-1342

Dr. Nazmun Naher
Professor
Chairman
Examination Committee

DEPARTMENT OF
AGROFORESTRY AND ENVIRONMENTAL SCIENCE
Sher-e-Bangla Agricultural University (SAU)
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that the thesis entitled "**STUDY ON SOLID WASTE MANAGEMENT PRACTICES AT SHER-E-BANGLA AGRICULTURAL UNIVERSITY CAMPUS**" submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN AGROFORESTRY AND ENVIRONMENTAL SCIENCE**, embodies the results of a piece of bonafide research work carried out by **ABDUL HALIM, Registration no. 08-02894** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2014
Place: Dhaka, Bangladesh

_____

Dr. Nuzmun Naher
Supervisor
Professor
Department of Agroforestry
and Environmental Science
SAU, Dhaka-1207

DEDICATED TO

MY

BELOVED MOTHER

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The Author

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LIST OF ABBREVIATIONS AND ACRONYMS

RO	Registrar office
CBO	Community Based Organization
CDM	Clean Development Mechanism
DCC	Dhaka City Corporation
Dept.	Department
DPHE	Department of Public Health and Engineering
FDI	Foreign Direct Investment
GIS	Geographical Information System
GoB	Government of Bangladesh
HH	Household
ISWM	Integrated Solid Waste Management
IWM	Integrated Waste Management
SAU	Sher-e-Bangla Agricultural University
LGED	Local Government and Engineering Department
MOEF	Ministry of Environment and Forest
MRF	Material Recovery Facility
NGO	Non-Government Organization
RCC	Rajshahi City Corporation
SWM	Solid Waste Management
Tk.	Taka
UNDP	United Nations Development Program
WCC	Waste Concern Consultant
AG	Agriculture Faculty
ABM	Agribusiness Management Faculty
ASVM	Animal Science and Veterinary Medicine Faculty
BAU	Bangladesh Agricultural University
NAFDAC	National Agency for Food and Drug Administration and Control

WHO	World Health Organization
EO	Estate Office
NSDH	Nabab Siraj-ud-Doula Hall
SBH	Sher-e-Bangla Hall
KKNIH	Kabi Kazi Nazrul Islam Hall
SKFB	Sheikh Kamal Faculty Building
ABMB	Agribusiness Management Faculty Building
AB	Academic Building

STUDY ON SOLID WASTE MANAGEMENT PRACTICES AT SHER-E-BANGLA AGRICULTURAL UNIVERSITY CAMPUS

ABSTRACT

A study was conducted on solid waste management at Sher-e-Bangla Agricultural University during January-June, 2014. The study area was 86.97 acre with a population about 7,500. A huge quantity of solid waste generates regularly in the study area and maximum amount of which remain unmanaged. As there is no proper solid waste management system, the residents remained hostage to the refuse that they generate regularly which results in much health and environmental problems. Considering the present situation, this study is undertaken with different objectives of analyzing the existing solid waste management system at Sher-e-Bangla Agricultural University campus, its performance analysis and recommended suggestions on the provisions to handle the consequences of existing system. To attain the objectives, the study encompasses the complete scenario of the present solid waste management system ranging from regular waste generation to final disposal of the waste and different support facilities. The study scrutinized the volume of waste generated per day, its composition, service level of present solid waste management system, problem issues associated with present system, its consequences, required institutional supports, technical assistances, etc which are prominent variable to develop an effective management system.

CHAPTER I

INTRODUCTION

Solid waste management is considered one of the important environmental concerns confronting authorities in developing countries, like Bangladesh. Solid waste management and its consequent impact on environment are critical. A standard solid waste management provides hygienic, efficient and economic collection, transportation and disposal of solid waste without polluting the environment. Rapid population growth, urbanization, industrialization and changing food habit patterns are generating huge amounts of solid waste. Solid waste term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services (Palnitkar, 2002). Solid waste can also be defined as useless, unwanted and discarded materials coming from production, household and consumption. Waste is produced in all level of human activities. Waste source include residential area, commercial area, industrial area, construction and demolition area and agricultural activities (Alam *et al.,* 2009). This issue of solid waste is not only because of the increasing quantities but also largely because of an inadequate management system. Solid waste management policy without considering integrated management plan along lack of appropriate technology is making the situation threatening to the environmental and public health. It may also be categorized according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic paper etc); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc).

Solid waste refers to non-liquid wastes. In general this does not include excreta, and sometimes nappies and the faeces of young children may be mixed with solid waste. Solid waste may create significant health problems and unpleasant living

environment if not disposed off safely and appropriately. Apart from this indisposed solid waste may cause of breeding sites for insect-vectors, pests, snakes and vermin (rats) which may increase the possibility of disease transmission. It may also pollute water sources, soil and air.

Municipal Solid Waste (MSW) is complex refuse consisting of various materials with different properties. Some of the components are stable while others degrade as a result of biological and chemical processes. Leachate resulting from this hazardous which may pollutes the soil and ground water. Leaching of this leachate and heavy metals into the soil leads to the contamination of both soil and groundwater (Fahid *et al.,* 2013). The sources of solid wastages are garbage, refuse, sludge and discarded material and the wastages are produced by industries, hospitals, or household community activities. Solid waste disposal poses a greater problem because of openly dumped can cause land pollution, water pollution and air pollution. Dhaka city is facing serious environmental degradation and public-health risk due to uncontrolled disposal of waste on streets and other public areas, clogged drainage system by indiscriminately dumped waste and contaminating the water resources near uncontrolled dumping sites.

Improper disposal of solid waste can be injurious to human health, and plant and animal life, contaminate surface and ground water, degrade the soil quality, provide harborage to vermin and disease vectors; interfere unreasonably with the enjoyment of life or property and degrade aesthetic appreciation of the natural environment.

The solid waste collection and disposal system is one of the essential elements of the community facilities plan for an urban area. To provide the best possible service to society, solid waste management systems must be efficiently integrated within the urban environment in which they function. Previously, environment was not an issue in a developing country like Bangladesh and solid waste

management was not the prime concern of environmentalists and the government. In the recent time, when certain NGO's started working and highlighting the pathetic state of municipal waste services provision in the country, that the decision makers realized the importance of this particular aspect of environmental management (Yousuf, 1996, Sarmin, 2000).

Solid waste management has so far been the most ignored issue in Bangladesh. But recently the concerned government and private agencies have started to consider this area to be an inseparable component of improved public health (Dahi, 1996). Rapid growth of industries, lack of financial resources, inadequate trained manpower, inappropriate technology and lack of awareness of the community are the major constraints of solid waste management.

The current municipal solid waste management practices especially collecting, processing and disposing are considered to be inefficient in the developing countries. The typical problems are low collection coverage and irregular collection services, crude open dumping and burning without air and water pollution control, the breeding of flies and vermin and the handling and control of informal waste picking or scavenging activities (Bartone, 1995). Systems of solid waste management vary with types of wastes and local conditions. The best systems are designed by fixing together the fundamental goals, a clear analysis of local conditions and factors, an understanding of the full range of technology options that are available and an awareness of the traditional wisdom and Systems that the local people have developed (Adams, 1999). Solid waste materials that are organic in nature, such as plant materials, food scraps, and paper products are increasingly being recycled. These materials are put through compost and/or a digestion system to control the biological process to decompose the organic matter and kill pathogens. The resulting stabilized organic material is then recycled as mulch or compost for agricultural or landscaping purposes (Marshal, 1995)

Waste management, particularly solid waste management is one of the important obligatory functions not only urban local authorities but also the awareness of the localized people of a residential area i.e. residents of a University campus people. But there is lack of a proper solid waste management system facility provided by the university authority. On the other hand residents of Sher-e-Bangla Agricultural University (SAU) are not concern about the problem. As a result, there found disorder at all levels of waste management and as a consequence of which the environmental condition of the study area is degrading. Sher-e-Bangla Agricultural University is a residential university of Bangladesh. It has five hostels commonly known as halls for its students: three of them are for male students and two are for the female students. Residential units are also available for teachers, officers and staffs. The residential units are the major source of huge solid waste generation every day. As there is no proper solid waste management system, the residents remained hostage to the refuse that they produced regularly. Indiscriminate littering on roads, lanes, and by-lanes led to emissions of bad smells from decomposed wastes and also the drains clogged with wastes. As a result, the living environment of the area is deteriorating. The formal solid waste management system of Sher-e-Bangla Agricultural University is operated by the 'Estate Office', which encompasses only a few portion of the total solid waste generated every day. Therefore an urgent remedy is needed to enhance the present situation.

Considering the above facts my research objectives are:

1. To make an assessment on the present solid waste generation scenario.
2. To investigate the existing solid waste management system of Sher-e-Bangla Agricultural University.

CHAPTER II
REVIEW OF LITERATURE

Bashir *et al.* (2014) found that the disposal methods of solid waste used by residents in the study area were very unsatisfactory. Majority of both nearby and far away residents indicated that the dumpsite is the breeding place for disease vectors, cause diseases and makes the place dirty. Many diseases are spreading in village because of solid waste and it has a bad effect on people health. Effected population is considered burden on the society that area cannot progress properly. The result is concluded that if people have more awareness and they look after their health and adopt safety habit for health they can less victim of solid waste disease.

The community-managed house-to-house waste collection service is gaining momentum in Dhaka City and the system has already increased garbage collection coverage by 20 percent of the generated waste and created approximately 500 jobs and proven to be appropriate for addressing local problems (Tania, 2014).

Sruti *et al.* (2014) showed the municipal solid waste disposal site for the city of Thrissur, in Kerala, India, has become an overflowing landfill because of the indiscriminate dumping of solid waste at the site. Leachate and soil samples were collected from this landfill-site and its adjacent area to study the possible impact of leachate percolation on soil quality. Concentration of various physicochemical parameters and engineering properties were determined in soil samples. Conductivity and compaction characteristics of soil were studied. The study indicated that leachate can modify the soil properties and significantly alter the behaviour of soil. There is a general deterioration in soil properties which is attributed to the chemistry of leachate and of soil.

Fahid *et al.* (2013) investigated the impact of discharging wastewater and disposing solid waste in Wadi Gaza environment. Groundwater and soil in Wadi Gaza are found to be seriously polluted with many pollutants in the area starting from the sea and extending to 5 km upstream of the sea. The pollution included heavy metals, fecal coliforms, organic matter, and nitrates. Moreover, the sea water at the outlet of the Wadi is seriously polluted with many types of Pollutants over a long distance. An immediate action should be initiated to stop the disposal of wastewater and solid waste into Wadi Gaza. This can be achieved by building a temporary wastewater treatment plant close to the Wadi to serve for an interim period of 5 to 7 years (the period expected for the construction of the central wastewater treatment plant).

Sankoh *et al.* (2013) examined the environmental and health impacts of households living around (nearby) and away (far away) from the Granville Brook dumpsite in Freetown, Sierra Leone. Results from the analysis of data revealed that both nearby residents and far away residents suffered from related diseases due to the location of the dumpsite closer to their settlements. It was discovered that residents less than fifty meters from the dumpsite are most affected by the dumpsite. Hence they were victims of malaria, chest pains, diarrhea, cholera, irritation of the skin, nose and eyes. This state of health of respondents in this study can be linked to pollution from the dumpsite. In the dry season, the smoke from the incineration of the dumpsite is an important source of air pollution for people living far away from the dumpsite. They therefore complained about chest pains. The study therefore concludes that the dumpsite should be properly located and managed to minimize its effects on the environment.

Masud (2013) reported that in Savar Pourashava wastes are generated from multifarious sources, stored and collected in unplanned manner, carried in the same way. The most devastating situation is that these wastes are dumped in open places without considering health, hygiene and environmental issues. Even no specific dumping zone is declared and maintained, only disposed road side and other open spaces imposing great threat to human health and environment. Everywhere in the waste management system and in the community, proper planning and due care is mostly required in order to reshape the waste management system. Collection, dumping and disposal capacity of the Pourashava should be increased which needs regular and proper collection of municipal tax.

Alhassan (2012) reported a laboratory investigation of the effects of municipal solid waste on the geotechnical properties of soils. Results of the investigation showed that Municipal Solid Waste (MSW) lowers the specific gravity, increases the natural moisture content, increases the fine particles content, lowers the maximum dry density with higher optimum moisture content, lowers both the cohesion and the angle of internal friction; increase the coefficient of permeability, coefficient of consolidation and coefficient of volume compressibility of the soil. These effects reduced with depth.

Abdullah *et al.* (2012) showed the open dumping is an important source of pollution, which can be displayed through analysis of data for climatic conditions, hydrology and geology of the country. The migration of gas and leachate from the landfill body into the surrounding environment present a serious environmental concern, which include groundwater pollution, air pollution with impact on climate through methane emission and potential health hazards.

Nartey *et al.* (2012) found the major pollutants into the Densu, Lafa, Bale Rivers and the Gbegbe lagoon (Glefe) have been identified to be organic waste, total and faecal coliforms. The sources of these pollutants into these water bodies are

through runoffs from the municipal landfills/dump sites and could also be attributed to indiscriminate defaecation and refuse disposal which had contributed to elevated levels of the pollutants. The low level of dissolved oxygen recorded for the entire study period is an indication that the waters in the study area could not support life sufficiently.

Eneje *et al* (2012) reported the concentration of heavy metals, total nitrogen, organic matter, soil pH, and cation exchange capacity were observed to be higher in soils at dumpsite compared to those obtained in adjacent soils 10 meters away. This implies that the municipal solid waste dumpsite have a significant impact on the environment. From this study, the municipal solid waste impacted or decreased the soil pH, OM and CEC down the depth, while heavy metals deposit increased down the depth.

Saadat *et al.* (2012) reported that the daily generation of solid waste in Jahangirnagar University campus is about 4757.502 kg and among which 75.5% is organic. These organic wastes are house hold waste so there is less chance for hazardous material when it will convert in to the compost. It is possible to generate 30 kW/h of electricity and about 300 metric tons of compost.

Ahmed *et al.* (2011) reported the poor disposal and handling of waste that leads to environmental degradation, destruction of the ecosystem and poses great risks to public health in Narayanganj City of Bangladesh. The study showed that there is a significant link between the improper management of urban solid wastes and environmental pollution. A large number of residences are not aware of the health hazard and solid waste related problems. Therefore, it is important to launch a long-term awareness building and campaigning program. He also repeated that the managing solid wastes of a city, community based projects have demonstration effect. NGOs can play an important role in initiating, innovating new concepts, providing technical knowledge and providing training to others. In Narayanganj

city a large number of residences are not aware about the impact of unplanned waste disposal on health and solid waste related problems. Many households are disposing garbage in nearby open spaces. Therefore, it is important to launch a long-term awareness and campaigning programme in the area so that people get motivated about enhancing own environmental conditions willingly. Narayanganj Pourashava does not yet have any solid wastes recycling project. Recycling contributes to resource conservation as well as environmental protection.

Irshad *et al.* (2011) concluded that the waste material produced tangible impacts on soil and water system of Nathiagali. The metal species were found higher on the site of waste accumulation and decreased with the increasing distance from the dumping site. The dumping place had the highest soil EC as compared to the nearby soils. The pH trend was found apparently inconsistent. Water samples exhibited higher content of heavy metals. Metal concentrations were found in excess to the WHO water quality standards. Therefore, an effective awareness, recycling and land filling techniques for the solid waste management in the study area is urgently needed.

Mohammed *et al.* (2011) showed the existing solid waste management system is affected by unfavorable economic, institutional, legislative, technical and operational constraints. A reliable waste collection service is needed and waste collection vehicles need to be appropriate to local conditions. More vehicles are required to cope with increasing waste generation. Wastes need to be sorted at source as much as possible, to reduce the amount requiring disposal. Co-operation among communities, the informal sector, the formal waste collectors and the authorities is necessary if recycling rates are to increase. Markets for recycled materials need to be encouraged. Small-scale waste composting plants could promote employment, income generation and poverty alleviation.

Nanda *et al.* (2011) investigated to determine the possible effect of leachate on soil in the solid waste dumping site which was seven years old, in which solid waste dumping in this site was in practice for a period of one to one and half years and later there was no further dumping took place in this site. This investigation indicates that, greater effect to higher depth in the continued dumping site could be expected, as the size of landfill and variety of solid wastes disposed increases, large amount of leachate will be generated and create environmental problems.

Nkwocha *et al.* (2011) investigated the effect of waste dump on the nearby Otamiri river. Results showed that the waste dump has significant effects on the river water quality, although the mean values of most parameters analyzed fell below NAFDAC and WHO standards for drinking water. The most important finding was the high concentration of coliform bacteria in the river water making it most unfit for domestic consumption. There were more pollution loads from the waste dump during the rainy season than during the dry season mainly because of increased leaching and run off arising from the dump.

Saidu (2011) conducted a study to evaluate the effect of solid waste dumps on ground water quality. Hand dug wells were selected close to the dumps site. All samples are not in conformity with WHO limit for bacteriological values which make the water to be unsafe for drinking, further treatment is recommended for the water. The study concludes that the hand dug well water around the refuse dumps sites is not safe for human consumption.

Salam (2010) studied the effects of the dumpsite on the surrounding human settlement in the Mangwaneni area of the Golf Course dumpsite in Manzini city. The result shows that both residents were affected by the location of the dumpsite closer to their settlements. It was also noted that the residents whose houses are less than 200 meters from the dumpsite are victims of malaria, chest pains, cholera, and diarrhea. The study concludes that dumpsites should be located at

least 200 meters away from human settlements. Therefore, the study recommends that dumpsites should be properly located and managed to minimize its effects on the environment.

Duong (2010) showed an Integrated Waste Management System is the most advantageous system for minimizing the solid waste pool effectively by 71%. The system includes integration of appropriate waste management strategies, such as the utilization of incinerators, applications of enhanced anaerobic processes, and addressing root causes of the problem by educating the people among other treatments.

Civeira (2010) found the MSW compost addition on the degraded soil recovered plant growth, raised residue decomposition, and improved physical and chemical properties. As expected, organic matter increased after MSW compost application. The results of this study showed that the use of MSW compost in this type of soils is an accurate alternative, since provides a nearby available source of nutrients and allows the full recovery of a severe damaged ecosystem with critical environmental problems.

Nkwachukwa *et al*. (2010) found the necessity to arouse and enhance public awareness regarding environmental protection by publicity and education to guide consumer preferences to support products that are produced with and ultimately generate little hazardous or solid waste. While it is left for EPA to use integrated waste management patterns, which is selecting and applying of suitable techniques technologies and management programs to achieve specific wastes management objectives and goals.

Ahammed *et al*. (2009) conducted a research study during 2005 to 2008 in four selected Pourashavas (Municipalities) of Bangladesh namely Bagerhat, Bogra, Potuakhali and Bhola and found traditional procedures was adopted for SWM program in the study area. A questionnaire survey was conducted in random

manner among 750 household out of 38,166 in total. It was explored that 63% inhabitants dispose of their SW in unsanitary means and 69 inhabitants expressed their satisfaction on SWM condition.

Ahsan *et al.* (2009) conducted a research at aimed to find potential municipal waste management options for Khulna city, where waste could be used as a resource rather than simply dumping it into the landfill site. Khulna City Corporation (KCC) and community based NGOs are able to manage about 42% of the total waste generated while the rest of them are unattended. In fact, most of the wastes are collected from door-to-door without any sorting and either dumped in open space or improperly land filled which is likely to contaminate the soil and ground water. In another experiment he attempt to link municipal governance and solid waste management with the purpose of creating sustainable urban SWM system of Mymensingh Pourashava. The translated report card with the indicators of good urban governance was conducted among different stakeholders i.e., municipal council, municipal official including conservancy section, civil society representatives and urban poor representatives including the waste pickers. It indicates that the level of governance in Mymensingh Pourashave is related to SWM in Mymensing Pourashava.

In the urban areas of Bangladesh, the existing practices of Municipal Solid Waste (MSW) management are standing far behind than the needs in all aspects: as a consequence, the urban environmental sustainability is in large threat and becomes a striking issue to the concerned stakeholders. To materialize the MSW management target perfectly, the community participation must be ensured and the levels of awareness based on the interactive dialogue among the concerned stakeholders (Alamgir, 2009).

Waste management has proved to be an of the Greece's most complicated environmental, political, legal and social problems as there are over than one thousand unauthorized dumping sites (Anastasiadis and Metaxas, 2009).

Municipal solid waste management is a serious environmental hazard and social problem in sylhet. Currently a gigantic, volume of solid waste (336 tons in 2006 and estimated 420 ton in 2008) is generated every day in Sylhet city and unfortunately solid waste management is being deteriorate day by day due to the limited resources to handle the increasing rate of generated waste. The major lacking as identifiable the study is awareness programs and programs simulating attitudinal and behavioral change regarding solid waste management among the public that were never been practiced in the past year. The conducted study showed the deteriorate situation of SWM in Sylhet City Corporation. Waste generation rate is being increased due to the lack of public awareness, haphazard urbanization, introduction of environmentally unfriendly materials, and changing consumption patterns it people (Chowdhury *et al*., 2009).

Now-a-days, a number of hardware and software techniques in form of scientific technology for collection and transfer of solid waste by utilities, treatment and final disposal as well as source separation by housewives, maid-servants, householders as well as a number of R's such as refuse, reduction, return, repair, replacement, recycling, reuse, renewal of energy and resource recovery, recharge, refit are available to mitigate solid waste problems throughout the world (Chowdhury, 2009).

Gabriel *et al*. (2009) investigated the impacts of a solid waste disposal site on environmental pollution. The dumpsite was found to be a significant source of pollution to soil, groundwater, surface water and riverbed sediments in its neighborhood. Concentrations of, among others, Pb and Cd in groundwater were as high as 15 and 35 mg/L, respectively. This reasserts the notion that proper

design, construction, and operation of dumpsites to reduce infiltration of rainwater and contain leachate can curtail pollution considerably.

Hossain *et al.* (2009) depicted that the solid waste generation in Dhaka city was about 5000 tons per day in which about 80% was biodegradable. It was also increasing with a rate of 5.6% per annum. It was assessed that a biogas electricity plant of 175.2 GWh (gross) capacities might run properly based on the biodegradable waste on Dhaka city, which will have a great economic and environmental benefit. Investment cost of such a biogas electricity plant will be 173.66 million of BDT and it will earn 18,820 million of BDT per year. It will also reduce 1130,538 tons of CO_2 equivalent emission.

Mofiz (2009) represented the problem of solid waste management (SWM) in Rajshahi metropolitan area. The primary, secondary date, interviews and personal observations were used. Wrong attitudes and perception of the people about sanitation issues contributed to solid waste management problems of Rajshahi city corporation (RCC). It was observed that the financial resources, institutional weakness, improper selection of technology, transportation systems and disposal options, public's lack of concern towards environmental cleanliness and sanitation have made this service unsatisfactory.

About 64% of its general solid wastes of Mohammadpur Thana, Dhaka city, were managed by Dhaka city corporation (DCC) (Rahman *et al.* 2009). Geographical information system (GIS) was used to propose an efficient scenario with relocating the existing waste bins and containers and another scenario was proposed with number of bins (25), containers (30) and existing illegal dumping sites (14) to attain an 80% waste collection efficiency including optimization and selection of waste collecting routes for Mohammadpur Thana. A participatory community management information system (COMMIS) and further suggestions for an integrated SWM were also recommended.

Rahman *et al.* (2009) illustrated that MSW remains unmanageable in the Dhaka city. To understand the solid waste management 36 and 41 no wards of Dhaka city were selected. MSW collection system of the study area was inadequate and inefficient. By extensive data collection it has been observed that only 70% to 80% of the total generated waste is collected and disposed per day by Dhaka City Corporation (DCC). The rest of the wastes remain on the roadside bins and curbside creating unhealthy environment.

Adjia *et al.* (2008) showed that municipal solid wastes used as fertilizer offers important benefits as a liming material because of its high pH and high organic carbon, Ca and Mg contents. However, it is clear that there is a potential problem of heavy metal contamination because of the excessive concentrations of Cu, Zn, Cd and Pb recorded in the municipal solid wastes used in periurban agriculture in Ngaoundere. The results revealed that the amended sites were polluted with Cu, Zn, Cd and Pb. This is therefore hazardous for agricultural purposes since the bioavailability of heavy metals depends also on their total concentrations in soil.

Raman *et al.* (2008) investigated the possible impact of solid waste effect on soil and ground water quality. The physical and chemical parameters such as temperature, pH, hardness, electrical conductivity, total dissolved solids, total suspended solids, alkalinity, calcium, magnesium, chloride, nitrate, sulphate, phosphate and the metals like sodium, potassium, copper, manganese, lead, cadmium, chromium, nickel, palladium, antimony were studied using various analytical techniques. It has been found that most of the parameters of water are not in the acceptable limit in accordance with the IS Drinking Water Quality Standards. It is concluded that the contamination is due to the solid waste materials that are dumped in the area.

Rana and Das (2008) also studied about solid waste management of Khulna city. Their concern was application of GIS in solid waste management to ensure a

standard system. GIS can be used as effective tool in selecting suitable disposal sites and determining optimum collection route. This paper explains GIS as an important decision support system to provide an opportunity to integrate spatial and other relevant data for selecting suitable disposal sites and optimum routes for transportation of solid waste.

Zahur (2007) studied on Solid waste management of Dhaka city: public private community. Results from this study shows that, solid waste is indiscriminate by dumped on roads and into open drains thus leading to serious health risk and degradation of living environment for millions of urban people. In the last decade, however, importance of community involvement in solid waste management and use of adapted technologies were recognized for improving the solid waste management system.

Waste is an unavoidable by product of human activities. Economic development, urbanization and improving living standards have led to an increase in the quantity and complexity of generated waste. Rapid growth of population and industrialization degrades the urban environment and places serious stress on natural resources, which undermines equitable and sustainable development. Inefficient management and disposal of solid waste is an obvious cause of degradation of the environment in most cities of the developing world. Municipal corporations of the developing countries are not able to handle increasing quantities of waste, which results in uncollected waste on roads and in other public places (Zahur, 2007).

Rahman (2006) focuses the analysis of current practices of household waste disposal, problems faced by the residents during waste disposal and their views for improvement of the waste management system. However, it has been found that traditional concepts and technologies usually adopted in waste collection is becoming insufficient and ineffective causing more than half of the generated

wastes (44%) remain uncollected and disposed of locally, which results in adverse impacts like water pollution, drainage congestion and finally, the degradation of the overall urban environment.

Hai *et al.* (2005) reported that the mixed waste dumped at dumping sites is characterized with high organic content and high moisture content (about 80% and 50-70% by weight, respectively). They suggested that to reduce the undesirable adverse impacts of overflowing of waste bins and accumulated wastes on roadsides, strict rules must be applied on the management related activities and the level of public awareness should be increased.

Urban solid waste management scenario of Bangladesh: Problems and Prospects were reported by (Enayetullah *et al.,* 2005). They found that the existing infrastructure for waste management shows that waste collection efficiency in different urban areas varies from 37% to 77% with an average of 55%. Huge amount of uncollected waste, a high percentage of which is organic, creates nuisance and pollutes the local environment quickly. Therefore, frequent removal is absolutely necessary for sound and hygienic surroundings. In the midst of limited capacity of municipal corporations to manage the waste, informal sector is playing a vital role by recycling a certain quantity of wastes - mainly the inorganic portions. Around 4 to 15% of the total generated waste is being recycled by the informal sector. It is estimated in the study that every year Tk. 10,706 million is being saved through recycling.

CHAPTER III
MATERIALS AND METHODS

3.1 Location and area

This study was conducted at Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, during January 2014 to June 2014. The study area was situated at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004). The campus stands on 86.92 acres (35.2 ha) of picturesque land covered by green plantations with a series of academic, administrative and residential buildings and a number of plots for crop cultivation, experimental farms, gardens and other related facilities. The experimental site was shown in the map of AEZ in Bangladesh in Appendix I

3.2 Climate

The climate in Bangladesh is subtropical mild winter (October to March); hot, humid summer (March to June); humid, warm rainy monsoon (June to October). The average maximum temperatures is 25°C in January with the average minimum 10°C, while in June the average maximum is 32°C with a minimum of 25°C in Dhaka city. The wettest month for Dhaka is July with an average of 367.9mm of precipitation falling while the driest month is December with 8.9 mm falling. The climatic data is presented in Appendix II.

3.3 Characteristics of vegetation

The total number of plants at sher-e- Bangla Agriculture University belongs to 152 families under 251 genera and 327 species respectively. Out of all plant species 19 timber species (including 15 genera and 11 families), 42 fruit plant species (29 genera 17 families), 61 medicinal plant species (55 genera and 34 families), 42 ornamental plant species (35 genera and 25 families), 81 flower plant species (53 genera 29 families), 41 vegetable plant species (30 genera 16 families), 13 spices plant species

(11 genera 8 families), 6 fodder plant species (6 genera and 5 families), 5 bamboo plant species (2 genera 1 families), 3 ficus plant species (1 genus and 1 family), 2 fibre plant species (2 genus and 2 family), 10 palm plants (10 genera and 3 families), 2 rubber plants (2 genera and 1 families) (Sultana *et a*l. 2012).

3.4 Population

The exact total population of the campus cannot be identified, but it is approximately 7500 including students, teachers, officers, staffs and unauthorized residents.

3.5 Structures

Sher-e-Bangla Agricultural University was not at the present state from beginning. The place where it located was full of jungle. The architect has designed the master plan for the campus with a number of structures and infrastructures. The master plan divides the campus into three major zones:

a. Academic and administrative structures
b. Student hostel
c. Residence for teachers, officers and other staffs.

The present status of structure developed by university authority is:
Total number of university owned structure: 51
Total area occupied by these structures: 711606.4 sq. ft.

3.6 Solid waste

Solid wastes can be defined as useless, unwanted and discarded materials coming from production and consumption. Solid waste includes all those wastes except waste water discharges and atmospheric emissions. So, a solid waste may either be a semi-solid, solid or even a liquid, Moreover a waste has been looked after as an abandoned material which has no consumer value to the person abandoning it. The

urban solid waste or municipal refuse has been defined by Cointreau and Johnson, in 1982 as "material for which the urban area requires no compensation upon abandonment. In addition, it qualifies as being within the responsibilities of the municipality to collect and dispose it". (Cointreau and Johnson, 1982).

3.7 Categories of solid waste

Solid waste classified as the following ways

Organic solid waste: Organic solid waste or green waste is organic material such as kitchen waste, food, garden and lawn clippings, leaves etc.

Combustibles solid waste: Combustible solid waste means solid waste that is combustible. Combustible Waste includes: Papers, woods, plastics, packaging for relief items, cardboards, cartons, woods, boxes, rags, cloths, beddings, leathers, brushes, timbers, logs, and stumps, carpeting and combustible construction and demolition debris etc.

Non-combustibles solid waste: For the purposes of this category, non-combustible inert wastes are non-hazardous, non-combustible, non-biodegradable, and chemically-inert solid waste that are not likely to decompose significantly. This may include: Ashes, noncombustible rubbish, asbestos and asbestos waste products, uncontaminated sand, soil, concrete, rubble, masonry, glasses, pottery, ceramics, bricks, and tiles.

Hazardous solid waste: Hazardous solid waste is waste that is dangerous or potentially harmful to our health or the environment. Hazardous waste can be liquids, solids or sludge. They can be discarded from commercial products like cleaning fluids or pesticides, oil, battery acid, medical waste or the by-products of manufacturing processes.

3.8 Source units of solid waste generation

Major sources of solid waste generation at Sher-e-Bangla Agricultural University are:

1. Residential units
2. Student hostels
3. Academic units
4. Administrative offices
5. Market places
6. Some common places (Cafeteria, Auditorium etc)
7. Street sweeping and drain cleaning and
8. Medical centre

3.9 Solid waste management system

Solid waste management encompasses all aspects concerning waste generation, onsite handling and storage, waste collection, transportation, treatment, reuse and recycling and final disposal.

3.10 Data collection

In order to achieve the objectives two types of survey was conducted.

3.10.1 Primary data

Primary data were collected through survey in different households, academic units, administrative office, student hostels, medical center, markets, some commercial areas, street and drain and through conducting interview with the waste management authority, officials and residents. In order to determine physical composition of solid waste generated in different areas, collected samples were separated and taken weight for physical composition identification. Global Positioning System (GPS) was used to collect exact location of the solid waste disposal sites for the map preparation.

3.10.2 Secondary data

Secondary data were collected from the Estate office, Registrar office, staffs, students, residents, reports and studies by related literature review.

3.11 Data analysis

Analysis was done by using M.S Excel.

3.12 Map preparation

A map was prepared through Google Earth software (ArcGIS 9.2) with its extensions indicating the solid waste dumping sites at SAU campus using collected GPS data incorporated in the Google Earth image.

3.13 Recommending strategies

It encompassed the tasks of trend analysis, exploration of gaps between the government policies, standards and the real life scenario, etc. associated with the provisioning of solid waste management system. It also focus the subsequent management basing on the collected data, information and exploring the possible measure or issue for an effective solid waste management system.

CHAPTER IV

RESULTS AND DISCUSSION

The solid waste management scenario of study area, Sher-e-Bangla Agricultural University was complex. Sher-e-Bangla Agricultural University did not have proper waste management system except few contribution of 'Estate Office', which managed only few portion of the total solid waste generated per day. SAU consists of a number of different land use all of which contributes to regular solid waste generation. But their significance varies from each other. Residential units showed maximum contribution to the total solid waste generation. Student hostels also generated huge amount. Solid waste also generated from market places. Beside all these solid waste from academic units, administrative offices and different common places also generated regularly. A portion of solid waste also generated from street sweeping and drain cleaning.

4.1 Residential unit

The university authority developed a number of residential buildings to facilitate accommodation of teachers, officers and staffs. Employees were accommodated on the basis of seniority to the A, B, C and D type quarters according to estate office. Bachelor quarters were also provided for teachers and officers.

Table 1: Residential units for teachers and other employees of SAU

Type	Number of unit
Vice-chancellors residents	1
A-type building	09
B-type building	04
C-type building	03
D-type building	02
Bachelor quarter	05
Unauthorized housing unit	05

Table 2. Solid waste generated from different residential units of SAU (per day)

Sources	Volume of waste generated (kg/day)				Total
	Organic	Combustibles	Non-combustibles	Hazardous	
Teachers quarter					
Meghna	1.70	0.50	0.20	-	**2.40**
Jumuna	1.80	0.70	0.30	-	**2.80**
Tista	1.00	0.30	0.10	-	**1.40**
Madhumoti	1.90	0.40	0.10	-	**2.40**
Titas	2.10	0.90	0.50	-	**3.50**
Karatoa	1.50	0.40	0.10	-	**2.00**
Gomati	1.70	0.60	0.20	0.01	**2.51**
Karnafuli	2.50	1.00	0.60	-	**4.10**
Garai	1.20	0.40	0.10	-	**1.70**
Padma	1.60	0.40	0.40	-	**2.40**
Surma	2.10	0.80	0.50	0.02	**3.42**
Gangchil	2.50	0.70	0.40	0.01	**3.61**
Egle	2.60	1.20	0.60	0.02	**4.42**
Ababil	1.80	0.50	0.10	-	**2.40**
Jui	7.40	2.20	1.10	0.03	**10.73**
Gandharaj	6.00	1.40	1.00	-	**8.40**
Rajanigandha	5.40	3.00	1.50	-	**9.90**
Madhabilata	10.80	4.20	2.20	-	**17.20**
Dolonchapa	11.40	7.70	3.40	0.02	**22.52**
Karabi	10.90	3.50	1.70	0.01	**16.11**
Shapla	41.20	11.80	5.80	0.25	**59.05**
Chamili	31.20	12.30	5.60	0.02	**49.12**
Massranga	22.30	7.20	2.60	0.02	**32.12**
Total (TQ)	**172.60**	**62.1**	**29.10**	**0.41**	**264.21**
Officers quarter					
Doyel	63.50	21.50	8.50	0.27	**93.77**
Hasnahena	17.60	5.10	2.00	0.02	**24.72**
Sharnalata	30.60	8.80	3.30	0.03	**42.73**
VC Banglow	4.00	1.50	0.60	0.02	**6.12**
Total (OQ)	**115.70**	**36.90**	**14.40**	**0.34**	**167.34**
Staff quarter					
Moyori	11.20	3.20	1.30	0.01	**15.71**
Balaka	26.70	6.70	3.80	0.12	**37.32**
Shama	9.50	2.30	1.10	-	**12.90**
Tin shed (labor)	32.50	11.20	4.60	0.02	**48.32**

Table 2 (cont'd)

Chandana	47.10	13.40	6.60	0.02	**67.12**
Payra	49.80	16.90	5.50	0.03	**72.23**
House (garage)	15.80	3.60	1.90	0.15	**21.45**
Ansar camp	10.30	4.50	2.10	0.02	**16.92**
Bot tala	275.00	80.00	30.00	0.50	**385.50**
Muslim para	260.00	80.00	38.00	0.60	**378.60**
Japani para	55.00	20.00	9.00	0.15	**84.15**
Soil fertility	25.00	8.50	4.50	0.05	**38.05**
Total (SQ)	**817.90**	**250.30**	**108.4**	**1.67**	**1178.27**
Total	**1106.20**	**349.30**	**151.90**	**2.42**	**1609.82**
Mean	**28.36**	**8.96**	**3.89**	**0.17**	**41.28**
SD	**58.83**	**17.66**	**7.54**	**0.22**	**84.02**

Field survey showed that the number of households living in the study area was about 730 (including 204 unauthorized settlements) which were the major source of solid waste generation. Field survey revealed that quantity of solid waste generated by households differs from each other. Rajput *et al*. (2009) reported solid waste generation in several developing countries and cities has been found in South East Asia region. Some important data can be mentioned such as 1.2 kg in Changging (1997), 0.6 kg in Shanghai (1993), 0.88 kg in Beijing (1991), 1.5 kg in Tokyo, 2.7 kg in Osaka, Japan (1993), 0.66 kg in Jakarta, Indonesia (1993), 1.29 kg in Kuala Lumpur, Malaysia (1989), 0.53 kg in Metro Manila Philippines (1995), 0.5 kg in Khulana, Dhaka, Chittagong, 0.4 kg Sylhat, Bangladesh (1991).

Plate 1. Residential buildings of SAU

Aruna *et al*. (2013) reported waste Generation (gm/capita/Day) was 0.372 kg/day in 2001 and 0.424kg/day in 2011.

Table 3. Average quantity of solid waste generated by each household (per day)

Types of waste	**Amount**
Organic	1.51 kg
Combustibles	0.47 kg
Non-combustibles	0.21 kg
Hazardous	0.003kg

4.2 Student hostels

Sher-e-Bangla Agricultural University was a residential public university in Bangladesh with good residential facilities for the students. There were five student hostels (two for female and three for male).

Plate 2. Student hostels of SAU

Different student hostels can accommodate 2,184 students with a seat but about 2,981 students were living in the hostels (in some cases doubling of regular students and also students were not regular in hostels) and the rest were accommodated at the extension room, and common room of different hostels. Some students also regularly commuted from different areas of Dhaka.

Table 4. Solid waste generated from different student hostels (per day)

Sources	Volume of waste generated (kg/day)				Total
	Organic	Combustibles	Non-combustibles	Hazardous	
Student Hostels					
BFMH	51.60	12.30	1.50	2.00	**67.40**
KKNIH	93.80	23.40	3.40	3.50	**124.10**
SBH	85.00	22.20	3.00	3.10	**113.30**
NSDH	45.30	11.90	1.40	1.10	**59.70**
KSHH	57.60	17.80	2.70	3.60	**81.70**
Total	**333.3**	**87.60**	**12.00**	**13.30**	**446.20**
Mean	**66.66**	**17.52**	**2.40**	**2.66**	**89.24**
SD	**21.44**	**5.37**	**0.90**	**1.08**	**28.29**

Note. Begum Fazilatunnesa Mujib Hall (BFMH), Kabi Kazi Nazrul Islam Hall (KKNIH), Sher-e-Bangla Hall (SBH), Nabab Siraj-ud-Doula Hall (NSDH), Krishokrotno SheikhHasina Hall (KSHH).

MSW generation rates range between 0.3 and 0.6 kg/ capita/day in Indian cities (Pattnaik and Reddy, 2010). DCC and JICA (2005) reported daily per person waste generation rate varies from 0.49 – 0.6 kg in Bangladesh. Student hostels at SAU were the second major contributor of total solid waste generation. Table 6 shows the solid waste generation scenario of each hostel and also shows their types with amount.

4.3 Academic unit

There were three faculties and 32 departments in the university. The names of the faculties were Faculty of Agriculture, Faculty of Agribusiness Management and Faculty of Animal Science and Veterinary Medicine. The departments under the Faculty of Agriculture: Agricultural Botany, Soil Science, Horticulture, Agronomy, Agricultural Extension and Information System, Entomology, Genetics and Plant Breeding, Biotechnology, Plant Pathology, Agricultural Chemistry, Biochemistry, Agroforestry and Environmental Science, Fisheries, Agricultural Engineering and Language department.

Plate 3. Academic structures of SAU

The departments under the Faculty of Agribusiness Management: Agricultural Economics, Agribusiness and Marketing, Management and Finance, Development and Poverty Studies, Agricultural Statistics. The departments under the Faculty of Animal Science and Veterinary Medicine: Dairy Science, Histology and Physiology, Microbiology and Parasitology, Animal Production and Management, Poultry Science, Animal Nutrition, Genetics and Breeding, Pathology, Pharmacology and Toxicology, Surgery and Theriogenology and Medicine and Public Health.

Table 5: Solid waste generated from different academic units (per day)

Sources (Department of Faculties)	Volume of waste generated (kg/day)				Total
	Organic	Combustibles	Non-combustibles	Hazardous	
Faculty of Agriculture					
Agronomy	0.20	0.50	0.10	0.25	**1.05**
Horticulture	0.70	0.40	0.10	0.15	**1.35**
Soil Science	0.30	0.30	0.20	0.07	**0.87**
Agricultural Botany	0.50	0.30	0.10	0.07	**0.97**
AEIS	0.15	0.50	0.10	-	**0.75**
Entomology	0.20	0.30	-	0.009	**0.51**
GEPB	0.10	0.30	-	-	**0.40**
Biotechnology	0.20	0.20	-	0.006	**0.41**
Plant Pathology	0.40	0.30	0.20	0.004	**0.90**
AGCH	0.30	0.20	-	0.004	**0.50**
Biochemistry	0.10	0.25	-	0.008	**0.36**
AFES	1.00	0.30	0.20	-	**1.50**
Fisheries	0.10	0.20	-	-	**0.30**
FAME	0.10	0.20	0.20	0.008	**0.51**
Language	0.05	0.20	-	-	**0.25**
Dean office	0.10	0.30	-	-	**0.40**
Total(AG)	**4.50**	**4.75**	**1.20**	**0.579**	**10.13**
Faculty of Agribusiness Management					
AGEC	0.10	0.20	0.10	-	**0.40**
AGMA	0.05	0.10	-	-	**0.15**
MAFI	0.04	0.10	-	-	**0.14**
DEPS	0.06	0.20	0.10	-	**0.36**
AGST	0.02	0.20	0.10	-	**0.32**
Dean office	0.09	0.30	0.20	-	**0.59**
Total(ABM)	**0.36**	**1.10**	**0.50**		**1.96**
Faculty of Animal Science and Veterinary Medicine					
Dairy Science	0.05	0.10	0.10	-	**0.25**
ANHP	0.09	0.30	0.10	-	**0.49**
MIPA	0.10	0.20	0.05	0.007	**0.36**
APMA	0.10	0.10	-	-	**0.20**
Poultry Science	0.05	0.10	-	-	**0.15**
ANGB	0.07	0.10	-	0.006	**0.18**
Pathology	0.05	0.10	-	0.004	**0.15**
PTOX	0.04	0.06	-	0.006	**0.11**
MEPH	0.08	0.09	0.03	0.005	**0.21**
SUTH	0.10	0.20	-	-	**0.3**
Dean office	0.10	0.20	-	-	**0.30**
Central library	0.10	0.20	-	-	**0.30**
Total(ASVM)	**0.99**	**1.85**	**0.32**	**0.028**	**3.19**
Total	**5.85**	**7.7**	**2.02**	**0.607**	**16.18**

Mean	**0.16**	**0.21**	**0.12**	**0.04**	**0.45**
SD	**0.20**	**0.11**	**0.06**	**0.07**	**0.34**

Note. Agricultural extension and information system (AEIS), Genetics and plant breeding (GEPB), Biochemistry, Agroforestry and environmental science (AFES), Agricultural chemistry (AGCH), Agricultural engineering (FAME), Agricultural Economics (AGEC), Agribusiness and Marketing (AGBM), Management and Finance (MAFI), Development and Poverty Studies (DEPS), Agricultural Statistics (AGST), Anatomy, Histology and Physiology (ANHP), Microbiology and Parasitology (MIPA), Animal Production and Management (APMA), Animal Nutrition, Genetics and Breeding (ANGB), Pharmacology and Toxicology (PTOX), Surgery and theriogenology (SUTH), Medicine and public health (MEPH).

Waste was also generated from different academic buildings. The three faculties with thirty two academic departments, Central library in the university contribute to solid waste generation, the maximum of which waste are combustibles like papers.

4.4 Administrative offices

Besides the entire academic unit there were number administrative offices which also take part in regular solid waste generation. The maximum of solid waste that generated from administrative offices were papers.

Plate 4. Administration structure of SAU

Table 6: Solid waste generated from administrative unit (per day)

Sources (Administrative Offices)	Volume of waste generated (kg/day)				Total
	Organic	Combustibles	Non-combustibles	Hazardous	
Registrar office	0.20	0.30	0.20	-	**0.70**
VC office	0.10	0.20	0.05	-	**0.35**
PVC office	0.05	0.10	0.05	-	**0.20**
Accounce office	0.10	0.20	0.02	-	**0.32**
Treasurer's office	0.05	0.10	0.01	-	**0.16**
Controller office	0.05	0.20	-	-	**0.25**
PD office	0.10	0.20	-	-	**0.30**
Engineering office	0.05	0.20	0.10	-	**0.35**
Estate Office	0.10	0.10	0.10	-	**0.30**
TS office	0.10	0.05	-	-	**0.15**
PI office	0.10	0.05	0.10	-	**0.25**
Others: TC,T, etc	0.20	0.10	0.10	-	**0.40**
DB fast truck	0.05	0.20	-	-	**0.25**
Total	**1.25**	**2.00**	**0.73**	-	**3.98**
Mean	**0.09**	**0.15**	**0.06**	**0**	**0.30**
SD	**0.05**	**0.07**	**0.06**	**0**	**0.14**

Note. Vice Chancellors (VC), Pro-vice Chancellors (PVC), Planning and Development (PD), Teachers association (TS), Physical Instructors (PI), Teachers club (TC), Transport (T), Duch Bangle (DB).

4.5 Market places

The university authority developed a number of shops to meet up the regular demand of the residents. All the commercial shops were developed along the major entrance gate first gate and also second gate beside central playing ground. Different student hostels also had their own shops to facilitate them.

A number of shops available in the temporary market of SAU situated at the first gate of the campus and pervez market including vegetable shops, grocery shops, shelon etc. those were the significant source of solid waste.

Vegetable shops were the major source of kitchen waste which falls into organic category. Combustible solid waste, especially paper also generate from grocery shops.

Table 7. Solid waste generated from different market places (per day)

Sources (Commercial places)	Volume of waste generated (kg/day)				Total
	Organic	Combustibles	Non-combustibles	Hazardous	
Parvez market	11.00	4.50	1.80	0.02	**17.32**
TM	50.00	23.00	7.20	0.05	**80.25**
Total	**61.00**	**27.50**	**9.00**	**0.07**	**97.57**
Mean	**30.5**	**13.75**	**4.5**	**0.035**	**48.78**
SD	**27.58**	**13.08**	**3.82**	**0.02**	**44.49**

Note: Temporary market (TM)

4.6 Some common places

Common places include cafeteria, auditorium, religious places, central field, etc which also had a significant contribution of total solid waste generation. Among all these cafeteria generates a large amount of organic and non-combustible solid waste regularly.

Table 8. Solid waste generated from some common places (per day)

Sources(Other common places)	Volume of waste generated per (kg/day)				Total
	Organic	Combustibles	Non-combustibles	Hazardous	
Cafeteria	22.80	1.20	4.20	0.02	**28.22**
Auditorium	1.20	3.50	0.70	-	**5.40**
Mosques	1.00	0.20	0.10	-	**1.30**
Gymnasium	0.50	0.10	0.20	-	**0.80**
Total	**25.50**	**5.00**	**5.20**	**0.02**	**35.72**
Mean	**6.375**	**1.25**	**1.30**	**0.01**	**8.93**
SD	**10.95**	**1.58**	**1.95**	**0.01**	**13.02**

4.7 Street sweeping and drain cleaning

A major portion of total solid waste was collected from street sweeping and drain cleaning. The employees under estate office were engaged to collect waste from street and road around the administrative and academic units and store in the bins. Cleaners sweep the road regularly and clean the drain with interval.

Table 9. Solid waste generated from street sweeping and drain cleaning (per day)

Sources (Street sweeping and drain cleaning)	Volume of waste generated per (kg/day)				Total
	Organic	Combustibles	Non-combustibles	Hazardous	
Roads	9.00	34.50	1.30	-	**44.80**
Drains	5.60	14.20	3.10	0.06	**22.96**
Other gardens	23.20	5.30	0.70	-	**29.20**
Central field	1.20	0.70	0.40	-	**2.30**
Open spaces	3.20	2.30	1.00	-	**6.50**
Total	**42.20**	**57.00**	**6.50**	**0.06**	**105.76**
Mean	**8.44**	**11.40**	**1.30**	**0.012**	**21.15**
SD	**8.75**	**13.93**	**1.06**	**0.03**	**17.30**

4.8 Medical centre

The medical of SAU was very small and solid waste generated very little amount.

Table 10. Solid waste generated from medical centre (per day)

Sources (Medical Waste)	Volume of waste generated (kg/day)				Total
	Organic	Combustibles	Non-combustibles	Hazardous	
Medical	0.30	0.50	-	-	**0.80**

4.9 Total solid waste generation of SAU campus

Table 11. Solid waste generation scenario at SAU campus

Sources	Volume of waste generated (kg/day)				Total
	Organic	Combustibles	Non-combustibles	Hazardous	
Residential units	1106.20	349.30	151.90	2.42	**1609.82**
Student hostels	333.30	87.60	12.0	13.30	**446.20**
AO	1.25	2.00	0.73	-	**3.98**
Academic units	5.85	7.70	2.02	0.607	**16.18**
Market places	61.00	27.50	9.00	0.07	**97.57**
Medical	0.30	0.50	-	-	**0.80**
OCP	25.50	5.00	5.20	0.02	**35.72**
SSDC	42.20	57.00	6.50	0.06	**105.76**
Total	**1575.60**	**536.60**	**187.35**	**16.68**	**2,316.20**
Mean	**196.95**	**67.08**	**23.42**	**2.06**	**289.50**
SD	**383.71**	**118.19**	**52.08**	**4.62**	**553.22**

Note. Administrative offices (AO), Other common places (OCP), Street sweeping and drain cleaning (SSDC)

Table 3 shows the total solid waste generated at Sher-e-Bangla Agricultural University every day. From the above table it has been estimated that, Sher-e-Bangla Agricultural University generated about 2.32 tons of solid waste per day with a per capita of about 0.31 kg/day. Municipal solid waste generation has been recorded much higher in western and some eastern developed countries. Solid waste generation kg/capita/day was found 2 kg in USA, 1.89 kg in Australia, 1.8 kg in Canada, 1.83 kg in Ireland, 1.1 kg in Belgium and Switzerland, 0.99 kg in

Spain, 0.96 kg in Italy, 0.85 kg in 0.85 kg in Mexico and Greece during 1992 as per report and expected to be increased at least 25% by 2005 due to population and economic revolution (Rajput *et a*l., 2009). Total waste generated in the urban areas of Bangladesh per day was 13,332.89 tons and per capita waste generation rate was 0.41 kg/day (Enayetullah *et al*., 2005).

4.10 Evaluation of solid waste generation

4.10.1 Scenario of solid waste generation from residential unit

4.10.1.1 Source contribution of solid waste generation

At SAU campus there were 23 units of teacher quarters, 4 officers quarters and 12 staff quarters. Among them staff quarters contributed maximum portion (73%) of solid waste generation and officer quarters contributed the lowest portion (10%) (Figure 1). Staff quarter generated maximum amount solid waste because staff quarter having huge number of authorized and unauthorized families. But unfortunately most of them are out of formal solid waste disposal system and they disposed their solid waste in the open places which was the main cause of environmental degradation of the SAU campus. Makurdi, an urban city in Benue state, generated a household solid waste of 0.54Kg/capita/day (Sha'Ato *et a*l., 2006). Imam *et al*. (2007) reported between 0.55Kg and 0.58Kg of solid waste per person per day was generated in Abuja. Each household generated on an average 2.193 kg solid waste per day and 0.55 kg per capita per day at SAU campus.

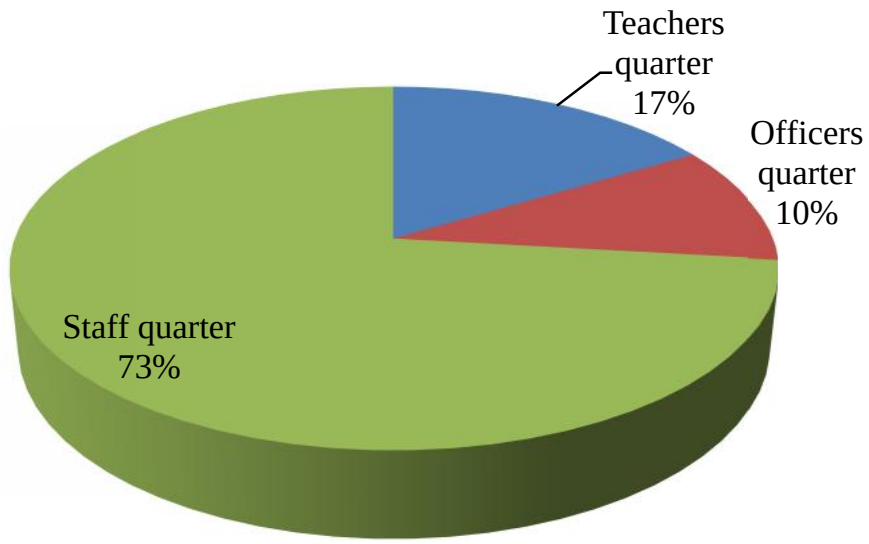

Figure 1. Contribution of different residence quarters on solid waste generation

4.10.1.2 Characteristics of solid waste of residential units

Among the solid waste produced from residential units 68.72% was the organic solid waste. Although hazardous solid waste contributed a very little percentage (0.15%) (Figure 2) of total solid waste in case of residential units but it contributed to more environmental degradation.

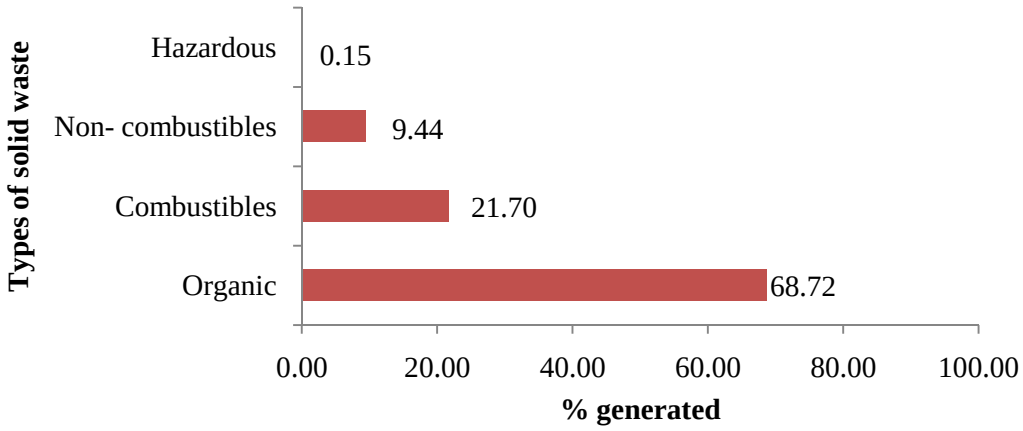

Figure 2. Characteristics of solid waste disposed from residential units

4.10.2 Scenario of solid waste generation from student hostels

4.10.2.1 Source contribution of solid waste generation

There were five student hostels at SAU campus. Among them Kabi Kazi Nazrul Islam Hall contributed the highest part (28%) of solid waste and Sher-e-Bangla Hall also contributed a major part (26%). On the other hand Nabab Siraj-ud-Doula Hall contributed the lowest part (13%) of solid waste (figure 3). In some Nigerian cities as follows: Abeokuta in Ogun state (0.60Kg/person/day), Ado-Ekiti in Ekiti state (0.71Kg/person/day), Akure in Ondo state (0.54Kg/person /day), Ile-Ife in Osun state (0.46Kg/person/day) and Ibadan in Oyo state (0.71Kg/person/day) (Adewumi et al., 2005). Sridhar and Adeoye (2003) reported Nigeria having a population of 120 million generated 0.58Kg solid waste per person per day. The amount of solid waste depended on the number of students lived in the hostels and the average solid waste generated per capita of student was 0.15kg.

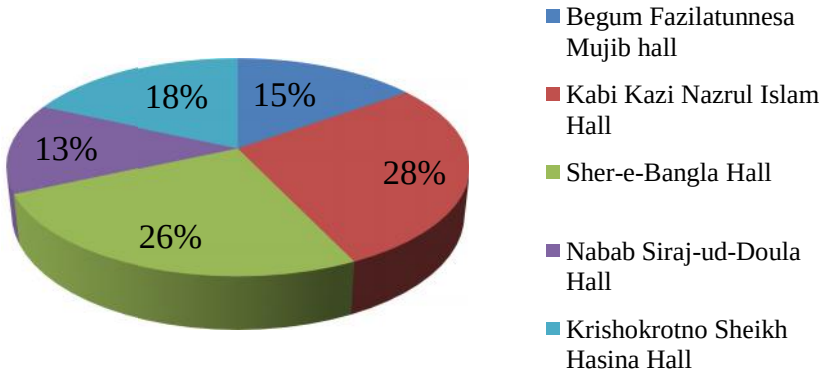

Figure 3. Different student hostels and their contribution on solid waste generation

4.10.2.2 Characteristics of solid waste of student hostels

The figure 4 shows the contribution of solid waste generation from the student hostels according to the solid waste characteristics. Among the solid waste produced from student hostels 74.70% was the organic solid waste. Combustibles solid waste was the second highest portion and the amount was 19.63%. Although

hazardous solid waste generated very small amount (2.98%) but this can cause environmental degradation very dangerously due to its toxic nature. Non-combustible solid waste was the lowest amount (2.69%) produced from student hostels.

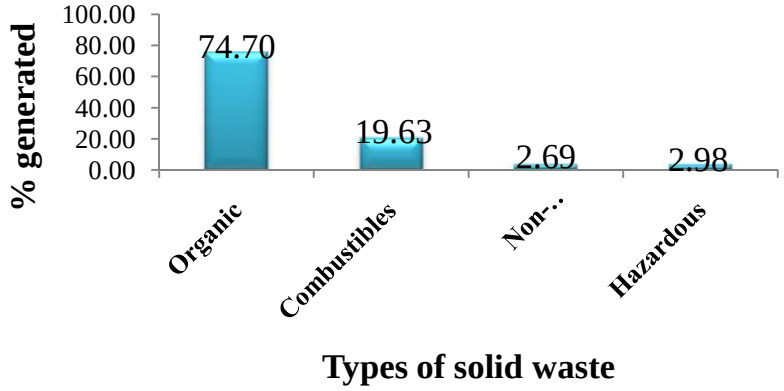

Figure 4. Characteristics of solid waste disposed from student hostels

4.10.3 Scenario of solid waste generation from academic units

4.10.3.1 Source contribution of solid waste generation

Among the three faculties of SAU, Agriculture faculty generated most of the solid waste. It contributed 66% and faculty of Agribusiness Management contributed the lowest portion (13%) of solid waste (figure 5). Agriculture faculty generated the maximum amount of solid waste among three faculties because it had more departments as well as teachers. Another reason was the practical classes in Agriculture Faculty. Most of the Department of Agriculture Faculty used crop/ plant parts during practical classes which contributed more organic solid waste.

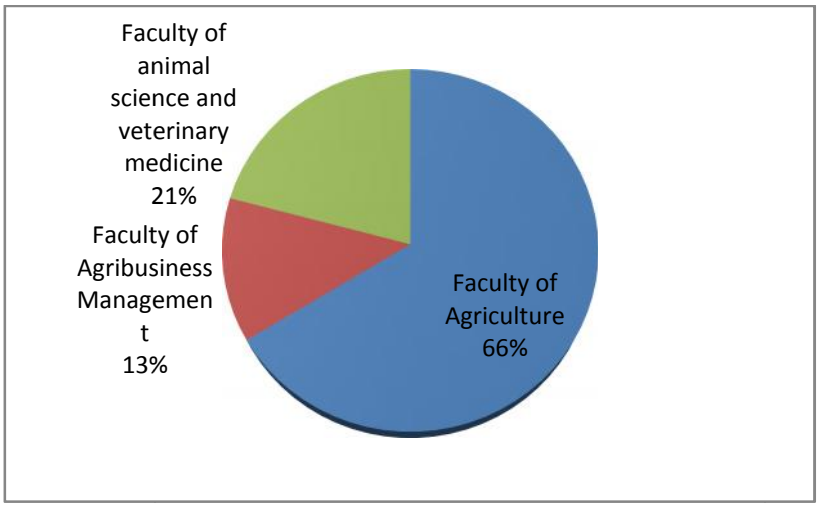

Figure 5. Different faculties and their contribution on solid waste generation

4.10.3.2 Characteristics of solid waste of academic units

The figure 6 shows the contribution of waste generation from the Academic units. According to the solid waste characteristics, combustibles solid waste contributed the highest portion (47.60%) of solid waste generated from academic units. The reason was huge amount of paper was used in different departments. Hazardous solid waste also generated a high percentage (3.75%) compare to other units because of practical classes and farm where different hazardous substances were used.

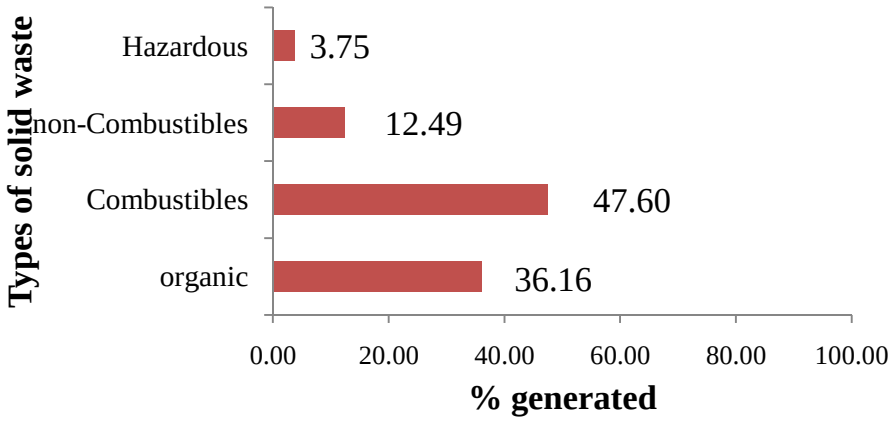

Figure 6. Characteristics of solid waste disposed from faculties

4.10.4 Scenario of solid waste generation from administrative offices

Combustible solid waste contributed maximum portion (50.25%) of solid waste generated in the administrative offices. Combustibles solid waste was the maximum due to use of huge amount of papers in the offices. Hazardous solid waste was not found (0.00%) at administrative offices (figure 7). This unit is free from hazardous solid waste generation.

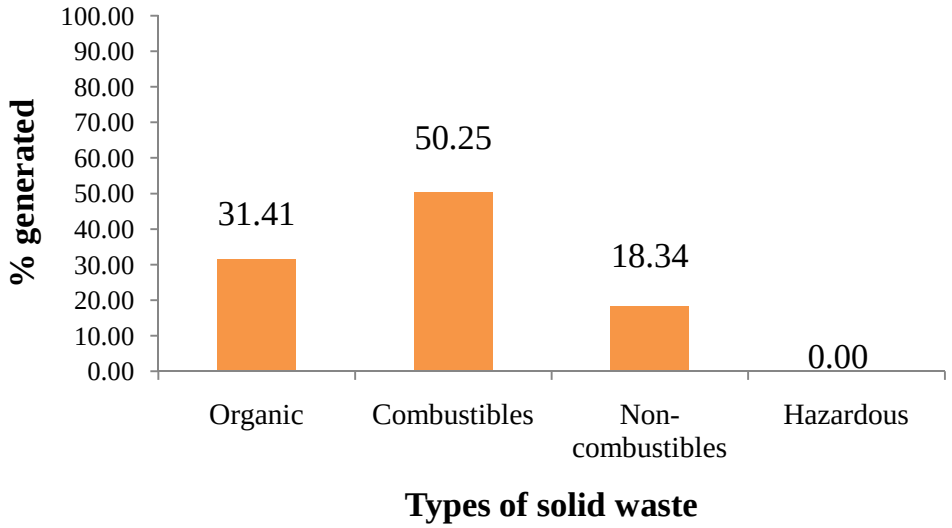

Figure 7. Characteristics of solid waste disposed from administrative offices

4.10.5 Scenario of solid waste generation from market places

Market places of SAU, temporary market generated huge amount of solid waste especially organic solid waste. Among all types of solid waste organic solid waste was the maximum amount (62.52%) and combustibles solid waste generation was 28.18%. Hazardous solid waste was the minimum portion (0.07%) and non-combustibles solid waste 9.22% (figure 8).

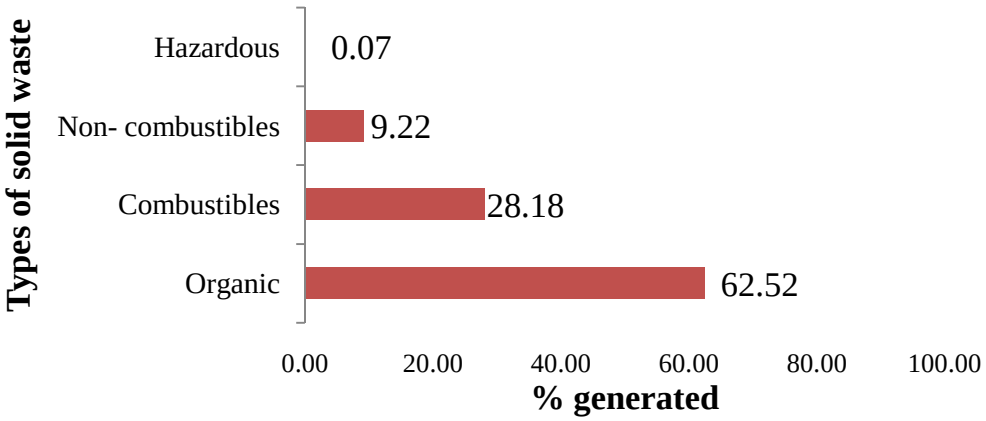

Figure 8. Characteristics of solid waste disposed from market places

4.10.6 Scenario of solid waste generation from some common places

From figure 9, it was found that cafeteria was the main contributor of solid waste generation among the common places and organic solid waste was the major portion (71.39%) of solid waste generated from common places. Non-combustibles solid waste generated higher amount (14.56%) then combustibles solid waste (14.0) due to higher amount of earthen pot used in the cafeteria. Hazardous solid waste was found very little amount (0.06%).

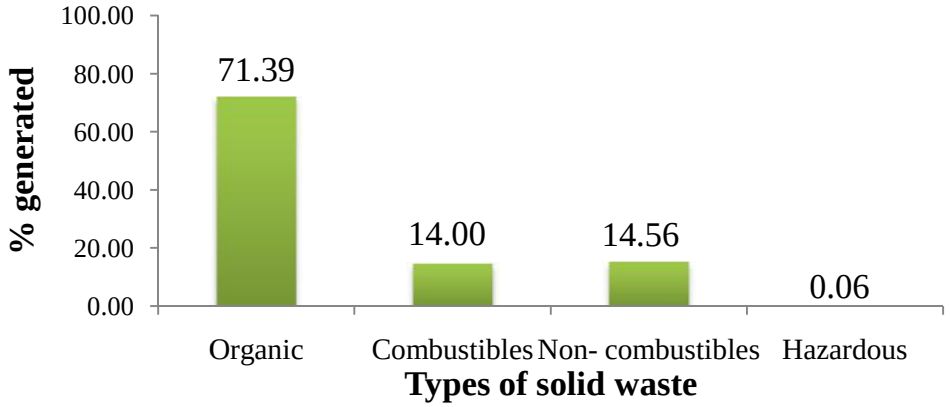

Figure 9. Characteristics of solid waste disposed from other common places

4.10.7 Scenario of solid waste generation from street sweeping and drain cleaning

The figure 10 shows the combustibles solid waste was the highest portion (53.90%) of solid waste generated from street sweeping and drain cleaning and organic solid waste (39.90%). Hazardous solid waste was only 0.06% of total solid waste generated from street sweeping and drain cleaning. Non-combustibles solid waste was 6.15%.

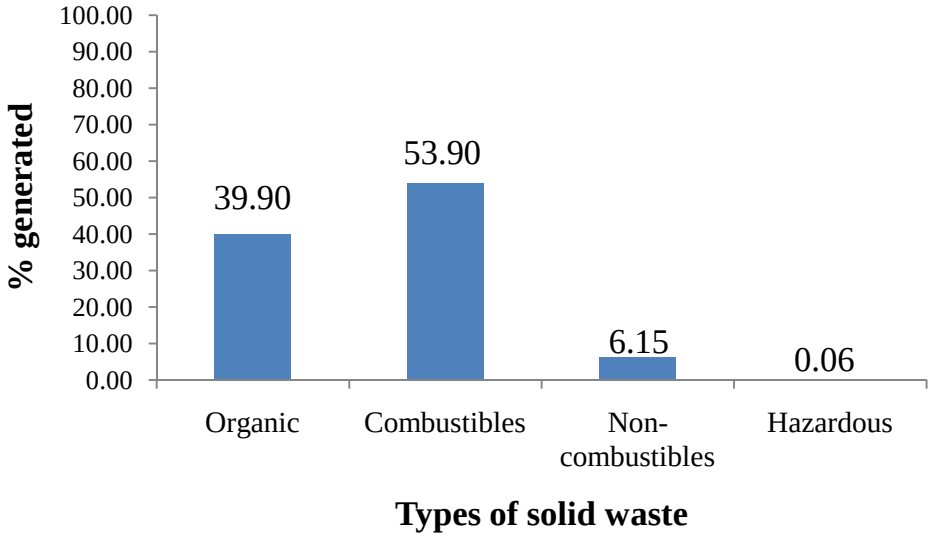

Figure 10. Characteristics of solid waste disposed from street sweeping and drain cleaning

4.10.8 Organic solid waste generation scenario at SAU

Figure 11 shows that among the solid waste generation sources residential units generated most of the organic solid waste (70.21%) and student hostels contributed 21.15%. On the other hand medical contributed the lowest portion of organic solid waste (0.02%) and second lowest was 0.08% which was generated from administrative offices.

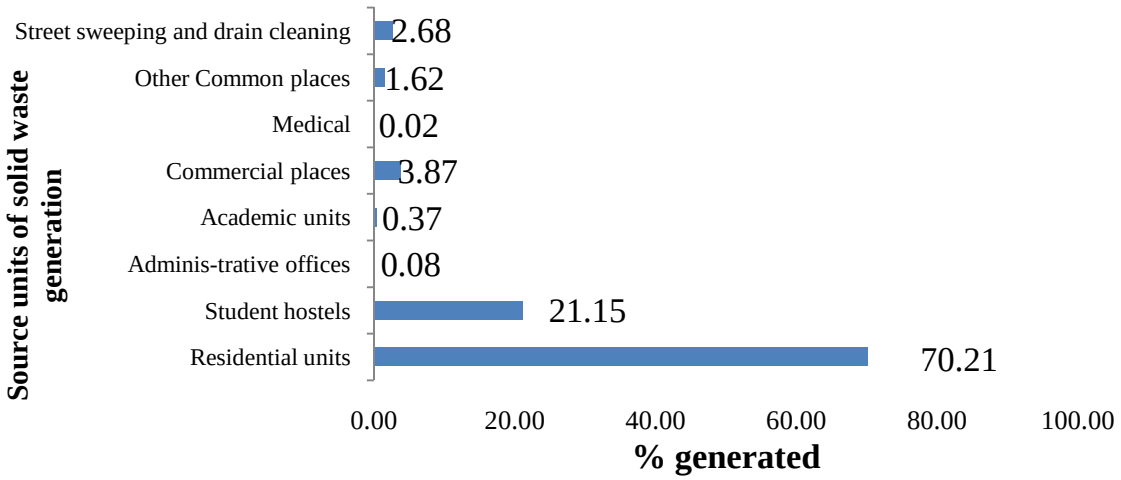

Figure 11. Sources of organic solid waste generation and their contribution

4.10.9 Combustibles solid waste generation scenario at SAU

Residential unit was the highest contributor (65.10%) of combustible solid waste and medical centre is the lowest contributor (0.09%) of combustibles solid waste generation. Student hostels and street sweeping and drain cleaning had also enough contribution of combustibles solid waste generation. As well as market places contributed 5.12% of combustibles solid waste (figure 12).

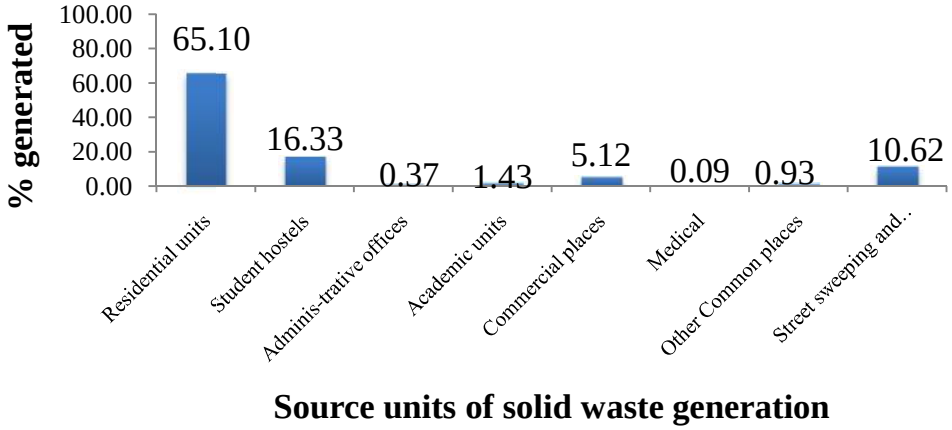

Figure 12. Sources of combustibles solid waste generation and their contribution

4.10.10 Non-combustibles solid waste generation scenario at SAU

The highest portion of non-combustibles solid waste generation occurred in the residential unit which was 81.08%. Medical unit did not generate any non-combustibles solid waste. Student hostels and commercial places contributed 6.41% and 4.80% respectively (Figure 13). Other solid waste generation units contribute very little portion of non-combustibles solid waste.

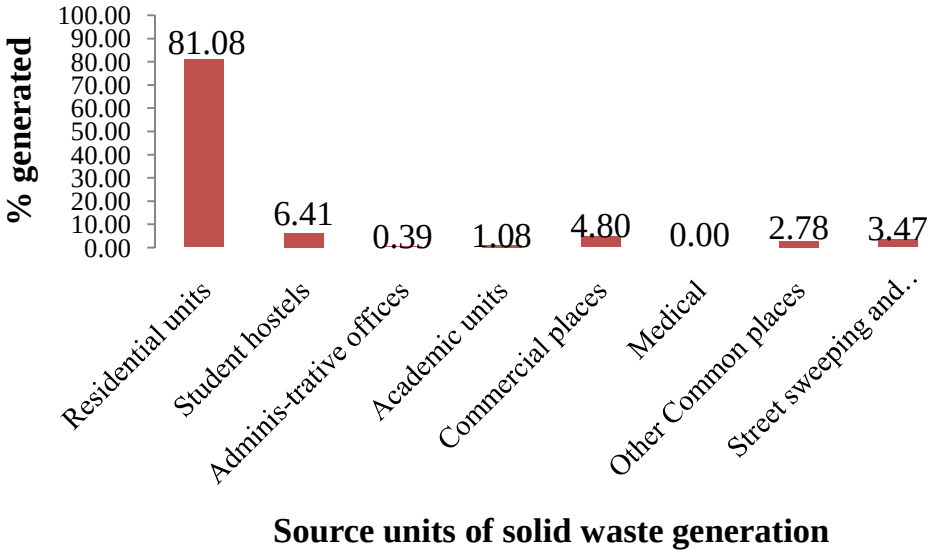

Figure 13. Sources of non-combustibles solid waste generation and their contribution

4.10.11 Hazardous solid waste generation scenario at SAU

From figure 14, it was found that student hostels were the major contributor of hazardous solid waste generation. This unit generated 79.75% of total hazardous solid waste where residential unit and academic unit contributed 14.51% and 3.64% of hazardous solid waste respectively. Other solid waste generation source units generated very negligible portion of total hazardous solid waste.

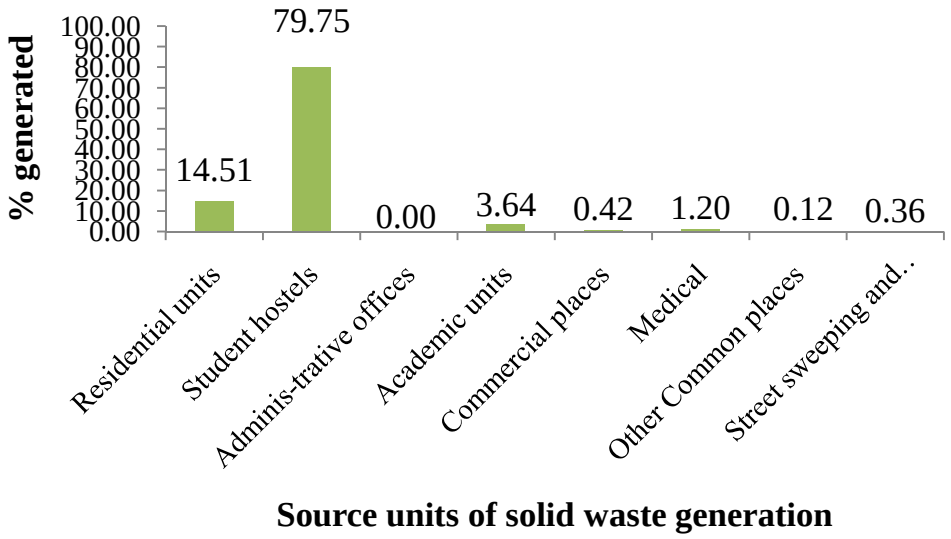

Figure 14. Sources of hazardous solid waste generation and their contribution

4.10.12 Scenario of solid waste generation at SAU

4.10.12.1 Source contribution of solid waste generation

Figure15 shows the contribution of solid waste generation from different source units. Among all the source units residential units generated the maximum amount of solid waste (69.50%). Student hostels contribute 19.26% and different academic and administrative offices have 0.70% and 0.17% respectively. Market places constituted 4.21% of the total solid waste generation where 4.57% of solid waste also accumulated through street sweeping and drain cleaning. A very few portion was generated from the medical centre.

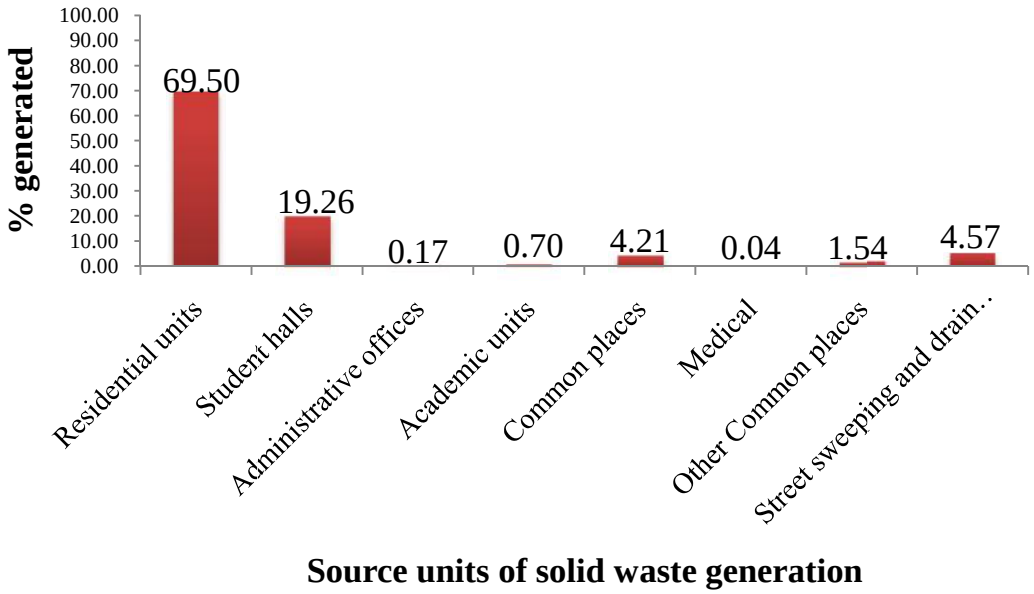

Figure 15. Sources of total solid waste generation and their contribution

4.10.12.2 Characteristics of solid waste

The trend of solid waste generation indicates that kitchen and vegetable waste constituted the major portion of waste being disposed from households, different student hostels and hotels in commercial places. The amount of paper, dry leaves, plastic items, etc were comparatively greater than other waste. Although the quantity of hazardous solid waste generated regularly was very little but there was no proper disposal neither any treatment system to manage. A substantial portion (69% to 77%) of solid waste in the urban areas is compostable. Average compostable content of the waste is 74% with the remaining 26% being non-compostable. (Enayetullah *et al*., 2005). At SAU campus among four types solid waste organic solid waste contributed the highest portion (68%) and hazardous solid waste contributes the lowest portion (1%) (Figure 16). The average quantity of solid waste generated by each household is organic 3.50 kg, combustibles 0.50 kg, non-combustibles 0.25 kg and hazardous 0.002kg (Haque, 2011).

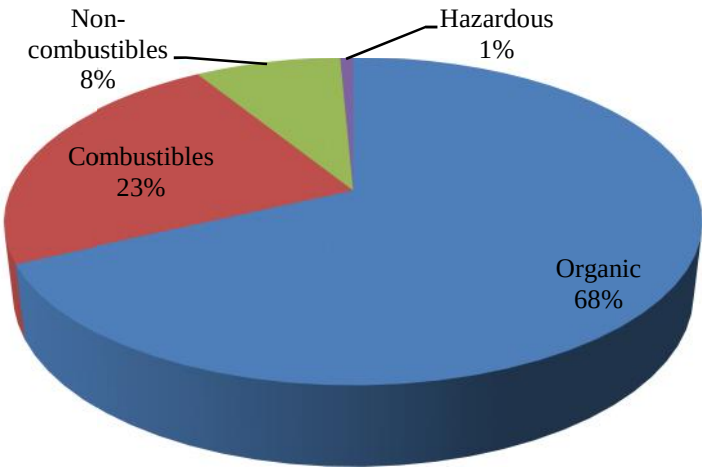

Figure 16. Characteristics of solid waste disposed from Sher-e-Bangla Agricultural University

4.11 Existing solid waste management system of SAU

4.11.1 Primary storage of solid waste

Solid waste generated from different units at SAU. At first the producer stored the solid in the plastic bucket especially in the residential units and student hostels without separating as its classification. In case of administrative unit, academic units and road and drains some recruited staff collected the solid waste and stored in the dust beans. But in some cases especially in the market places and road site the solid waste producer threw here and there indiscriminately.

4.11.2 Collection and transportation of solid waste

Estate department was responsible for collection and transportation of solid waste. Estate department recruited 4 staff and provide 2 vans for removal of solid waste from the solid waste generating units to final disposal site. But the staffs were not assigned to collect the solid waste from the whole area of SAU campus. They are assigned to collect the solid waste from some specific area (academic units, administrative unit, two student hostels, a small portion of residential units, a

small portion of roads and drain sites) and most of the area was remained out of collection of solid waste. They collect the solid waste every day.

Plate 5. Pictures of solid waste collection, transportation and disposal system at SAU

4.11.3 Disposal system of solid waste

After collection of solid waste they disposed the solid waste at the final disposal site which was situated at the south-east corner of the SAU campus. But from where solid waste was not collected by the recruited staffs, the solid waste was disposed by the producer without maintaining any rules and regulation. They disposed indiscriminately beside the solid waste generating area especially in the low land and water bodies, roads sites and drains. At SAU campus about 28 solid waste disposal sites situated. But only one solid waste disposal site (south-east corner of SAU campus) is permitted and all most all the disposal sites (27) have no permission for solid waste disposal. With an interval the solid waste was incinerated openly under the open sky.

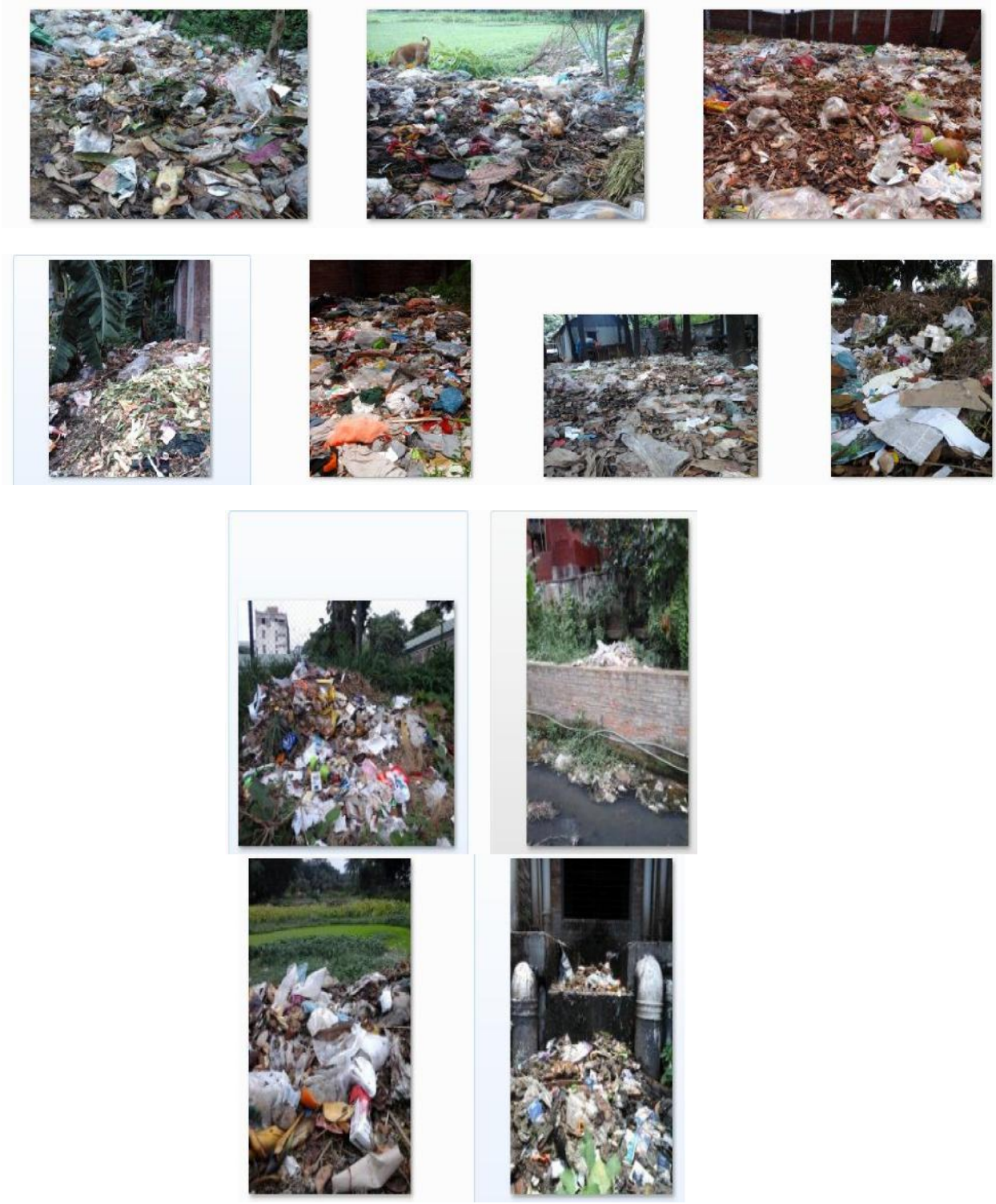

Plate 6. Pictures of various solid waste disposal sites of SAU

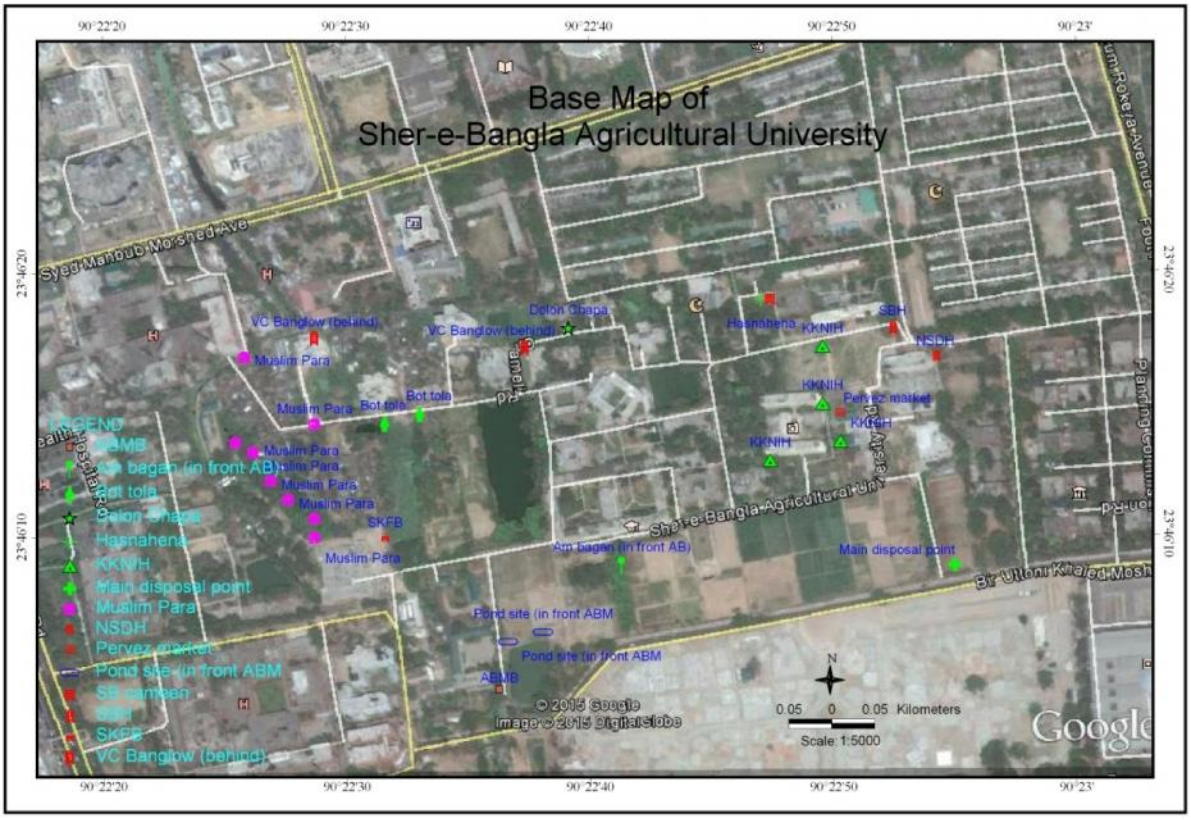

Plate 7: Map of Sher-e-Bangla Agricultural University showing the solid waste disposal sites

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summery

The study area consists of a number of different land use all of which contributes to regular solid waste generation, but their significance varies from each other. Residential units show maximum contribution to the total solid waste generation.

a. Sher-e-Bangla Agricultural University generated 2.32 tons of solid waste per day with a per capita of about 0.31 kg/day.
b. The average quantity of solid waste generated by each household was Organic: 1.51 kg, Combustibles: 0.47 kg, Non-combustibles: 0.21 kg, Hazardous: 0.003kg kg and an average total of 2.193 kg/day.
c. Solid wastes were primarily stored by the users. Plastic bucket are usually used for the initial storage of the solid waste. At storage stage solid waste were not segregated into kitchen waste and others (combustibles and non-combustibles and hazardous).
d. In case of household, solid waste were primarily collected by servants or family members for onsite disposal. But in academic, administrative offices, residential hostels and other offices, waste are collected by different employee appointed by the authority.
e. In some areas, there was a formal transportation facility for transfer the solid waste to the final disposal area.
f. Solid wastes were disposed without proper disposal method. Burring or incineration is often used.

5.2 Conclusion

The existing solid waste management system of Sher-e-Bangla Agricultural University was not at satisfactory level. Now a day's solid waste management is an important issue for enhancing environment. The environment in part of the study area bearded signs of polluted environmental condition because of the accumulated uncontrolled garbage on the roads, open spaces adjacent to the living area and drains filled with solid waste. It requires staff that is continually learning new strategies, complying with government regulations and adapting and advancing techniques of solid waste diversion, collection and disposal. To comply with the ever-growing concern about sustainable" environment, the management of solid waste should be considered with due importance. Destiny of our future lies on the betterment of the environment and it is the high time to resist the environmental degradation to ensure a better living condition.

Recommendation

1. Proper arrangement of on-site disposal facilities with assurance of regularity in collection and transportation of solid waste from the bins and primary dumping sites.
2. Improvement of existing supports facilities ranging from efficiency of the manpower to the quality of other support facilities is required.
3. Increase awareness to the people about the resource recovery from the solid waste. Strong community intervention and integration is also needed.
4. Liaison should be maintained with Dhaka Uttor City Corporation for regular removal of solid waste from final disposal site.
5. Manure should be produced by using organic solid waste.
6. Besides all these, there should be compatible adequate monitoring system and policy regulations to guide the solid waste management system of the study area.

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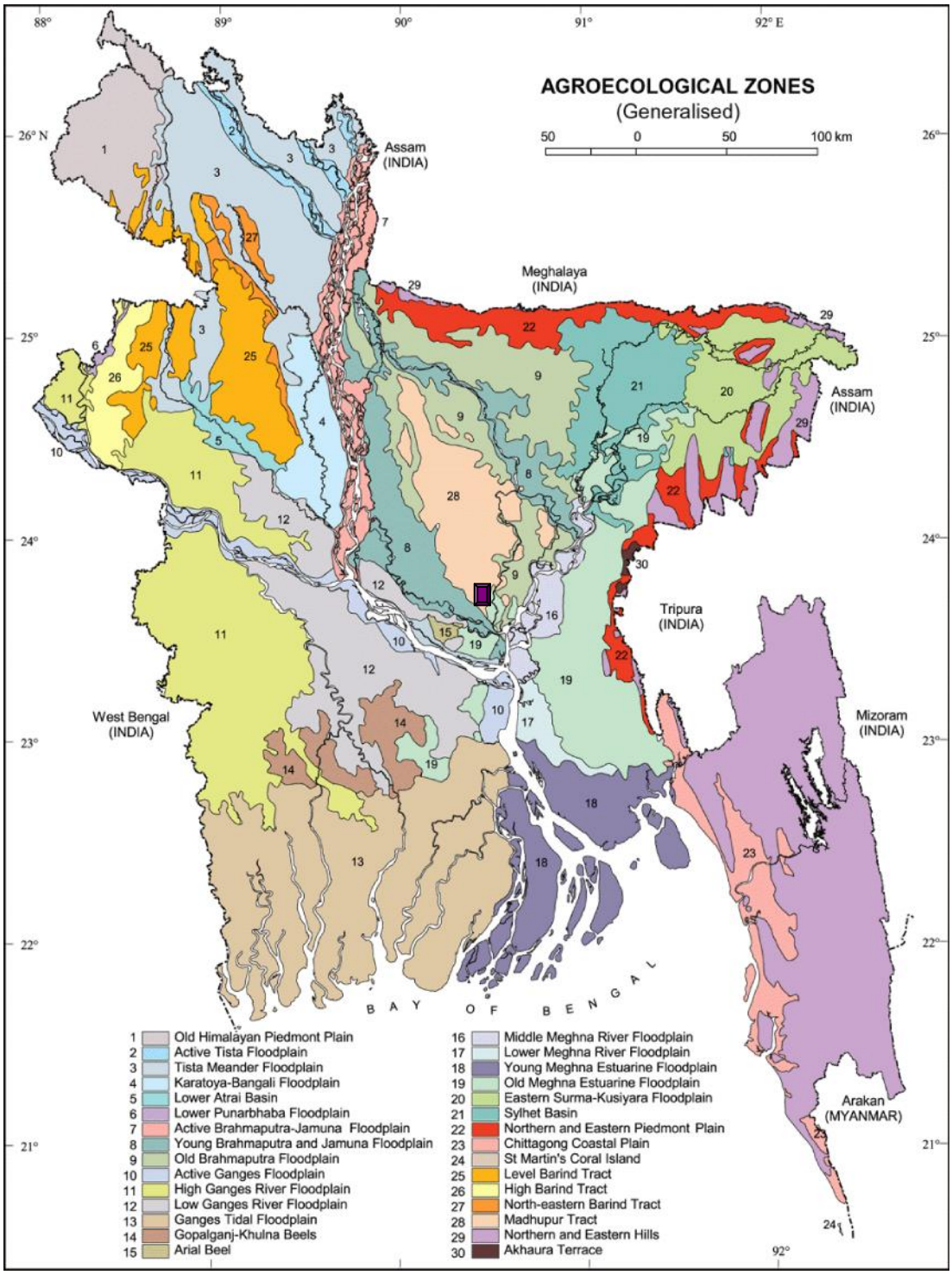
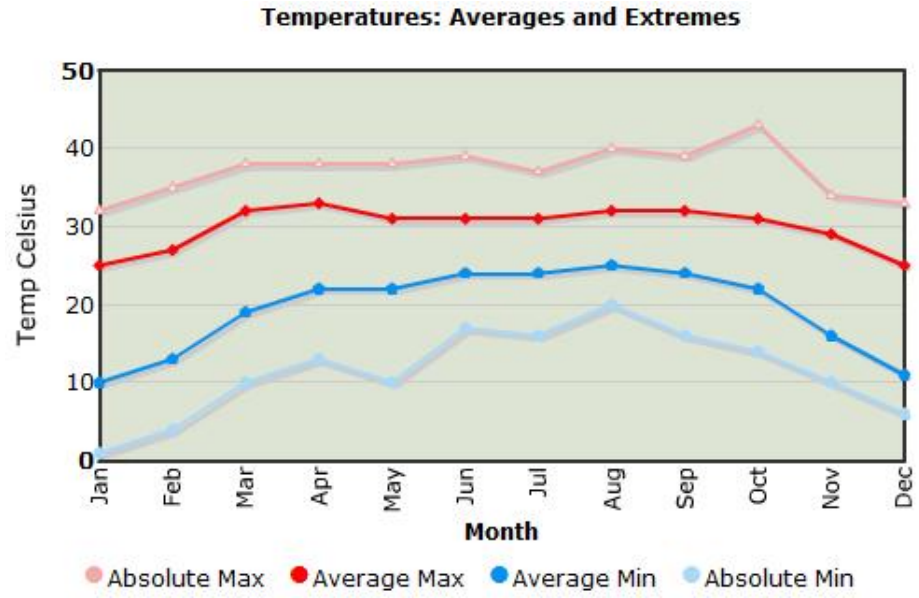
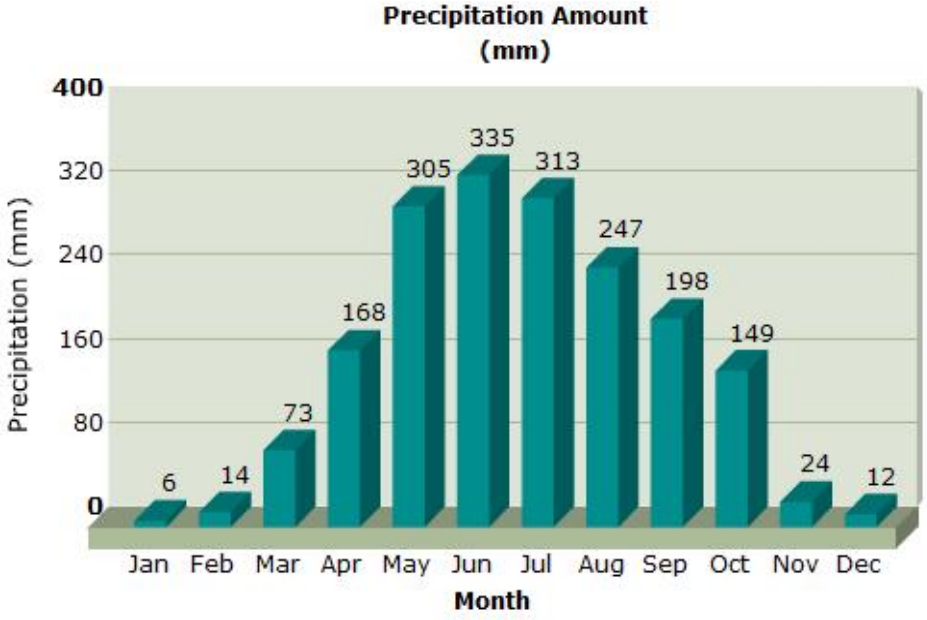
APPENDICES

Appendix I. Experimental location on the map of Agro-Ecological Zones of Bangladesh



Appendix II. Yearly trends: weather averages & extremes, Dhaka





Source:http://www.myweather2.com/HolidayDestinations/Bangladesh/Dhaka/climate-profile.aspx?month=10

Table 12: GPS location of solid waste disposal sites at Sher-e-Bangla Agricultural University campus

SL No.	Location	Latitude	Longitude
1	Am bagan (in front AB)	23.77058	90.37525
2	Pond site (in front ABM)	23.76986	90.37444
3	Pond site (in front ABM)	23.76975	90.374
4	ABMB	23.76928	90.37389
5	SKFB	23.77086	90.37261
6	Muslim Para	23.77089	90.37183
7	Muslim Para	23.77108	90.37175
8	Muslim Para	23.77125	90.37153
9	Muslim Para	23.77147	90.37131
10	Muslim Para	23.77175	90.37108
11	Muslim Para	23.77189	90.37094
12	Muslim Para	23.77208	90.37181
13	Muslim Para	23.77275	90.37097
14	Bot tola	23.77214	90.37264
15	Bot tola	23.77222	90.37297
16	VC house (behind)	23.77294	90.37419
17	VC house (behind)	23.77303	90.37181
18	Dolon Chapa	23.77306	90.37472
19	Hasnahena	23.77336	90.37686
20	SB canteen	23.77342	90.37703
21	SBH	23.77311	90.37844
22	NSDH	23.77278	90.37886
23	KKNIH	23.77294	90.37761
24	KKNIH	23.77228	90.37764
25	Pervez market	23.77222	90.37775
26	KKNIH	23.77186	90.37775
27	KKNIH	23.77167	90.377
28	Main disposal point	23.77056	90.37914