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Identification of Appropriate Landfill Sites for the City of Chittagong

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ABSTRACT

Urban solid waste management is a serious environmental issue confronting the cities in developing countries like Bangladesh. Apathy towards the problem, inadequacy of field level information and data, and resource constraints may be blamed for the dismal situation of solid waste management often visible in our cities. The most common problems associated with the absence of sustainable solid waste management practice include diseases transmission, odour nuisance, atmospheric and water pollution, visual blight, fire hazards and economic losses. In the three major cities of Bangladesh, Dhaka, Chittagong & Khulna, per capita production of solid waste is around 0.4kg /capita / day, but only a fraction of this waste is carried to the final disposal site. A recent study on Municipal Solid Waste Management, funded by Bangladesh Municipal Development Fund (BMDF), found that waste generated in Chittagong was 0.352kg/cap/day. Considering per capita generation of solid waste as 0.352kg to 0.4kg per capita per day, for a population of 25, 92,459 distributed within the 41 wards of the city (BBS 2011), total solid waste generated in Chittagong will be around 913 tons to 1037 tons per day in 2012.

Currently, Chittagong City Corporation has only two dumping yards: one at Ananda Bazar, Halishahar at the mid western part of the city and the other at Arefin Nagar, Pahartali at the northern tip of the city. None of these sites are sanitary landfill. Considering the city area of 168 sq.kms, only two dumping sites are not sufficient to cater to the requirement of the city. Long distances between the collection points and the disposal site are responsible for inefficient utilization of the CCC trucks and the resulting increase in the haulage time that eventually increases the costs of collection and disposal.

This paper aims to identify a number of appropriate landfill sites within the city for cost effective, efficient and safe disposal of solid wastes. An appropriate landfill site must satisfy environmental safety criteria and attributes that will enable the wastes to be isolated so that there is no risk to people and the environment. The criteria utilized for identifying appropriate landfill locations include natural physical characteristics as well as socioeconomic, ecological, engineering and land-use parameters. This study utilized Geographic Information System (GIS) and Multi-Criteria Decision Method (MCDM) for the identification and selection of appropriate landfill sites within the city of Chittagong. Thirteen sites were identified initially. Out of these sites four were found to be most appropriate and suitable for use as landfill. The sites thus identified, if utilized by CCC, are expected to bring a major change, in terms of cost effectiveness, efficiency and safety, in the current scenario of solid waste management in the city.

Keywords: Solid Waste Management, Sustainable, Geographic Information System, Multi-Criteria Decision Method, Chittagong, Bangladesh

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INTRODUCTION

Background information

Bangladesh is one of the most densely populated countries in the world having a population of 965 per square km (BBS 2011). Rapid urbanization has also become a visible feature, especially in the three major cities of Bangladesh: Dhaka, Chittagong & Khulna, after the liberation of Bangladesh in 1971. While the total population of the country has been increasing at 1.37% per annum (BBS 2011), the urban population is growing at about 3.27% per annum (Aqua Consultant et.al 2012). This rapid urbanization has created a strain on the resources of local bodies like cities, towns and municipalities, which are often finding it difficult to cope with the increasing demands of the city dwellers for urban services and civic amenities. Solid waste management is one such area of urban services where funds are often in short supply; always giving way to other pressing needs like health care and education. Chittagong is the second largest city in Bangladesh having a population of about five million including people living in the urban fringes. Managing solid waste efficiently and arranging resources for it has become a serious concern of the city authority. Currently, Chittagong City Corporation has only two dumping yards: one at Ananda Bazar, Halishahar at the mid western part of the city and the other at Arefin Nagar, Pahartali at the northern tip of the city. None of these sites are sanitary landfill.

Problem statement:

Chittagong is the second largest city of Bangladesh. According to the preliminary results of the population and housing census 2011, the city has a population of 25, 92,459 distributed within the 41 wards of the city (BBS 2011). The city is growing. It grew at the rate of 4.527% per annum between the years 1991 -2001. However, it appears, the growth has slowed down between the years 2001 to 2011. The city grew at the rate of 2.81% per annum in average during the last decade (BBS 1997, 2002, 2011). Sujauddin reported a per capita generation of 0.25kg of solid waste in Chittagong based on their field survey and analysis of solid wastes generated in a small community in Chittagong city (Sujauddin, M et al 2007). Compared to other similar cities in South Asia, this per capita generation of solid waste in Chittagong appears to be very low. Inferring from the waste generation in similar cities in South Asia, Ashraf estimated a per capita per day generation of 0.4kg of solid wastes in Chittagong (Ashraf 1994). A recent study on Municipal Solid Waste Management, funded by Bangladesh Municipal Development Fund (BMDF), found that waste generated in Chittagong was 0.352kg/cap/day. This finding by BMDF appears to be more realistic. Therefore, considering per capita generation of solid waste as 0.352kg to 0.4kg per day, total solid waste generated in Chittagong will be around 913 tons to 1037 tons per day in 2012. Mr.Shafiqul Mannan, Chief Conservancy Officer, Chittagong City Corporation (CCC) claims that nearly 90% of the waste generated in Chittagong are collected and disposed of by them. Currently, they are using 60 trucks with a varying capacity of three to five tons for collection and disposal of solid wastes within the city. These trucks can give only three to four trips per day: two trips during daytime and two trips during the night. These trucks could give a maximum of 240 to 250 trips, according to him, in a day (Mannan 2012). For an efficient and sustainable solid waste management system, these trucks should be better utilized giving more trips per day than what it is giving now. Considering the hauling distances covered by the waste trucks and the travel time required, dependence on these two sites only, eccentrically located at the northern and mid western end of the city, does not seem to be justified on economical consideration. Several sanitary landfill sites at appropriate location evenly distributed within the city might be the answer to the problem outlined above.

AIMS AND OBJECTIVES

Identifying appropriate sites to be used as sanitary landfill within the city area is the aim of this study. If the current city area of 168 sq. km is sub-divided into four quadrants and at the least four appropriate sites, each for one of the quadrants, could be identified for using as sanitary landfill, efficiency of solid waste collection and disposal could be greatly increased. Haulage distance and time for city corporation garbage trucks will be greatly reduced. Garbage trucks will be able to give more trips as against the current practice of three to four trips per day by each truck. This paper aims to identify appropriate landfill sites within the city by using geographic information system and multi criteria decision analysis. In course of the decision making process, environmental, economical and ecological factors will be taken into consideration.

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STUDY AREA

For analysing the problems and issues relating to solid waste management in the City, we have taken the City of Chittagong in its current setting as our study area. It is the second largest city of Bangladesh and has an area of about 168 sq.km. It is located between 22°-14´ and 22°-24´-30´´ N Latitude and 91°-46´ and 91°-53´ E Longitude on the Right Bank of the river Karnaphuli. As per census 2011, the city has a population of 25, 92,439 people. Considering the urban fringes, estimated population of the city will be around five million. The study area is illustrated in Fig.1.

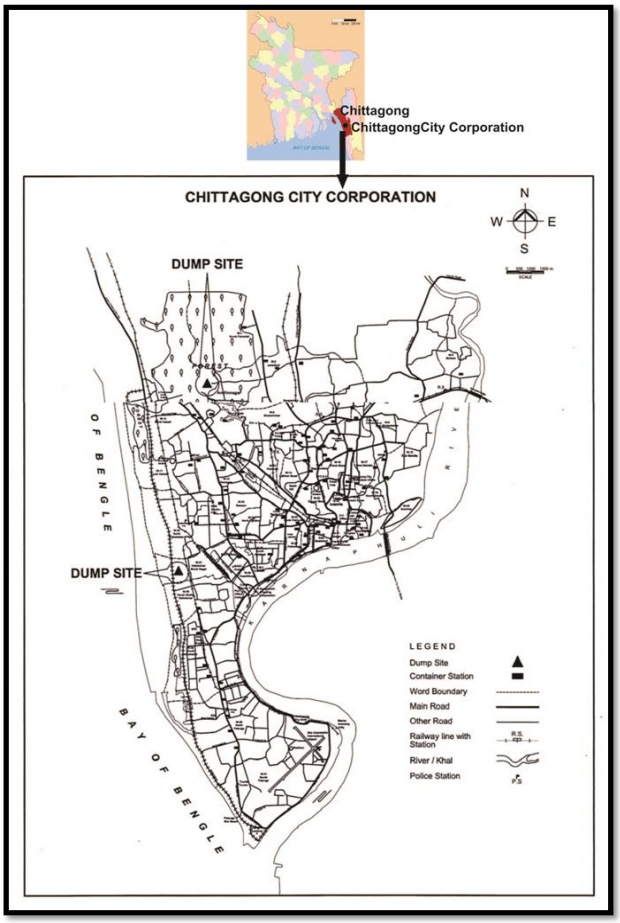

Fig 1: Chittagong City Corporation (CCC)

PRESENT SCENARIO OF SOLID WASTE COLLECTION IN THE CITY AREA

Current capacity of the Chittagong City Corporation:

At present there are two dumping yards at Arefin Nagar, Pahartali and Anandabazar, Halishahar. Arefin Nagar yard has an area of 73 acres while Halishahar yard is smaller in size and has an area of ten acres. The dumping yards have no provision of leachate collection. Assuming weight of solid waste as 500kg per cubic meter and allowable height of fill as four meter, we will need around 42 to 46 acres of land in Chittagong, to be used as landfill, per year at the present generation of around 913 tons to 1037 tons of solid waste per day. If we assume, conservatively, five years will be necessary to convert and remove at least 60% of the garbage as compost from the landfill site, the city will need around 322 acres of landfill at the present stage to begin with. Land requirement will be more if we have to accommodate the increased generation over the years because of population growth. Amongst the total wastes disposed of in Chittagong, 71.7% is organic and 28.3% is inorganic waste at household level. Currently, 12.41% of all wastes generated are recycled and only 1% is composted (Aqua consultant et.al 2012). According to the information given by the Chief Conservancy Officer,

CCC, 50% of the solid wastes generated goes to Anandabazar for disposal and the remaining 50% goes to Arefin Nagar at Pahartali. CCC has a fleet of 84 trucks out of which 60 trucks are in working condition (Mannan 2012). Open fixed bed truck are expected to make minimum 3 trips per day while dump trucks are expected to make 4 trips per day and container trucks are expected to make between 6-8 trips per day. According to load carrying capacity of the trucks and number of trips they can make in a single day, total waste carrying capacity of the existing waste collection fleet of CCC is estimated at 830 tons per day. There are 507 rickshaw vans used for garbage collection from the households in different city wards. The number of trips made by each rickshaw van varies between 2 to 4 trips and wastes carried vary between 350 kg to 400 kg. There are 1269 dustbins and demountable containers at 76 locations within the city (Aqua Consultant et.al 2012).

Limitations of the existing dumping yards within the city

Table 5: Limitations of the existing dumping yards in the city

Site name	Specific location	Buffer zone-Separator	Soil cover	Protection against rain	Leachate treatment	Gas monitoring system	Accessibility	Physical condition	Environmental acceptability
Arefin Nagar	Asian women university is located within 100m	No	No	No	No	No	Not good	Poor, leachate is flowing and has chance to mix with surface water	Odour, pollution and noise are found, no incineration. No social acceptance
Halishahar	RCC protect. wall along the sea shore within 10 meter	No	No	No	No	No	Good	Mixing of medical waste, cattle grazing is common, vehicle moves across the land fill	Odour, pollution and noise are found. Waste is incinerated. Not socially accepted

Case study: lessons from Sugandha Residential Area

Sugandha Residential Area is one of the posh residential areas in Chittagong. During the Pakistan period, it was a dumping yard for solid wastes. After relocation of dumping sites to Yakub Nagar & Halishahar, CCC turned the site into a residential area. Several residential plots were created and sold. The plot owners while building structure on it faced problem because their structural engineers did not allow them to place foundation on this decompose-able fill. They either had to remove all the fill materials or go for costly cast in situ piles in foundation. Double expenses in the form of public and private expenditure were incurred in filling the area once and then removing the fill again. If the dumping site or landfill site is selected as a part of a conscious land use plan, the site could be used as a park, playground, botanical garden or alike. This could have saved the inconvenience and cost of excavating and removing the fill for laying foundation. If we can consciously identify landfill sites, keeping in mind that these sites will be eventually used as a playground, park, open space, vegetable

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garden, botanical garden, green corridor etc., city will be benefited. After using a landfill for fifteen or twenty years, the site can be abandoned as a landfill and can be converted into a playground or park at a reasonable cost.

METHODOLOGY

Primary data from the field trips, reconnaissance survey, literature survey, key person interview, newspaper reports, web sites etc. were the main source of crude data and information. GIS Maps produced by Chittagong Development Authority (CDA) including Physical Feature Survey Maps and the Contour Maps, Structure Plan, Transportation & Drainage Master Plan, Detail Area Plan for Chittagong and photography were extensively used in analysing, processing and recording the data and information collected. Two types of analysis were done: GIS based analysis and Multi Criteria Decision (MCD) based analysis.

GIS based analysis: To conduct this analysis, Geographic Information System (GIS) software was used. As a first step, different buffer zones were created to separate residential, commercial, community facilities, health facilities, educational institution, pucca access roads, agricultural land etc. from the proposed landfill sites. The following table indicates the minimum buffer distances kept between the landfill sites and the existing land usages while identifying the appropriate landfill sites.

Table-1. Minimum buffer distances from the proposed landfill sites considered for different land usages in this study

Description	**Minimum Distance from proposed landfill**
Residential	300 meter
Commercial	300 meter
Community facilities like bazaar	500 meter
Educational Institutions	500 meter
Health Facilities	500 meter
Water bodies like khals and rivers	300 meter
Ponds over the size of 0.5 acres	300 meter
Pucca access roads	200 meter
Agricultural land	200 meter

Digital Elevation Model (DEM) was prepared from contour map to determine the land characteristics.

MCD based analysis: This step involves analyzing the suitability of the landfill sites on the basis of criteria like hydrological characteristics, climate, wind direction, underground soil condition, socio economic parameters, distance from the water body, land price, accessibility etc. Detail Area Plan (DAP) for Chittagong has barred filling of any pond over the size of 0.5 acres. Therefore, all endeavours were made to locate the landfill sites, at the least, 200 meter away from the ponds over the size of 0.5 acres. To prevent leachate reaching the water table information regarding soil characteristics were analyzed. Landfills with clay layer underneath were considered highly suitable and tagged very high. A study with soil in Khulna found sub soils in four selected locations in and around Khulna City suitable as a compacted clay liner for the construction of sanitary landfill (S.Akhter et al 2008). Considering the suitability as sub soil, silty clay is tagged high while mixed silty or sandy clay is tagged moderate and sandy soil: low respectively.

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RATIONALE BEHIND THE STUDY

Chittagong City Corporation covers an area of 168 sq km generating 913 to 1037 tons of waste per day. It is facing difficulty in coping with the problems of solid waste collection and disposal. Its present system of solid waste collection and disposal is not efficient and cost effective. With the gradual increase in population, the situation is going to deteriorate even further. The city with its existing manpower and expertise is not in a position to find a way out of this problem. The present study has tried to pin point the problem and its magnitude. It has tried to give a solution, too. The city might consider implementation of the solution proposed.

FINDINGS

After compiling all buffer layers and applying multi criteria decision analysis, this study has identified thirteen primary locations falling within the four quadrants of the city area. Characteristics of these sites are given below:

Table 2: Characteristics of primarily identified landfill sites

Site no.	Location	Specific Location	Elevation	Soil suitability based on bore log analysis	Land Price per Katha)	Land size	Accessibility	Remarks
1	South of the city in South Patenga, ward-41	Near Naval Academy	Low land 3.5m above mean sea level	Bore log not available	5 lacs	-------	Good	Satisfies most of the controlling criteria. There is a small pond and a khal passes through the area
2	South of the city in South Patenga, Ward-41	Beside Patenga CNG Station.	Low land 3m above mean sea level	Bore log not available	5 lacs	--------	Good	Satisfies most of the controlling criteria. Near char land (shoal) There are several small water bodies over the size of 0.5 acres
3	South of the city at South Halishahar, Ward-39	Near CEPZ – Approx. 1km from BRAC Primary School.	Low land 2.5m above mean sea level	Moderate	8 Lacs	About 80 acres	Good	Satisfies most of the controlling criteria. Near char land (Shoal)
4	South of the city at South Patenga, Ward-41)	Situated at Taltola, Bandartila	Low land 2.7m above mean sea level	Bore log not available	----------	--------	Good	Satisfies most of the controlling criteria. One khal divides the area. Near land under port use

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5	South of the city at South Patenga, Ward-41)	Situated at Hosain Ahmad Para, near airport.	Low land 3.5m from mean sea level	Bore log not availabl e	----------	--------	Good	Satisfies most of the controlling criteria. Rail line crosses the area. One ditch and a pond greater than 0.5 acre in size exist.
6	West of the city at North Middle Halishah ar, Ward-37+North Halishah ar, Ward-26+ South Kattali, Ward-11+ North Kattali, Ward-10)	About one km from Chittagon g Polytechni c for Girls.	Low land 2.5m above mean sea level	Moderat e	5 lacs	About 160 acres	Good	Satisfies most of the controlling criteria. Several types of water bodies were found scattered in this area.
7	East of the city at Boxirhat, ward-35+ East Bakalia, Ward-18)	About 2km away from the east of Little Bird K.G school.	Low land 2.5m above mean sea level	Very high	----------	--------	Moderat e	Satisfies most of the controlling criteria. Safe distance away from the river. One khal has entry to the site.
8	East of the city at Mohra, Ward-5)	About 1.5 km away from the east of Hamidpur Primary School.	Low land 2.5m above mean sea level	Very high	8 Lacs	About 50 acres	Good	Satisfies most of the controlling criteria. Safe distance away from the river
9	North Eastern part of the city at Mohra, Ward-5	About 1.5 km away from North-East of Chowdhur y Bill Govt.Prim ary School.	Low land 3.5m above mean sea level	Very high	---------- -	--------	Good	Satisfies most of the controlling criteria. A number of ponds >.5 acres in size were seen around the site
10	North	About	Low	High	----------	--------	Good	Satisfies all

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	Eastern part of the city at Chandgaon,ward-4	100m away from CDA Anannya Residential Area	land 3m above mean sea level		-			controlling criteria.
11	North of the city at North Pahartali, Ward-9)	Approx. 500m away from West of Darul Quran Madrasa	Moderately high land 7m above mean sea level	Moderate	15 lacs	About 110 acres	Good	Satisfies all controlling criteria. Situated in hilly region Slums are existing
12	North of the city at Jalalabad,Ward-2)	Just near the cantonment area	Moderately high land 6.5m from mean sea level	Very high	----------		Good	Satisfies all controlling criteria.
13	North of the city at South Pahartali, Ward-1)	About 2km from the west of Chittagong University	High land 16m above mean sea level	Bore log not available	----------		Good	Satisfies most of the controlling criteria. Situated in the hilly region -One Khal exist.

Source: Field information, collection and analysis 2012

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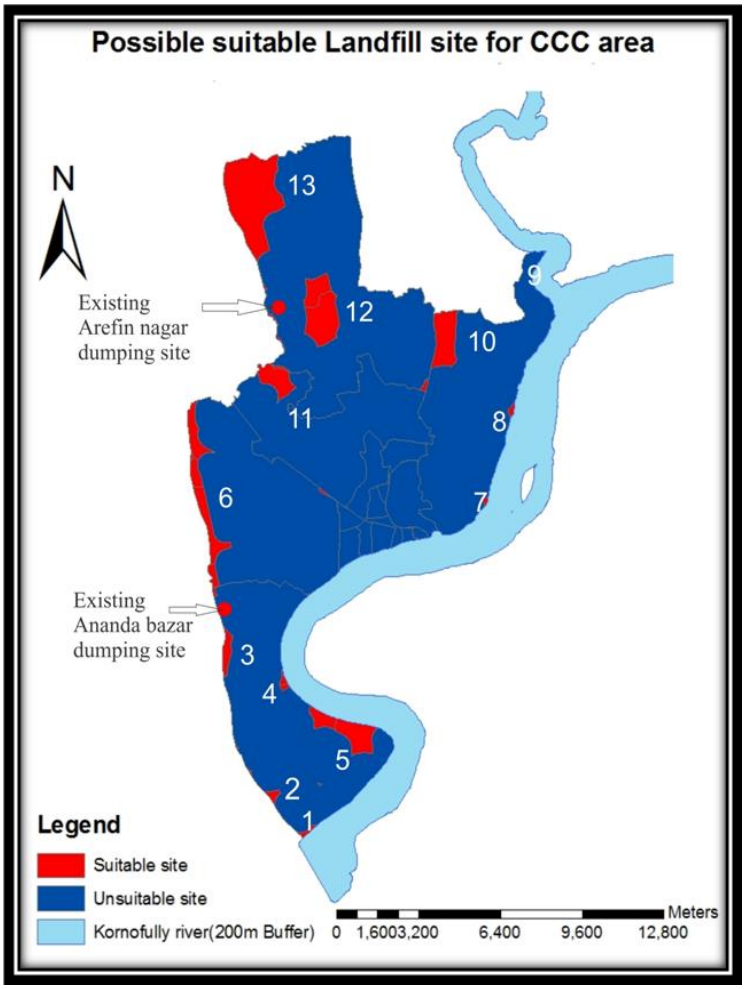

Fig 2: Possible landfill sites within the city

Appropriate sites

Among the 13 possible suitable sites identified for establishing sanitary landfills in the city, four were found most suitable. Site no 3 is located in South Halishahar, Ward No.39. It can cater to the requirement of the southern part of the city especially Patenga and part of Halishahar. Site no 6 spreads between four wards namely: North Middle HaliShahar-Ward 37, North Halishahar-Ward 26, South Kattaly-Ward 11 and North Kattali-Ward 10. It can serve the western part of the city area. Site No.11 at North Pahartali-Ward 9 can cater to the requirement of northern part of the city. Site no.8 is in Mohara-Ward 5. It will be most suitable for serving areas located in the east of the city. The aforementioned sites, considered suitable as a landfill, are illustrated in Figure-2.

Characteristics of the four most appropriate sites

Site no 3: The site is located approximately 1 km away from BRAC primary school in South Halishahar. It satisfies the entire buffer requirements elaborated in Table-1. It is located in a low-lying area and its elevation is 2.5m above mean sea level. Sub soil is mixed silty or sandy clay. Considering the possibility of infiltration of leachate into the groundwater table, the site can be termed moderately suitable as a landfill. The site is accessible from a pucca road. Accessibility can be termed as good. The total area of the site is about 80 acres. Land price is around Taka eight lacs per katha which is equivalent to Taka 49 million per acre. Soil characteristics of the site is given in Table-3

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Table-3. Soil Characteristics of Site No. 3

Ward No	39	
Borehole Location	CEPZ	
Depth (m)	**Lithology**	SPT N Value
0-1.5	Silty sand	2
1.5-4.5	Silty sand with clay	8,11
4.5-10.5	Medium sand with clayey silt	11,17
10.5-19.5	Medium sand with clayey silt	18

Source: Soil quality analysis, 2012

The site is in zone-DPZ-3 of the Detailed Area Plan (DAP) for Chittagong published in the year 2008. It is located near the sea and the zoning provisions in DPZ-3 earmarked it as a tourist spot. After using the site for a number of years as a landfill, it can be converted into a tourist spot with landscaping, eateries, amusement park etc.

Site no 6: The site is located approximately one km away from west of Chittagong Girls Polytechnic. It satisfies the entire buffer requirements elaborated in Table-1. It is located in a low-lying area and its elevation is 2.5m above mean sea level. Sub soil is mixed silty or sandy clay. Considering the possibility of infiltration of leachate into the groundwater table, the site can be termed moderately suitable as a landfill. The site is accessible from a pucca road. Accessibility can be termed as good. It is a low-lying area: 2.5m above mean sea level. Land price of this area is about five lacs per Katha which is equivalent to Taka 30 million per acre. The site is about 160 acres in size. Soil characteristics of the site is given in Table-4

Table-4. Soil Characteristics of Site No. 6

Ward No	37	
Borehole Location	Wapda circle	
Depth (m)	**Lithology**	**SPT N Value**
0-1.5	Medium sand	7
1.5-3	Medium sand with clay silt	5
3-10.5	Inorganic soil with silty clay	13
10.5-13.5	Stiff silty clay	16

Source: Soil quality analysis, 2012

The site is in zone-DPZ-2 of the Detailed Area Plan (DAP) for Chittagong. The zoning provision allows Children park or alike in the area. After its use as a landfill, the site can be developed as a children park with space allocation for open-air concert, football ground etc. It can also be developed into a recreational area.

Site no 8: The site is located about 1.5 km away from Hamidpur Primary School in Ward 5, Mohara. It satisfies the entire buffer requirements elaborated in Table-1. It is located in a low-lying area and its elevation is 2.5m above mean sea level. At a depth of 1.5m from the ground level, the site has a grey soft to medium stiff inorganic clay of low to medium plasticity. This clay layer extends up to the depth of about 18m. The sub soil with a clay layer, about 16m thick, can be considered highly suitable for preventing leachate contaminating the ground water. Access is from a pucca road. Accessibility can be

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termed as good. Land price is around Taka eight lacs per katha equivalent to about Taka 49 million per acre. The site is about 50 acres in size. Soil characteristics of the area is given in Table-5

Table-5. Soil Characteristics of Site No. 8

Ward No	5	
Borehole Location	Nazir Ali Tendal Road, Mohora, Chandgaon	
Depth (m)	**Lithology**	SPT N Value
0-1.5	Light grey soft inorganic silty clay of low to medium plasticity	3
1.5-5.5	Grey soft to medium stiff inorganic clay of low to medium plasticity	4,5
5.5-18.5	Grey very soft inorganic clay silt of low plasticity	1,4

Source: Soil quality analysis, 2012

The site falls within zone DPZ-4 of DAP 2008. It is located near the river Karnafuli. DAP has proposed establishment of leisure centre, riverside promenade, picnic spot etc. in this area. After its use as a landfill, the site can be used for land usages proposed in DAP.

Site no 11: The site is located approximately 500 m away from the west of Darul Quran Madrasa. It satisfies the entire buffer requirements elaborated in Table-1. It is located in a hilly area having elevation 7 m above mean sea level. At a depth of about 3m from the ground level, the site has a grey soft to very soft clay layer extending up to a depth of about 12 m. The sub soil with a clay layer, about 10m thick, can be considered highly suitable for preventing leachate contaminating the ground water. Another soft clay layer starts from a depth of 17m and extends up to 20m. Accessibility is from pucca road and can be termed as good. Land price is around Taka 15 lacs per katha which is equivalent to about Taka 91 million per acre. The site has an area of about 110 acres. Soil characteristics of the site is given in Table-6

Table-6. Soil Characteristics of Site No. 11

Ward No	9	
Borehole Location	Near Panjabi Lane Foy's Lake Area	
Depth (m)	**Lithology**	**SPT N Value**
0-2.74	Brown filing sand	2
2.74-12.8	Grey, soft to very soft clay	2
12.8-16.77	Grey, Medium dense, silty sand	12,14
16.77-19.82	Grey soft clay	2

Source: Soil quality analysis, 2012

Site no 11 falls in Zone-DPZ-5 of the Detailed Area Plan (DAP). It is located in a hilly area. DAP wants it to be preserved. In the 1961 Master Plan, a botanical garden was proposed in that hilly region. After its use as a landfill, the site can be effectively developed into a botanical garden. A botanical garden in the northern part of the city might become its lung in future. In fact, even now, Chittagong does not have a botanical garden.

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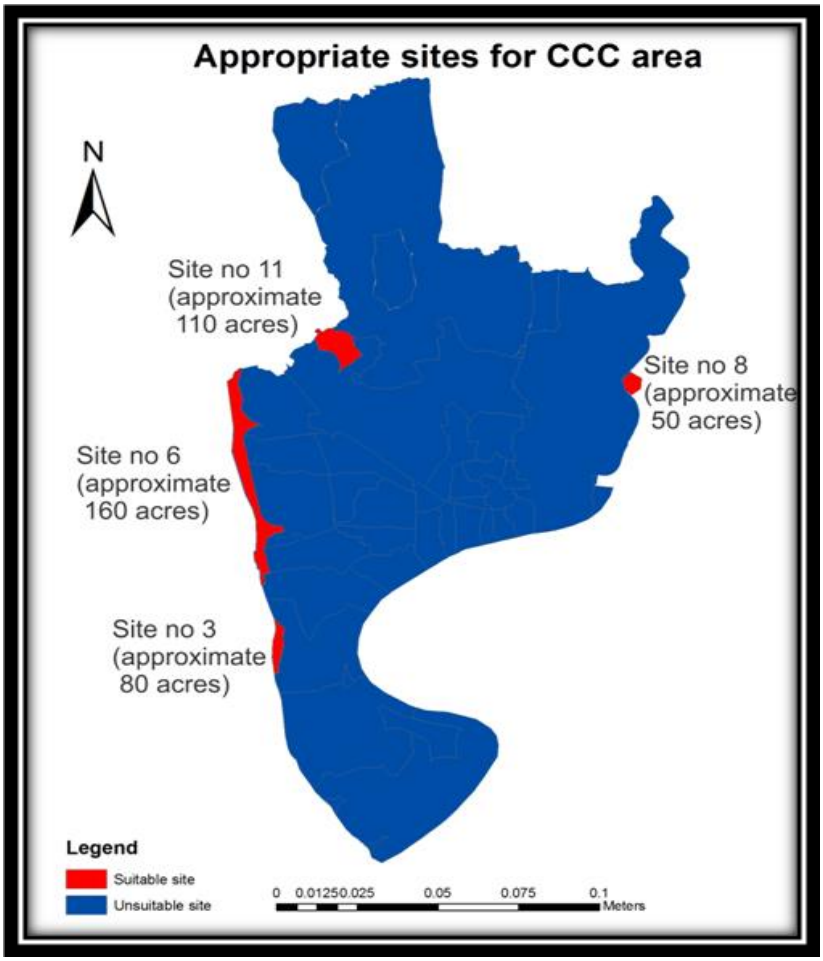

Fig 3: Most Appropriate Landfill Sites

ENVIRONMENTAL CONSIDERATIONS CONCERNING THE LANDFILLS

Site no 3, 6, and 8 are located in a low-lying area. Site no 11 is located in a hilly area. All these areas might encounter problem with leachate during the rainy season. The following procedures could be adopted to mitigate the problem. Schematic representation of a sanitary landfill with design components is shown in Fig.4.

- Synthetic liners including plastic geo-membranes, geo-mats, geo-grids, geo-textiles that commonly contain bentonite clays could be used to trap leachate. Synthetic liners in double layers could be used underneath the fill for creating a leachate trap. Leachate thus accumulated can be removed subsequently by using leachate collection pipes (Sener 2004).

- Cell system could be introduced to prevent infiltration of rainwater. The cell thickness may range from 8 to 30 feet (2.4 to 9.1m) but 15 feet (4.6m) thickness is commonly used. The width of the working face is limited to 2 feet (.6m). The first lift of the waste should be 5 feet (1.5m) or less with careful removal of the oversize pieces to prevent damage to the underlying leachate collection system. The thickness of the daily cover should be 6 to 12 inches (159 to 300mm). If the lift surface is anticipated to remain exposed for more than 30 days, an intermediate cover having a thickness of one foot should be used. This one feet thickness of cover will be more resistant to erosion compared to the usual daily cover (Sener 2004). When the operational life of the landfill is over, a final layer of soil and optimum synthetic liners should be used on top along with a vegetative cover to limit percolation and erosion.

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- As several types of water body exists in site no 6, water body with less than 0 .5 acre in size may be filled considering the scarcity of land. Water bodies above the size of 0.5 acres should be preserved. A schematic representation of a sanitary landfill is shown in Figure-4.

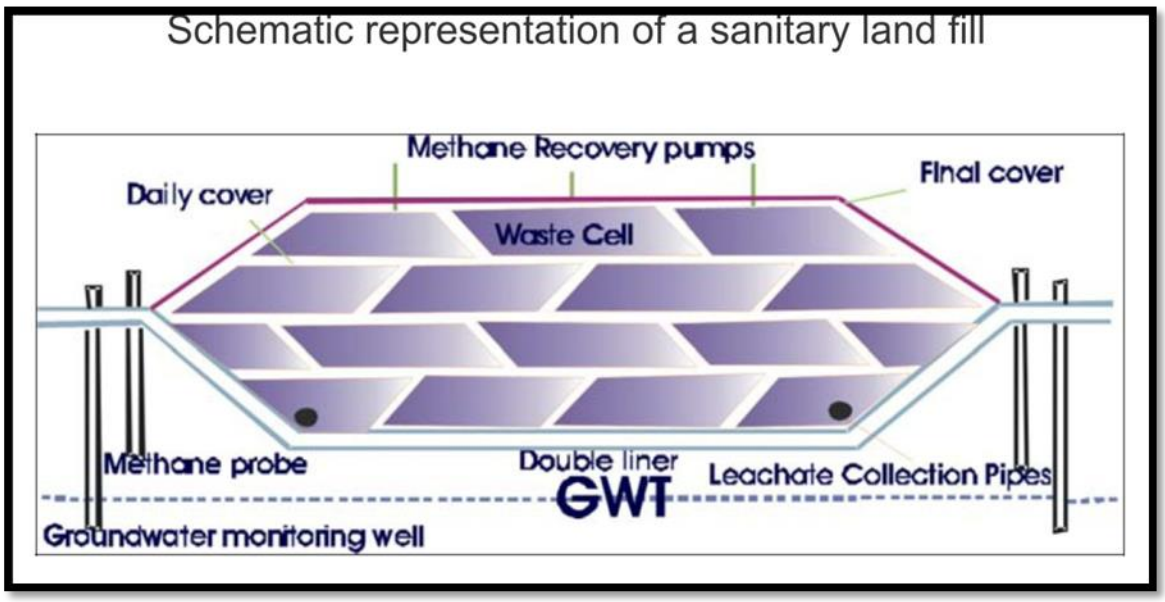

Fig 4. Schematic representations of a sanitary land fill with design components

Source: Tchobanoglous *et al.*,1993; Bagchi,1994

- Chittagong is a populous city. High-density development may take place around the landfills in future. A twenty-meter buffer zone with trees and shrubs is to be created surrounding the landfill. This buffer zone will help reduce odour and at the same time create a green visual barrier between other usages of land. Since wind blows generally form the southwest direction, there must be a green barrier on the eastern side of Site- 6 and Site- 3.

LIMITATION OF THE STUDY

- Soil characteristics mentioned in this study will be indicative in nature. Information based on one boring result will not be sufficient to justify a site as more suitable or less suitable as a landfill considering the permeability as a controlling parameter. More bore log results, distributed throughout a landfill, are to be analyzed; hydraulic conductivity of the sub soil-clay layer is to be assessed. Hydraulic conductivity should be around: k= 10^{-7} cm per sec to be effective as a soil liner. Chemical composition of the subsoil was not analyzed. Chemical composition of subsoil is an important parameter controlling the permeability of the subsoil underneath the fills. For projects needing huge investment, these analyses should be done before arriving at a final conclusion on appropriate landfill site.

- Not much information was available on area specific ground water condition.

- An average value of land price was given. Price varies depending on the location. Price is always high near the access road. Information regarding price was collected by interviewing local people only.

CONCLUSION

The findings of this study may give essential inputs to the policy makers in Chittagong City Corporation. They may use the information provided for identifying appropriate landfill locations for the city. The current dependence of the city on only two dumping yards, eccentrically located on the western side of the city, is not cost effective and therefore a revision in their waste disposal strategy is necessary.

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