Study on Planning and Design of Transfer Station for Municipal Solid Waste Management in Khulna City of Bangladesh

by

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Declaration

This is to certify that the thesis work entitled as "Study on Planning and Design of Transfer Station for Municipal Solid Waste Management in Khulna City of Bangladesh" has been carried out by Iffat Jahan in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above research work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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This is to certify that the thesis work submitted by Iffat Jahan entitled as "Study on Planning and Design of Transfer Station for Municipal Solid Waste Management in Khulna City of Bangladesh" has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh in January 2011.

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Dedication

Dedicated to my Parents

Md. Fakhruddin
&
Mrs. Kamrunnahar

ABSTRACT

The present scenario of municipal solid waste (MSW) management in Khulna City is not satisfactory and poses a great threat to human health and nature. The Secondary Disposal Site (SDS) is causing much nuisance to both traffic flows and neighborhood, and deteriorating city environment. Realizing the present situation of MSW management, it is evident that there is a strong need to change the present secondary disposal system. These problems can be solved by removing these disposal sites with a well designed Transfer Station (TS) Networks. This study highlights the adaptation of transfer station methodologies, sitting, planning and design of transfer station (TS) in Khulna City Corporation (KCC). The study enlightens the planning of TS considering sitting guidelines, location of TS, buffer zones and design of TS .From the study 18 TS location points have been identified on the basis of one km buffer zone and eight numbers of location points for TS have been found out on the basis of two km buffer zone. The location points are summarized as Mirerdanga, Maniktala, Moheshwar pasha, Daulatpur, Khalishpur, Alamnagar, Mongla Port Area, Mujgunni, Rayermahal, Choto Boyra, Nirala, Shibbari Mor, Tootpara, Labonchara, Deana, Boyra, Sonadanga and Rupsha. Again, on the basis of two km radial distance, KCC map has been subdivided into eight influence areas showing eight location points which are Mirerdanga, Shahipara, Daulatpur, Khalishpur, Choto Boyra, Sheikhpara, Tootpara and Labonchora. Total population of KCC areas 11, 74,648 having generated waste of 406 tonnes/day and wastes to be deposited in TS be 370 tonnes/day. From the study, three types of TS have been designed (TS with ramp, TS with conveyor belt and TS with hydraulic lift having covered or uncovered facilities) considering minimum land area, estimated waste to be hauled at TS, types of vehicles used in TS, mechanisms used in TS, size, capacity and availability of primary and secondary collection vehicle, capacity of demountable containers, hours of operation, sufficient space for movement of truck, and other facilities involved in the facilities of TS. The involvement of private sectors from home and abroad and city authorities can evaluate this study to come forward by solving this issue with sustainable technology and finance. In this context, Bangladesh can get the advantages by bringing foreign investment to convert the SDS into sustainable TS setup successfully based on the socio-economic settings and technological capabilities.

Table of Contents

List of Tables

List of Figures

List of Boxes

Abbreviations

ADP	Annual Development Programme
ARRPET	Asian Regional Research Program on Environmental Technology
CB	Community Bin
CBO	Community Based Organisation
CDIA	Cities Development Initiative for Asia
CDM	Cleaner Development Mechanism
DBP	Dustbin Points
DoE	Department of Environment
DtD	Door-to-door collection
GIS	Geographic Information System
HIS	Indian Health Service
HRD	Human Resource Development
KCC	Khulna City Corporation
KDA	Khulna Development Authority
KCPA	Khulna City Project Area
M(o)LGRDC	Ministry of Local Government, Rural Development & Cooperatives
LDACs	Least Developed Asian Countries
LGED	Local Government Engineering Department
NGO	Non-Governmental Organisation
PSSL	Pilot Scale Sanitary Landfill
RCRA	Resource Recovery and Conservation Act
SDS	Secondary Disposal Site

SMEs	Small and Medium Enterprises
SWMD	Solid Waste Management Department
SAP	Sector Analysis Paper (for SWM)
SMEs	Small and Medium Enterprises
TS	Transfer Station
UDS	Ultimate Disposal Site
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER I

Introduction

1.1 General

Solid Waste Management has so far been ignored and least studied environmental issues in Bangladesh, like in most developing countries. However, recently the concerned stakeholders have begun to consider this area to be an inseparable part to protect human and nature. Affluent industrialized economies are facing an ever–increasing load of wastes and declining landfill space to dispose of these materials. Due to absence of an integrated system, there are many loop holes and constraints in the existing waste management practice, which ultimately failed to improve the overall system. Sustainable management of waste with the overall goal of minimizing its impact on the environment in an economically and socially acceptable way is a challenge for the coming decades. The safe and reliable long-term disposal of solid wastes is an important component of integrated waste management.

The present scenario of solid waste management in Khulna City is not satisfactory. During the last few decades, the problem of MSW management has shown an alarming dimension in the developing countries. In the rapidly growing cities of developing countries like Bangladesh, due to lack of proper management, lack of people's awareness, motivation and participation, inappropriate technology, ineffective legislation, financial constrains and law enforcement municipal solid management possesses a great threat to human health and nature and has been regarded as one of the major issues to the city authority.

This study highlights the present situation of MSW, existing management of MSW, transfer station methodologies, planning, zoning and design of transfer station (TS) for efficient waste handling capacity and in compliance with environmental standards and guidelines followed by the acts and other regulations. The proposed study locations of KCC area is about 45.65 sqkm but the future extended area of Khulna City projected area (KCPA) will be around 70 sqkm. Basic principles for the planning and design of TS should be in the maximum distance of two km from the door to door (DtD) collection considering minimum public or environmental objection. One and two km radial distance have been evaluated in this study to draw buffer zone on data based KCC map by using Geographic Information System (GIS) to compare which one serves more satisfactorily. In case of door to door collection system, rickshaw vans will be preferable to use. Manual labor intensive system should also be introduced. Transfer Station should be able to handle the waste comes from the catchments and waste should be protected from monsoon rains. So, the TS should be located near the center of waste catchments areas with an access road adequate for heavy trucks where rickshaw vans will be considered as the major transporting vehicles of waste. Ramps (which are not motorized), hydraulic lift systems suitable for use by rickshaw vans, conveyor belt systems to convey the wastes without lifting or moving the rickshaw van, the use of demountable containers and the consideration of social conditions of the area are all required. The planning and sitting of transfer station will depend considering the land use plan, population, waste generation rate, proximity to collection area, amount of waste deposition and accessibility of haul routes to disposal facility considering future perspective. Considering all the above parameters, TS should be planned and designed in convenient locations in a proper manner that would meet technical requirements and minimize any adverse impacts to the neighboring communities. From the present situation of waste management system, it was recognized that there is a need to change the present secondary disposal system and it will be a transfer station, which can make a change in the present scenarios.

1.2 Background of the Study

Solid Waste management is indispensable, especially in densely populated urban areas for a clean, healthier environment, appropriate and sustainable method. In most of the least developed Asian Countries (LDACs) including Bangladesh, municipal solid waste (MSW) remains unmanageable and is one of the striking issues, environmentally and socially (WasteSafe, 2005). In Bangladesh, specifically in the urban areas, appropriate measures for waste disposal are urgently needed due to the rapid population growth, which resulting the huge increase of MSW. Indiscriminate throwing of solid waste by the generators at the waste collection stations and improper collection system have resulted in scattered garbage, offensive odor, polluted water and breeding place for mosquitoes and flies. The sanitary environment in the urban areas has deteriorated causing adverse impacts on the health of the residents. Furthermore, partially collected wastes are disposed unscientifically at the final disposal site in an open low-lying areas or abandoned land, even along the roads, causing serious adverse environmental impacts, which threat to human and nature.

The most important tier of MSW management is the secondary disposal of solid waste of the currently available and poorly managed community bin (CBs), Secondary Disposal Site (SDSs) and dustbin point (DBPs). Realizing the present situation of MSW management, it is evident that there is a strong need to change the present secondary disposal system. SDS is considered as the facilities where large amount of wastes are accumulated and finally transferred to the desired sites by large vehicles such as open or closed Trucks, Demountable haul container, roadside spaces and unused open-lying areas (Chowdhury and Alamgir, 2006). However, it is true that even having these constraints the overall situation of solid waste management in Khulna city could be improved introducing a sustainable system (SAP 2008). These problems can be solved by removing these unmanaged and unpleasant sites with a well designed Transfer Station (TS) Networks. In true sense there is no TS in Bangladesh.

A transfer station is defined as a solid waste processing site where solid waste is transferred from one vehicle to another vehicle or storage device for temporary storage until transferred to a permanent disposal site approved the solid waste management authority or permitted by

any other solid waste management authority having jurisdiction over the location of their permanent disposal site. Waste transfer stations play an important role in a community's total waste management System, serving as the link between a community's solid waste collection program and a final waste disposal facility. However, transfer station schemes face a number of requirements, such as adequate finance, appropriate technology, sufficient land, proper location, assured supply and consistency of waste streams, design, and operation and maintenance facilities. These aspects should be incorporated properly in coherent way in the planning and design process of Transfer Station to solve the ongoing MSW management problems in Khulna City.

1.3 Objectives of the Study

1) To observe the present scenario of solid waste management in Khulna City.
2) Apply the sitting criteria to evaluate potential transfer station sites.
3) To identify the location of transfer station Using Geographic Information System (GIS).
4) Design of typical Transfer Station (TS).
5) To propose an acceptable and sustainable transfer station technology for Khulna City in Bangladesh.

1.4 Organization of the Thesis

The report consists of six chapters. Chapter 1 provides background information about municipal solid waste system and has set out the problem formulation, objectives, scope and limitation of the study area and the research framework. Chapter 2 encompasses the Literature review of the thesis includes waste definition, types, sources, necessity and goal of MSW management, present situation of on-site storage in Bangladesh, Transfer Station, need for constructing TS, benefits, use of TS, types of TS, TS systems, transfer technology of TS , planning guidelines of TS, types of waste accepted and unaccepted, and necessity of TS in Bangladesh. Chapter 3 deals with the overview of the study area, scenario of Secondary Disposal of Waste and the existing solid waste management system. This is

achieved through a theoretical description concerning location, city layout, geology, population, socio-economic condition, environmental condition, land use and infrastructure, nature of municipal solid waste generation, storage collection, transport and disposal systems adopted and overall practices executed in Khulna City Corporation. Informal management system is reviewed as well as household participation involvement of NGOs, CBOs and private sectors and behavior in household solid waste management system. Chapter 4 analyzes methods and materials of TS and recent research of TS. Chapter 5 comprises of planning and location of TS, TS design, types of vehicles used in TS, sizing of TS, facility operating hours, interacting with the public and overall TS facilities. Chapter 5 presents result and discussion and sustainability of TS and chapter 6 shows an evaluation of objectives, as well as the conclusions and recommendations. It also identifies limitations of the study and provides recommendations for further research.

1.5 Limitations of the Thesis

The limitations faced in this research are mainly reliable data and length of the study period. Population census was last counted in 2001. As a result, population was not counted properly. Population density and waste generation rate also varied with these relevant data. Besides GIS data based map was not up to date. That's why, the proposed extended area of KCC has not been considered to find out the layout of TS.

CHAPTER II

Literature Review

2.1 General

Waste is an integrated part of our daily life. It is produced at all levels of human activities. In the recent years, waste generation and its management is an issue concerned to all stakeholders due to its social and environmental impacts. This section describes the fundamentals of wastes, present situation of solid waste management (SWM) and perspectives of TS.

2.1.1 Definition of Waste

Concise Oxford Dictionary provides the definition of 'waste' as lack of use or value, or 'useless remains'. Waste means unnecessary depletion of natural resources, redundant costs and environmental damage that could be avoided. It is the by-product of human activities which no longer has any value to its original owner and which is discarded. Therefore, waste is a material considered useless and unwanted. It is generally solid. Physically, it contains the same materials as are found in useful products; it only differs from the useful production by its lack of value.

2.1.2 Types of Solid Waste

Solid wastes can be classified by a multitude of schemes in terms of:

- physical state (solid, liquid, gaseous)

- by original use (packaging waste, food waste, etc.)
- by material (glass, paper, etc.)
- by physical properties (combustible, compostable, recyclable)
- by origin or source (domestic, commercial, agricultural, industrial, etc.)
- by safety level (hazardous, non-hazardous).

As the municipal solid waste (MSW) is the most concerned type of wastes in the urban areas due to its source, nature and quantity, this paper will mainly concerns MSW.

2.2 Sources of MSW

Municipal solid waste (MSW) are the heterogeneous composition of wastes, organic and inorganic, rapidly and slowly biodegradable, fresh and putrescible, hazardous and non-hazardous, generated in various sources in urban areas due to human activities (Ahmed and Rahman 2000). Table 2.1 shows the types of MSW with various sources.

Table 2.1 Types of MSW associated with various sources within a community

Sources	Typical waste generators	Types of solid wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes & household hazardous wastes.
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes.
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special and hazardous wastes,
Institutional	Schools, hospitals, offices.	Same as commercial.

Construction and demolition	New construction, road repair, renovation, buildings demolition	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, recreational areas, water and wastewater treatment plants.	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge.
Process (manufacturing, etc.)	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing.	Industrial process wastes, scrap materials, off-specification products, slay, tailings.
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms.	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides).

Source: **Daniel with L. Thomas. 1999.**

2.3 Goal of MSW Management

The objective of proper waste management is to make every municipal authority responsible for the implementation of the various provisions and also to develop an effective infrastructure for collection, storage, segregation, transportation, processing and disposal of MSW. The goals of proper solid waste management can be listed as the followings:

(a) to ensure the protection of the public health and environment;

(b) to utilize valuable resources and encourage resource conservation and recovery;

(c) to avoid waste generation and volume reduction through source reduction and waste minimization measures, including composting, recycling, re-use, recovery, and others;

(d) to ensure segregation, collection, transport, storage, treatment & disposal of solid waste;

(e) to improve solid waste management and resource conservation techniques;

(f) to encourage greater private sector participation in solid waste management;

(g) to establish cooperation among national/local governments, NGOs and private sectors;

(h) to encourage cooperation and self-regulation among waste generators;

(i) to institutionalize public participation in the waste management programs; and

(j) to strengthening academic curricula to promote awareness among the citizens.

2.4 Needs of Safe and Sustainable Management

MSW is one of the sectors which makes hazards and nuisance in the daily urban life and creates the path of long terms adverse environmental impacts if not managed safely and properly. As the MSW is an inevitable consequence of human activities in any economy, a system needs to develop and implement which is environmentally safe, socially acceptable, economically viable and sustainable. The ultimate goal of waste management is the absence of waste, i.e. to get rid of it, to use it as a resource, or not to have it in the first place. Waste management in the narrow sense directs the flows of materials so that their impact on the environment, the depletion of resources, and the resulting costs are minimized. As the solid waste management is very complex in nature due to the involvement of very diversified actors, a safe and sustainable system needs to practice in a pragmatic way of setting priorities is to minimize the total impact of waste on the environment, i.e. the impacts on water, air, soil have to be minimized as well as the consumption of energy, materials and landfill space. Some objectives appear to be crucial for safe and sustainable waste management:

- Protection of health and the environment;
- Conservation of resources such as materials, energy, and space;
- After-care-free waste management, meaning that neither landfills nor incineration, recycling or other treatments leave problems to be solved by future generations.

2.5 Present Situation of On-site Storage in Bangladesh

On-site storage can be classified as the secondary disposal site (SDS), transfer station (TS) and handover point, which receives wastes from primary sources and transfers to the designated locations for processing/recycling/treatment and mostly for ultimate disposal. In Bangladesh city authority is solely responsible for providing SDS. They collect wastes from SDS and transfers for final disposal as per existing City Corporation Act. These sites are located in the selected places based on population, space availability, accessibility and other unseen factors. Wastes are deposited in SDS directly by the generators, NGOs, CBOs and city authorities. In some cases, especially for the residential areas along narrow streets, where SDS is not suitable, community bins are provided from where wastes are transferred to SDS. The wide variety of types and shapes of community bins are built by the civic bodies and/or authority, which are located on the roadside at frequent intervals. Community bins are mostly made of concrete but masonry and steel container are also available. The concrete and masonry bins are in variable sizes but normally rectangular in shape of one meter wide, one meter high and one/two meter long. Generally there is a door at one side and no cover on the top of the community bins. Wastes from community bins are transferred to SDS mostly by city authorities through non-motorized, rickshaw van and hand trolley.

In DCC areas, there are more than 846 SDS, 460 community bins and 206 waste containers. For the last two years, in six wards two private organizations are involved to dispose the waste from SDS to ultimate disposal sites (UDS). They built their own SDS of large size and practiced better management. In Chittagong City Corporation (CCC) areas, the total number of SDS and community bins is 1506 in which 489 masonry bins, 66 concrete bins, 32 steel containers and 558 open spaces. Beside this, there are huge numbers of unauthorized small dumping size spreading throughout CCC. In KCC, There are more than 60 SDS, around 1200 community bins and 28 haul containers, located on roadsides throughout the city. In RCC areas, there are 44 open space types SDS and about 190 community bins spreading over the whole city. Presently there is no dustbin in RCC areas because in a recent attempt all the dustbins were removed from SDS. Rickshaw van pullers collect wastes from different sources and dump it to the open spaces randomly at SDS.

There are 150 SDS in BCC randomly over the whole city, as a result, in some words, of BCC, there is no SDS. In SCC areas, there are about 74 SDS out of which only 30 to 35 sites are in use now. Concrete/masonry bins are placed in most SDS. Recently, three large sized SDS with better facilities are constructed with assistance of the NGOs.

In the MSW management tier, SDS plays a very pivotal role. But the situation of SDS in each city is very much unpleasant, alarming and it reveals as an ineffective step causing most nuisance and deteriorating city environment at large scale. As the location and design of the dustbins are not suitable, peoples don't prefer to use dustbin usually. They throw the wastes around the dustbins. Where haul container is located, its opening is so high that people just throw their waste towards it. All the dustbins are usually open, so birds; dogs and scavengers search for foods and valuable items. Also during rainfall, the wastes spread in the surrounding areas. This creates very unhygienic condition for the environment. As a result, those uncontrolled wastes are creating public nuisance. Due to this, in some community the local people demolished the dustbins, which again spread the wastes in wider areas. Most of the dustbins are very old and already out of order due to lack of maintenance. In most cases the community bins on the roadside are of inadequate capacity resulting in spillage of wastes which become extremely unsightly and a public nuisance. This situation can be improved by proper installation of TS which serves more environmentally susceptible and environmentally acceptable option for solid waste management strategies.

2.6 Transfer Station

Waste transfer stations play an important role in a community's total waste management system, serving as the link between a community's solid waste collection program and a final waste disposal facility.

A transfer station is defined as a solid waste processing site where solid waste is transferred from one vehicle to another vehicle or storage device for temporary storage until transferred to a permanent disposal site approved the solid waste management authority or permitted by

any other solid waste management authority having jurisdiction over the location of their permanent disposal site.

A transfer station is a facility designed to accept, process and transfer municipal solid waste. Wastes are brought to the facility by collection vehicles (garbage trucks) as well as self-haul vehicles ranging from passenger cars to dump trucks. The waste is dumped onto a concrete floor (the "tipping" floor) inside of a large building. Hazardous wastes and other materials that should not be landfilled are sorted out and processed separately. The garbage is then loaded into large-capacity trucks and shipped to a landfill or other processing, treatment and disposal facilities and is typically off the site within 24 hours. Transfer stations are an essential component of all modern integrated waste management systems. They provide a safe, efficient and cost-effective means to process and transfer solid waste from the generators to the disposal sites. In its simplest form, a transfer station is a facility with a designated receiving area where waste collection vehicles discharge their loads. They can be designed to look like warehouses or low-rise offices buildings. Typically, the transfer station building is located on a much larger site with other waste management, resource recovery and recycling operations. Transfer stations are usually sited on industrially-zoned land due to the nature of the business (operation of heavy equipment, big trucks and commodities warehousing).

2.6.1 Needs for Transfer Station

There are two principal reasons for constructing a transfer station:

- Economics — If the destination of the wastes is far away from the area in which they are collected, then it may be more economical to transfer the wastes to large vehicles for haulage than to haul them directly in the original collection vehicles. This situation is becoming increasingly common, as landfills become more difficult to site and, therefore, more remote from populated areas.
- Service — for a rural area without a garbage collection service, a transfer station is often provided as a service to local residents, so that they do not have far to drive to drop off their wastes. A transfer station is often established at a landfill after it has

been closed because people are accustomed to taking their waste to that location. Such a transfer station may or may not be economical.

- Opportunity to recover recyclables

Ideally, a transfer station should be sited as close as possible to the centroid of the population served, in order to minimize collection costs, or some distance along the haul route to the landfill. The transfer station should be sited and operated so as to create no environmental or health hazard, and no nuisance.

2.6.2 Benefits

- Large transfer trailers replace several collection vehicles for the hauling of waste to the disposal site
- Collection vehicles are rapidly routed back to work, at-site or turn-around time is reduced compared to the normal time associated with disposal
- Paved roads/tipping surfaces at transfer station reduce maintenance costs
- Disposal facilities can be located far from populated areas which may diffuse local sitting opposition
- Waste stream inspection opportunity when unloading onto tipping floor or into compactors - spotters remove hazardous wastes
- Provides another opportunity for recycling, compaction, and/or baling
- Easy use of multiple disposal sites

2.6.3 Why Use Waste Transfer Stations?

The primary reason for using a transfer station is to reduce the cost of transporting waste to disposal facilities. Consolidating smaller loads from collection vehicles into larger transfer vehicles reduces hauling costs by enabling collection crews to spend less time traveling to and from distant disposal sites and more time collecting waste. This also reduces fuel consumption and collection vehicle maintenance costs, plus produces less overall traffic, air emissions, and road wear.

In addition, a transfer station also provides:

• An opportunity to screen waste prior to disposal.

• Flexibility in selecting waste disposal options.

• An opportunity to serve as a convenience center for public use.

At many transfer stations, workers screen incoming wastes on conveyor systems, tipping floors, or in receiving pits. Waste screening has two components: separating recyclables from the waste stream and identifying any wastes that might be inappropriate for disposal (e.g., hazardous wastes or materials, white goods, whole tires, auto batteries, or infectious waste). Identifying and removing recyclables reduces the weight and volume of waste sent for final disposal and, depending on local recycling markets, might generate revenue. Screening for inappropriate wastes is more efficient at the transfer station than the landfill. Waste transfer stations also offer more flexibility in terms of disposal options. Decision makers have the opportunity to select the

Most cost-effective and/or environmentally protective disposal sites, even if they are more distant. They can consider multiple disposal facilities, secure competitive disposal fees, and choose a desired method of disposal.

Finally, transfer stations often include convenience centers open to public use. These centers enable individual citizens to deliver waste directly to the transfer station facility for ultimate disposal. Some convenience centers offer programs to manage yard waste, bulky items, household hazardous waste, and recyclables. These multipurpose convenience centers are assets to the community because they assist in achieving recycling goals, increase the public's knowledge of proper materials management, and divert materials that would otherwise burden existing disposal capacity.

2.6.4 How will the Transfer Station be used?

The most important factors to consider when designing a transfer station are:

• Will the transfer station receive waste from the general public or limit access to collection vehicles? If access will not be limited, how will citizen traffic be separated from commercial traffic to ensure safe and efficient unloading?

• What types of waste will the transfer station accept?

• What type of transfer technology will be used?

• How will waste be shipped? Truck, rail, or barge?
• What volume of material will the transfer station manage?
• How much waste will the facility be designed to receive during peak flows?

Two other factors to consider when developing a transfer station's design include:
• How will environmental impacts to the surrounding area be minimized?
• How will employee health and safety be ensured?

2.6.5 Types of Transfer Station

Transfer stations are used to accomplish transfer of solid wastes from collection and other small vehicles to larger transport equipment. Depending on the method used to load the transport vehicles, transfer station may be classified into four general types:

1. Direct Dump Stations
- Collection Vehicles to Transfer Trailers
2. Pit/Platform Non compaction Stations
- Dumping-Recovery-Loading
3. Hopper Compaction Stations
- Loading though a hopper to compactor trailer
4. Push pit Compaction Stations
- -Dumping-Recovery-Loading-Compaction

Station Equipment

1. Fixed equipment
- scales
- hoppers
- hydraulic push pits
- bridge crane with clamshell bucket
- Stationary Compactors

2. Mobile Equipment -

- front end loaders
- clamshell dozers (push and break up waste, load transport vehicles)

Transfer station may also be classified with respect to capacity-

(a) Large > 500 tons/day,

(b) Medium 100- 500 tons/day,

(c) Small < 100 tons/day (Tchobanoglous *et al.*, 1993).

2.6.6 Transfer System

1. Green Box

This rural system is shown in Figure 2.1, at the end of this section. It is similar to that used for commercial establishments in urban areas. Metal containers with hinged lids, varying in size from 2.3 to 6.1 cubic metres (three to eight cubic yards) are placed at strategic locations such as cross-roads, city works yards and rural stores. The containers are picked up and emptied by front, rear, or side loading compaction trucks. One cubic metre of packer truck capacity would equal about three cubic metres of bin capacity. Therefore, as an example, a 22 m^3 truck could service eleven 6 m^3 bins on one trip. Although economical in terms of capital cost, the relatively small bins are unable to accommodate large items such as furniture and demolition/land clearing/construction (DLC) waste. They are awkward to use because waste must be lifted up to be dumped. A problem with multiple bins (i.e. more than three) is that people become frustrated on finding successive bins full, and may dump their waste indiscriminately. A transfer station employing small bins is normally considered suitable only for small annual tonnages, say less than 100 tonnes/year, and for serving areas that have some other convenient alternative for disposing of bulky waste. (www.env.gov.bc.ca)

2. Dedicated Truck

Some rural areas have found it convenient to arrange for a compaction waste collection truck to be available at a specified location, on a regular schedule, for an advertised time period, usually once per week. Local residents bring their waste to the truck, and are

charged a prearranged rate per bag or can by the truck driver. Although this system is not a "transfer station" it can be a substitute for one, and has the advantages of requiring no capital cost, assuming a collection contractor is available, only minimal operating cost for a subsidy and advertising, and users pay much of the cost directly for the service. The major disadvantages are that it is relatively expensive, and that service can usually only be afforded for limited periods, say one day per week or less.

3. Rolloff Container

This rural system, illustrated in Figure 2.2, uses large steel containers, typically varying from eleven to thirty-eight cubic metres (fifteen to fifty cubic yards). Full containers are picked up by a rollon/rolloff tilt frame truck, and transported singly or in pairs by a truck/pup arrangement, to the landfill. An empty container is deposited by the same truck that picks up the full one. Rolloff bins often achieve their legal load limit without compaction. For example, the legal payload for a 38 m^3 (50 cu yd) bin is about 8 tonnes, which is equivalent to a density of about 210 kg/m^3.

The best rolloff station designs incorporate elevated ramps, with the bins sitting at a lower level, so that waste can be dropped down into the bin, and hinged counterweighted lids that are easy to move. A sheet metal or screened cover is often used over the bin to reduce blowing litter and exclude birds and animals. Site development can include fencing, a lockable gate, and paved roads.

This system is fairly economical in terms of capital cost, is capable of accepting all household solid waste, is uncomplicated, is flexible because more containers can be added when volumes increase, and is generally well accepted by the public. However, the bins cannot successfully receive waste from standard collection trucks. These trucks must direct haul to the landfill. Scheduling is the major concern with this system. Haul costs can be high because containers may not be completely filled. In summary, rolloff stations are the most common and accepted system in BC.

i. Hydraulically Tippable Containers

These come in a wide range of sizes. The smallest are up to three cubic metre roadside units that use a quick-connect hydraulic system on a side loading collection truck to tip the bins into the truck. Larger units, as shown in Figure 2.3, with a capacity of about thirty cubic metres, use their own hydraulic system to tip their contents into a large transfer trailer, typically holding 90 m, and hauled by a tractor. The large units are set up similar to rolloff stations, with a ramp leading to an upper level, so that waste can be thrown down into the container. The transfer trailer parks at the lower level to receive waste. The advantages of this type of system, compared to a rolloff system, are that it can receive waste from standard collection trucks, and that only the waste is hauled. The expense of hauling containers is avoided. Disadvantages of this system, compared to rolloff bins, are problems caused by cold weather on the hydraulic cylinders, potential damage to the hydraulic systems resulting from vandalism and fire, and problems that arise from overloading with heavy material, which becomes jammed in the hopper.

ii. Direct Dump

Sometimes called a "push pit" system, these urban transfer stations, as shown in Figure 2.5 at the end of this chapter, allow waste collection trucks to dump their loads either directly to a large transfer trailer parked at a lower level, or to a tipping floor, from which it is usually pushed by a loader or Bobcat into a 90 m^3 trailer. A variation on this theme is for the waste to be lifted from the tipping floor or bunker by a crane, thus eliminating the need for a lower level for the transfer trailer. The tipping floor and trailer are usually housed in a building. Other amenities generally provided at a larger station include weigh scales, bins for receiving recyclables, a storage area for white goods, and an office, washroom, and lunchroom for staff.

iii. Compaction

The use of compaction at a transfer station may be economically advantageous, since it allows a greater weight to be hauled in a given container. The economic viability of compaction depends on the nature of the wastes, the type of vehicle used to collect wastes,

and the distance from the transfer station to the landfill. Wastes containing a significant amount of dense material, and/or waste collected in packer trucks (even though it rebounds upon dumping) may already achieve legal truck weight limits without compaction. The fundamental question in deciding whether to use compaction or not is this: Can the legal gross vehicle weight of the transport units be reached without compaction? Compactors may be used even at small facilities. Rolloff compactors are available and are sometimes used at rural transfer stations, as shown in Figure 2.4. These compactors typically achieve a compaction ratio of about 6:1. They are limited as to the size and type of waste they can accept, so often a standard roll off container is provided to receive bulky objects and demolition debris. There is a variety of compactors available for urban direct dump transfer stations; waste may be compacted directly in the trailer that receives it, or in a separate receiving compactor that then discharges to the transfer trailer.

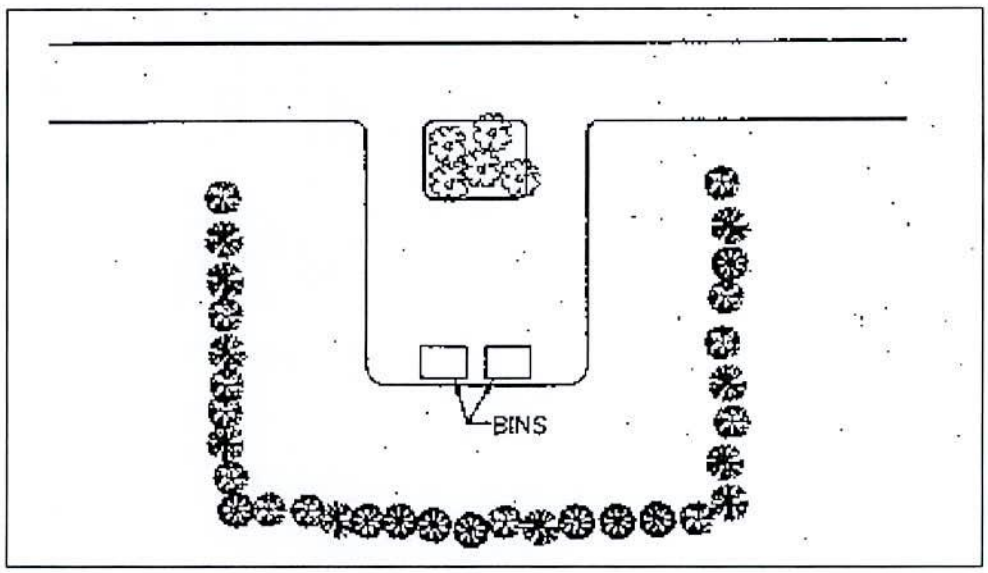


Figure 2.1 Typical green box site

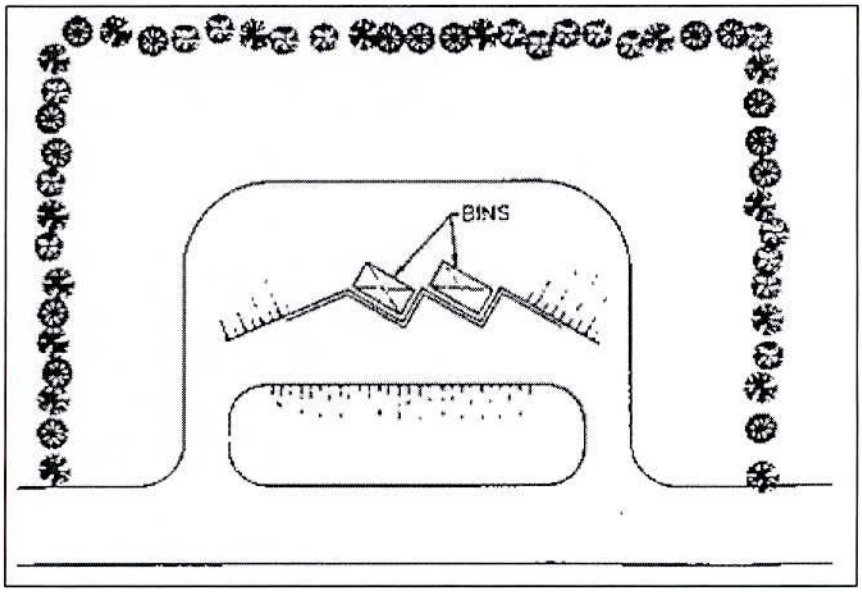


Figure 2.2 Typical Rolloff Bin Site

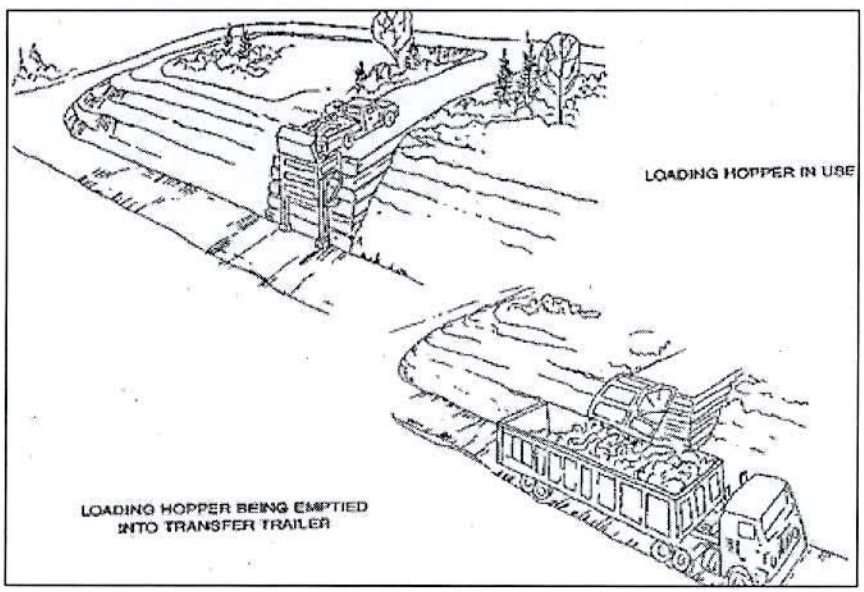


Figure 2.3 Transfer Station with Hydraulically Tippable (Transtor) Bin

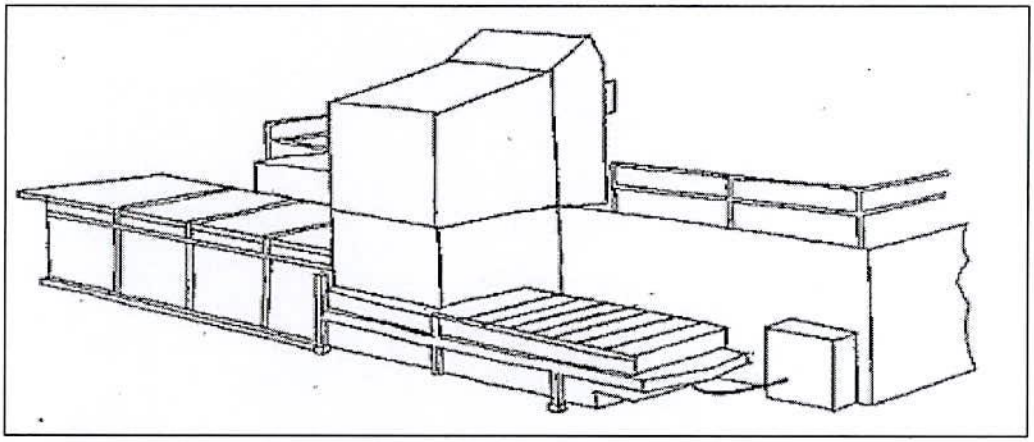


Figure 2.4 Typical Compaction Type Rolloff Facility

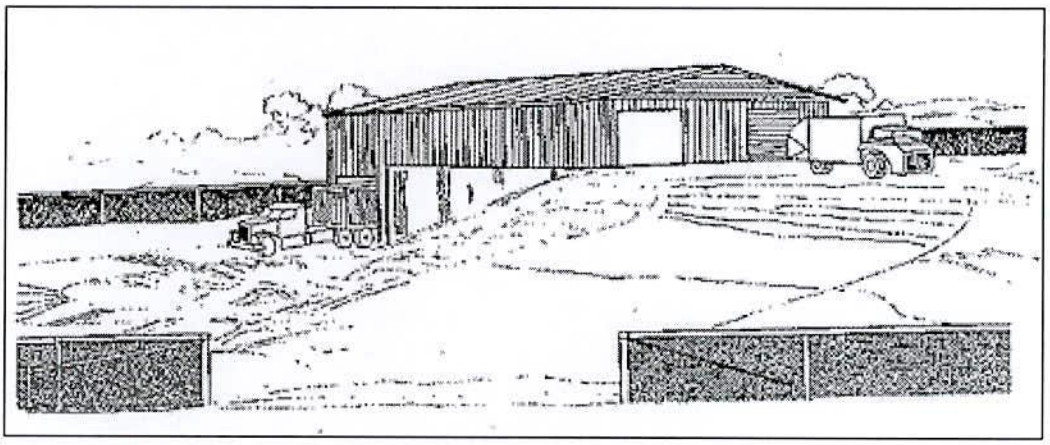


Figure 2.5 **Transfer Station Push Pit System**

2.7 Basic Transfer Station Technologies

Waste can be unloaded directly into the "open top" of the trailer (Figure 2.6A), but is most often unloaded on the tipping floor to allow for materials recovery and waste inspection before being pushed into the trailer. Large trailers, usually 100 cubic yards or more, are necessary to get a good payload because the waste is not compacted. This is a simple

technology that does not rely on sophisticated equipment (e.g., compactor or baler). Its flexibility makes it the preferred option for low-volume operations.

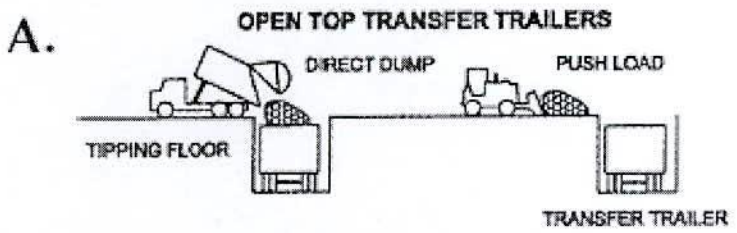


Figure 2.6A Open Top Transfer Trailers

The surge pit (Figure 2.6B) is not a loading technology, but an intermediate step normally used with open-top or precompactor systems. The pit can store peak waste flow, thus reducing the number of transfer trailers needed. A tracked loader or bulldozer is used to compact the waste before loading, increasing payload. Because waste is often unloaded directly into the surge pit, this technology might deter materials recovery and waste screening efforts.

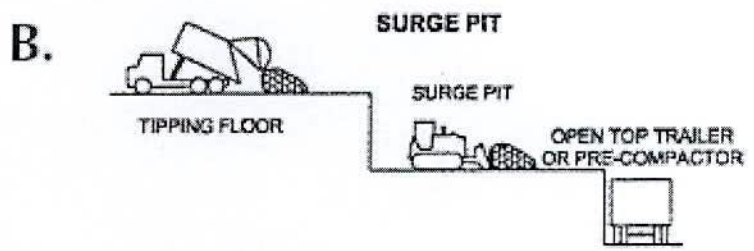


Figure 2.6B Surge Pit

Stationary compactors (Figure 2.6C) use a hydraulic ram to compact waste into the transfer trailer. Because the trailer must be designed to resist the compactive force, it is usually made of reinforced steel. The heavy trailer and the weight of the onboard unloading ram reduce the payload available for waste. This technology is declining in popularity.

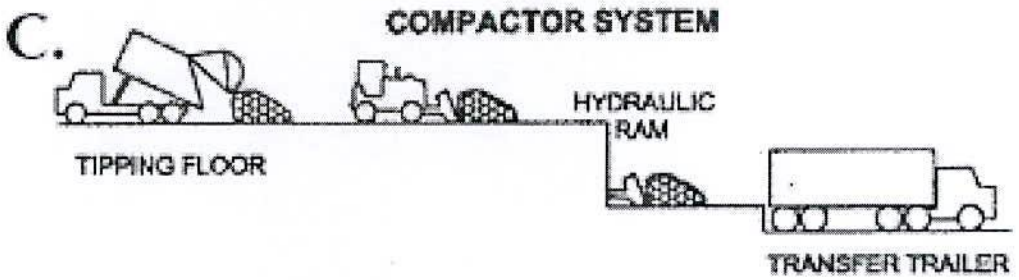


Figure 2.6C Compactor System

Precompactor systems (Figure 2.6D) use a hydraulic ram inside a cylinder to create a dense "log" of waste. The log is pushed into a trailer that uses "walking floor" technology to unload or relies on a tipper at the landfill to unload by gravity. Most precompactor installations have two units in case one unit requires repair. The capital cost is relatively high at more than $250,000 per unit, but the superior payload can offset these initial costs.

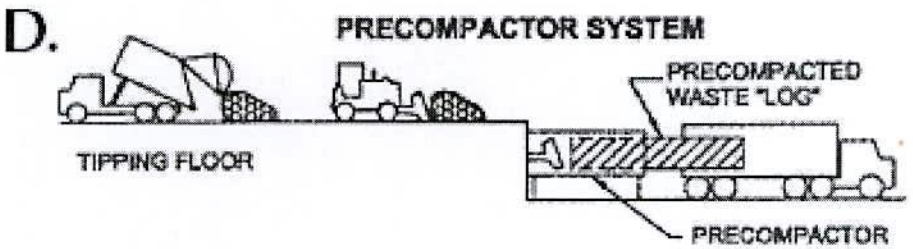


Figure 2.6D Precompactor System

Balers (Figure: 2.6E) are units that compress waste into dense, self-contained bales. Wire straps may be used to hold the bales intact. They are usually moved by forklifts and transported by flatbed trailers. The baler units can also be used for recyclables such as paper and metal. Payloads are very high, but so are capital costs. Most baling stations have at least two units in case one is down, and they cost more than $500,000 apiece. This high-technology option is normally used only in high-volume operations, and special equipment or accommodations might be required at the Landfill (or balefill).

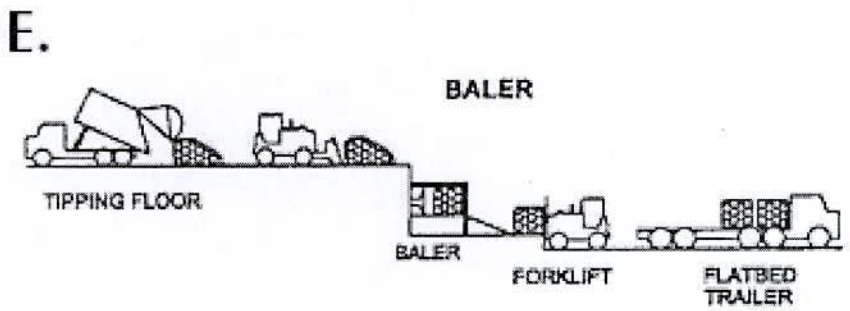


Figure 2.6E Baler

In this alternative, waste is tipped at a transfer station, then loaded into intermodal containers (Figure: 2.6F). These containers typically have moisture- and odor-control features and are designed to fit on both flatbed trailers and railroad flatcars. The containers may be loaded directly onto railcars or transferred by truck to a train terminal. The sealed containers can be stored on site for more than 24 hours until enough containers are filled to permit economic transport to the landfill. At the landfill, these containers are usually unloaded by tippers. This option allows for reduction of total truck traffic on local roads and can make distant disposal sites economically viable.

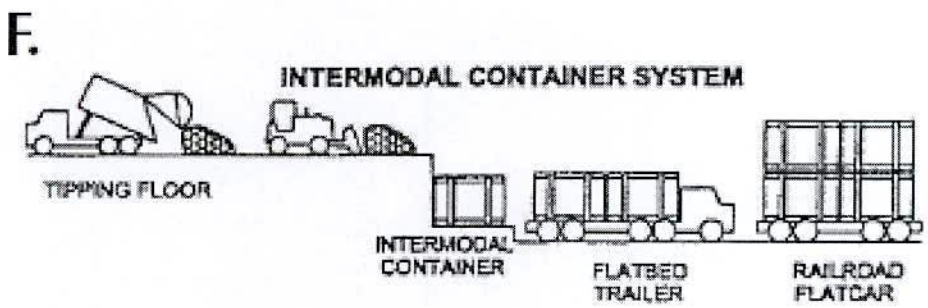


Figure 2.6F **Intermodal Container System**

2.8 Sitting guidelines of Transfer Station

A variety of issues must be taken into account during the planning and sitting stages of transfer station development. Ideally, a transfer station should be sited as close as possible to the centroid of the population served, in order to minimize collection costs, or some distance along the haul route to the landfill and should be operated so as to create no environmental or health hazard, and no nuisance. The sitting of a transfer station will be planned and designed based on the evaluation of the following important aspects:

- Location: Centroid of waste stream, Heavy Collectors, Existing/future traffic patterns, Railway.
- Zoning: Adjacent zoning – different, how close - across the street, Neighbors? Type of businesses, Surrounding properties, type, quality, Area undergoing change.
- Environmental: Contaminated site, Wetland, Endangered Species, Migratory route, Flood Plain, Historically or archeologically significant site.
- Infrastructure: Water, Fire flow, Sewer, Restrictions, Electricity, Supply, Permitting Requirements.
- Visual: Exposed site, Highway, public R.O.W., High rise, Hillside residential, Buffering, Design.
- Noise: Sensitive receptors, Retirement, school, hospital, Echo condition, Neighbors.
- Wind: Predominant direction, Seasonal gusts, Exposed / protected area, what lies downwind.
- Area: Size, Configuration.

2.9 Types of Waste Accepted in Transfer Station

The types of wastes that are accepted to drop off into the transfer station are the followings:

- Municipal solid waste (MSW): is generated by households, businesses, institutions, and industry. MSW typically contains a wide variety of materials including discarded containers, packaging, food wastes, and paper products. MSW includes a mixture of

putrescible (easily degradable) and nonputrescible inert) materials. This includes all household garbage and refuse.

- Yard Waste/ Green waste. Lawn clipping, leaves, tree branches and wood. Yard waste is often diverted so that it may be composted or mulched instead of going for disposal.
- Household hazardous waste. Household hazardous waste (HHW) is a catchall term for a wide variety of common household products found under our sink, in our laundry room and out in the garage. HHW includes antifreeze, paint, motor oil, brake fluid, batteries, pesticides, herbicides, solvents, lubricants, gasoline, kerosene, car care products, wood preservatives, fluorescent light bulbs, flares, pool chemicals, drain cleaners, adhesives, polishers, bleach, ammonia, acetone (finger nail polish remover), prescription drugs and many other chemicals and compounds and other materials generated around the home that are best kept out of the landfill.
- Electronic waste (or E-Waste) includes anything with a circuit board or chip.
- Construction and demolition waste. This is generated by new construction or by tearing down old buildings. It typically consists of concrete, brick, wood, masonry, roofing materials, sheetrock, plaster, metals and tree stumps. Sometimes C & D debris is managed separately from MSW; other times it is mixed with MSW.
- Special wastes. This includes items such as tires and appliances.
- Recyclable materials: It include discarded materials that can be reprocessed for manufacture into new products such as can, bottles, ferrous metals, papers, motor oil and scrap metal.

2.10 Unacceptable Wastes

Just about the only things that will not be accepted in transfer station are old cars, radioactive wastes, lead acid batteries and explosives, large bulky objects such as tree stumps, mattresses, or furniture; infectious medical waste; hazardous waste; explosives; fuel tanks (even if empty); appliances; dead animals; asbestos; liquids and sludges; and dustprone materials. This is a general list; some transfer stations might be set up to process these wastes, while others might have a longer list of unacceptable materials. While these

and other unacceptable wastes represent a small fraction of the solid waste stream, properly managing them can require significant effort by the transfer station operator and the local solid waste management authority.

2.11 Management System of Transfer Station

General

a. Transfer stations shall be operated in a manner that will preclude degradation of land, air, surface water, or ground water.

b. Transfer stations shall be maintained and operated to conform to the Plan of Operation submitted at the time of permit application and approved by the Department.

2. Details of operation and maintenance

a. Storage of solid waste

Solid waste shall not remain at the transfer station for more than 72 hours without the written approval of the Conservancy Department. Any solid waste that is to be kept at the site overnight shall be stored in an impervious enclosed structure.

b. Disposition of solid waste leaving the facility

All solid waste accepted at the transfer station must, upon leaving the transfer station, be delivered to a processing or disposal facility authorized by the Department (or by the appropriate environmental agency, if outside) to accept that type of waste.

c. Control of nuisances and hazards

Litter

The permit tee shall provide for routine maintenance and general cleanliness of the entire site, as well as litter removal along roads approaching the site if accumulations of litter along the approach roads are clearly the result of the operation of the transfer station.

Vectors

The permit tee shall implement a vector control plan to prevent the establishment of habitats for nuisance organisms (e.g., flies, maggots, roaches, rodents, and similar vermin) and to mitigate nuisances and hazards to human health and the environment.

Air Pollution

The operation of the transfer station shall comply and the regulations Governing the Control of Air Pollution.

Fire

Equipment shall be available on site to control fires, and arrangements shall be made with the local fire protection agency to provide immediate services when needed. If deemed necessary by the Department, a separate area shall be provided for temporary placement of hot loads received at the facility. The hot load area shall be located away from trees, bushes, and structures and loads shall be extinguished immediately upon unloading.

d. Access

Access to the site shall be limited to those times when an attendant is on duty and to those persons authorized to use the site for the disposal of solid waste. This section shall not be construed to limit right of entry by the Secretary or his/her duly authorized designee pursuant.

e. Personnel

Sufficient numbers and types of personnel shall be available at the site to insure capability for operation in accordance with these regulations. In 2010, 5-6 labors are required for management of Transfer station satisfactorily. But in future, excessive growth rate of population will increase the generation of waste. As a result, the waste personnel required for 2025 is about 10-15.

f. Health and safety

In transfer station, health and safety should be ensured of the waste related workers for proper management of solid waste.

g. Equipment

Adequate numbers and types of equipment commensurate with the size of the operation shall be available at the site to insure operation of the facility in accordance with the provisions of these regulations and the plan of operation. All waste handling equipment shall be cleaned routinely and maintained according to the manufacturer's recommendations.

3. Record Keeping

The following information must be recorded in a timely manner and the records retained by the owner or operator for at least three years:

a. A record of the solid waste commercial haulers (company name, address, and telephone number) using the facility and the type and weight or volume of solid waste delivered by each hauler to the transfer station each day.

b. A record of the type and weight or volume of solid waste delivered from the transfer station to its final destination each day.

c. A record of fires, spills, and uncontrolled releases that occur at the facility, and of hot loads received.

d. Fire and safety inspections.

e. Major equipment maintenance.

f. Destination of the solid waste.

4. Reporting

a. The permittee shall submit to the Department on an annual basis a report summarizing facility operations for the preceding calendar year. The due date for this annual report will be specified in the facility's permit. The report shall be on a form acceptable to the Department and shall describe and summarize all environmental monitoring and construction activities conducted within the year covered by the report. The report shall include, but not necessarily be limited to, the following:

(1) Type and weight or volume of waste received.

(2) A complete list of commercial haulers that hauled waste to or from the facility during the year covered by the report.

(3) Destination of the solid waste and the type and weight or volume of waste delivered to the destination.

(4) Descriptions of any intentional or accidental deviations from the approved Plan of Operation.

(5) Descriptions of all construction or corrective work conducted on the site in accordance with approved plans or to achieve compliance with these regulations.

(6) An updated estimate of the cost of closing the facility.

(7) Any additional information specified by the Department.

b. The owner or operator shall notify the Department immediately if either of the following occurs:

(1) A fire that requires the services of a fire protection agency.

(2) A spill or uncontrolled release that may endanger human health or the environment.

5. Prohibitions

a. Solid waste generated outside of the State of Delaware shall not be combined, commingled or aggregated with solid waste that was generated in Delaware and that is required, pursuant to regulations promulgated by the Delaware Solid Waste Authority (DSWA), to be disposed of at a DSWA facility.

b. No liquids, other than those used to disinfect, to suppress dust, or to absorb or cover odors from the solid waste, shall be added to the solid waste.

c. Open burning is prohibited on any transfer station site.

d. Scavenging is prohibited at any transfer station.

2.12 Necessity of Transfer Station in Bangladesh

In Khulna City Corporation (KCC), secondary collection of waste comprises of collection of waste from the community bins and open waste collection points for onward transportation by the municipal trucks (open and flat bedded) to waste dump site. In primary collection, waste is transported by the generator to the nearby community bin or open waste collection points and in some cases it is collected by rickshaw van or municipal staff by handcarts and transported to the community bin or secondary waste collection points. These secondary waste collection points have become a source of environmental pollution and nuisance due to lack of interface between primary and secondary collection and becomes a hazard for the existence of human beings. Moreover, scavengers are common feature at secondary collection points, collecting recyclables in unhygienic manner-although they are helping to reduce the waste. So, alternative option of SDS should be considered. In such situation option should be keep open to solve this problems by Transfer Station (TS) and the suitability of such options needs to be explored. Proper functioning of TS can reduce hauling costs, the occurrence of illegal dumping of littering and scavenging of wastes in the cities along road sites and the increase of the overall efficiency of the system. In order to have a proper interface between primary and secondary waste collection system in the Khulna city, transfer station should be proposed instead of the community bins, dustbin points and roadsides. Transfer station is a facility in which solid waste from primary collection vehicle (like rickshaw van) is consolidated into loads for subsequent transfer by 3 ton or 5 ton trucks or by other means to landfill site or composting facility without creating any environmental pollution or hazard. Moreover, transfer station may be adopted to serve as resource recovery facility. In a developing country like Bangladesh, TS can play a major role to overcome overall mismanagement of waste. There was no active transfer station in Bangladesh in true sense. Recently in Mymensingh district, Design of TS has been implemented and construction work will be carried out very soon by the incorporation of GTZ Bangladesh which will be funded by ADB. In Rajshahi city, a small scale transfer station has been introduced. In Dhaka city, some small sized transfer stations have been installed and already they are under operations. So in KCC areas, the current status of SDS can be tainted by the replacement of an ideal planned and designed TS that can enrolls foremost task to develop the mismanagement of waste taken as a whole.

CHAPTER III

Overview of the Study Areas and SWM in Khulna City

3.1 General

Bangladesh is situated in southern Asia, on the delta of the two largest rivers on the Indian subcontinent—the Ganges and the Jamuna (Brahmaputra). In 2010, Bangladesh has been estimated to be one of the ten most highly populated countries with an estimated population of just under 160 million. This makes the population density of about 875 people per sq km (2,267 people per sq mi) higher than other countries (www.asianinfo.org) and one of the fastest urbanizing countries is a land of physical, climatic, geographic, ecological, social, cultural and linguistic diversity. Khulna was declared as a municipality in 1884. It achieved its status as a City Corporation after another hundred years in 1984. However, initial industrialization took place during the 1960s (Ahmed, 2002). At present there are 522 urban centers in the country including 309 municipalities and 6 City Corporations (BBS, 1997 and bdnews.com). With over 3.3% annual growth in urban population in Bangladesh during 1991-2001 census years, solid waste generation has also increased proportionately with the growth of urban population. This has been creating a higher per capita waste generation rendering the existing management system ineffective and has put on the risk of massive failure. The land of Bangladesh is of enormous beauty, hundreds of serpentine rivers, crystal clear water lakes surrounded by ever green hills, luxuriant tropical rain forests, beautiful cascades of green tea gardens, world's largest mangrove forest etc.

This chapter describes the general information such as location, city layout, geology, climate, population, socio-economic and environmental condition, land use and infrastructure of the study area Khulna City Corporation (KCC) and overview of MSW management such as source storage, primary collection, on-site storage, waste collection

from on-site storage & transportation, disposal at Ultimate disposal site (UDS) and also problems of existing management practices of MSW in KCC are described here.

3.2 General Information

3.2.1 Location

Khulna is the third largest city in Bangladesh. It is located on the banks of the Rupsha and Bhairab rivers in Khulna District. It is the divisional headquarters of Khulna Division and a major industrial and commercial center. It has a seaport named Mongla, the second largest seaport of the country on its outskirts, 38 km from Khulna City. Khulna city, the third biggest industrial city of the country, is located at the south-western part. Khulna city is characterized by Ganges tidal floodplains with low relief, criss-crossed by rivers and water channels and surrounded by tidal marshes and swamps. Surrounding districts are Satkhira, Bagerhat, Narial and Jessore. The Khulna City Corporation (KCC) consists in total of 31 wards. The city map of Khulna is shown in Figure 3.1.

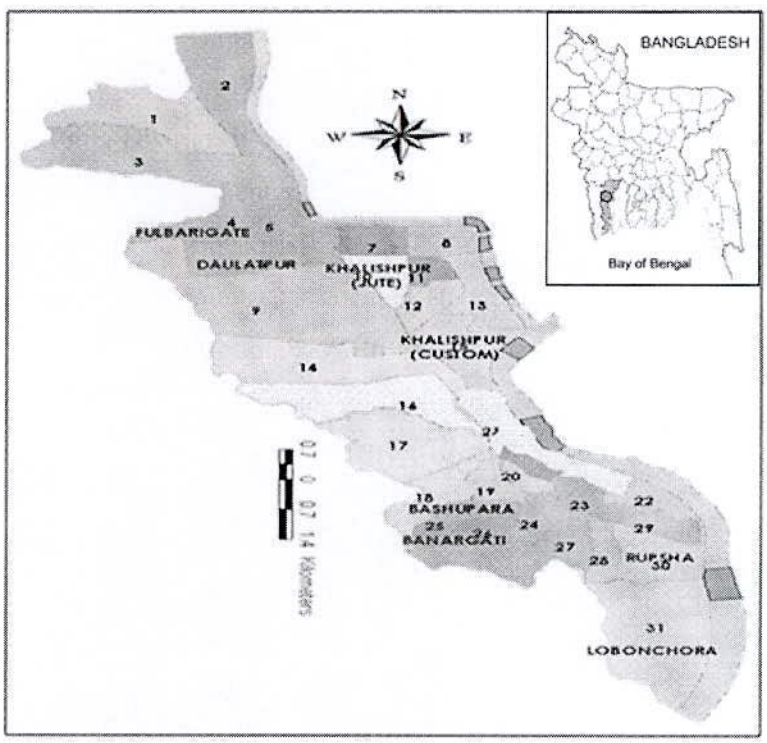


Figure 3.1 Study Area: Map of Khulna City

3.2.2 City layout

Khulna is located in south-western part of Bangladesh with a total area of 45 sqkm², while the district itself is about 4394.46 km². The city of Khulna is in the northern part of the district, and is mainly an expansion of trade centers close to the Rupsha and Bhairab rivers. The Bhairab on northern side, Rupsa River in the middle part and Pasur on the southern side flows along eastern margin of the city and Mayur on the northern side and Hatia River on the southern side flow along the western side of the city (Figure 3.2). It lies south of Jessore and Narail, East of Satkhira, West of Bagerhat and North of the Bay of Bengal. It lies between 22°49' North Latitude and 89°34' East Longitudes and its elevation is 2.13 meters above mean sea level (BBS, 2004). It is the part of the largest delta in the world. In the southern part of the delta lies the Sundarban, the world's largest mangrove forest. It is connected by river, road, and rail to the major cities of the southern Gangetic delta. The physical shape of Khulna city is controlled by its geo-physical conditions. It is a long-shaped city extending from southeast to northeast along the Bhairab-Rupsha River.

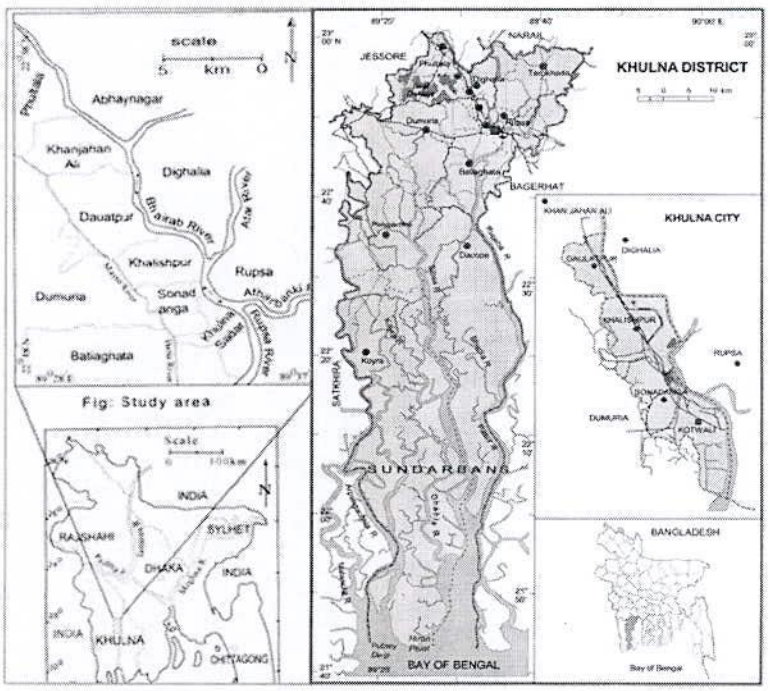


Figure 3.2 Khulna City Layout

3.2.3 Geology

The Khulna City Corporation (KCC) in southwest part of Bangladesh lies on young Holocene-Recent Alluvium of the Ganges deltaic plain in north and Ganges tidal plain in south. The area is composed of coarse to very fine sand, silt and silty clay up to a depth of 300m with peaty soil and calcareous as well as non-calcareous soil at the top. Figure 3.3 below describes geological map of Khulna City Corporation and its adjoining area.

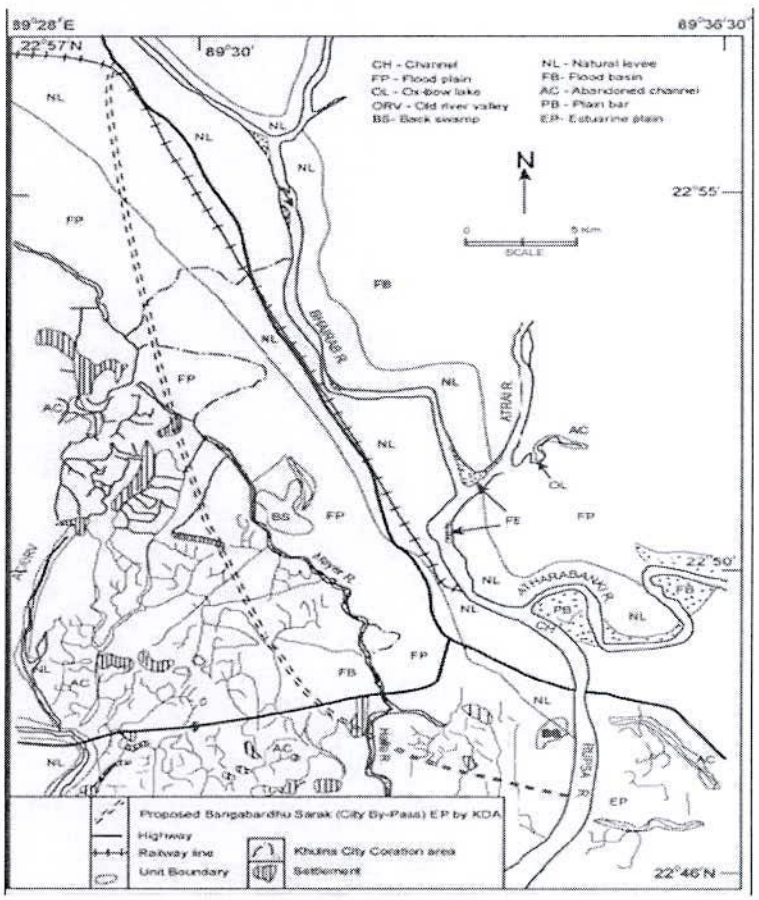


Figure 3.3 Geological Map of Khulna City Corporation (www.ru.ac.bd)

Local geology: The soil of the Rupsa-Bhairab-Pasur rivers on the east covers the natural levee, floodplain-estuarine plain, oxbow lake etc and the soil of the Mayur- Hatia rivers on the west covers flood plain, flood basin, swamp, abandoned channel etc and is characterized by tidal and flood inundation with low relief. The elevation of the area varies from 3.90 m in

north to 2.70 m towards southwest direction. On the basis of geomorphology, relief and drainage, sediment characteristics, vegetation cover, water logging and flooding, the study area has been divided into nine geomorphological units, characteristics of which are described below.

a) Channel: Khulna City area is bounded by the river of Bhairab on the northeast, Rupsa on the southeast and Pasur in further down south. The Atharobanki river meets with Rupsa and Atai river meets with the Bhairab River on the central east and the Mayur River-Hatia Rivers lie on the west. These rivers are virtually the distributaries of Ganges River, which carry sediments from upstream. The rivers also experience semidiurnal flood tides from the Bay of Bengal. The Rupsa-Bhairab-Pasur are the active tidal rivers with strong current which carries coarser sediments from upstream and finer sediments mainly clay from downstream by flood tide. Sand grains are gray in colour and very fine to coarse grained and moderately sorted.

b) Natural levee: Natural levee is long broad low ridge of sand and coarse silt, built by the River Rupsa and Bhairab bordering the flood plain and along both banks of them. The sediments are gray in colour and moderately sorted.

Flood Plain: Flood plain is a broad flat area gently sloping towards flood basins in the west as well as east from the natural levees of the combined Bhairab - Rupsa river system. Flood plains are occasionally inundated by high flood but the depth of such flooding does not exceeding one meter except in few low-lying areas. Aerially flood plain covers about 50% of the area. Deposits consist of clay, silty clay and very fine sand.

d) Flood Basin: This geomorphologic unit is the lowest lying part of the area. The flood basins remain water logged during most of the year. Some of the flood basins start drying at the end of November. These are mostly concentrated in the southwestern part of the study area. Deposits consist of gray clay and grayish black carbonaceous clay/peaty clay with some silt.

e) Ox-bow Lake: Ox-bow lake is mainly seen in the eastern part of the Atai River. Ox-bow lake is crescent shaped body of standing water situated by the side of a stream in the abandoned channel of meandering river when the stream formed a neck cutoff and the ends of the original bend were silted up. It consists of fine to medium sand with gray clay on top horizon. It is a part of abandoned channel.

f) Abandoned Channel or Old River Valley: These are narrow depressed areas having channel like morphologies. These are once the tributaries/ distributaries of the main trunk channels of the Bairab- Rupsa, Atharabanki and Mayur River. Deposits consist of dark gray clay and silt.

g) Point Bar: Point bar is a lateral ridge of sand and / gravel developed on the inside of a meander by the slow addition of individual accretions accompanying migration of the channel toward the outer bank of a meandering river. The point bars are present at places in the Atharabanki meandering channels in the eastern part of that area. Deposits consist of light colored fine to medium sand.

h) Back Swamp: A depressed area occupied by swamp or marsh is developed on a flood plain of the river with poor drainage. Back swamps occur in the southwestern part of the area.

i) Estuarine plain: The estuarine plains are low laying narrow areas adjacent to tidal rivers which are inundated every day by tides coming from Bay of Bengal in the south. These plains consist of clay with silty materials.

3.2.4 Population

Khulna city is a densely populated area with 18,424 populations per square kilometer (KDA, 2004). According to BBS in 2001 census, total population in Khulna city area is 7,73,000. Khulna city, with a city area of 45.65 sq. km and with population of about 1.5 million was claimed by city authority in the year of 2005. The population of the city, under the jurisdiction of the City Corporation, was 855,650 in 2007. The wider Statistical Metropolitan Area had at the same time an estimated population of 1,388,425. Khulna is a medium size city in the context of Bangladesh, even though it has a population of more than 1 million people and the population growth rate is around 5% per year.

On this basis, the population of the KCC (Khulna City Corporation) is expected to be around 1.33 million in 2015. These projections give a likely range for the 2015 population of the KCC of 1.2 to 1.4 million with a population of around 1.33 million considered to be most likely is shown in Table 3.1.

Table 3.1 **Population Projections, 2009-2025**

Projection	Growth Rate 2001-2009	Current Pop. 2009	Growth Rate 2009-15	Future Pop. 2015	Growth Rate 2015-25	Future Pop. 2025
High	2.9%	1,207,354	2.7%	1,417,222	2.37%	1,756,297
Low	1.5%	1,082,287	1.3%	1,170,192	0.97%	1,263,049

Source: (CDIA, 2009)

3.2.5 Socio-economic Condition

Khulna city is strategically focused as far as its development potentialities are concerned. Like the other big cities of Bangladesh, notably Dhaka and Chittagong, Khulna is undergoing a major transformation, due to its immensely growing population and its status as Bangladesh's third largest city. Because of its strategic location of only 45 km from the port of Mongla, Khulna is considered as being a port city like Chittagong. 25% of all trade handled in Bangladesh passes through Mongla. While the rest goes through Chittagong. Khulna is also known as the city of Shrimps, because 75% of all shrimps exported from Bangladesh are cultivated in the Khulna zone. In addition to this, a major portion of the

Golden Fiber (Jute) is exported through Khulna Zone. Khulna has some heavy and medium type industries like Khulna Hardboard Mills, Bangladesh Oxygen Company, Khulna Oxygen Company, Platinum Jubilee Jute Mills, Star Jute Mills, and Dada Match Factory. Khulna is famous for its fish and seafood industries. Lobster, Prawn, Catfish, Shrimp and Crab are now being exported abroad from Khulna. Khulna is also famous for its coconuts.

Khulna City is strategically located in an important hub as its development potentialities are concerned. After late 1960, the economic condition of the city deteriorated. The economy of a city can best be revealed through the income pattern of the city dwellers. The average household income per month is Taka 5,543. It is equivalent to per capita yearly income of US$ 360. In Khulna City, more than 60 per cent are earning US$ 58 to 167 per month. (KDA, 2004)

The export of shrimp and the related activities such as shrimp processing, packaging, transportation, shipping, banking, insurance etc, have further reinforced the development of Khulna City to a great extent. The construction of a Rupsha bridge over the Rupsha River and the starting of an Export Processing Zone at Mongla help to boost the overall socio-economic activities in Khulna City. The construction of proposed Airport at Khulna will further contribute in this development. The main Socio-economic problems of the Khulna City Corporation are lack of job opportunities; market outlets for products produced through different micro-credit facilities; lack of capital; lack of adequate micro-credit facilities for the poor; lack of financial, technical and physical support facilities for informal sector's activities; lack of job opportunities for the women; local resources not properly exploited; lack of transparency in the allocation of the Annual Development Programme (ADP) to the different agencies; and, lack of comprehensive information base of the economy. Income labels of people in Khulna City are shown in Figure 3.4.

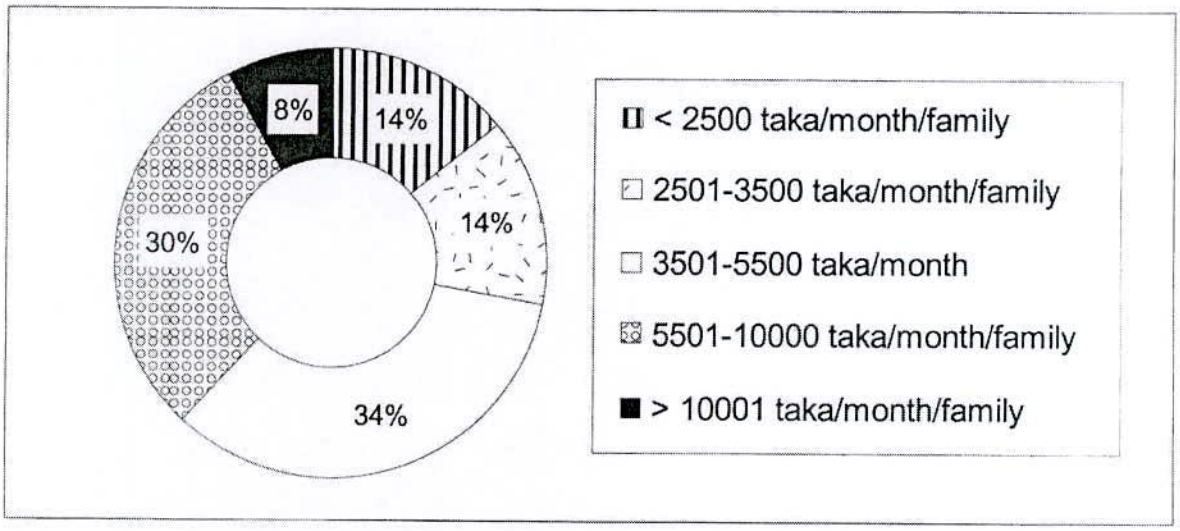


Figure 3.4 Income Levels of people in Khulna City (WasteSafe, 2005)

3.2.6 Environmental Condition

Khulna City is located on a natural levee of the Rupsha and Bhairab rivers and characterized by Ganges tidal floodplains with low relief, criss-crossed by rivers and water channels and surrounded by tidal marshes and swamps. The impact of urbanization in terms of mass poverty, gross inequality, high unemployment, under-employment, over-crowded housing and the proliferation of Slum areas and squatters and general deterioration in overall environmental conditions have become the major concerns of the city . There is clear evidence that clean water is in short supply, there are unhygienic sanitation conditions, high incidence of diseases, along with violent crimes and social tensions in several towns and cities.

3.2.7 Land Use and Infrastructure

Khulna is the third largest metropolitan and industrial city of Bangladesh. The small-scale private real estate business is flourishing day by day in KCC. The causes of the increment of the small-scale private real estate business and its impacts on the urbanization pattern are hindering the harmonic growth of the city. This business is growing in expense of deteriorated living environment, high traffic congestion, high land value and house rent etc. Land use pattern are shown in Table 3.2.

Table 3.2 Land use pattern in Khulna city

Land use parameter	% of the total land area	Actually found land area
Residential	40-65%	80-85%
Community facilities	5-10%	2.5-3.5%
Roads and streets	20-30%	10-12%
Open space (parks and play grounds)	5-10%	0%
Shopping	5-10%	0%

Source: Field survey of (KCC, 2003).

In observed land use composition with respect to the standard are stated in Table 3.2. Here it is seen that for maximizing the profit the private developers are selling more than 80% of the total project area (in terms of residential). Khulna structure Plan has proposed expansion area in the western side up to the Khulna Bypass Road. On the other side, the Bhairab –Rupsha River restricts city expansion. The largest segment of the expansion zone is around Rupsha Bridge (KDA, 2000). This is the area where the real estate business is flourishing.

3.3 Current Situation of MSW Management in Khulna City

In Khulna city, KCC is liable to overall management of MSW in urban areas as per the Municipality Act. Solid waste management (SWM) in Khulna, like other cities of Bangladesh, is hampered by the absence of adequate national or local legislation relating to the municipal SWM and the treatment and disposal of hazardous waste. In particular, there are no mandatory regulations or performance standards for city corporations (e.g. KCC) to establish and manage an effective SWM system. The city authority cannot attempt properly due to severe financial constraints, required infrastructures, absence of appropriate and sustainable technology, lack of motivation, awareness and participation, and the absence of effective legislation. As a result SWM in Khulna has developed in a piecemeal and

uninterested manner with NGOs, CBOs, informal recyclers and private enterprises being involved along with KCC (WasteSafe, 2005). However, some Non-Governmental Organizations (NGOs), Community Based Organization (CBOs) and Private sectors have been started to work with city authority's initiatives to solve this striking social and environmental issues. Generally, in the City Corporation and/or municipality, Conservancy Department is responsible for solid waste management including other utility services. There is no independent wing with sufficient authority to deal the MSW problems in the urban areas; however, recently city authority has taken the initiates to alter the administrative set-up in developing an independent wing to deal MSW problems. The following major drawbacks and bottlenecks in SWM of KCC can be short listed as:

a. Lack of adequate and trained man-power.
b. Low managerial, technical & financial resources available to operate SWM system.
c. Poor service, inadequate solid waste collection, old disposal equipment, unhygienic methods of dumping waste in the present landfill due to deficiencies in the SWM system and the organizational set-up.
d. No direct relationship between payment of conservancy rates and service quality.
e. Only 50 – 60% of the total waste was dumped and the rest is haphazardly disposed in nearby drains, streets, low-lying open spaces and/or vacant lands.
f. Dustbins are often not adequate and properly located.
g. Activities relating solid waste disposal of other organizations are not properly linked with KCC's activities.
h. People involved in collection and disposal of solid waste don't follow hygienic practices.
i. Negligence of duties responsible for road sweeping.
j. Absence of effective accountability of the activities.
k. Inadequate contextual legal support to address the solid waste management.
l. Lack of regular supervision of activities.
m. Delay in decision making (SAP, 2008)

n. The lack of public awareness and commitment leads to indiscriminate dumping of waste.

3.4 Waste Generation

Household waste

There are no reliable data regarding household waste generation in Khulna. Nevertheless a variety of estimations, research papers and investigations are considered here as the available information pool.

Experience from the transport department showed that the distribution over the year changes depending on the seasonal conditions and waste generation patterns. The rainy season extends from mid June to mid September (mid October). Due to the accelerated growing conditions in the season, food consumptions are very high during October to March due to mild weather and the availability of vegetables, fish and crops. During this period, people have more work, more income and buy more and it can be expected 15 – 20% more generated waste amount (maximum 336 t/day). In the Summer (April to June) and rainy season (July to September), people has less work, less income, less vegetables and fish availability and, moreover, weather is hot so food consumption is less and the generated waste amount is reduced to minimum level of 224 t/day as shown in Figure 3.6.

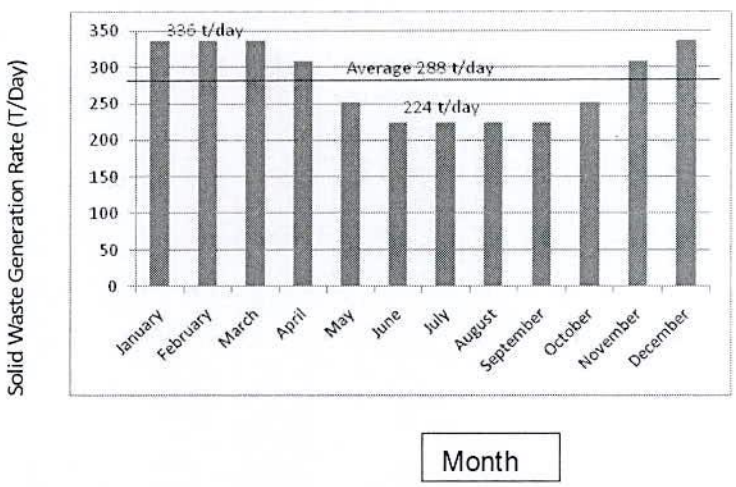


Figure 3.6: Annual distribution of generated solid waste in KCC areas (CDIA, 2009)

Waste composition in percentage is taken from a recent analyze of Alamgir And Ahsan 2007 and calculated on the estimated solid waste amount as presented in Table 3.3.

Table 3.3 Solid waste composition Khulna city (Alamgir and Ahsan, 2007)

Waste category	Share [%]	Generated solid waste amount 2009 in t/day (present study)
Organic matter Biowaste	78.85	227.1
Paper	9.42	27.1
Plastic	3.08	8.9
Textiles and wood	1.35	3.9
Leather and rubber	0.57	1.6
Metal	1.15	3.3
Glass	0.57	1.6
Other	5.00	14.4
Total	100.00	288

Commercial and institutional waste

The MPKC (2002) stated that 8% of the Domestic/Urban waste is designated as Commercial Waste (23.0 t/day) and 12% as Market Waste (34.6 t/day). No specific strategy is implemented. The MPKC (2002) also stated that 3% of the Domestic/Urban Waste is designated as Institutional Waste (8.6 t/day). No specific strategy is implemented.

Health care waste

In the absence of integrated, safe and sustainable management of solid wastes and ineffectiveness of legislation and law enforcement, hazardous portion of wastes generated in the health care facilities, in general, have also been disposed off in the secondary points i.e.

on-site storage in and around hospital premises with the main stream of mixed normal household waste. The waste is collected by the KCC's vehicles and transported to the ultimate disposal sites of MSW.

Studies show that the generation of health care waste varies from 0.70 to 1.2 kg/bed/day and the percentage of hazardous portion varies from 10% to 30% (Rahman *et al.* 1999; Ullah, 1999, Alamgir *et al.*, 2003 and 2008). Health care waste amount was 426 – 730 kg/day of which 42.6 – 219 kg/day is hazardous waste as recorded in the year of 2002 for the facilities available.

Alamgir *et al.* (2003) analysed for Khulna city a share of 86% non-hazardous hospital waste, 11.6% general hospital wastes, 1.7% non-sharp or reusable wastes and 0.7% sharp wastes. The MPKC 2002 stated hospital / clinic waste that can be divided into 80% general and 20% hazardous waste.

3.5 Institutional and Financial Set up

To manage wastes and to provide service to the waste generators five systems of SWM have been practiced side by side in Khulna. These are: (i) Waste generators, (ii) The formal sector, (iii) The community initiatives, (iv) The private enterprises and (v) The informal sector as described in Table 3.4. In fact, strong coordination and partnership among these systems is not existent which is essential needed to promote an effective and sustainable SWM system.

Table 3.4 Institutional set up

	Institution	Tasks
Waste Generators	Households, Industry, Commercial sector, Institutions,	Store the waste in one particular place for example in plastic buckets and deliver it to the waste collectors that visit the houses or dispose it into a nearby dustbin, also to some persons who do throw their waste in nearby low lying areas or at other places.
Formal Sector	KCC	Administrates solely the Khulna city area, no planning responsibilities neither regarding the city area nor regarding adjacent areas, responsible for collection, transportation and disposal of waste within KCC area.
Community Initiatives	Non Governmental organizations (NGOs) and Community Based Organizations (CBOs)	Collect the solid waste for selected individual households, transporting these wastes to the secondary points as well as to final disposal sites, minimization and recycling, making awareness among the citizens, forming committees at local level Problem: resource recovery, financial issues i.e. cost recovery/effectiveness
Private Enterprises	Small and Medium Enterprises (SMEs)	Overtaking of contracts regarding municipal services, revenue generation through business initiatives in recycling field.
Informal Sector	Individuals, families, Groups or Societies	Comprise all unregistered, unregulated activities related to waste, mainly recycling, basic motivation is self-organised revenue generation driven to work by poverty and absence of better employment possibilities. They work on self-employed basis or as informally organized groups. Informal waste worker carry out economical valuable service but often faces social marginalization, economic insecurity, health hazards and lack of access to normal social services.

The formal sector

KCC as city authority is responsible for collection, transportation and disposal of solid waste. For this system the issues of transfer stations, resource recovery, financial issues i.e. cost recovery/effectiveness, minimization and recycling are insufficiently considered. As per legal mandate, KCC collects and disposes solid waste from the community bins (CB) and other secondary disposal sites (SDS including DBP). KCC is not providing satisfactorily level conservancy services. It collects an average of 50 – 60% of the total waste and the rest

is haphazardly disposed in nearby drains, streets, low-lying open spaces and/or vacant land. Insignificant portion is also collected by the scavengers and the recycling sector. This results in odour and obnoxious conditions in Khulna city. KCC cleaners sweep the roads and clean the drains and accumulate the waste at the road and drain sides. The cleaners collect the wastes in cane baskets and load them into trucks to dump them at the SDS. The city dwellers also dump their household wastes at the nearby CB or SDS/DBP. KCC trucks collect these wastes for final disposal at Rajbandh landfill area located at a distance of 8 kilometers from the city centre.

In 2008, KCC took the necessary steps for the reorganization of the conservancy department and applied for the split up of the conservancy department into a conservancy wing and a waste management wing. For this reorganization most of the existing waste related labours should be shifted to the waste management wing. Furthermore the entire workforce shall be increase by 3 times. KCC justifies with the 20 years extension and growth since the old organogram was passed in 1987. With the increased staff KCC will improve the service and handle the increased amount of solid waste. No operational change and/or other relevant changes are planned.

The residents of the city/town are supposed to pay property based taxes (total 20% of rent value of a property) including conservancy rates for the services rendered by the city corporation/municipality authority for keeping clean the city. The conservancy rates charged is 6% in the case of KCC.

Waste management activity accounts for up to 30% of the municipal expenditures. On the other hand side there is no direct relationship between payment of holding tax (including conservancy rates) and service quality. Since Waste Management is viewed as government responsibility and there is a reluctance to pay increased taxes without experiencing increased service quality. Because there are no separate tariffs for institutional, commercial and industrial waste generators, the household sector cross-subsidies the management of their waste as they generate larger waste quantities (SAP, 2008).

The community initiatives

In order to bridge the gap between the solid waste generation at households' levels and its disposal at the dustbins levels, Non Governmental organizations (NGOs) and Community Based Organizations (CBOs) are playing significant roles in collecting the solid waste through door-to-door collection (DtD) system from the individual households. These organizations are also involved in transporting these wastes to the secondary points. NGO also transports hospital wastes to the ultimate disposal site. The issues of resource recovery, financial issues i.e. cost recovery/effectiveness, minimization and recycling are considered and a number of efforts are being undertaken to sustain the system of SWM through involving the community people more directly. CBOs and NGOs are actively engaged in making awareness among the citizens and forming committees at the local level about proper storage and disposal of waste.

The informal system

The informal private sector comprises unregistered, unregulated activities carried out by individuals, families, groups or small enterprises. Their basic motivation is self-organized revenue generation driven to work by poverty and absence of better employment possibilities. They work on self-employed basis or as informally organized groups. Informal waste worker carry out economical valuable service but often faces social marginalization, economic insecurity, health hazards and lack of access to normal social services (ARRPET, 2004).

The marginal, social and economical unstable situation of the informal waste workers makes it difficult to integrate their contribution into the SWM-system. Therefore, informal workers require organizational and technical support to promote their social rehabilitation, to protect themselves from health hazard and to alleviate the socio-economic conditions of their daily life.

Private enterprises

Based on the good experience made with the privatization of municipal services in the field of waste management in some KCC wards, it is realized that privatization approach could be an important part for solving the existing problems in this sector. Presently in three wards of KCC (5 and 10 in 2008, 29 in 1995) the DtD collection including transfer of collected wastes from SDS to UDS have been contracted to private enterprises. Bangladesh offers an example of community-based micro-enterprise primary waste collection systems and has experience to offer this aspect to other countries. Although service coverage is far from universal, the model of franchising (or micro-licensing) primary collection services is well known, highly socialized and rapidly replicating across the urban areas of the country. Standards vary but the model is well accepted (SAP, 2008).

The private company was entrusted since 1995 in Ward 29 to execute the door to door collection of solid waste from source and subsequent disposal to the designated SDS, the road sweeping, the drain cleaning, the sludge removal and the disposal of collected waste to UDS at Rajbandh from SDS. This type of privatization of SWM started in 1995 until 1998 by SHUBASHTI under the supervision of Local Government Engineering Department (LGED). Since 2003 the service of ward 29 is tendered on an annual basis and the now "Mutual Enterprise" got the contract for the current year at a monthly contract rate of 74,620 BDT. Supervision takes place through daily communication with the conservancy department of KCC and countersign by ward commissioner. Fixed times from 8am to 2pm are agreed with the households. 6 Rickshaw vans with one driver and one helper are needed for the DtD collection of solid waste to the SDS. 8 female street sweepers and 6 male drain cleaners are employed to serve the ward.

3.6 Policy and Legislation

Until now there is no policy, legal or planning framework at a national level for the management of municipal solid waste (MSW) and hazardous waste (SAP, 2008). Related legal provisions at the national and local levels are stated in Table 3.5.

Table 3.5 Waste related legal provisions at the national and local levels (CDIA, 2009)

Level	Legal provision	Content	Institution
Central Government National Level	" Bangladesh Environment Conservation Act, 1995"	Conservation of the environment, improvement of environmental standards and control and mitigation of environmental pollution, defition of "waste" as substance that can be harmful to the environment. No specific Waste Management Act, Regulation or Guideline in place	Department of Environment (DoE)
Local Government City Corporation Level	Khulna Municipal Corporation Ordinance 1984,	Corporation shall make adequate arrangements for the removal, collection and proper disposal of refuge from all public streets, public latrines, urinals, drains, public buildings and land vested No binding and obligatory regulations	City Corporation Conservancy departments
Local Government Municipality level	Pourashovas i.e. Municipality Ordinance, 1977	Same regulation as for Municipal Corporation No binding and obligatory regulations	Municipalities Conservancy departments

The Ministry of Local Government, Rural Development and Co-operatives (MoLGRDC) provide funds through an Annual Development Program to KCC for undertaking development programs in the area of SWM both directly and indirectly. The direct financial assistance is in purchasing equipments for SWM and indirectly in constructing drains. Provided funds are insufficient in context to the volume of works and are not following an overall coordinated and agreed infrastructure investment plan. KCC has no planning responsibilities neither regarding the city area nor regarding adjacent areas. For this purpose, Khulna development authority (KDA) was established under central government as regional planning and development authority for a specifically defined task.

3.7 Functional Elements of SWM in Khulna City

The SWM is a complete chain which connects the various relevant links i.e. components starting from generation point to the ultimate disposal. The functional element of SWM at Khulna is almost similar to that of the other cities of Bangladesh. The functional elements indicating the flow of wastes from the starting point till the collection from on-site storage

for ultimate disposal is shown in Figure 3.7 and hence discussed briefly in the following sections.

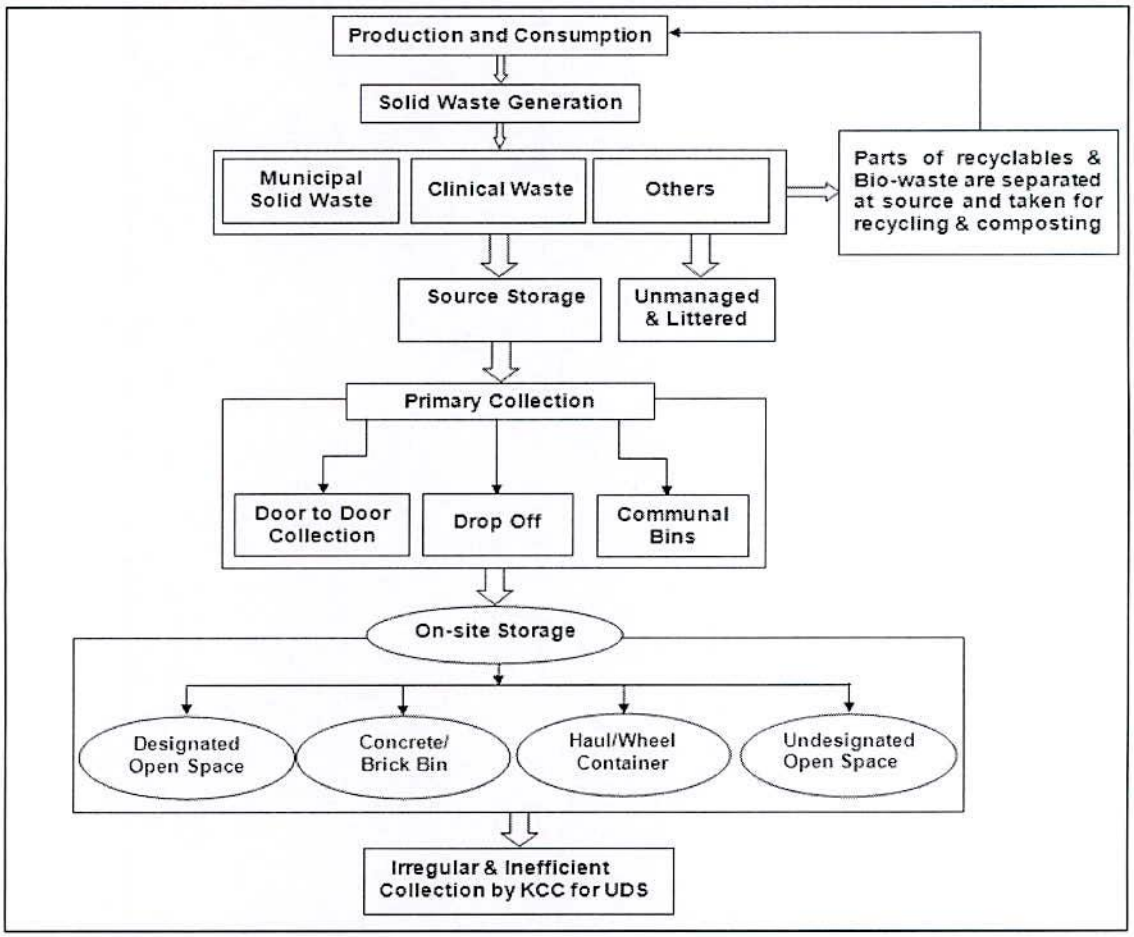


Figure 3.7 Functional elements of SWM in KCC (Jahan *et al.*, 2009)

3.7.1 Primary Collection and Transport

Primary collection includes the concentration of the household wastes. This is currently done by the house owners or families (children, servants, housewives, home owner, etc.) or via DtD by 14 NGO, 5 CBO, 3 private enterprises. In Khulna city, primary collection of solid waste management is accomplished in three ways:

a) DtD Collection System,
b) Communal Collection System &
c) Drop off.

In DtD collection service, the house holders store wastes in a bin, basket or bag within their house premises. Waste collection workers collect the bin, basket or bag, empty it into the collection vehicle and return the containers to the premises. DtD collection is done mainly by NGO, CBOs and city authority who charge a fee for periodic removal of waste where rickshaw van is used for major transporting vehicle for DtD collection of waste as shown in Figure 3.8. In the areas where DtD systems are not available, house dwellers or servants carry wastes to nearby community bins/secondary sites or similar facilities at their own responsibility. City dwellers also dispose waste to the open land/road sides/drains indiscriminately. It was estimated that fewer than 30% of KCC households had access to waste disposal facilities (CDIA, 2009). While this situation has improved due to the increased involvement of NGOs and the private sector, currently only 50-60% of household waste is collected while most of the remainder (40-50%) being disposed of indiscriminately in drains, at roadsides and into vacant areas. City authority has some limited numbers of non-motorized Rickshaw vans and Hand trolley those are mainly used for the collection of MSW from community bins located at roadside, home side, near market and transfer to the SDS. Non-motorized rickshaw vans are generally used to operate the collection system. One driver and one helper are assigned for each van and the collection generally occurs daily for 8 to 9 hours (7 am to 5 pm) from residential sources as well as some offices. Non-motorized rickshaw vans are almost similar 3-wheeler type, which are used in different cities of Bangladesh. The capacity varies from 250 to 350 kg/van/ trip. DtD collection service is aesthetically and environmentally more satisfactory but comparatively more expensive.

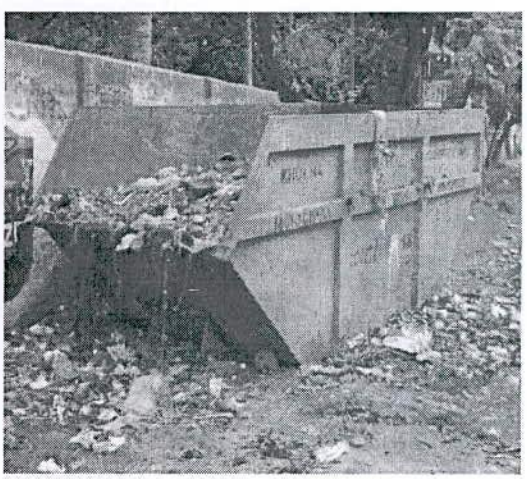
Figure 3.8 Newly designed manually driven Rickshaw Van for Door-to-door collection

3.7.2 On-site Storage

On-site storage is the secondary disposal site (SDS), Transfer Station and Handover Points, which receives wastes from primary source and transferred to the designated location for processing/recycling/treatment and mostly for ultimate disposal. There is no transfer station and handover point in Bangladesh in true sense. SDS is considered as the facilities where large amount of wastes are accumulated at open spaces, dustbin points, and containers (shown Figure: 3.9) and finally transferred to the desired sites by large vehicles such as open or closed Trucks, Demountable haul container truck, etc. Containers of different shapes, sizes and functionality are available. In Bangladesh, city authority is solely responsible for providing SDS, collection of wastes from SDS and transfers them for final disposal as per existing City Corporation Act. SDSs are located in the selected places based on population, space availability, accessibility and other local factors such as desire of influential city dwellers or public representatives. Wastes are deposited in SDS directly by the generators, NGOs, CBOs and city authorities. City corporation's motorized vehicles collect the wastes from SDS and transfer to the UDS. Some NGOS transfer their collected organic wastes to composting plants. In some cases, especially for the residential areas along narrow streets where SDS is not suitable, community bins are provided from where wastes are transferred to SDS. Community bins are mostly made of the concrete but masonry and steel container are also available. The concrete and masonry bins are in variable sizes but normally rectangular in shape of 1mx1mx1 m. Generally there is a door at one side and no cover on the top of the community bins. Wastes from community bins are transferred to SDS mostly by city authorities through non-motorized Rickshaw van and hand trolley. In KCC, there are more than 60 SDS, around 1200 community bins and 28 haul containers, located on roadsides throughout the city (Chowdhury, 2006).

(a) Designated Open Space

(a) Dustbin Point



Demountable Container

Figure 3.9 On-site Storage facilities in Khulna City

A field survey shows that the SDS including DBP can be divided into three main categories (open space, dustbins and container) with some sub categories. Open spaces with a share of 47% are in two-thirds located on earthen ground. From them 2/3 possess of insufficient space resulting in obstacles for the surrounding. Only one-fourths is on more or less solid platforms. Dustbins with a share of 43% are located to three-fourths on the roadside and to 15% in drains. One-thirds of them are broken and only a few possess of sufficient space that they are not an obstacle for the traffic. Only 10% of the SDS's are made of containers mainly on concrete platforms. At all SDS, the rickshaw van drops the waste on the ground and it requires additional reloading work to fill the KCC's demountable container and transport vehicles. The reloading activities often cause traffic interferences because of the location of the SDS at/on the roads. Scavengers pick for valuables and spread the waste in the surrounding. The analysis is presented in Table 3.6.

Table 3.6 Present scenarios of some studied SDS in Khulna City (Diaz et al. 1998)

Category	No.	Percentage	Remarks / Intermediate use
Open space	41	38 %	Open spaces with insufficient space and located on/at roads and drains should be closed, open spaces with sufficient spaces (on platforms) should be developed to container locations on solid platform
On earthen ground	29	71 %	
Insufficient space	31	76 %	
On solid platform	10	24 %	
On/at road	37	90 %	
On/at drain	26	63 %	
Dustbin	58	54 %	Dustbin locations with insufficient space and located on/at roads and drains should be closed, dustbin locations with sufficient spaces should be developed to container locations on solid platform
broken	20	34 %	
Insufficient space	52	90 %	
On/at road	56	97 %	
On/at drain	44	79 %	
Container	8	8 %	Proper management should be ensured
On earthen ground	2	25 %	
	6		
On solid platform	7	75%	
Open	1	87%	
Closed		13%	

3.7.3 Waste Collection from On-site Storage

Wastes irrespective of types are generally disposed at the SDS. In general, city authority collects wastes from the SDS and disposed to the designated UDS. SDS are often in poor condition and/or badly located (e.g. near or on drain, footpath obstructing pedestrian movement), it always remains with wastes even just immediately after the collection shown in Figure 3.10 and transfer of wastes, its operation often causes traffic jam and waste spreading, flies, dogs and even by scavengers. The situation of SDS in the city is very much unpleasant and it reveals as an effective step causing most nuisances and deteriorating city environment at a large scale. All the SDS of Bangladesh does not have minimum infrastructure requirements and environmental protections. It is evident that all the disposal sites are posed to high threat to health and environment. As a result, city authorities are facing very complicated situations for the management of vast quantities of MSW. Due to non-engineered situation, the existing sites are also going to early closure. Peoples are also protested to close some existing sites because of their hazards nature. So, the existing practices will not get the support from concerned stakeholders in future. So the transfer Station may provide a safety measure in a good waste management system addressing this social and environmental issue despite the realization that only affordable disposal solution in Bangladesh for the foreseeable future –is to establish Transfer station (TS).

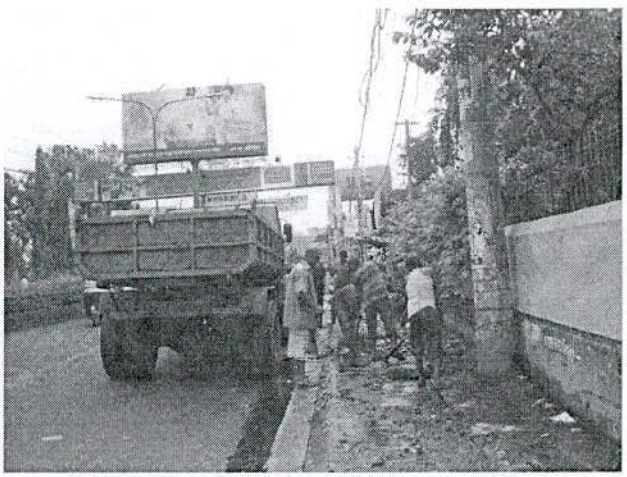


Figure 3.10 Waste collections from SDS

3.7.4 Waste Transport from On-Site Storage

Generally collection vehicles of KCC such as covered waste truck, normal truck, open truck, waste truck with compactor, Tractor with trolley, haul container truck, power tiller with trolley are used for waste collection from SDS and transportation. Figure 3.11 shows the

typical waste collection and transportation in Khulna metropolitan city. The conservancy department of KCC daily transports the MSW deposited in the SDSs. Due to the inherent constraints of resources and mismanagements, the transport efficiency is revealed as 60 to 70% (CDIA 2009). The details of transport used for disposal solid waste in Khulna city with the vehicle fleet is listed in Table 3.7. 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. However, it is true that even having these constraints the overall situation of management of solid waste in Khulna city could be improved introducing a sustainable system (SAP 2008). There is no implemented time related operation plan of the SDS indicating time slots for the city dwellers to drop the wastes until the waste is reloaded to a KCC truck. Average transport velocity in urban areas is 20–25km/h at daytime, 25–30km/h at night time while it is 50–60km/h in rural areas. In average a truck needs 3–4h/tour because of long loading time and low speed on the roads. Given time for the CBOs and NGOs for waste delivery to the SDSs is daily 10am, after 10am the KCC trucks normally load the waste and transport it to the UDS. However, the time schedules are not maintained properly. It also varies at different locations. Normally 40% of the trucks are under repair (WasteSafe 2005). Table 3.8 shows that KCC can transport between 70–200 t/day. This is well below the estimated daily generation of waste (300 t/day). The situation is exacerbated by the division of SWM responsibilities between the transportation and conservancy departments of KCC.

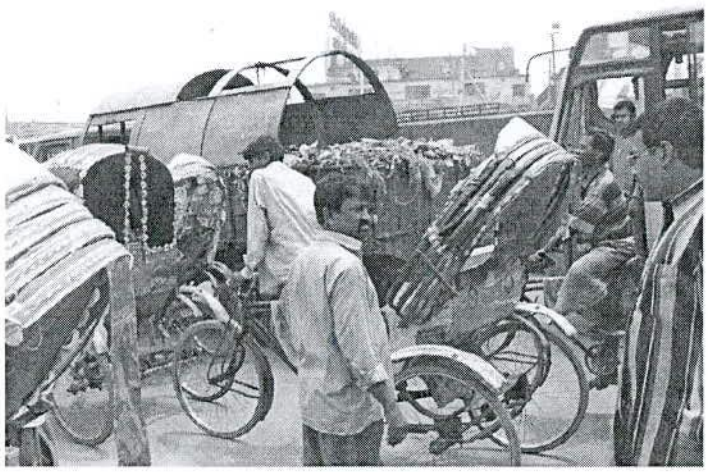


Figure 3.11 Waste carrying vehicles for the UDS

Table 3.7 **Vehicles used for the secondary disposal of Solid Waste by the Conservancy Section of KCC. (CDIA 2009)**

Vehicle Type	No.	Pay-load [tons]	Location
Covered Trucks	3	5	Mobile
Dump Truck – large	9	7	Mobile
- medium	8	5	
Tipping Truck (container carrier)	L: 5	L: 5	Mobile
	M: 2	M: 2.5	
Wheel loader	1		landfill
Back wheel loader	1		landfill
Chain dozer	1		landfill
Chain dozer carrier	1		landfill
Garbage loader	1		SDS
Tractor with trolley	1	4	Mobile
Power Tiller with trolley	2	0.25	Mobile
Side Tipper Trucks with double containers	1	2	Mobile
Demountable Container	20	5	Mobile

Table 3.8 **KCC Transport Capacity for SWM (After CDIA 2009)**

Vehicle Type	No. of	Payload	Transport capacity [tons/day]		
	vehicle	[tons]	1	2	3
Covered Trucks	3	5	15	30	45
Dump Trucks	9	7	63	126	189
	8	5	40	80	120
Tipping Truck (container	5	5	25	50	75
carrier)	2	2.5	5	10	15
Tractor with trolley	1	4	4	8	12
Power Tiller with trolley	2	0.25	0.5	1	1.5
Side Tipp. Trucks double cont.	1	2	2	4	6
	Total		154.5	309	463.5
	75 % for SWM		115.9	231.8	347.6
	60 % in operation		69.5	139.1	208.6

3.7.5 Waste Disposal at Ultimate Disposal Site

The existing UDS of KCC is located at the Mouza Rajbandh under Batiaghata Upazila, Khulna District, besides Khulna-Stakhira Highway, which is around 8.0 km West away from the city centre (Hotel Royal and Castle Salam Square) with a total area of 4.85 hector. as recorded in 2000. The existing UDS has been filled-up by the year 2009.

The site has been characterized as an open dumping without taking any engineering means as sanitary/engineered/controlled landfill. 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 sides. This causes serious pollution to the surrounding

environment, ground water, and soil and is very hazardous to health. Environmental pollution and emissions is an enormous problem. The following are the major problems created in Khulna as far as the solid waste collection and dumping are concerned: open dumping, creating odour, spreading bad smell, spreading waste by birds and underground leaching (SAP, 2008). WasteSafe (2005) designated this open dumping site is in the rank of High Hazard predicted based on HIS (Indian Health Service) and RCRA (Resource Recovery and Conservation Act). Development of 5 new dumping sides at Rajbandh has been recommended (Old and New Rajbandh), Aronghata, Chachibunia, Phultala and Karnopur (MPKC, 2002). The groundwater table in most areas is very near to the ground surface and the leachate may likely come in contact with surface water and ground water aquifer. Potential ground water resources in and around Khulna City are at Phultala, Beel Dakatia, Naihata (Rupsha), Arjanti (Rupsha) and Dumuria.

3.8 Recycling and Treatment

Non-biodegradables

A study of 2007 reveals that about 11.12 tons/day plastic (about 70 % of the total generated Plastic) was recovered daily in Khulna.

Households, institutes and market places are the primary source of plastic. it is collected on various stages: at the lowest stage the waste bin collectors are street children called "Tokai" (a local name used all over Bangladesh). They came from nearby slum areas and separate the plastic waste from the CB and SDS/DBP. House to house collectors locally called "Feriwalas" collect or buy uncontaminated plastic waste at source. Both the "Tokai" and "Feriwalas" sell their recyclable plastic to recyclable dealers. As reported some NGOs also involved in recycling activities regarding plastics, glass and other materials. Small recyclable dealer's collection is below 250 kg/day. Normally small recyclable dealer separate the recovered plastic and sell it to medium recyclable dealer. Medium recyclable dealer often also deal with other materials like paper, glass or metal. Medium and large recyclable dealers finally sell to the recycling industry. The recycling industry uses locally available technology such as manual sorting, cleaning, mechanical heating / cooling, die casting or molding.

In Khulna also 11 small industries are involved in plastic recycling. They sell 3.6 tons/day plastic for reuse on the market and recycle 7.51 tons/day into water pot, paper, cast-iron products, plastic produce wheel of toys etc.

A recent estimation shows that in this sector at Khulna city about 1,500 employees are involved. Moreover, it is revealed that in an average, the small dealers make a profit 100-150 BDT/day, while the large dealers make 5,000 to 7,000 BDT/day. However only the initial steps of the entire recycling process are located in Khulna and the sorted and cleaned materials are shipped to Dhaka for further use.

Biowaste

Since the major waste fraction is biodegradable, composting as technique to recycle organics into the agriculture is of high importance. Some NGO in Khulna have already started composting waste and transform those into fertilizers, but capacity is low and plants were shut down or start with delays. Currently, three NGO run compost plants on a low level with monthly throughputs of 1–25 t. They employ between 2–13 people, their salary is within 600–2,000 BDT/month. As production cost was estimated as 3.25BDT/kg of compost.

Treatment of Hospital Waste

NGO Prodipan has run separate collection and treatment of hospital waste for around a third of health care facilities in Khulna since 2000. General and kitchen waste was disposed together with other household waste at the UDS. Re-usable waste was shredded, cleaned and stored for recycling. Sharp waste was encapsulated in a 2.13m deep concrete chamber. Remaining general medical waste was treated in local burning unit with residuals disposed of at the UDS.

The incinerator constructed by PRODIPAN was located at the Rajbandh UDS and consisted of a burning chamber of 1.5x1.5x1.8m sized and a chimney of 11.2m height of an opening vent at the top is 0.45x.045m. Kerosene fuel was spreading over the wastes to accelerate burning. The burning continued for about 2 hours. After cooling down naturally (nearly 18 hours), the ashes were dumped in a nearby earthen pit. There was no system to monitor the quality of gas emission and ashes produced due to the crude and inadequate

burning process for hazardous hospital waste. The incinerator has been out of service for some time and there is no longer any controlled treatment of hospital waste.

3.9 Other issues

a) Legal Aspects

A new SWM – law has to deal out responsibilities and duties in SWM to ensure the introduction of environmental responsible SWM standards into corresponding laws. Legislation for SWM needs to be strengthened at two levels: national and local. Box -1 sets out the requirements for national level legislation while Box -2 does likewise for local legislation.

Box -1. Legislative Strengthening – National Level

- Waste generators are responsible for their waste separation
  - Households: source separation into organic and recyclable waste, hazardous waste
  - Commercial enterprises: organic and inorganic waste, hazardous waste,
  - Health care facilities: organic and inorganic waste, hazardous waste
- Waste generators have to deliver the waste collected by daily door-to-door collection to the local municipality (here: KCC) and transfer ownership to them.
- Local municipality (here: KCC) has responsibility and duty for proper circle flow management within their boundaries to dispose of the waste by environmental responsible SWM procedures and under sustainable environmental standards, to organize DtD, to concentrate the waste at Transfer Stations (TS) and to organize the transport from designated waste treatment plants and ultimate disposal sites.
- Local municipality (here: KCC) has the right to take fee to finance the operation of SWM.
- Local municipality (here: KCC) has the right to transfer municipal service operation (e.g. tasks within SWM) to third parties.
- Introduction of hand over certificates to supervise waste shipment

- Environmental responsible and sustainable SWM standards have to be defined
- By-laws and/or amendments to introduce SWM-aspects in future infrastructure and settlement development .
- The need of a clear penalty system to fine littering, wild dumping and non-compliance with the SWM-rules.

Box -2. Legislative Strengthening – Municipality Level

- Considering waste management needs in new residential area development so that adequate space is provided for transfer stations.
- Planning interventions in spontaneously developed areas
- Recognitions of special requirements in town planning
  Road size for collection vehicles
  Plots for transfer stations with sufficient access of appropriate type of vehicles and road connection to main road
- Quality standards of compost
- Necessary financial and other related support to set-up waste recovery industry.

b) **Awareness building and social aspects**

Community participation programs and public awareness campaigns are the precondition for the implementation of all improvements in SWM in order to inform, motivate and train the public to cooperate and participate with the SWM service and to improve knowledge regarding public health issues which result from indiscriminate waste disposal.

A variety of awareness building measures are needed to ensure the active participation of local residents in key aspects of the intended SWM-system, namely source storage and separation, door to door collection and the avoidance of littering. In order to achieve this, a variety of programs and campaigns are proposed; these are set out in Table 3.9.

Table 3.9: Awareness Building Measures for KCC area

Components	Responsible authority or organization	Stakeholder, area covered
Leaflets, posters, stickers	KCC	Entire city: households, commercial places, institutions, etc.
House-to-house motivation	NGO, CBO or civic societies	Entire city: ward wise
Group meeting (ward level)	Ward councilor	In every ward
Group meeting (central body)	KCC	Entire city
Rally	KCC, DoE, NGO, CBO, Environmental group	Every school
Art competition	Ward councilor/committee	In every ward
Street drama	Ward councilor/committee	In every ward
Billboard/ Festoon	KCC, private enterprise	Entire city (at important locations)
Annual fair	KCC	Entire city (central event)
Mass media	KCC	All electronic and news media

c) **Human Resource Development**

The implementation of the SWM proposals described above will not be possible without a significant strengthening of the technical and managerial capacity of the staff of KCC and other institutions (KCC, CBO, NGO, "Informal waste worker associations"). HRD is therefore seen as an essential element of the study's proposals. HRD training proposals and modules need to be designed to reflect the different responsibilities and academic backgrounds of all those involved in SWM operations.

In the longer term, the establishment of a training center and/or arrangement with an institution which is strong in waste management to operate the HRD (Shown in Table 3.10) scheme should be taken into consideration.

Table 3.10: Human Resource Development for SWM

Target groups	Organizations	Contents	Methods of presentation
Upper management	KCC, NGO, CBO, private enterprise, labour union, acad. Field, recycling associate.	General SWM, infrastructure development, financial aspects, organization of municipal services, occupational health	Workshop with high share of theoretical content, field trips to SWM facilities
Middle management		General SWM, financial aspects, organization of municipal services, specific waste management, occupational health	Workshop with high share of theoretical content, field trips to SWM facilities
Lower Management	KCC, NGO, CBO, private enterprises	General SWM, organization of municipal services, specific waste management, waste collection and transport, waste treatment, Waste recycling, landfill, occupational health	Training, workshop with balanced relation between theoretical / Practical content, field trips, short internship at practical. SWM facility.
Super-visors	KCC, NGO, CBO, private enterprises	General SWM, specific waste management, waste collection and transport, waste treatment, waste recycling, landfill, occupational health	Training workshops. with balanced relation between theoretical / practical content, field trips, internship.
DtD staff	KCC, NGO, CBO, private enterprises	General SWM, specific waste management, waste collection and transport, occupational health	Instruction with high share of practical training at pilot plants or regular operation plants
TS staff	KCC, NGO, CBO, private enterprise	General SWM, specific waste management, waste collection/transport, waste recycling, occupational health	
Compost staff	KCC, NGO, CBO, private enterprise	General SWM, specific waste management, composting, occupational health	
MBT plant staff	KCC, NGO, CBO, private enterprises	General SWM, specific waste management, MBT, occupational health	

Recycling staff	NGO, CBO, private enterprises, recycling associate.	General SWM, specific waste management, waste collection/transport, waste recycling, occupational health	
Landfill staff	KCC, private enterprise	General SWM, specific waste management, landfill, occupational health	

d) **The Clean Development Mechanism**

The Clean Development Mechanism (CDM) is an international system of carbon emission-reductions trading set up under the United Nations Framework Convention on Climate Change (UNFCCC). It has already been applied to the waste management sector in Bangladesh on a limited scale through a pioneering pilot project for aerobic composting as a means of reducing greenhouse gas emissions. CDM projects offer an exciting new avenue for investment and revenue generation, with substantial potential environmental benefits where it is approved to be implemented (SAP, 2008) because they help reduce greenhouse gas emission.

CHAPTER IV

Materials and Methods

4.1 General

The methods used in the study area include collections of primary data such as topographic map, GIS based KCC map, GIS Software (Arcview 3.2a and Arcview 3.3), Individual ward numbers information and respective population density and waste amount. A detailed investigation over the whole study area was carried out during January, 2010 to July, 2010.

4.2 Research Framework

At the beginning of this study, present status of the Secondary Disposal Sites in Khulna City was identified by conducting physical inspection as well as taking information from the secondary sources. The planning and strategy was finalized to design necessary aspects of Transfer Station. A brief description of the procedures of the research works are provided below and working steps are shown in Figure 4.1.

i) GIS based KCC map and GIS software (Arcview 3.2(a) and 3.3) were collected at first.

ii) Secondly, Primary raw data was collected from nearest sources shown in Table 4.1 from KCC using GIS Survey technique and field inspection.

iii) Then influence area was drawn on the basis of one km radial distance as rickshaw van will be the major transporting vehicle for waste transport and a rickshaw van can cover maximum two km travel distance/tour which will reduce cost. Two km radial

distance was also considered to compare between the two buffer zones covering wards to take decision which one can play more effectively.

iv) Then location layout and points of Transfer Station was sketched on each influence areas.

v) After that, total population was estimated on that influence areas considering future perspectives.

vi) Then, waste generation rate was counted on that influence areas.

vii) Size and facility of the Transfer Station was identified on the basis of population, waste generation rates and the land availability.

viii) Also types of transfer station were investigated and finally design of Transfer Station was accomplished.

Further details of map and Table are shown in chapter V in planning and design of Transfer Station (TS) section.

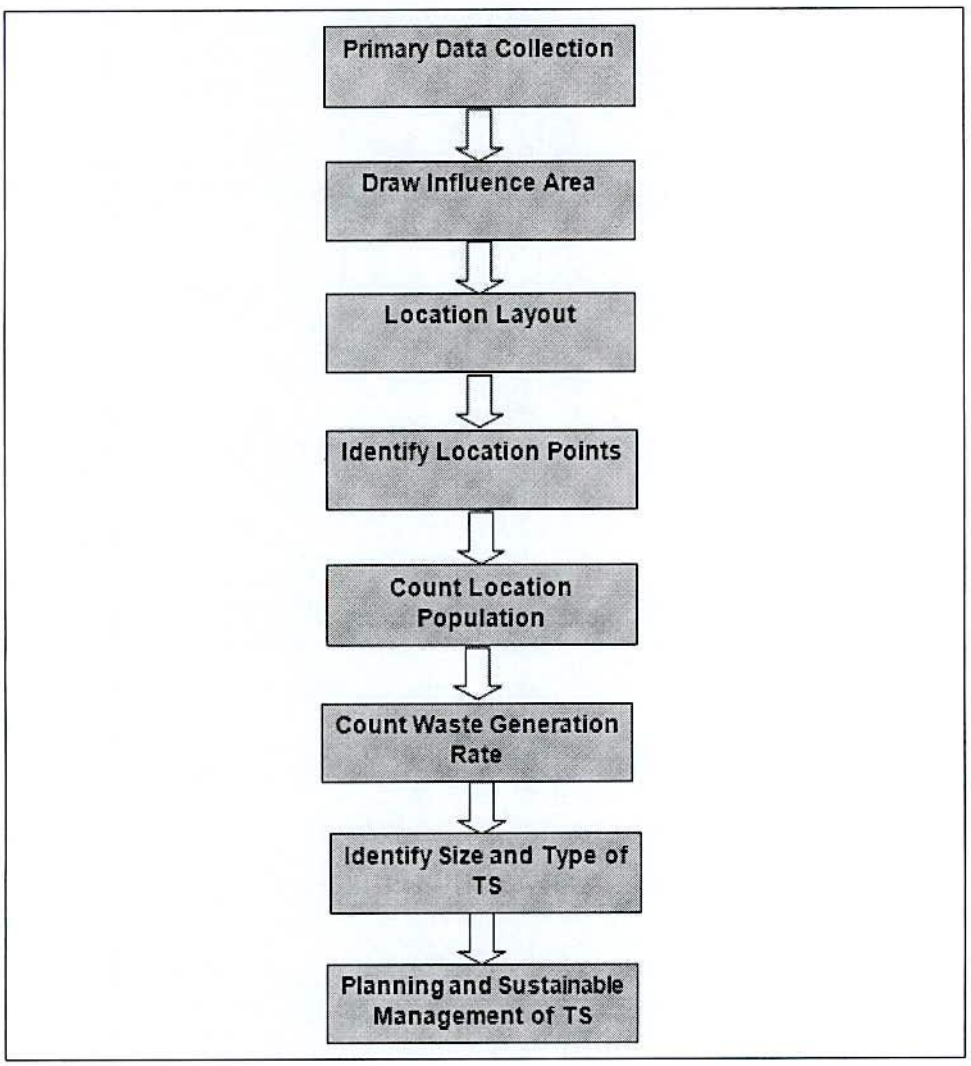


Figure 4.1 Working Steps of Transfer Station

Table 4.1 Ward wise Area and Population Data of Khulna City Corporation

	Ward wise Area and Population Data of Khulna City Corporation					
Ward No.	Area (sq. km)	Population	population density person/sq.km	Waste amount tons/day	Area (acre)	Population density per Acre person/acre
1	3.37	37,090	11006	12.833	832.74	44.54
2	5.27	24,065	4566	8.326	1302.24	18.48
3	3.22	39,535	12278	13.679	795.68	49.69
4	3.24	22,412	6917	7.755	800.62	27.99
5	0.57	30,430	53386	10.529	140.85	216.05
6	0.50	40,336	80672	13.956	123.55	326.47
7	0.44	24,442	55550	8.457	108.73	224.80
8	0.37	31,564	85308	10.921	91.43	345.23
9	2.90	44,081	15200	15.252	716.61	61.51
10	0.98	55,205	56332	19.101	242.16	227.97
11	0.48	35,668	74308	12.341	118.61	300.72
12	1.00	35,945	35945	12.437	247.11	145.46
13	1.22	32,572	26698	11.270	301.47	108.04
14	1.73	37,567	21715	12.998	427.49	87.88
15	2.39	32,824	13734	11.357	590.58	55.58
16	2.30	45,492	19779	15.740	568.34	80.04
17	3.43	45,388	13233	15.704	847.57	53.55

18	0.64	28,389	44358	9.823	158.15	179.51
19	0.54	37,601	69631	13.010	133.44	281.79
20	0.30	36,711	122370	12.702	74.13	495.21
21	0.58	37,304	64317	12.907	143.32	260.28
22	1.16	40,046	34522	13.856	286.64	139.71
23	0.83	34,469	41529	11.926	205.10	168.06
24	0.53	52,624	99291	18.208	130.97	401.81
25	1.10	33,339	30308	11.535	271.82	122.65
26	0.85	33,108	38951	11.455	210.04	157.63
27	0.86	50,835	59110	17.589	212.51	239.21
28	0.57	35,304	61937	12.215	140.85	250.65
29	0.91	34,070	37440	11.788	224.87	151.51
30	1.72	59,385	34526	20.547	425.02	139.72
31	1.65	46,464	28160	16.077	407.72	113.96
Total	**45.65**	**1,174,265**		**406.296**	**11280.35**	

4.3 Review of Recent Research work in this field

The concept of Transfer Station in solid waste management is one of the very up-and-coming events especially in Developing countries like Bangladesh. Recently, various workshops and research works are going on Transfer station. Comments from the stakeholder workshop stated that it is very important to include separation activities on a temporary basis on TS. From stakeholders' views, CDIA report stated possible locations and design configuration of TS in Khulna City Corporation and it is estimated that 12 TS would be required.

At present no effective transfer Station technologies have been practiced in Khulna City Corporation and even in any major cities of Bangladesh. Recently, some of construction works of Transfer Stations (TS) are in the order in Mymensingh by German Technical Cooperation (GTZ, Bangladesh). In Rajshahi, a small scale transfer station technologies have been introduced. The reliable information is collected based on the data of primary and secondary sources. Effective and appropriate technology of TS can reduce the current mismanagement of solid waste disposal facilities and this new practice can serve a clean, hygienic and unpolluted environment to live more suitably. The change of MSW collection, sorting at household level, recycling -reuse, effective installation of TS and proper disposal of solid waste to the final landfill site can add to the facilities of appropriate solid waste management in a hygienic way. Public attitudes about and willingness to participate in MSW management are the main driving forces in such endeavors. Still many research works should be carried out on TS. No fruitful work on TS had yet not been completed.

CHAPTER V

Planning and Design of Transfer Station

5.1 General

A variety of issues must be taken into account during the planning and sitting stages of transfer station development. This chapter discusses planning of Transfer station considering the sitting guidelines of TS, types of waste transfer stations typically accept and unacceptable waste as described in chapter two, factors affecting a transfer station's size and capacity. Also highlights the issues regarding selection of the location of TS, location layout, design of TS and its environmental impacts.

5.2 Planning Of Transfer Station

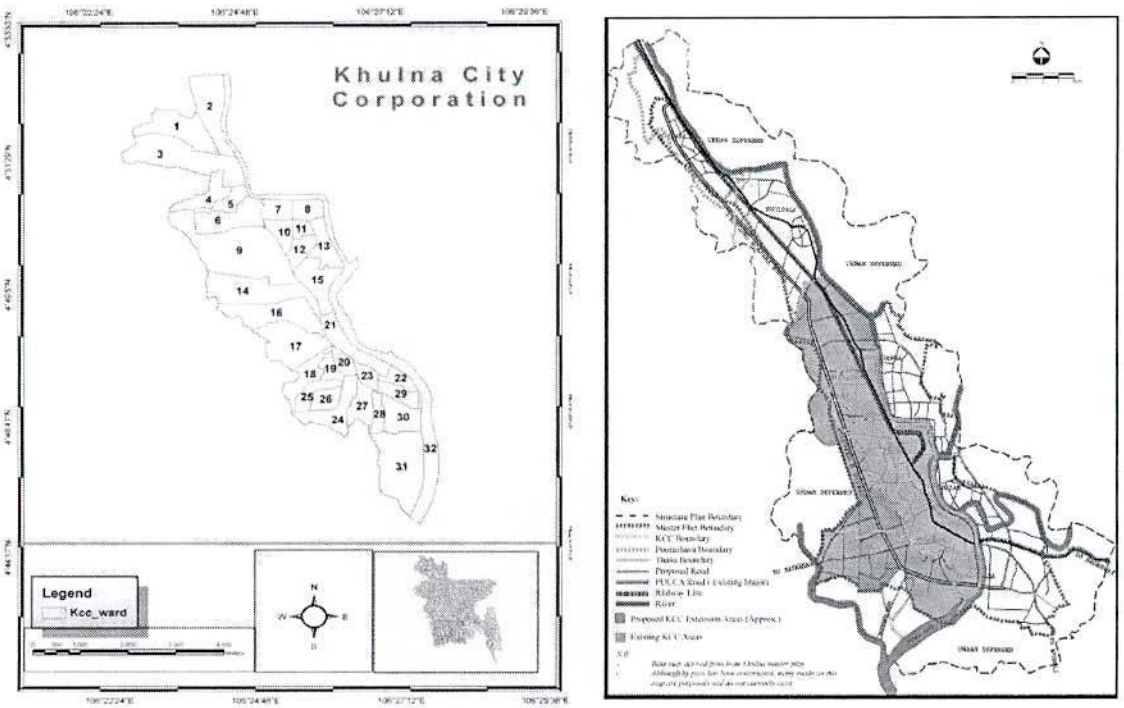
Proper planning of transfer station is very important before its implementation to cover an area and to serve a community. All the relevant aspects need to consider with great care. However, to make tentative plan about the locations of transfer station in Khulna city, here, limited number of parameters are considered as discussed in the following sections.

5.2.1 Khulna City Plan and Layout

The location and the city plan layout play a vital role in the planning of transfer station for MSW management in any urban areas. Khulna City is a linear shaped city based on the flood free natural levees (height from 2.13 to 4.27m) on both sides of the Bhairab-Ruphsa River. Its elevation decreased sharply to the east and west directions down to flood plains (height from 1.22 to 1.52m). The Khulna City Cooperation (KCC) is shown in Figure 5.1.

ALAMGIR and AHSAN 2007 analyzed the waste generation with regard to the income level of the city dweller and found differences from 0.368 kg/capita/day (high socio-economic level) to 0.203 kg/capita/day (low socio-economic) with an average of 0.297 kg/capita/day. However, an informal estimation of KCC'S population by its authority is considered as 1.5 million since 2005 as reported in various reports (WasteSafe 2005). In such estimation, the amount of wastes will be higher than that of as stated earlier.

The area of KCC is 45.67sq.km. KCC is structured in 31 Wards. The current (2009) population of KCC will be assumed at 960,000 inhabitants and for KCPA at 1,169,000 inhabitants. All proposals are based on a population of the KCC of 1,174,265 in 2010 and incorporate likely changes in per capita waste generation and its composition. These projections imply an approximate 50% increase in daily waste generation from 288 tons to 406.30 tons in 2010. Map of KCC and KCPA are shown in Figure 5.1.



(a) KCC Map **(b) KCPA Map**

Figure 5.1 Map of Khulna City and the surrounding area

5.2.2 Planning Criteria to Set up Transfer Station in KCC

To make a sustainable transfer station system, the existing practice on SWM at Khulna city is considered in the planning. Presently, the DtD collection system by rickshaw van is proved as an effective and popular method to bring the wastes into the SDSs. The Rickshaw van is driven manually and collected wastes with the help of one driver and one helper. In this circumstance, the location of transfer station should not be far from 2 km distance from the source, while rickshaw van will be considered as the major transporting vehicles of waste from generation source to SDSs. As presented in Table 5.1 for primary collection, rickshaw van can carry waste 0.25 to 0.5ton/tour and transport waste amount is about 0.25 to 1.5tones daily. It can travel maximum 8 working hours and can cover the area maximum 1km radius. Other important aspects need to consider at the design stage to materialize the transfer station concept are: incoming waste amount and type, type of outgoing vehicle, land availability and accessibility, sorting/ no sorting facilities, covered or uncovered, financial sustainability and the management, etc. Features of rickshaw van are shown below in Table 5.1.

Table 5.1 **Rickshaw van transport capacity, acceptable distance and tours per day (After CDIA 2009)**

No. of Rickshaw vans	Transport capacity per van [kg]	Acceptable transport radius [km]	Tours per day	Transport capacity per day [kg]
1	500 375 250	1	2-3	1,000 – 1,500 750 – 1,025 500 - 750

5.2.3 Location of Ultimate Disposal Sites

The existing UDS of Khulna city is located at the Mouza Rajbandh (Figure: 4.2) under Batiaghata Upazilla, Khulna District, besides Khulna-Satkhira Highway, which is around 8.0 km west away from the city centre (Hotel Royal and Castle Salam Square). The

Pilot Scale Sanitary Landfill (PSSL) was designed by Wastesafe team of KUET and hence constructed in Rajbandh, Khulna, which is now in final covering stage. The wastes are collected from SDSs and transported by KCC's initiatives and hence finally disposed in UDS. The used transferring vehicles have an average transport velocity of 20–25km/h at daytime and 25–30km/h at night time with a wide variation of pay load ranging from 0.25 to 7tons (CDIA 2009). In an average, a truck needs 3–4h/tour because of long loading time and low speed in the city areas. However, the time schedules are not maintained properly. It also varies at different locations. There are some proposal made by Khulna Development authority (KDA) in its Master Plan (2002) for the possible future UDS. These possible sites are Aronghata, Chachibunia, Phultala and Karnopur (MPKC 2002) as shown in Figure 5.2. All these sites are located in the west side of newly constructed Khulna by-pass. So there exists very good communication with different parts of KCC. These aspects should be taken into consideration for the effective functioning of TS to be developed in the different locations of the city. The distance, road links and traffic congestion in the roads between the TS and UDS might play very vital role in the planning. The use of manually driven rickshaw van can be considered as an alternative of existing KCC's vehicles to transfer the wastes in the UDS.

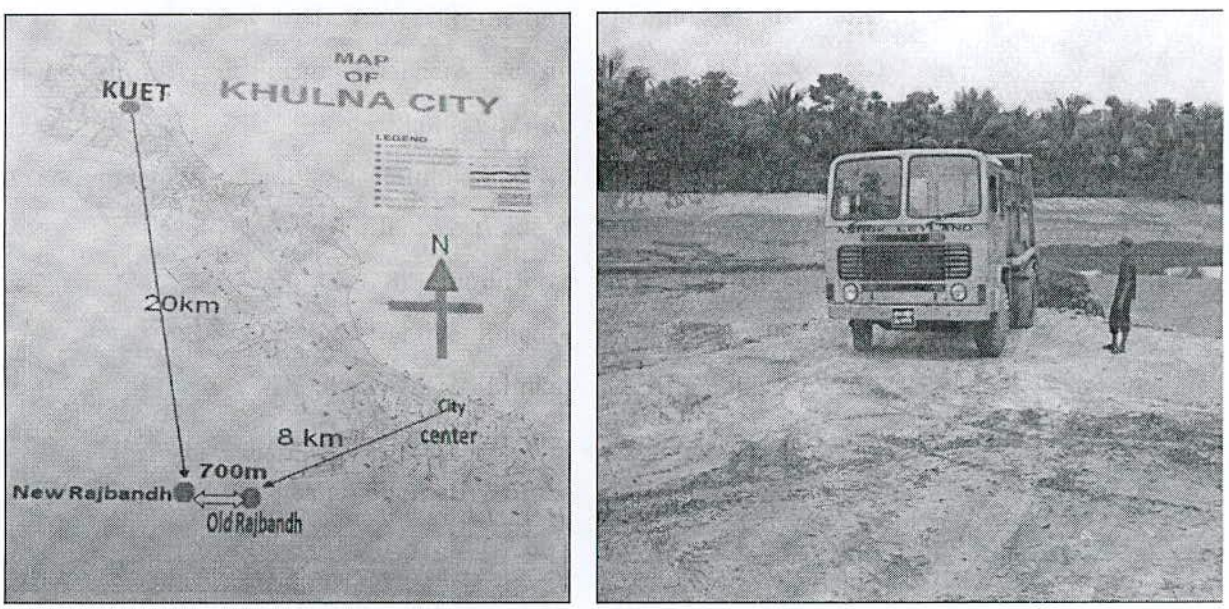


Figure 5.2 Location of Ultimate Disposal in KCC (Kashem, 2009)

5.3 **Location of transfer station**

On the development of appropriate waste transfer station schemes, the socio economic needs of the respective community, technical, financial and environmental aspects need to consider, besides other aspects such as city layout, population and waste amount. As the transport media of incoming wastes to the transfer station is Rickshaw Van, in this study the locations are outlined only considering the zone of influences surrounding the transfer station that can be covered by a manually driven Rickshaw van at a time i.e. per trip travelling capability.

5.3.1 **On the basis of one km buffer**

On the basis of such a tentative estimation i.e. 2 km covering distance, land availability, impacts on neighborhood characters, traffic compatibility and location of road, the KCC has been divided into 18 numbers of influence regions or buffer zones as shown in Fig 5.3. In this proposal and planning, 18 Transfer stations have been suggested tentatively to install in these influence regions. These identified locations for sitting of transfer stations are (i) Mirerdanga, (ii) Maniktala, (iii) Moheshwar pasha, (iv) Daulatpur, (v) Khalishpur, vi) Alamnagar vii) Mongla Port Area viii) Mujgunni ix) Rayermahal x) Choto boyra xi) Nirala xii) Shibbari Mor xiii) Tootpara xiv) Labonchara xv) Deana, Pabla xvi) Boyra xvii) Sonadanga xviii) Rupsha are shown in Figure 5.3.

Mirerdanga covers 15% of ward no. 1 and 55% of ward no. 2, Maniktala covers 70% of ward no. 1 and 50% of ward no. 3, Maheswarpasha covers 45% of ward no. 2, 15% of ward no. 1, 25% of ward no. 3, Daulatpur covers 25% of ward no. 3, 30% of ward no. 4, 80% of ward no. 5 and 10% of ward no. 6. Others are shown in the Table 5.2. Population density per acre is calculated on the basis of the portion of the covering parts of various wards and area in acre are also calculated from space covering the wards from GIS software. Finally, total population, waste amount (tons/day) and waste to be disposed (tons/day) into the transfer station are estimated where 8.87% are recyclables that are extracted from the total waste shown in Table 5.2. This estimated waste amount is required to estimate the capacity of TS prior to design of a transfer station. The selected location of proposed transfer station requires available area to be built.

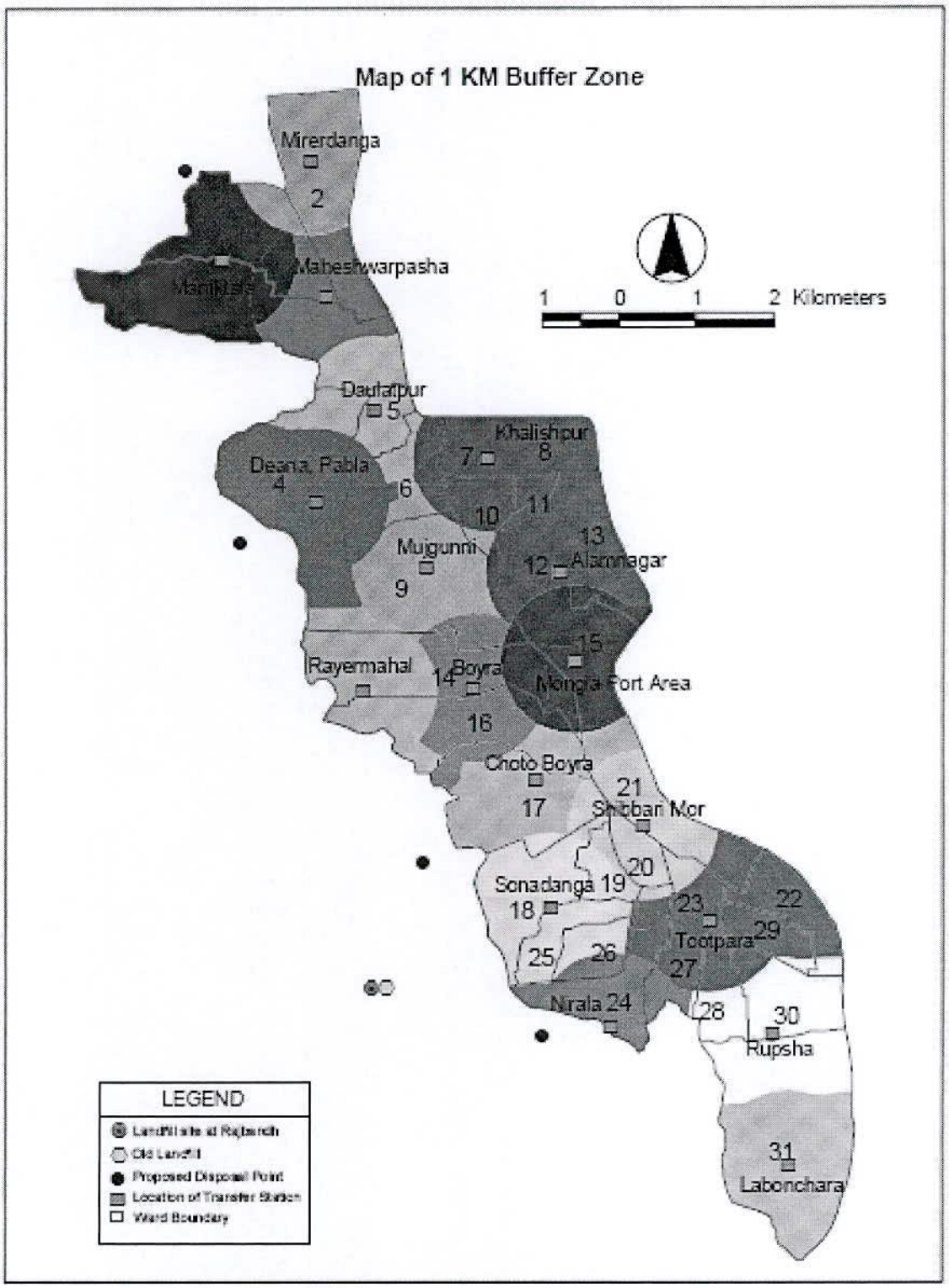


Figure 5.3 Location of TS on the basis of one Km radial distance

Table 5.2 Location of Transfer Station and perspective waste generation (tons/day)

Nodal point	Point	Ward No.	Population density (per km^2)	Area (Sq Km)	Total Population	Waste amount (tons/day)	Wastes to be deposited (tons/day)
1	Mirerdanga	15% of 1 and 55% of 2	4,162	3.20	12652	4.38	3.99
2	Maniktala	70% of 1 and 50% of 3	13,842	3.94	26287	9.10	8.29
3	Maheshwarpasha	45% of 2, 15% of 1, 25% of 3	6,775	3.64	7196	2.49	2.27
4	Daulatpur	25% of 3, 30% of 4, 80% of 5 and 10% of 6	55,921	2.29	31689	10.96	9.99
5	Khalishpur	30% of 6, 7,8, 60% of 10, 50% of 11, 12, 30% of 6,	2,30,214	1.88	81530	28.21	25.71
6	Alamnagar	10% of 9, 25% of 10, 50 % 11, 12, 80% of 13, 10% of 15	10,434	2.98	110701	38.30	34.91
7	Mongla Port Area	20% of 13, 30% of 14, 90% 15	24,215	2.88	34871	12.07	11.00
8	Mujgunni	15% of 6, 15% of 10, 55% of 9	28,911	1.81	52329	18.11	16.50
9	Rayermahal	10% of 9, 45% of 14, 40% of 16	19,202	1.95	38067	13.17	12.00
10	Choto Boyra	25% of 16, 70% of 17, 20% of 21	27,071	3.05	82150	28.42	25.90

11	Nirala	60% of 24,35% of 26, 40% of 27	96,851	0.96	46234	16.00	14.58
12	Shibbari Mor	15 % of 18, 30 % of 19, 20, 60 % of 21, 4o % of 23, 10 % of 24, 15% of 17.	2,13,647	1.77	127714	44.19	40.27
13	Tootpara	20 % of 30, 50 % of 28, 80 % of 22, 90% of 29, 60 % of 23, 20% of 21, 5 % of 25, 10 % of 26, 60% of 27, 30% of 24.	2,07,631	3.79	196671	68.05	62.01
14	Labonchara	60% of 31	16,896	0.98	16467	5.70	5.19
15	Deana, Pabla	70 of 4, 45% of 6, 20 % 5, 15% of 9.	44,102	3.03	40993	14.18	12.93
16	Boyra	10 % of 9, 25% of 14, 35 % of 16, 15 of 17.	5,856	1.98	30824	10.67	9.72
17	Sonadanga	90 % of 25, 85 % of 18, 70 % of 19, 55 % of 26, 15 % of 17.	1,27,131	2.88	131658	45.55	41.51
18	Rupsha	40% of 31, 80% of 30, 50% of 28, 22% of 22, 10% of 29.	41,506	2.64	106334	36.79	33.53
Total				**45.65**	**11,74,367**	**406.33**	**370.29**

5.3.2 Location of transfer station on the basis of two km radial distance

Location of transfer station on the basis of two km radial distances are shown Figure 5.4. Here the KCC map has been subdivided into eight influence areas showing eight location points for the TS. The location points are i) Mirerdanga ii) Shahipara, iii) Daulatpur, iv) Khalishpur, v) Chotoboyra, vi) shikhpara vii) Tootpara & viii) Labonchora are shown in Figure 5.4.

The nodal points influence 4 km buffer area. Mirerdanga point covers 60% of 1, 90% of 2, Shahipara point covers 40% of 1, 10% of 2, 80% of 3, 25% of 4, Daulatpur point covers 20% of 3, 60% of 4, 5, 95% 6, 7, 50% of 8, 55% of 10, Khalishpur point covers 25% of 9, 45% of 10, 11, 12, 13, 35% of 14, 99% of 15, Choto Boyra covers 15% of 4, 6, 75% of 9, 60% of 14, 80% of 16, 45% of 17, 5% of 6, Sheikhpara covers 5% of 14,20% of 16,55% of 17,18,50% of 19, 65% of 20,65% of 21,5% of 23,70% of 25, 45% of 26, Tootpara covers 50% of 19, 35% of 20, 35% of 21, 95% of 23, 22, 24, 29, 55% of 26, 27, 15% of 28, 90% of 30 and Labonchara point covers 28% of 28, 10% of 30, 31. Finally, population density, total population, waste amount (tons/day) and wastes to be disposed (91.13% of total waste generation) are estimated are shown in Table 5.3.

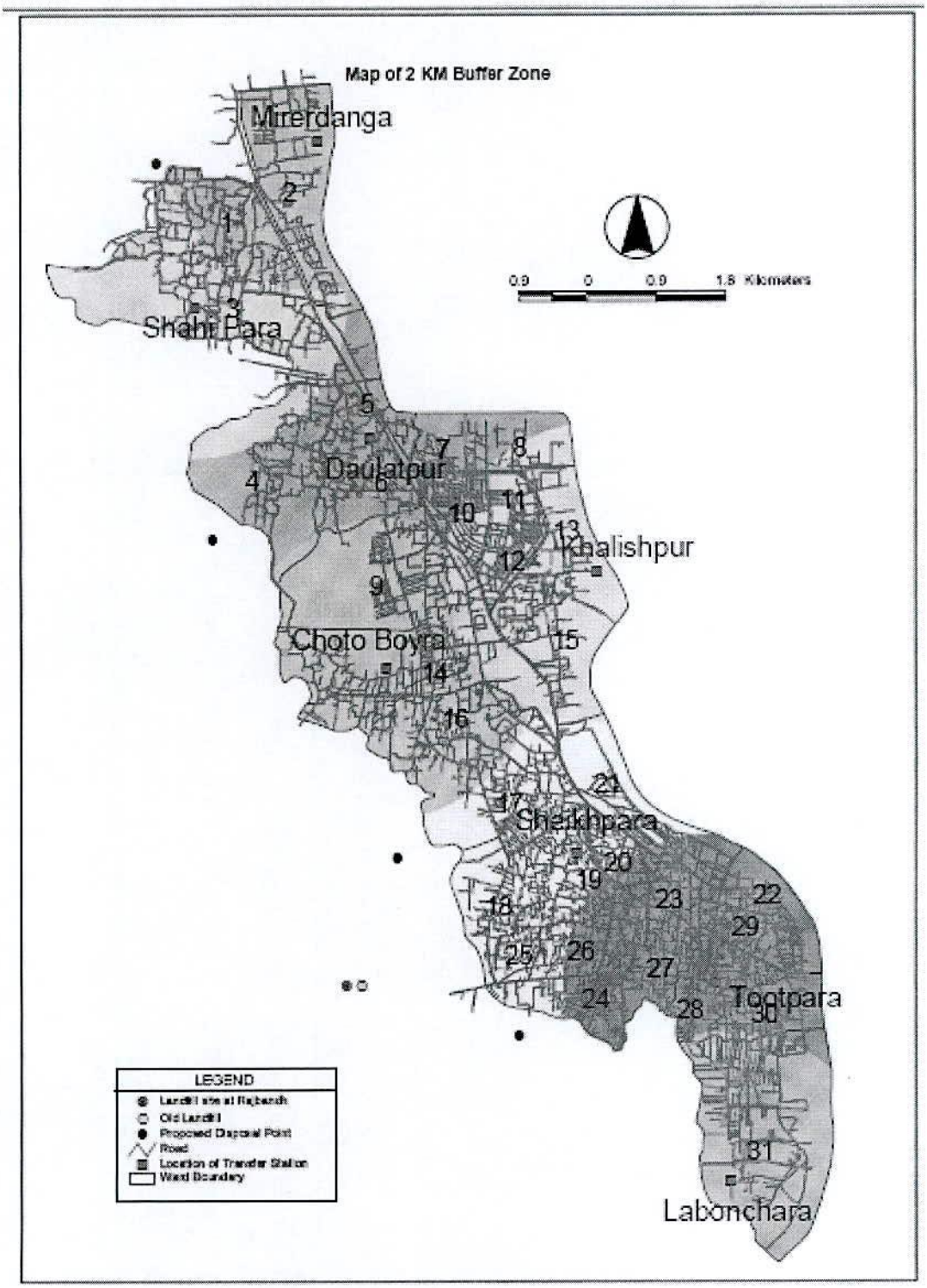


Figure 5.4 Location of TS on the basis of 2 Km radial distance

Table 5.3 Location of Transfer Station on the basis of 2 km radial distance and perspective waste generation (tons/day)

Nodal point	Point	Ward No.	Population density (per km^2)	Area (Sq Km)	Total Population	Waste amount (tons/day)	Wastes to be deposited (tons/day)
1	Mirerdanga	60% of 1, 90% of 2	22,620	6.75	46703	16.16	14.73
2	Shahi Para	40% of 1, 10% of 2, 80% of 3, 25% of 4	25,250	5.26	55890	19.34	17.62
3	Daulatpur	20% of 3, 60% of 4, 5, 95% 6, 7, 50% of 8, 55% of 10	1,46,253	4.81	255544	88.42	80.58
4	Khalishpur	25% of 9, 45% of 10, 11, 12, 13, 35% of 14, 99% of 15	3,54,250	6.81	265972	92.03	83.86
5	Choto Boyra	15% of 4,6,75% of 9,60% of 14,80% of 16, 45%of 17,5% of 6	15,814	7.25	57362	19.85	18.09
6	Sheikh Para	5% of 14, 20% of 16, 55% of 17, 18, 50% of 19, 65% of 20, 65% of 21, 5% of 23, 70% of 25, 45% of 26	1,00,408	5.20	131140	45.37	41.35
7	Tootpara	50% of 19, 35% of 20, 35% of 21, 95% of 23, 22, 24, 29, 55%of 26, 27, 15% of 28, 90% of 30	4,35,424	7.26	265418	91.83	83.69
8	Labonchora	28% of 28, 10% of 30, 31.	74,626	2.30	96618	33.43	30.46
Total				**45.65**	**11,74,648**	**406.43**	**370.38**

On the basis of 1 km radial distance, Population density is categorized into three groups:

1. Dense: (More than 1 Lac/km^2)
2. Moderate: (Upto 1 Lac/km^2)
3. Low: (Upto 50,000/km^2)

Serial No	Population Density Criteria	Rate of Population per km^2	Types of Transfer Station
1	Low	Upto 50,000	Direct Dump, Uncovered
2	Moderate	Upto 1 Lac	Direct Dump, Covered/Uncovered
3	Dense	More than 1 Lac	Hopper compaction, Covered

Table: 5.4 shows available land area of different nodal points of TS calculated from GIS software, distance and directions of that area from landmark and proposed TS types. Types of transfer station are clarified on the basis of population density criteria above into dense (More than 1 Lac/km^2), Moderate (Upto 1 Lac/km^2) and Low (Upto 50,000/km^2).

Table 5.4 Buffer area, location and type of Transfer Station considering 1 km radial distance

(1 Km buffer Area and Location)

Serial No	Area Name	Area (sqm)	Landmark of Influence Zone	Distance of TS From landmark (m)	Direction	Propose TS Type	Reason for types of TS
1	Mirerdanga	1505.43	From Cholera Hospital	450	North	Direct Dump, Uncovered	Low density
			Fulbarigate Primary school	650	South		
2	Maniktala	319.70	Palli Tirtha Primary School	350	East	Direct Dump, Uncovered	Low density
			MP Saheed Zia College	450	North		
3	Maheshwar-pasha	242.81	Maheshwarpasha High School	650	East	Direct Dump, Uncovered	Low density
			PWD office	250	North		
4	Daulatpur	157.83	Muhsin High School	300	South	Direct Dump, Covered/Uncovered	Moderate
			BL College	600	North		
5	Khalishpur	1780.62	Padma Gate Jame Mosque	250	South	Hopper compaction, Covered	Dense
			People Jute Mill	650	South		
6	Alamnagar	1845.37	Khalishpur Maddyamic High School	600	North	Direct Dump, Uncovered	Low density
			Rotary High School	550	East		
7	Mongla Port Area	360.17	BNS Titumir	400	South	Direct Dump, Uncovered	Low density
			Port Hospital	150	North		
8	Mujgunni	303.51	Navy High School	120	West	Direct Dump, Uncovered	Low density
			Abu Naser Hospital	200	South		

9	Rayermahal	182.11	Hazi M. Mohsin College	750	North	Direct Dump, Uncovered	Low density
			Police Line High School	750	South		
10	Choto Boyra	659.64	Khulna Art College	550	South	Direct Dump, Uncovered	Low density
			Choto Boyra Primary School	100	North		
11	Nirala	202.34	Ahmadia Muslim Darul Fazal Madrasa	300	south-west	Direct Dump, Covered/ Uncovered	Moderate
			Nirala Nurai Madrasa	600	South		
12	Shibbari Mor	254.95	Khulna Railway Station	250	South	Hopper compaction, Covered	Dense
			KDA Bhaban	450	East		
13	Tootpara	178.06	City College	280	East	Hopper compaction, Covered	Dense
			Tootpara Model Primary School	300	North		
14	Labonchara	752.72	Al Amin Jame Mosque	450	South-east	Direct Dump, Uncovered	Low density
			Hazi Maleq Primary School	350	North-west		
15	Deana, Pabla	530.14	Pabla Primary School	600	West	Direct Dump, Uncovered	Low density
16	Boyra	829.61	Boyra College	250	West	Direct Dump, Uncovered	Low density
			Boyra Technical Institute	700	East		
17	Sonadanga	433.01	Day Night High School	250	East	Direct Dump, Covered/ Uncovered	Moderate
			KCC Truck Terminal	650	East		
18	Rupsha	546.33	Al Madina Primary School	200	South	Direct Dump, Uncovered	Low density
			Matiakhali Govt. High School	300	West		

On the basis of 2 km radial distance, Population density is categorized into three groups:

1. Dense: (Upto 1 Lac/km^2)
2. Moderate: (Upto 2.5 Lac/km^2)

Serial No	Population Density Criteria	Rate of Population per km^2	Types of Transfer Station
1	Low	Upto 1 Lac	Direct Dump, Uncovered
2	Moderate	Upto 2.5 Lac	Direct Dump, Covered/Uncovered
3	Dense	More than 2.5 Lac	Hopper compaction, Covered

3. Low: (More than 2.5 Lac/km^2)

Table: 5.5 shows available land area of different nodal points of TS calculated from GIS software, distance and directions of that area from landmark and proposed TS types. Types of transfer station are clarified on the basis of population density criteria above into dense (Up to 1 Lac/km^2), Moderate (Up to 2.5 Lac/km^2) and Low (More than 2.5 Lac/km^2).

Table 5.5 Buffer area, location and type of Transfer Station considering 2 km radial distance

(2 Km buffer Area and Location)

Serial No	Area Name	Area (sqm)	Landmark of Influence Zone	Distance of TS From landmark (m)	Direction	Propose TS Type	Reason for types of TS
1	Mirerdanga	5321.62	Cholera Hospital	500	North	Direct Dump, Uncovered	Low density
			Police High school	1000	South		
2	Shahipara	566.56	Maheshwarpasha High School	700	West	Direct Dump, Uncovered	Low density
3	Daulatpur	607.03	Day Night College	100	North	Direct Dump, Covered/ Uncovered	Moderate
			BL College	300	South		
4	Khalishpur	368.26	Khalishpur Maddyamik High School	500	East	Hopper compaction, Covered	Densely populated
			BNS Titumir	800	East		
5	Choto Boyra	3451.97	Boyra Police Line	400	South-West	Direct Dump, Uncovered	Low density
			Boyra Technical Institute	150	North		
6	Sheikhpara	428.97	PWD High School	130	West	Direct Dump, Covered/ Uncovered	Moderate
			Khulna College	360	North		
7	Tootpara	202.34	Govt. Sundarban College	450	South	Hopper compaction, Covered	Densely populated
			Dada Match Factory	650	North		
8	Labonchara	938.87	Islam Para Primary School	690	South	Direct Dump, Uncovered	Low density
			Aruna Mannan Mahila Madrasa	350	South		

5.4 Types of Vehicles used in Transfer Station

1. Rickshaw van
2. Truck and Trailer type
    - Tipping Garbage truck

    a. Front Loader:

    Loader machine acts backside of the truck to pick up the demountable container weighing 3 ton of waste and carry the container to the landfill for ultimate disposal.

    b. Side loader:

    Loader machine acts side of the truck to carry demountable container weighing capacity 5 tons and carry the container to the landfill for ultimate disposal.

    - Covered truck
    - Uncovered Truck
3. Compaction/non compaction
4. Unloading mechanisms
    - Push out blade
    - Conveyor belt
    - Hydraulic lift
    - Ramp
    - Pull off system

Various types of vehicles are shown in Figure 5.5. and in Table 5.6.

Table 5.6 Types of Vehicles used in Transfer Station (SWM Sector Report (final), 2009)

Sort of vehicle, description	No. of vehicle	Payload [ton]	Transport capacity [tour/day] 1*	2*	3*
Covered Trucks	3	5	15	30	45
Dump Trucks	9 8	7 5	63 40	126 80	189 120
Tipping Truck (container carrier)	5 2	5 2,5	25 5	50 10	75 15
Tractor with trolley	1	4	4	8	12
Power Tiller with trolley	2	0,25	0.5	1	1.5
Side Tipp. Trucks double cont.	1	2	2	4	6
		Total**	154.5	309 463.5	
		75 % for SWM	115,9	231.8 347,6	
		thereof 60 % running	69,5	139.1 208,6	

* Tours per day per vehicle.

** Assuming all KCC vehicles used for SWM and none are being repaired.

Figure 5.5 (A) Side loader Tipping Truck

Figure 5.5 (B) Front Loader Tipping Truck

Figure 5.5(C) Dump Truck

Figure 5.5(C) Dump Truck

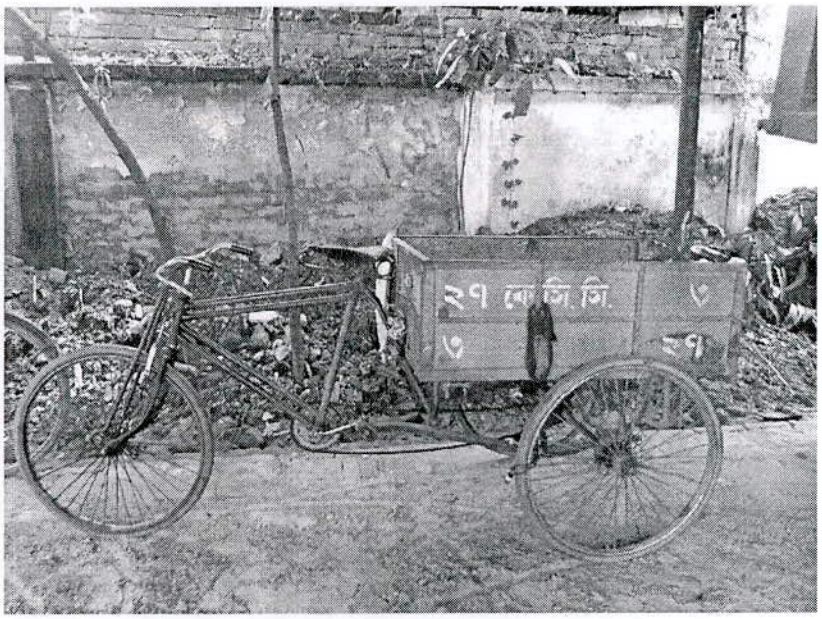


Figure 5.5(D) Rickshaw Van for Primary Collection of waste

5.5 Size of Transfer Station

The transfer station should have a large enough capacity to manage the wastes that are expected to be handled at the facility throughout its operating life. Factor that should be considered in determining the appropriate size of a transfer facility include:

- Number and Capacity of collection vehicles at the facility
- Desirable Storage on Tipping floor/ Demountable container
- Time required to unload collection vehicles
- Waste Recovery/sorting
- Transfer Trailer type / capacity
- Hours of operation
- Availability of transfer trailers waiting for loading
- Time to load trailers
- Desired number of containers available in the facility.
- Capacity and size of the containers in the transfer station
- Space for office room for staff should be included at the facility

- Available space for the movement of loading and unloading vehicles.
- Types of method or instruments used in the transfer station.

5.6 Design and Configuration of Transfer Station

From the recommendation of stakeholders' dialogue and realizing the present situation of solid waste management, it was evident that there is a strong need to change the present secondary disposal system. In this instant, introduction of transfer station can be a viable option. From these perceptions, three types of transfer station have been designed. The main features of this transfer station are given at the Table 5.7.

Table 5.7 Main features of TS

Deloading vehicles	Onloading vehicles	Equipment on station	Throughput [t/day]	Spacial requirement [m^2]
Rickshaw Vans	Container carriers Compactor trucks	Loading gang 4 – 5 labour	50	495

Transfer Station has been designed into three categories:

5.6.1 Transfer Station with Ramp

The land required for such transfer station is 22.48 m Length and 22.03 m width. This is typical dimensions considering all facilities in the transfer station and availability of land. Like, a RCC ramp of 9.76 m x1.52 m size needs to have a minimum slope of 1:7 so that ground water percolation would not happen for easy movement of rickshaw van and to unload the wastes over a 1.52 m high platform. The movement of truck can perform easily at the yard of transfer station so that it will not make any trouble in the movement of other traffics and the pedestrians. Transfer Station should include staff room to manage the whole day loading and unloading of

waste successfully. In Figure 4.6, staff room (3.05m x 3.05m), yard for truck movement (19.81m x 13.72m) having dual opening (entrance and exit) for the movement of waste loading trucks and 16 capacity of container having total about 50 ton capacity of waste with shed facilities transfer station are shown in Figure 5.6 and 5.7.

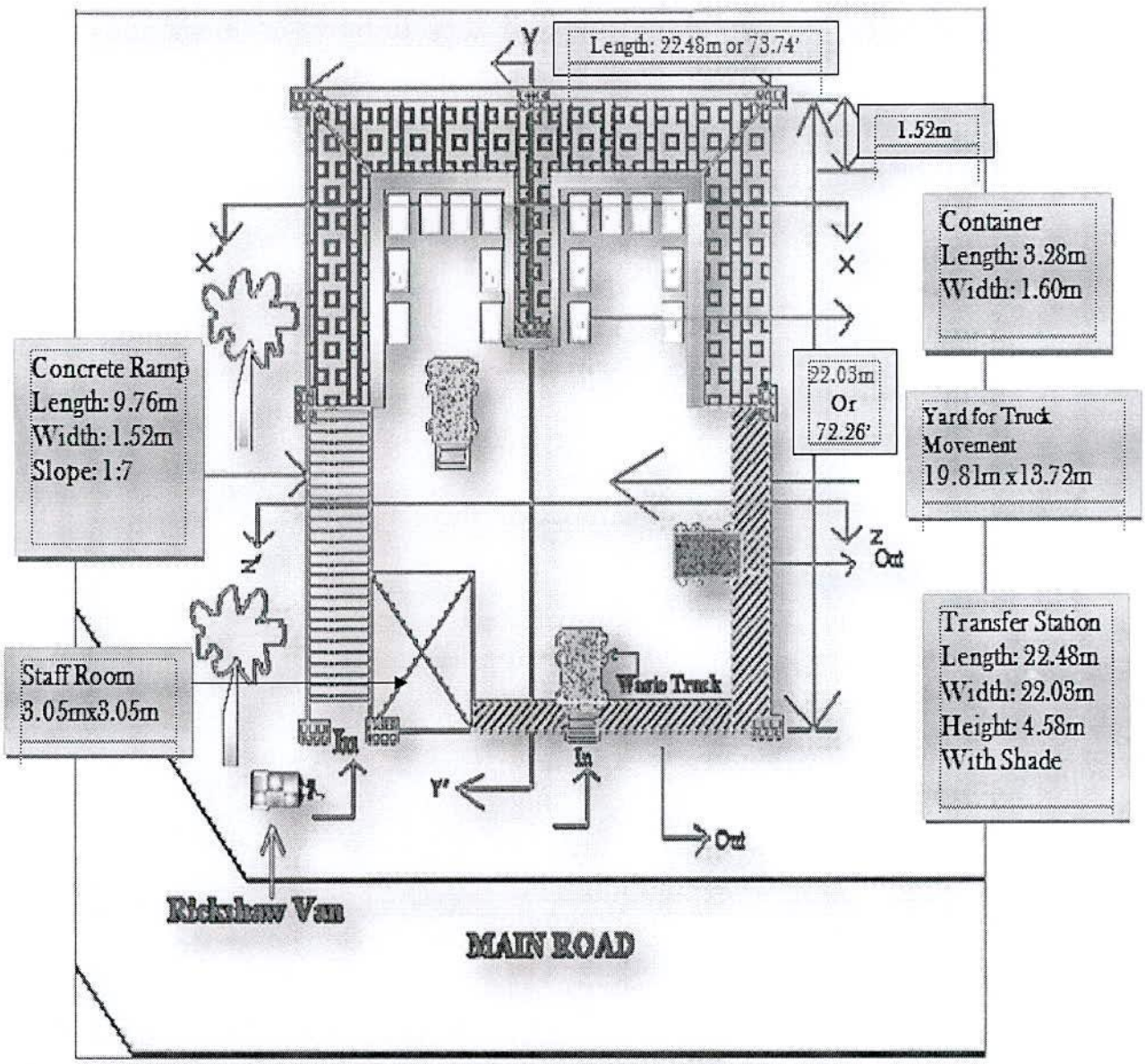
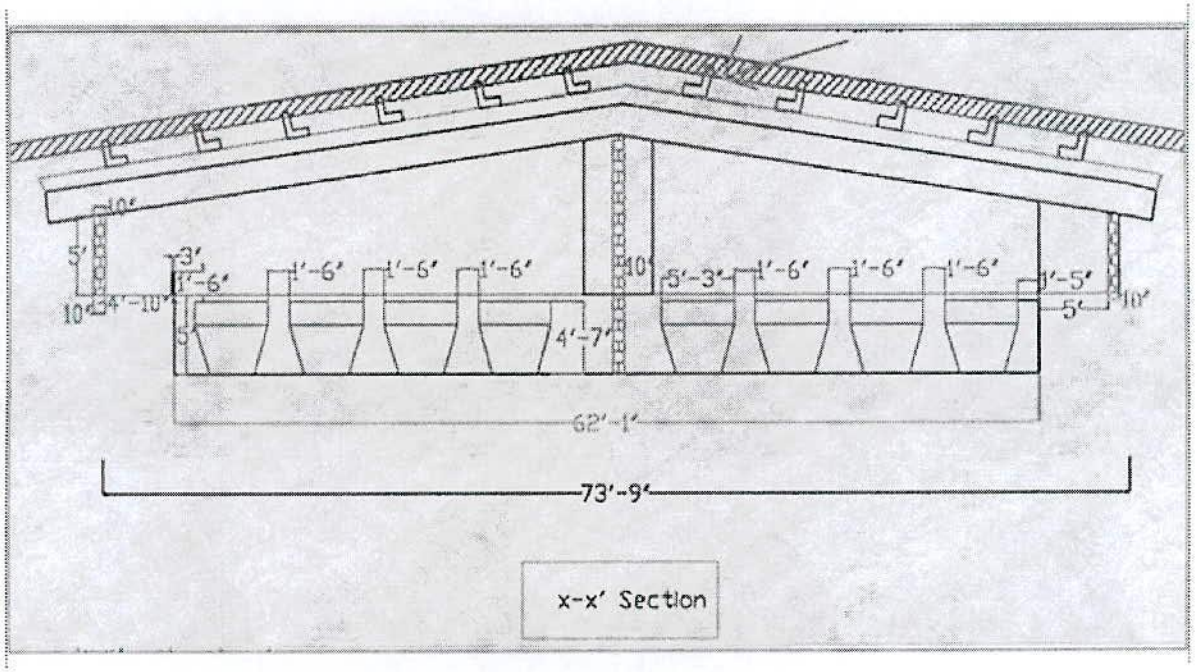
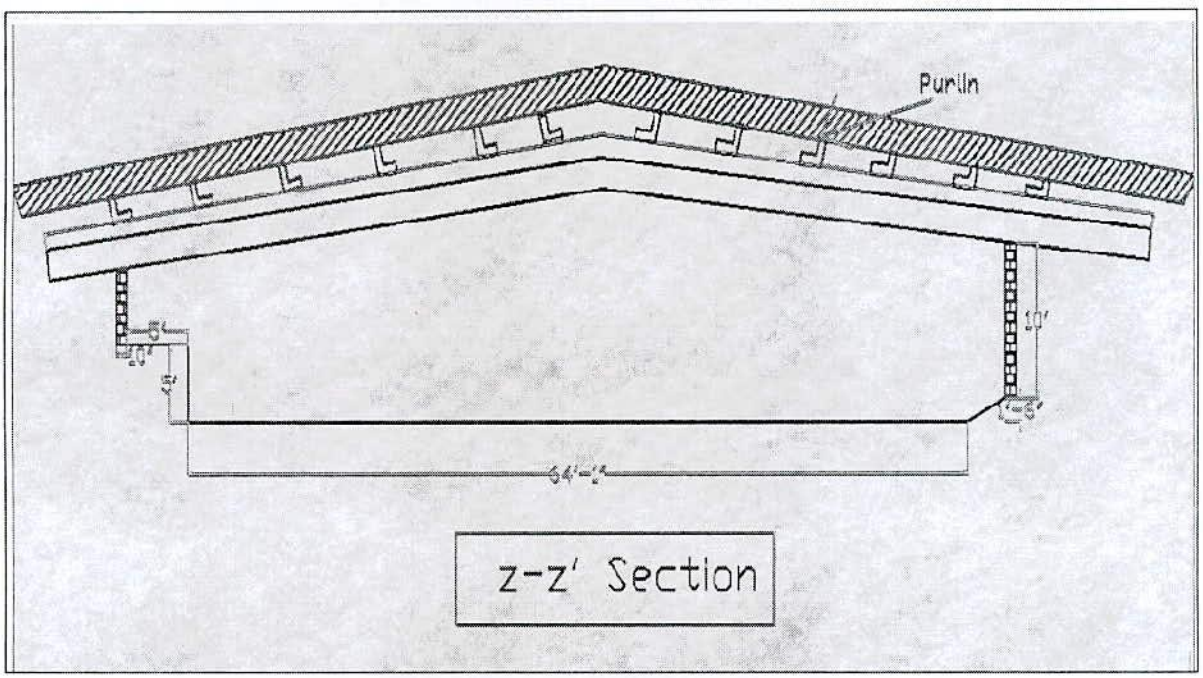


Figure 5.6 Design of Transfer Station with Ramp



b) X-X' Section



c) Z-Z' Section

Figure 5.7 Design of Transfer Station with Ramp, a) X-X' Section, b) Z-Z' Section

5.6.2 Transfer Station with Hydraulic Lift

Considering the same dimension of the design of TS with ramp, the land required for such transfer station is 22.48 m x 22.03 m. A hydraulic lift of 2.13 m x1.52 m size having a moving platform and four vertical posts for uplift the waste carrying rickshaw van over a 1.52 m high platform. The movement of truck can perform easily at the yard of transfer station so that it will not make any trouble in the movement of other traffics and the pedestrians. Transfer Station should include staff room to manage the whole day loading and unloading of waste mechanism successfully. It should also have a sorting room (4.57 mx 3.05m). In Figure 4.8, staff room (3.05m x 3.05m), yard for truck movement (15.59 x 13.32m) having dual opening for movement of waste loading trucks with shed facilities and 16 capacity of container having total about 50 ton capacity waste transfer station are shown below in Figure 5.8.

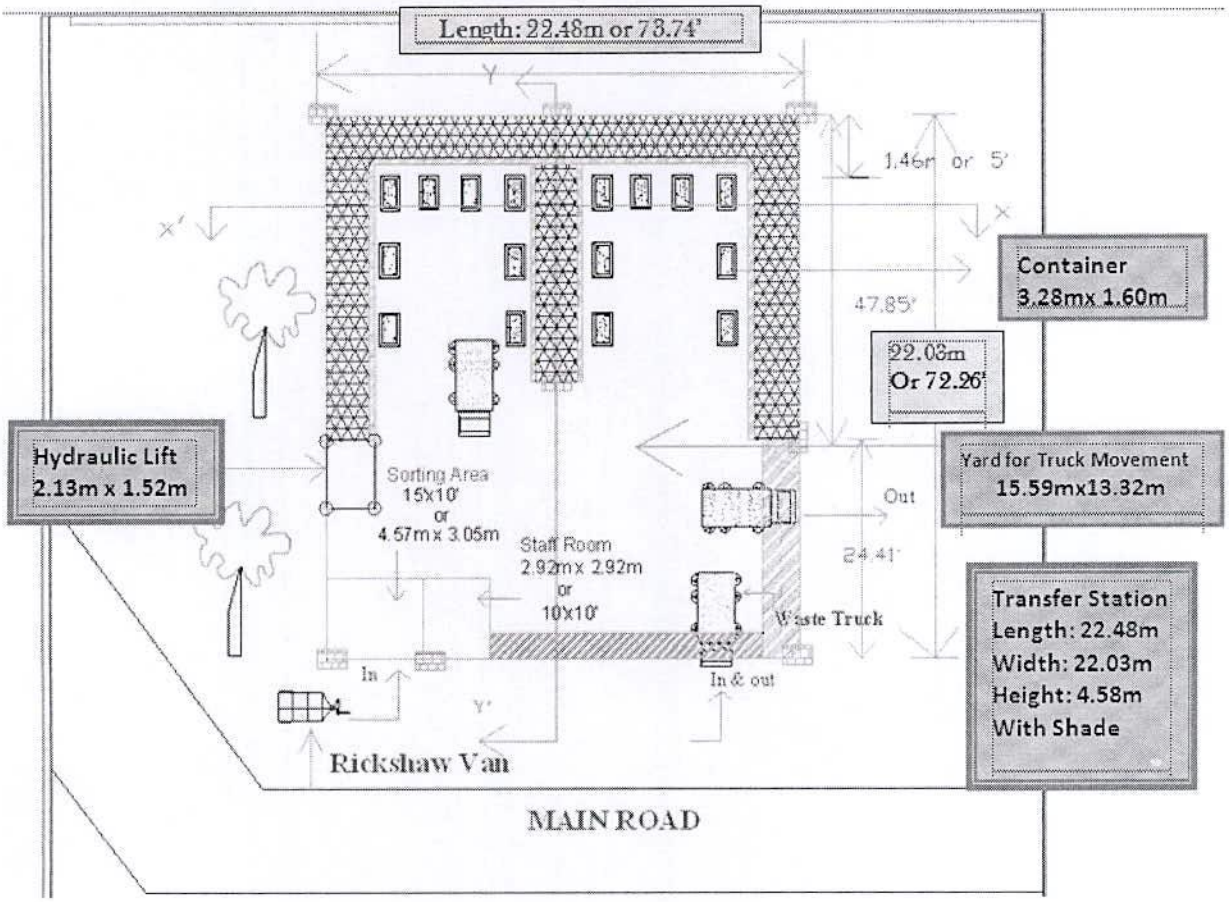


Figure 5.8 Design of Transfer Station with Hydraulic Lift

5.6.3 Transfer Station with Conveyor Belt:

Considering the same dimension of the design of TS with ramp, the land required for such transfer station is 22.48 m x 22.03 m.This types of TS includes conveyor belt facilities to convey waste to the desired location after sorting without moving rickshaw van. Transfer Station should include staff room as well as waste sorting room to separate waste before pouring the sorted waste onto the conveyor belt. In Figure 4.9, staff room (3.05m x 3.05 m), a sorting room (3.05mx 2.43m), yard for truck movement (19.81m x 13.72m) having dual opening for movement of waste loading trucks with shed facilities and 16 capacity of container having total about 50 ton capacity waste transfer station are shown below in Figure 5.9.

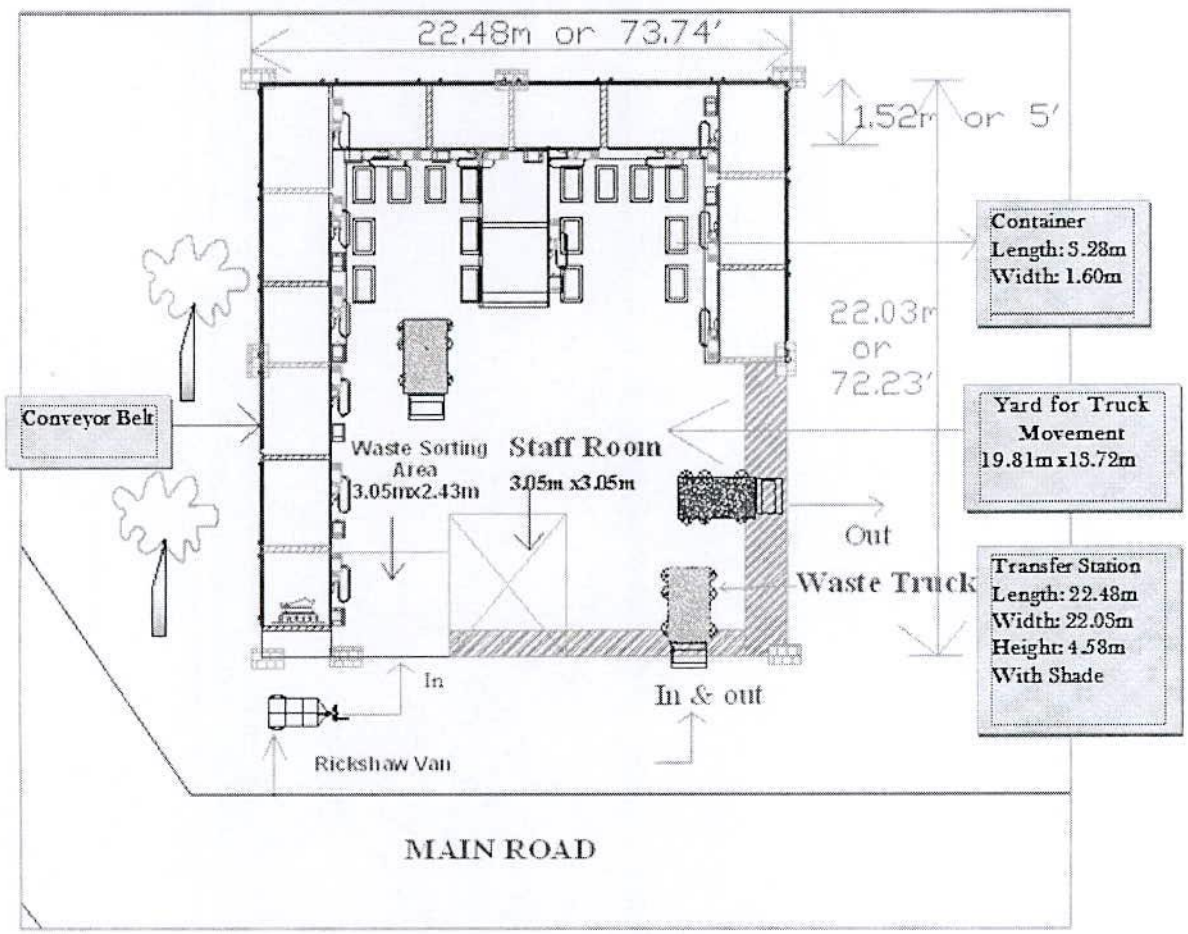


Figure 5.9 Design of Transfer Station with Conveyor Belt

5.7 Daily Operation

The Transfer Station designed should have prescribed times for daily operation. Operating hours must accommodate the collection schedules of vehicles delivering waste to the facility. Operating hours need to consider the local setting of the transfer station, including neighboring land uses, as well as the operating hours of the disposal facility receiving waste from the transfer station. Operating hours vary considerably depending on individual circumstances. Many large facilities located in urban industrial zones operate 24 hours, 7 days per week. Urban, suburban, and rural transfer stations of various sizes commonly open early in the morning (6 a.m. to 7 a.m.) and close in the late afternoon (4 p.m. to 5 p.m.). In many cases the last trailer must be loaded with sufficient time to reach the disposal site before it closes (typically 4 p.m to 6 p.m.). Transfer stations that serve both the general public and waste hauling companies typically operate 6 or 7 days per week. Facilities that are not open to the public typically operate 5 or 6 days per week because many waste hauling companies do not operate on Sundays and have limited operations on Saturdays. Many smaller and rural facilities operate only on certain days of the week and have limited hours. Operations often extend beyond the "open for customers" hours, however, as workers load waste into transfer vehicles, clean the facility, and perform equipment maintenance.

5.8 Interaction with the Stakeholders

Every transfer station has neighbors, whether they are industrial, commercial, residential, or merely vacant land. Vehicles traveling to and from a transfer station could significantly affect a residential neighborhood a mile away if those vehicles travel on residential streets. So it is very important part of successful transfer station operations is engaging in constructive dialogue with the surrounding community.

The appropriate level of interaction between transfer station personnel or representatives and their neighbors varies depending on many factors. While a transfer station located adjacent to

homes and restaurants might find that monthly meetings with neighbors, landscaping improvements, commitments to employ local workers, an odor reporting hotline, and daily cleanup of litter are more appropriate. When developing a community outreach plan, transfer station operators should consider the following:

• Develop a clear explanation of the need for the transfer station and the benefits it will provide to the immediate community and surrounding area.

• Develop a clear process for addressing community concerns that is communicated to the neighborhood even before the facility becomes operational.

• Designate one person as the official contact for neighborhood questions and concerns. Ideally, this person would regularly work at the transfer station and be available to respond quickly to questions and concerns.

The person should also be good at listening carefully to community concerns before responding. Advertising an e-mail address or Web site is another way to provide information and allow community input.

• Organize periodic facility tours. Neighbors unfamiliar with the transfer station's operations are more likely to have misconceptions or misunderstand the facility's role.

• Establish positive relationships by working with community-based organizations, improvement districts, civic associations, business associations, youth employment bureaus, and other organizations. Interaction with the community should focus on positive issues, not just occasions when a neighbor is upset about odor, litter, or traffic.

• Offer support services such as newspaper drives, household hazardous waste (HHW) drop-off days, and spring cleaning disposal at the facility.

5.9 Transfer Station Facilities

Transfer Station designed should have the following facilities for proper installment and to maintain the facilities successfully.

- Office/ Staff room
- Weighing station/Sorting Facilities
- Number, Length, Capacity and Type of scales
- On site roads
- Site Access Control
- Buffer and Landscaping areas
- Fuel Storage/Supply
- Electricity
- Water Supply/Drainage/Sewerage

CHAPTER VI

Results and Discussion

6.1 General

The situation of Secondary disposal sites in Khulna city is not perfect. Transfer Station (TS) can play a vital role to overcome the current situation of solid waste management system. This chapter depicts the source storage and primary collection of waste, recommend types, size and capacity of household bins, sites of TS, types of TS and sustainability of TS. The outcome of this research might create a new opportunity to develop current solid waste management system by planning and designing of TS properly with replacement of SDSs.

6.2 Source Storage and Primary Waste collection

Residential wastes are the main sources of MSW. The other important sources are commercial wastes including markets, hotels, restaurants and others, institutional wastes include wastes from schools, colleges, universities and government offices and medical wastes and municipal services wastes include wastes from street sweeping, drain cleaning but excluding treatment facilities, etc. In Khulna City a small fraction of the generated wastes are actually stored for collection and management. A little fraction are also recycled and reused from stored wastes at households and a considerable portion of wastes, are not properly stored, collected or disposed in the designated places for ultimate disposal. As a result, the unmanageable increasing quantity of MSW creates alarming environmental problems. Householders those cooperating existing management system, store wastes in a plastic or metal container of different size and shape and keep it inside the house or premises, mostly in kitchen or corridor. Waste collection workers collect the container, then dispose into the collection van and return the empty container. Study

reveals that source storages and separation of organic, inorganic and hazards wastes are highly neglected by the city dwellers. Generally single bin is practiced and the collection van also has single compartment, so the waste becomes mixed.

Source storage and waste collection system shall be improved by

- Sorting of waste at house hold level into three categories:

1. Organic waste (Green color Bin),
2. Inorganic waste (Blue Color Bin) and
3. Hazardous waste (Red Color Bin)

- Introducing house-to-house waste collection system in all residential areas using modified rickshaw vans with containers. Each rickshaw van will carry and cover the waste into different compartment of the containers. This will also increase the collection coverage as less amount of waste will be disposed illegally.
- Concrete bin shall be replaced by a transfer station with direct loading to secondary collection vehicle shall be introduced.
- Litter bin of adequate size shall be introduced in markets, bus stands, and other important public places for proper storage of waste.
- House to house primary waste collection can be entrusted to NGOs/CBOs/ private sectors with households/customers directly paying service charge.
-Additional trucks, tractor and trailer as well as rickshaw van shall be purchased to meet the demand. Selection of vehicle shall be based on local road condition.

House-to-house primary collection of waste with the new idea of container system (organic, inorganic and hazardous) will promote waste reduction and segregation of waste. Household Solid waste composition data reveals that maximum organic waste produced at household level is 2.5 kg/day, household inorganic non-hazardous waste amount is 0.20 kg/day and household inorganic hazardous waste amount is 0.1 kg/day for medium sized family (Wastesafe 2005 Draft Report). We considered the capacity of organic waste produced at household level is 3 kg/day, household inorganic non-hazardous waste amount is 1.5 kg/day and household inorganic hazardous waste amount is 0.8 kg/day considering future perspectives. Some recommended types of bins of different color, size and capacity are suggested at household level are shown in Figure 6.1.

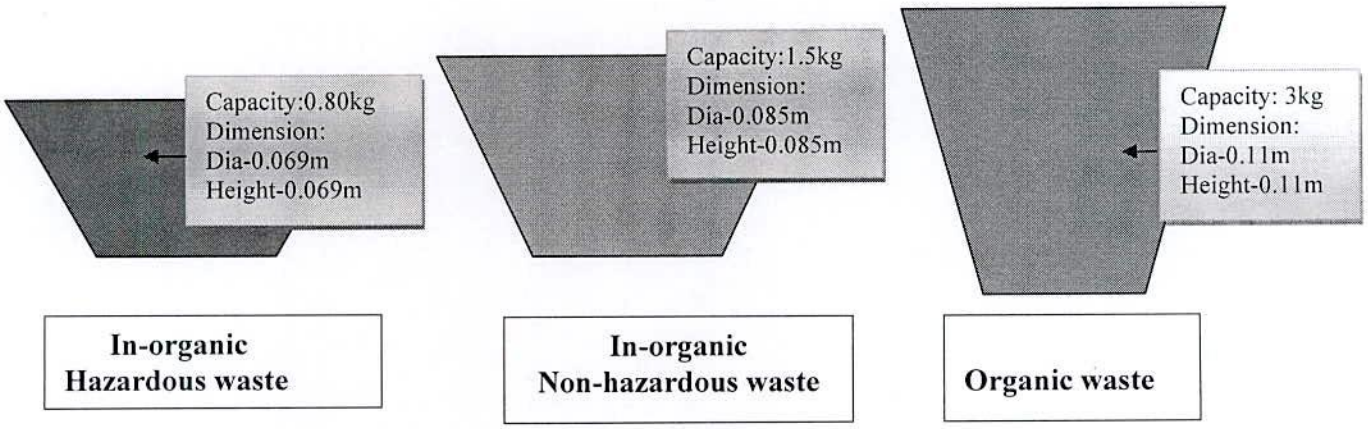


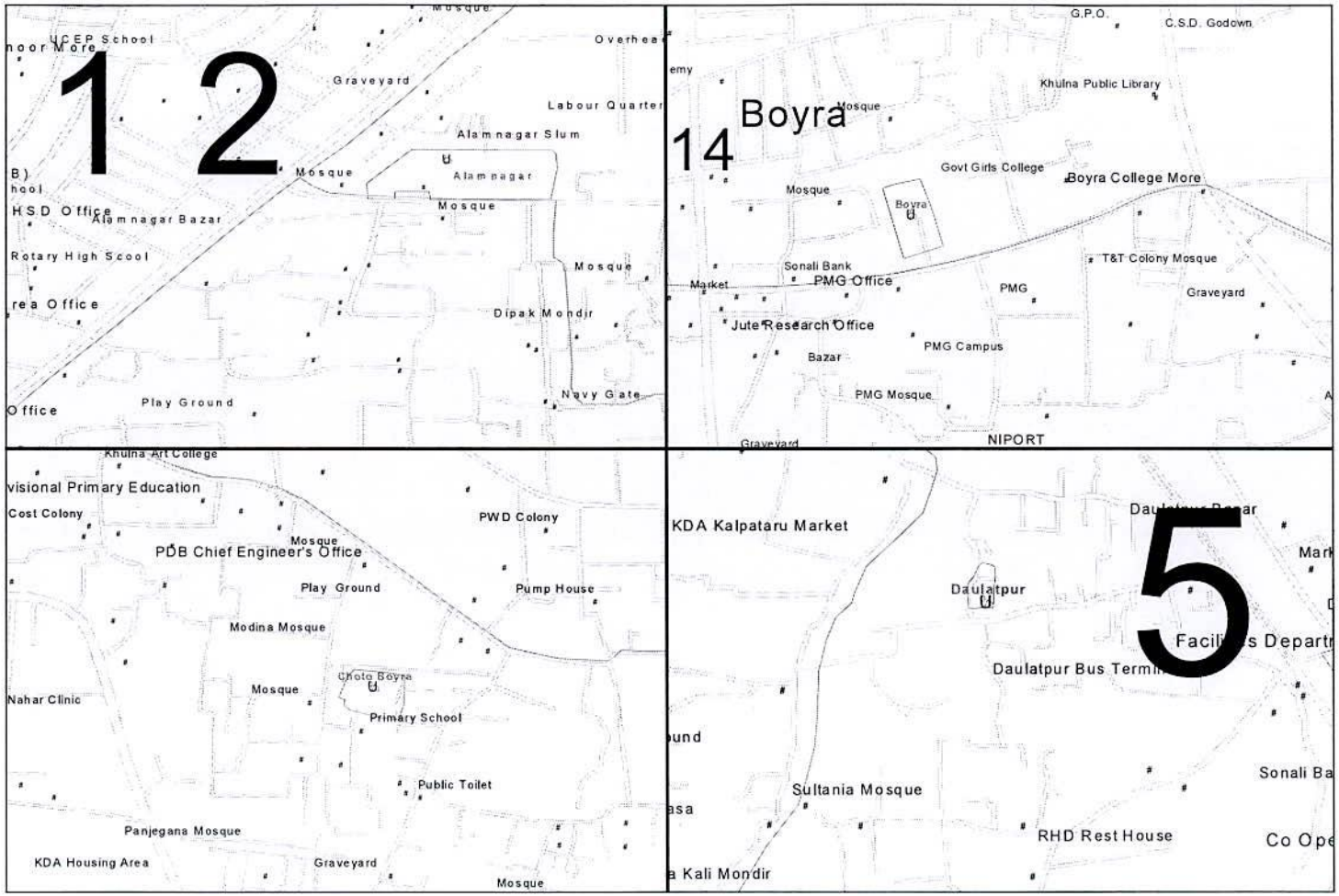
Figure 6.1 Recommended types of bins

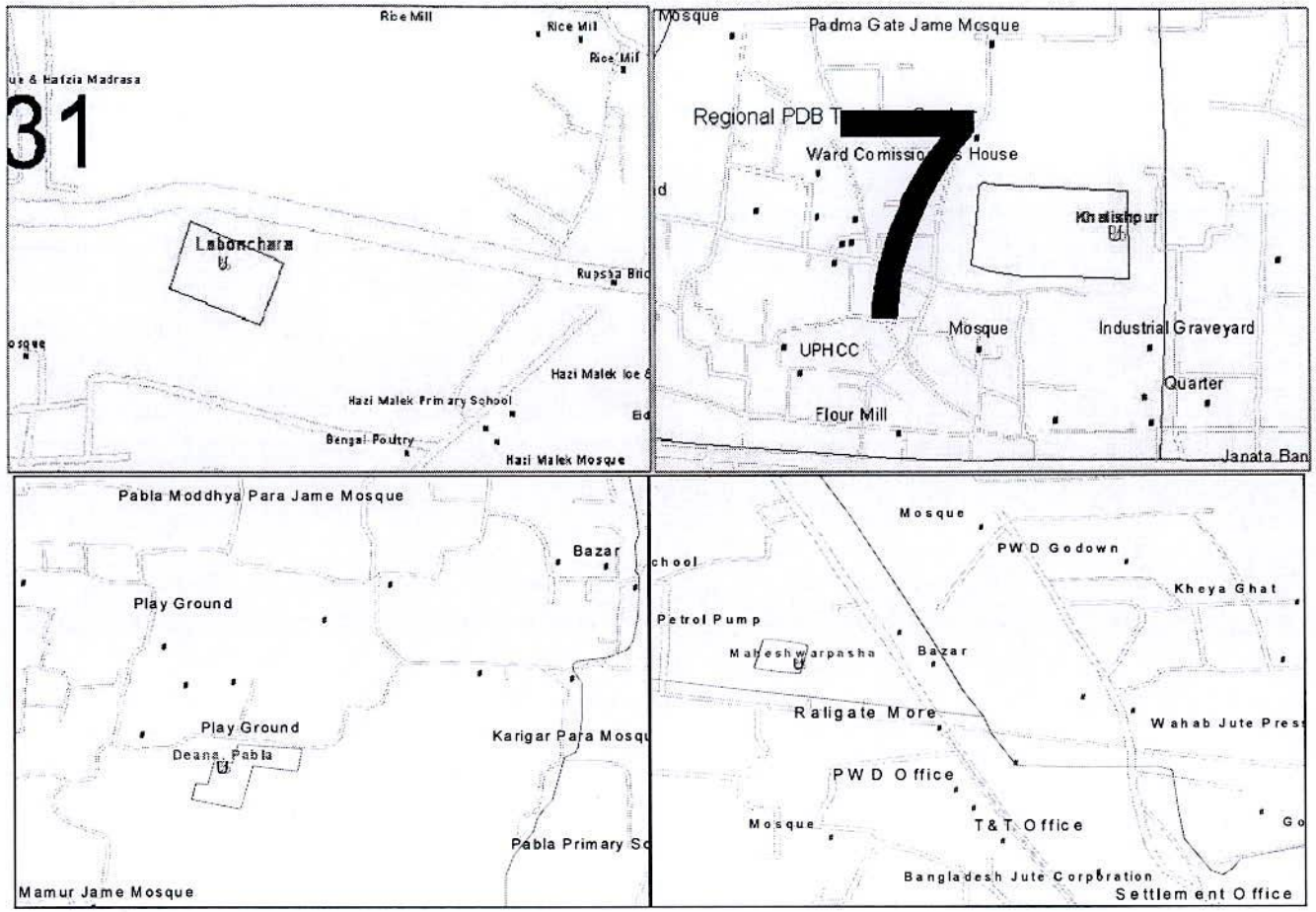
Table 6.1 Major types of MSW in source and SSD by physical verification.

Waste Type	Composition (%)		Source
	Source	SSD	Waste amount (ton/day)
Organic wastes	93.90	85.10	381.52
In-organic non-hazardous wastes	3.50	12.60	14.22
In-organic hazardous wastes	2.60	2.30	1.056

6.3 Sites of Transfer Station

In Khulna city, several sites have been selected for the proposed TS on the basis of one km and two km radial distance considering the factors affecting the selections of sites. On the basis of two km buffer area Khulna city has been subdivided into 18 no of buffer zones with suitable TS locations. Again, on the basis of four km buffer area Khulna city has been subdivided into 8 no. of buffer zones with TS locations. The Figure 6.2 and Figure 6.3 show different sites of Transfer Station (TS) on the basis of one km radial distance and two km radial-distance.


12
Graveyard
Labour Quarter
Alamnagar Slum
Alamnagar
Mosque
Alamnagar Bazar
Rotary High Scool
Dipak Mondir
Navy Gate
Play Ground
14
Boyra
G.P.O.
C.S.D. Godown
Khulna Public Library
Govt Girls College
Boyra College More
Boyra
Sonali Bank
PMG Office
T&T Colony Mosque
Graveyard
Jute Research Office
PMG Campus
Bazar
PMG Mosque
NIPORT
Khulna Art College
PWD Colony
PDB Chief Engineer's Office
Play Ground
Pump House
Modina Mosque
Choto Boyra
Primary School
Public Toilet
Panjegana Mosque
KDA Housing Area
Graveyard
Mosque
KDA Kalpataru Market
5
Daulatpur
Daulatpur Bus Termi
Sultania Mosque
RHD Rest House


Rice Mill
Rice Mill
Rice Mil
31
Laboncharo
Rupsha Bric
Hazi Malek Primary School
Bengal Poultry
Hazi Malek Mosque
Mosque
Padma Gate Jame Mosque
Regional PDB T
Ward Comissio
House
7
Khalishpur
Mosque
Industrial Graveyard
UPHCC
Quarter
Flour Mill
Janata Ban
Pabla Moddhya Para Jame Mosque
Bazar
Play Ground
Play Ground
Deana Pabla
Karigar Para Mosqu
Pabla Primary Sc
Mamur Jame Mosque
Mosque
PWD Godown
Kheya Ghat
Petrol Pump
Maheshwarpasha
Bazar
Raligate More
Wahab Jute Pres
PWD Office
Mosque
T&T Office
Bangladesh Jute Corporation
Settlement Office

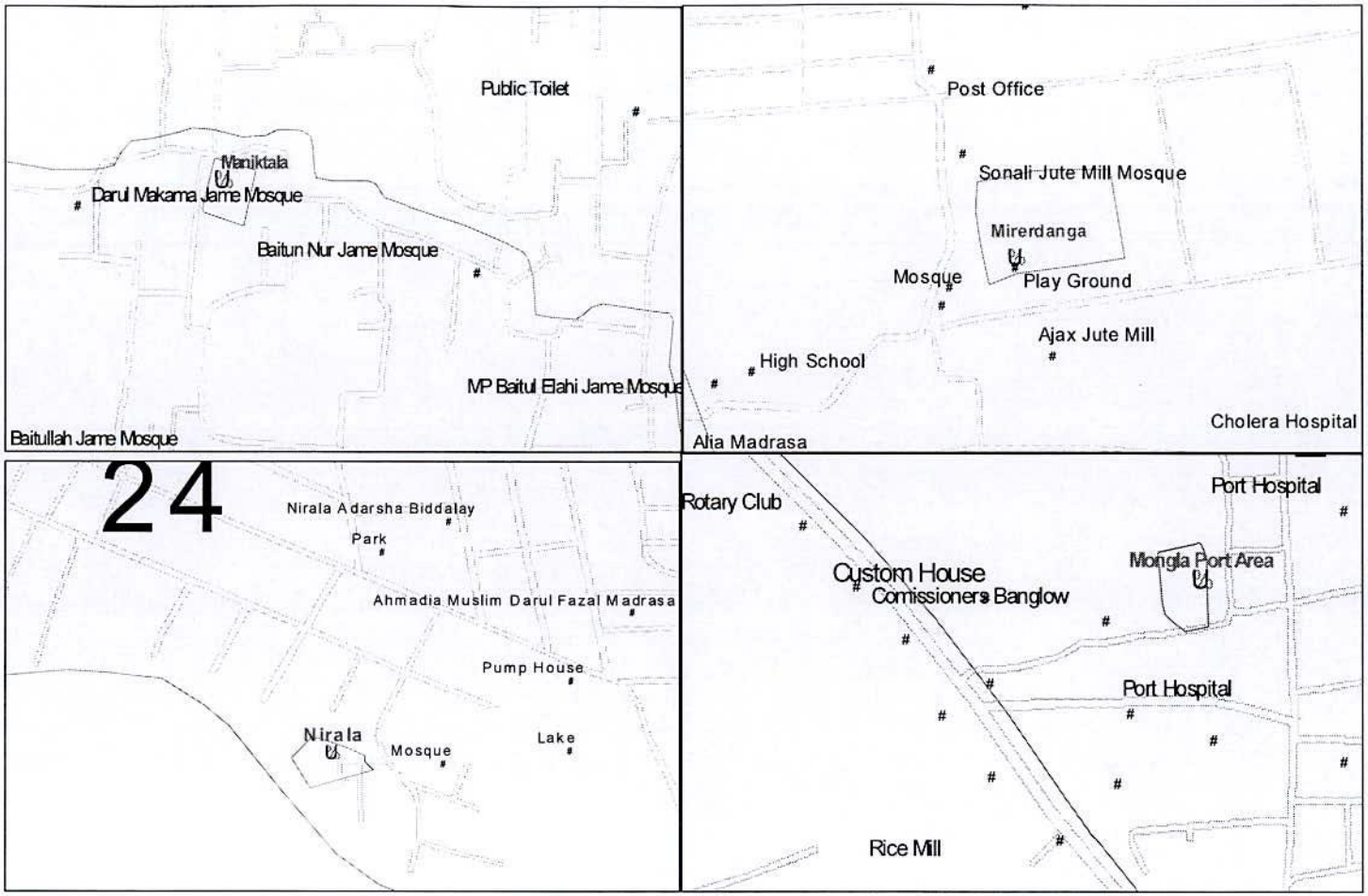
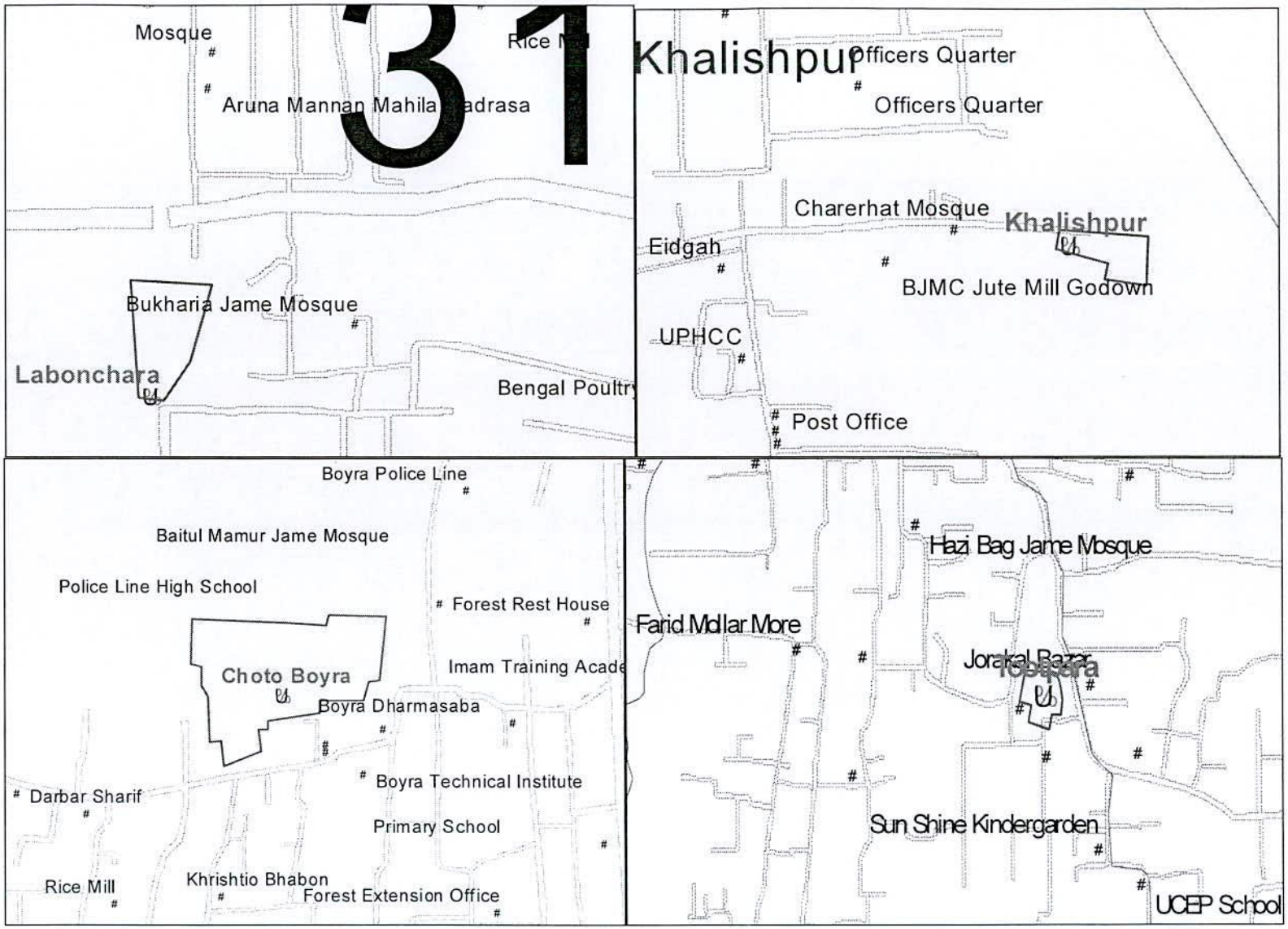


Figure 6.2 Sites of Transfer Station on the basis of one km radial distance


31
Mosque
Aruna Mannan Mahila Madrasa
Bukharia Jame Mosque
Labonchara
Bengal Poultry
Khalishpur
Officers Quarter
Officers Quarter
Charerhat Mosque
Khalishpur
Eidgah
BJMC Jute Mill Godown
UPHCC
Post Office
Boyra Police Line
Baitul Mamur Jame Mosque
Police Line High School
Forest Rest House
Choto Boyra
Imam Training Acade
Boyra Dharmasaba
Boyra Technical Institute
Darbar Sharif
Primary School
Rice Mill
Khrishtio Bhabon
Forest Extension Office
Hazi Bag Jame Mosque
Farid Mollar More
Sun Shine Kindergarden
UCEP School

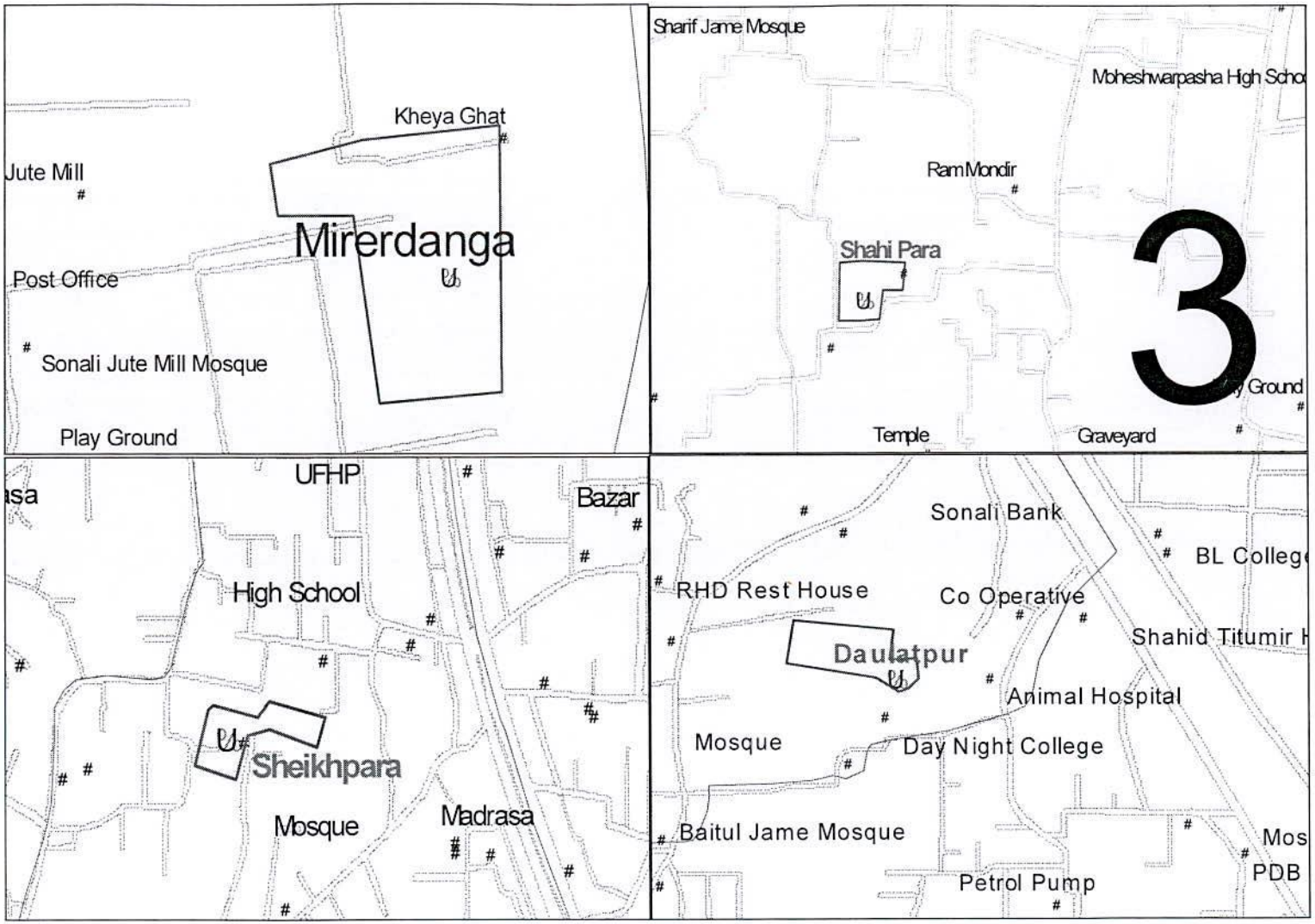


Figure 6.3 Sites of Transfer Station on the basis of two km radial distance

6.4 Types of Transfer Station

The basic types of TS have been described in the chapter two. From the design standpoint, TS can be classified as open/ uncovered and closed/ covered. Open type transfer station includes open top containers; there is no option to compact the collected waste material, only to collect it in different fractions. Closed type transfer station includes covered facilities with sorting of waste.

Depending on the method of conveying waste to the desired location (i.e Demountable Container), TS may be classified of three types:

a) TS with ramp.
b) TS with conveyor belt system.
c) TS with hydraulic lift.

Front view of the developed transfer station is presented in Figure 6.4 which is applicable for the design of the transfer station with ramp facilities.

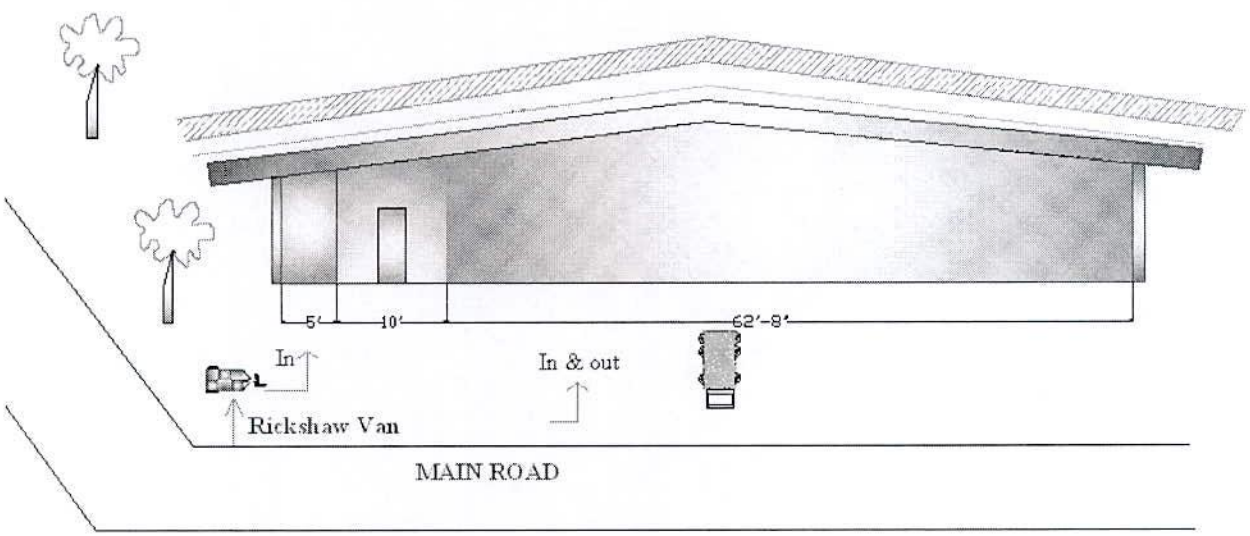


Figure 6.4 Front view of TS with ramp facilities

Ramps are common practices in solid waste management system. Workers show less interest to uplift the rickshaw van dragging up the sloped ramp because it requires hard labor to push the heavy loaded rickshaw van to the desired upper platform. To overcome this deficiency, hydraulic belt system can play a vital role. But, in this process, pneumatic system is applied for conveying the waste to the desired location. From design and operational standpoint, pneumatic systems are more complex than hydraulic system because of the complex control valves and ancillary mechanisms that are required. Besides, installation costs for systems are quite high, they are most cost effective when used in new facilities. In four-post hydraulic lift systems, platform is used to uplift the loaded rickshaw van to the higher platform so that the rickshaw van can easily move and discharge its waste to the preset demountable containers. This system is more effective and efficient involves the movable hydraulically operated platforms. After being emptied, the rickshaw van return back and visit house to house again for primary collection of waste.

6.5 Sustainability of Transfer Station

Solid waste management in Bangladesh is in the primitive stage and needs modernization through innovative and appropriate approach for its proper management. There is no internationally accepted definition of sustainable TS. Despite the differences of wording, a general consensus is reached that a sustainable TS is reached at safe condition to the end of aftercare i.e. a state where the undisturbed contents no longer pose a threat to human health and environment. Sustainability of TS can be described into two categories:

6.5.1 Institutional sustainability

Institutional sustainability can be achieved by the involvement of Khulna City Corporation, Khulna development authority, private enterprises such as NGOs/CBOs and other private organizations from abroad. Khulna City Corporation is liable for overall solid waste management. Khulna development authority can play a vital role for proper planning of TS. KDA should review planning, construction and infrastructure standards so that they can be made more flexible with a greater emphasis on minimum standards that reflect the reality of the type of transfer station affordable by different income groups. In this way, the current situation whereby KDA exerts little control over the activities of private developers can be avoided. KCC can

contribute fund for establishment and installment of proper planned and designed TS. Finally, steps should be taken to remedy the current situation whereby KDA is the statutory planning authority with the finance and the compulsory purchase powers to implement this projects but KCC is the democratically elected organization responsible for Khulna. This issue is complex and is unlikely to be easily resolved. It is therefore suggested that a joint standing committee is established to discuss ongoing projects and the support that each can provide to the others' proposals and functions. KCC will monitor and will be liable to the transaction of vehicles from primary collection to till final disposal of waste to the UDS. NGOs, CBOs and other private enterprises such as prodipon, waste concern, muktir alo etc. will be involved in the overall management of solid waste safely. Government and non-government organizations will also be engaged in these activities to keep the TS system sustainable. Sustainability of the developed TS station can be achieved by the following steps below in Figure 6.5:

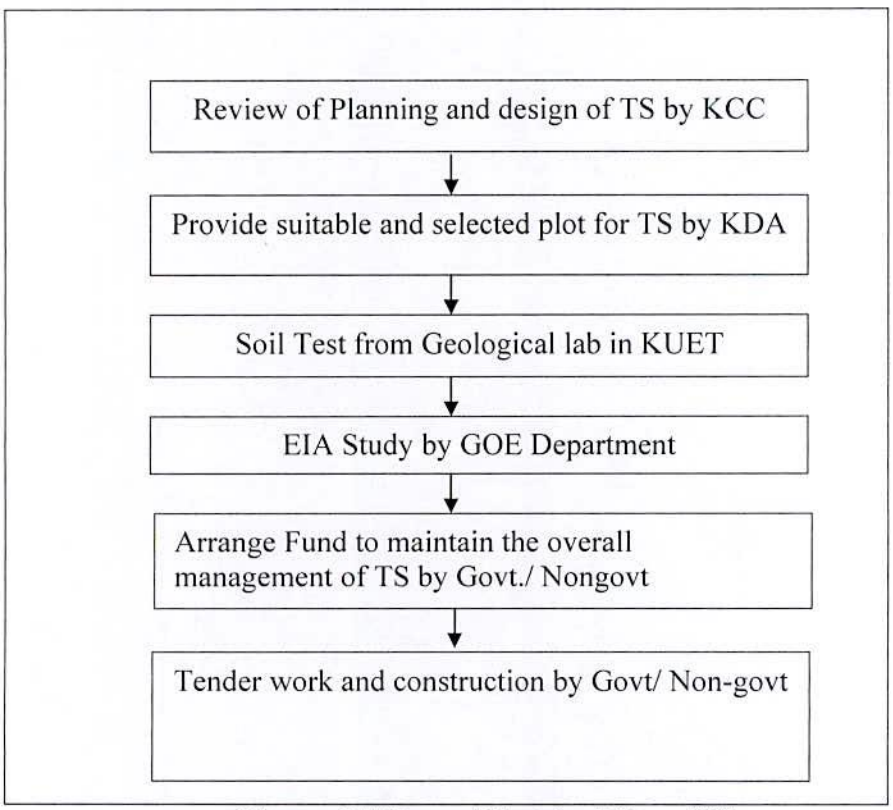


Figure 6.5 Steps of Sustainability of TS

6.5.2 Technological sustainability

In transfer station system, rickshaw van has been selected as major transporting vehicle, as rickshaw van can cover maximum 1 km radial distance, it should be used as primary collection vehicle. The TS should be accommodated in such a way that the change of configuration of vehicle in future can not disrupt the daily operation of waste. To convey the waste to the desired location without hard labor TS should provide conveyor belt system or hydraulic lift. Conveyor belt system acting on roller should be sufficient and active so that no power failure can disrupt the conveyance. Alternative backup power generators should be accommodated so that least some operations can continue during a power failure. Hydraulic lift should have two platforms vertically so that more than one collection vehicle can perform in operation in a short time without queuing in serial and avoid congestion of traffic.

6.5.3 Financial Sustainability

Financial sustainability of TS can be attained by diverting the discarded materials into reusable by product such as paper, newsprint, ferrous metals, plastic, glass containers, aluminum cans, motor oils and others such as wood, leather, slipper, shoes, batteries, silver, and tires etc. Again green waste commonly leaves, grass clippings, tree trimmings and brush etc. comes in the TS can be diverted to compost which increases the utility of waste in the TS. Methane gas produced from biodegradable fractions of MSW, which are essentially the putrescible organic fraction, the paper and board fraction and any non-synthetic textiles. This waste stored in the TS can be utilized by practical utilization of the biogas as source of energy or by microbial oxidation in a biocover. The outcome of this work would be helpful for evaluating the cost effectiveness and feasibility of possible mitigation strategies and emission reduction technologies which yields substantial energy, economic, environment, air quality, and public health benefits. Leachate water or contaminated waste water in the TS can also be treated and used in rain water harvesting system which can aid financial sustainability of TS.

6.5.4 Environmental Sustainability

Transfer Station design must account for environmental issues regardless of surrounding land use and zoning. Bangladesh is a highly populated country with highly generated waste. Minimizing the potentiality negative aspects associated with these facilities requires thoughtful design choices. Transfer station design in a coastal region like Khulna should be EIA (Environmental Impact Assessment) standards. EIA methodology is essential for systematic impacts prediction before installing a transfer station at the coastal region of Bangladesh. Careful planning, designing and operation of TS can minimize environmental impact issues regarding traffic, noise, odors, air emissions, water quality, vectors, litters etc. are described below.

a) Traffic

Transfer stations reduce overall traffic by consolidating smaller loads into larger vehicles. The transfer station, however, will generate additional amounts of traffic in its immediate area. This traffic can contribute to increased road congestion, air emissions, noise, and wear on roads. For this reason, waste transfer stations are often located in industrial areas that have ready access to major roadways. Travel routes and resulting traffic impacts typically receive significant attention during transfer station sitting and design. Some important design and operating features that should be used include:

- Selecting sites that have direct access to truck routes, highways and rail or barge terminals.
- Providing adequate space within the facility site so that customers waiting to use the transfer station do not interrupt traffic on public roads or impact nearby residences or businesses.
- Designating haul routes to and from the transfer station that avoid congested areas, residential areas, business districts, schools, hospitals and other sensitive areas.
- Designing safe intersections with public roads.

b) Noise

Heavy truck traffic and the operation of heavy-duty facility equipment (e.g., conveyors and front-end loaders) are the primary sources of noise from a transfer station. Design and operating

practices that help reduce noise include:

- Confining noisy activities within buildings or other enclosures as much as possible.
- Using landscaping, sound barriers, and earth berms to absorb exterior noise.
- Arranging the site so that traffic flows are not adjacent to properties that are sensitive to noise.
- Providing setback distances, called buffer zones, to separate noisy activities from adjacent land uses.
- Conducting activities that generate the most amount of noise during the day.

c) Odor

Garbage, particularly food waste and grass, has a high potential for odor. Proper facility design can significantly reduce odor problems. Carefully positioning the building and its doorways with respect to neighbors is a good first step. At the transfer building itself, exhaust fans with air filters and rooftop exhaust vents can further reduce off-site odor impacts. Some of the operating procedures that can help reduce odors include:

- "First-in, first-out" waste handling practices that keep waste on site only for short periods of time.
- Removing all waste from the tipping floor or pit by the end of each operating day so that these surfaces can be swept clean and washed down.
- "Good housekeeping" measures, including regular cleaning and disinfecting of surfaces and equipment that come into contact with waste.
- Water misting and/or deodorizing systems.

d) Rodents and Birds

Rodents and birds can be a nuisance and a potential health concern at waste transfer stations, but few basic design and operational elements can control them. For instance, good housekeeping practices are a simple and effective means of minimizing their presence. These practices include

removing all waste delivered to the facility by the end of each day, and cleaning the receiving floor daily (small, rural facilities may require several days to accumulate a full container of waste for transport). Receiving waste only within an enclosed structure and otherwise preventing litter can reduce the presence of birds. If problems persist in the vicinity, baiting and trapping can control rodents.

e) Litter

In the course of facility operations, it is likely that stray pieces of waste may become litter in and around the waste transfer station. Measures that can help reduce litter include:

- Positioning the main transfer building so that predominant winds are less likely to blow through the building and carry litter off-site.
- Installing perimeter landscaping and fencing to reduce wind speeds at the transfer station site and to trap any litter.
- Ensuring that tarps on open top trucks are secure.
- Providing skirting around loading chutes.
- Removing litter frequently to reduce the opportunity for it to travel offsite.
- Patrolling nearby access roads to control litter from truck traffic.

f) Air Emissions

Air emissions at transfer stations can come from unloading dry, dusty waste delivered to the transfer station, exhaust from trucks, loaders and other equipment, and driving over unpaved surfaces. The following can reduce air emissions:

- Requiring trucks delivering and picking up waste at the facility to reduce unnecessary engine idling.
- Working with fleet operators to reduce engine emissions (e.g., engine improvements or use of cleaner fuels).
- Spraying dusty wastes with water as they are unloaded.
- Ensuring that street sweeping operations use enough water to avoid kicking up dust.
- Paving all surfaces where trucks operate

6.6 Emergency Situation and Safety Measures

Transfer station may face various natural calamities such as flood, cyclones, storm, tidal disaster etc. It should be designed in a way that it can prevent such disasters. Transfer station staff should be familiar with procedures involving fire prevention and control. A "fire hazard-no smoking" sign should be posted at the entrance. Fire extinguishers should be available inside the buildings. Transfer station with permanent staff should have telephone communications available to enable the fire department, police and medical services to be contacted. Staff serving station should have a cellular telephone in their vehicle. At emergency situation, first aid kits should be available in the staff room in the Transfer Station.

Employees at the site shall work under all appropriate health and safety guidelines established by the Occupational Safety and Health Administration (OSHA). First aid equipment shall be available at the site. Health and safety issues at transfer station are related to dust inhalation. Overhead water sprays are used to keep the dust down in the storage–load transfer station. To prevent dust inhalation, workers should wear dust masks. Besides most transfer stations involve the dropping or pushing of waste down into a bin or container. It is important that safety features such as guard rails are incorporated to prevent people from falling into a bin and stop logs or bars to prevent vehicle accidents.

6.7 Constraints of the Proposed Planning and Design

Several practical steps have been undertaken in Khulna city to improve level of people's awareness and collection systems. Initiative suffers from a number of constraints such as financial inability; absence of logistic supports from city authority, evaluation of success changes, unavailable data related to KCC extended map, exact population and waste generation rate and absence of appropriate method. It is observed that taken initiates have already put positive impact on overall MSW management system. In designing of TS, limited sized site was found due to unavailable land and high population. Besides, site observation was not performed only GIS based information was considered to locate the sites. The results depict that the

probable locations of TS, conceptual design of TS and continuous monitoring, refinement of system and social movement rather than pure technical issue are required.

CHAPTER VII

Conclusions and Recommendations for Future Studies

7.1 Conclusion

The findings of this study can be concluded as the followings:

i. Existing on-site storage practices need to change immediately by adopting properly designed transfer station based on the prevailing conditions of the respective urban areas. Transfer Station initiatives represent ~5% of the new diversion initiatives of the SWMP.

ii. From the study, 18 Transfer station has been selected on the basis of one km radial distance and 8 no. of TS has been selected on the basis of two km radial distance.

iii. Several sites have been selected to install TS considering overall sitting factors.

iv. Three types of Transfer Station have been designed as a proposal such as Transfer Station with ramp, Transfer Station with conveyor belt and TS with hydraulic lift system having capacity of 50 tons for further implementations.

v. Covered and uncovered facilities have also been included with this system considering all facilities related to the design of TS.

vi. All institutional, technological, financial and environmental sustainability should be ensured for proper management of the TS.

7.2 Recommendations for future studies

The followings can be the interesting fields in developing transfer station for the future researchers:

- Acceptable and sustainable design of Transfer station should be implemented considering all financial, institutional and environmental aspects.

- EIA study should be needed before installment of a transfer station.

- National level policy, rules and regulations should need to improve the setting of the transfer station at the coastal region like Khulna.

- The basement and surroundings of the TS should be prepared on the basis of detailed soil analysis/ geotextile so that leachate can not penetrate into the underground and nearby lowland or pond water.

- The waste stored in the TS should be disposed to the landfill timely otherwise it should be covered so that flies, mosquitoes and other insects can not breed their number of populations.

- Exact gas utilization technique should have to be developed so that green house gases such as methane, carbon-dioxide etc. can not release into the atmosphere.

- Motorized vehicles for primary collection of waste should be introduced to increase the efficiency of loading and unloading of waste and to reduce the number of TS.

- Step should be taken to eliminate scavenging at TS in phases, but opportunities for waste picking at designated sorting stations should be provided.

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