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WASTE CONCERN

Assessment of a decentralised composting scheme in Dhaka, Bangladesh

Technical, operational, organisational and financial aspects

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Summary

In the residential area of Mirpur in Dhaka, Bangladesh, a pilot project for the decentralised treatment of organic waste through composting was started in 1995 by the initiative of Waste Concern, a national research based NGO. Organic waste is converted into compost using the "Indonesian Windrow Technique", a labour intensive aerobic and thermopile composting procedure.

For this study, key information on the Mirpur Composting Scheme was collected. This includes a description of the technical and operational aspects of the composting scheme (site-layout, process steps, mass flows, monitoring of physical and chemical parameters), the evaluation of financial parameters and the description of the legislative situation in Bangladesh concerning waste management. Recommendations are given for the implementation of new composting systems and aspects of marketing the final product (the compost) are discussed.

The study shows that the Mirpur waste collection and composting scheme is a good alternative to conventional solid waste management options as it reduces the amounts of waste to be transported and dumped in disposal sites, improves the quality of life of the residents in the collection area (cleaner environment) and produces a good and hygienic product from waste, which if used in agriculture, helps avoid the degradation of soils. The assessed scheme is economical viable if it is run near full capacity. Additionally it also saves significant costs for the municipality who is in charge and responsible for municipal solid waste management.

In Chapter 1 the background of Bangladesh (population growth, solid waste generation) is shortly described.
Chapter 2 gives an overview on the legislative framework concerning waste reuse and compost use in Bangladesh.
A short overview on composting and the advantages and problems if compost is used in agriculture is given in Chapter 3.
Chapter 4 shows the space that is required and the process steps that are needed in a waste collection and composting scheme.
The evaluation of the composting process including mass flows, temperature, chemical and physical parameters, man-hours and a household survey among the residents of the collection area is done in Chapter 5. The temperature curve (hygienisation) and the chemical parameters (nutrients) show that compost is a good and hygienic soil amendment. According to the survey, the residents of the area are satisfied with the provided service.
A financial analysis of the scheme follows in chapter 6: The introduction and running of a composting plant includes various costs (construction costs, salary costs) and the revenues can be distinguished into three types: income from collection fees, proceeds from the compost sale and proceeds from the sale of recyclables. Additionally, composting produces cost savings for the municipality. The Chapter shows the amount of this different costs and revenues and gives an commercial appraisal of the composting project through the discounting method of the Net Present Value.
Health aspects of the compost production and use are discussed in Chapter 7 which shows that there is no risk for workers and users if appropriate measures (e.g. equip-

ment of workers) are taken and the composting is carefully done. The quality of the compost is separately discussed in Chapter 8 and a comparison of different compost products and compost standards is made there.

In Chapter 9 marketing aspects are discussed and it is shown that it is the best solution to make use of private specialised marketing companies for the distribution and selling of the compost.

The steps that are recommended to introduce a community based composting activity are discussed in Chapter 10.

Chapter 11 gives some final comments and in Chapter 12 future research recommendations are made.

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Introduction

Objective of the study

Solid waste generation and its management is an issue of increasing concern in many developing countries. New ways have to be found to meet the rising problems - one solution is the introduction of composting activities. Composting activity in Bangladesh is not new; traditional rural techniques have been in use for many years. But mega-cities with a large amount of municipal solid waste and little processing space require different methods.
The objective of this study was to gain more information about these composting methods and their framework through collecting information about

1. The legislative framework concerning compost production and use
2. The process steps and layout of a composting system including mass flows
3. The development of various physical and chemical parameters of organic waste during the composting process
4. Health aspects of the compost production
5. The financial aspects of the composting unit including economic aspects such as cost savings for the municipality
6. The marketing aspects of the compost product

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Methods

The study is based on the experiences of Waste Concern with a Community Based Decentralised Composting Project in Mirpur, Section-2, Dhaka. The operation of the plant was started in 1995 with the aim of developing a low-cost technique for composting of municipal solid waste which is well-suited to Dhaka's waste stream, climate and socio-economic conditions.
Waste Concern is a national research based NGO (established in 1995) working in the field of Environment, Urban Solid Waste Management and Recycling. They work closely together with the government, the private sector and local communities to reach following goals:

- Improvement of the environment by promoting waste recycling activities in the country
- Conducting of research, experiments on solid waste management, recycling, clinical and hazardous waste management, waste water treatment and organic farming
- Development of community-private sector-municipal partnership for an improvement of the urban environment
- Creating of job opportunities by promoting recycling of waste.

The procedure to collect the information can be split up into different activities:

- Revue of existing literature about composting (focus on literature in the Asian context)
- Field work at the composting site in Mirpur and its neighbourhood (brief household survey to get a view of the service recipients (waste collection))
- Lab analysis of various parameters of organic waste at the Soil Resource Development Institute (SRDI)
- Conversation with different persons involved in solid waste management, composting, compost marketing and use

Limitations of the study

Some important limitations of the study need to be mentioned as they may influence the analysed data:

- The study was conducted over a period of three months during the dry season (January - March 2001), thus does not reflect the seasonal variability.
- Analysis of mass flows and other chemical and physical parameters focus on only one composting pile.
- The household survey conducted does not cover the whole collection area: Using a map, a sample area was chosen from the total collection area. This area covers about one fifth of the whole area. An estimated number of 170 households live in it, of which 30 households (18%) were sampled by questionnaire.

1. Background

Dhaka, the capital of Bangladesh, is one of the fastest growing and densest populated cities of the world. At present (1999) 10.41 million people live in this mega-city within an area of 1353 sq. km. and it is estimated by the Bangladesh Bureau of Statistics that the population of Dhaka will reach 15 million in 2015 and 20 million in 2025 due to population growth and urbanisation [Daily Star 2001]. The area of the Dhaka City Corporation (DCC), which includes 360 sq. km., is inhabited by about 7 million people. Around 3500 tons of solid waste are daily generated from residential, commercial and industrial activities. DCC, which is responsible for the solid waste management, only manages to collect 1800 tons, which are dumped at different disposal sites. Of the uncollected waste it is estimated that 900 tons go to backyard and landfilling, 400 tons are recycled and 400 tons keep lying on the roadside [Bhuiyan, 1999]. The latter causes a bad impact on the surrounding environment because

- organic waste starts to decompose, thus emitting a strong odor as well as serving as breeding place for various insects (transmitter of diseases)
- leachate of the decomposing waste contaminates surface and sub-surface water
- non-degradables block surface drains.

The dumpsites themselves are not run in a sanitary way, which leads to a severe contamination of ground- and surface-water in and around the dumping yard. This situation, together with the fact that waste generation will increase with the same rate as the population in future, demands new ways to deal with the solid waste. One approach is the introduction of a composting activity. As at least 63 % of the totally generated solid waste in Dhaka City is biodegradable, decentralised composting can significantly reduce the waste to be collected and dumped [see Appendix A]. In addition, a good soil amendment can be produced out of the waste, which if used can helps avoid the degradation of soils.

2. Legislative framework concerning waste reuse and compost use

2.1 Laws and Ordinances

The existing environmental legislation (Environment Conservation Act 1995, DCC Ordinance 1983, Town Improvement Act 1953) does not specifically address the management and disposal of solid waste. Only the DCC Ordinance mentions that adequate arrangements for removal and disposal of waste should be made (DCC Ordinance, Art. 78), but no mention is made on the methods which should be used. Responsibility is given to the Conservancy division of DCC.

2.2 Policies

In recent years, some policies have been formulated, which include some general guidelines concerning solid waste management and compost use. These are in particular the National Environment Policy and the National Policy for Safe Water Supply and Sanitation.

2.2.1 Environmental Policy 1992 and Implementation work

The Environmental Policy emphasises that the use of organic fertiliser should be increased while the use of chemical fertiliser should be restricted as far as possible.
The responsibility for the implementation of this policy lies with the Ministry of Agriculture and the Department of Agricultural Extension.

2.2.2 National Policy for Water Supply and Sanitation 1998

As water supply and sanitation is a subsector of the sector of health, environment and water, it is important that its policy is consistent with the National Policy for Environment.
The policy's main goal is to improve the standard of public health and to ensure an improved environment. Its formulated objective is that everyone should have access to safe water and sanitation. This objective shall be achieved by co-operation of the government with NGOs, marketoriented business organisations and private organisations as well as through the participation of the citizens themselves (emphasis should be set on a change of their behaviour).
The Policy's main statements relating to waste/compost are the following:

- The sanitation system (including solid waste management) has to be self-sufficient and self-sustaining.
- The City Corporations or Paurasabhas (municipal authority) are responsible for the solid waste management (collection, treatment, disposal).
- The participation of NGOs and the private sector in sanitation has to be encouraged by the government.
- Appropriate measures should be taken to achieve the highest waste recycling rates that are possible.
- The use of organic waste treatment methods like composting and biogas production (digestion) will be promoted and contamination of water by various waste materials will be discouraged.

2.2.3 Implementation of the policies

The activities of Waste Concern have achieved some of the goals stated in the policy as the following example shows:

1. Thanks to the effort of Waste Concern, miscellaneous waste is sorted and the organic fraction is converted into compost at different sites in Dhaka. This reduces the waste that has to be disposed of to about 1/6 of the originally collected amount. At present only a minute share of the total city's waste is handled in this way. Every effort should be made to find more sites where organic waste can be composted.
2. The co-operation of government, NGOs and residents is realised at Baily Road and Green Road, Dhaka:
   - the land is provided free of charge by the Government (Public Works Department (PDW))
   - the barrel-type composting system is implemented through Waste Concern
   - the site is run by local people with the aid of Waste Concern
   - Waste Concern supervises the composting activity and buys the compost from the site-runners to encourage them to carry on (extra-income from compost)
   - the long-term goal could be that the plant can be run self-sustaining

2.3 Standards for compost in Bangladesh

A compost producer can get an approval from the Ministry for Agriculture through sending of a sample to them. The sample is tested in five different laboratories (Soil Resource Development Institute (SRDI), Dhaka University Soil Science Lab, Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI) and Bangladesh Standard Institution (BSI)) and some minimal nutrient concentrations (nitrogen (N), phosphor (P), potassium (K), organic matter, water content) to be maintained by the producer are derived from the results. These concentrations are fixed separately for every producer. The National Technical Committee may randomly visit the composting plant and analyse the compost to make sure that the quality is maintained. Therefore Bangladesh does not see reason to provide general compost standards (Appendix B).

3. An overview on composting and compost

3.1 The process of composting

Compost is the stable end product from the biological degradation of organic material. Composting is an aerobic decomposition process, in which micro-organisms convert the organic material into carbon dioxide (CO_2), water and humic substances. The principal variables which influence the efficiency of the decomposition are:

- The C/N-ratio of the organic material: optimal ratios between 25:1 and 40:1
- Oxygen supply through aeration (aerobic composting (with oxygen) is 10 to 20 times faster than anaerobic digestion [USEPA, 1994])
- Moisture content: optimal between 40 and 60 % [NRAES]
- Temperature: The composting process will go through various stages with different temperature ranges. The thermophilic stage (45 - 65°C) is an important step as it will kill pathogenic organisms and weed seeds. Temperature above 65°C will hinder microbiological activity and should be avoided.
- Acidity (pH): optimal values are between 5,5 and 8 [Lardinois, 1993]

3.2 Compost used in farming

The aim of the composting process is to produce an organic fertiliser which can be used without risk for agriculture and horticulture. The major parameters which influence the quality are:

- Organic matter as it improves the soil structure and increases the soil's ability to retain water and fertilising elements.
- Contents of N, P and K: These are the nutrients the most important for the cultivation of crops.
- Contents of micro-elements (Zn, Cu, B, Mn)

Compost possesses numerous agricultural advantages. It:

- improves the structure of soil which allows a better water and air circulation
- contains various nutrients and trace elements which increase the soil fertility
- releases these nutrients slowly, as they are held in organic form. Thus the nutrients are available through the whole growing season contrary to the nutrients from chemical fertiliser which are rapidly washed out.
- stimulates the biological activity which again has a positive effect on soil structure and nutrient release
- improves moisture retention, which is especially relevant in the dry season
- reduces soil erosion as result of the better soil structure.

However there also exist certain risks if low-quality compost is used in agriculture. A compost is of a low quality if

- it has high contents of heavy metals as these can be phytotoxic, can accumulate in the soil or can be taken up by the agricultural product so entering the food chain.
- it contains pathogenic organisms.

4. Description of the composting scheme

The following assessment focuses on the technology used at a Community Based Decentralised Composting Unit at Section-2, Mirpur, Dhaka. The composting scheme, which involves primary collection and composting of the organic fraction of municipal wastes, started in 1995 as a pilot and demonstration project by the initiative of Waste Concern. Organic wastes are composted using the "Indonesian Windrow Technique", a labour intensive aerobic and thermopilic composting procedure.
Another recently introduced composting scheme which involves a semi-aerobic Barrel Composting Technique was also assessed, however in much less detail.
The assessment in this study reflects the situation as it was encountered in January to April 2001 unless specified otherwise.

4.1 The Mirpur Composting Scheme

4.1.1 Setting and layout of the composting plant

The composting scheme is located within Section-2 of Mirpur Housing Estate on a plot of land provided to Waste Concern by the Lions Club (Dhaka North). The distance to the closest residents is approximately 10 m. In general the residents are part of a higher middle and higher income class.
The layout of the composting plant can be seen in Figure 1. The area in Mirpur is much larger than really needed for the composting activity. Table 1 therefore shows the actual and the minimum space required for the different process steps. Composting and maturing together need more than 50 % of the space when only considering the minimal required space.

PICTURE 1 COMPOSTING PILES OF THE MIRPUR COMPOSTING SCHEME

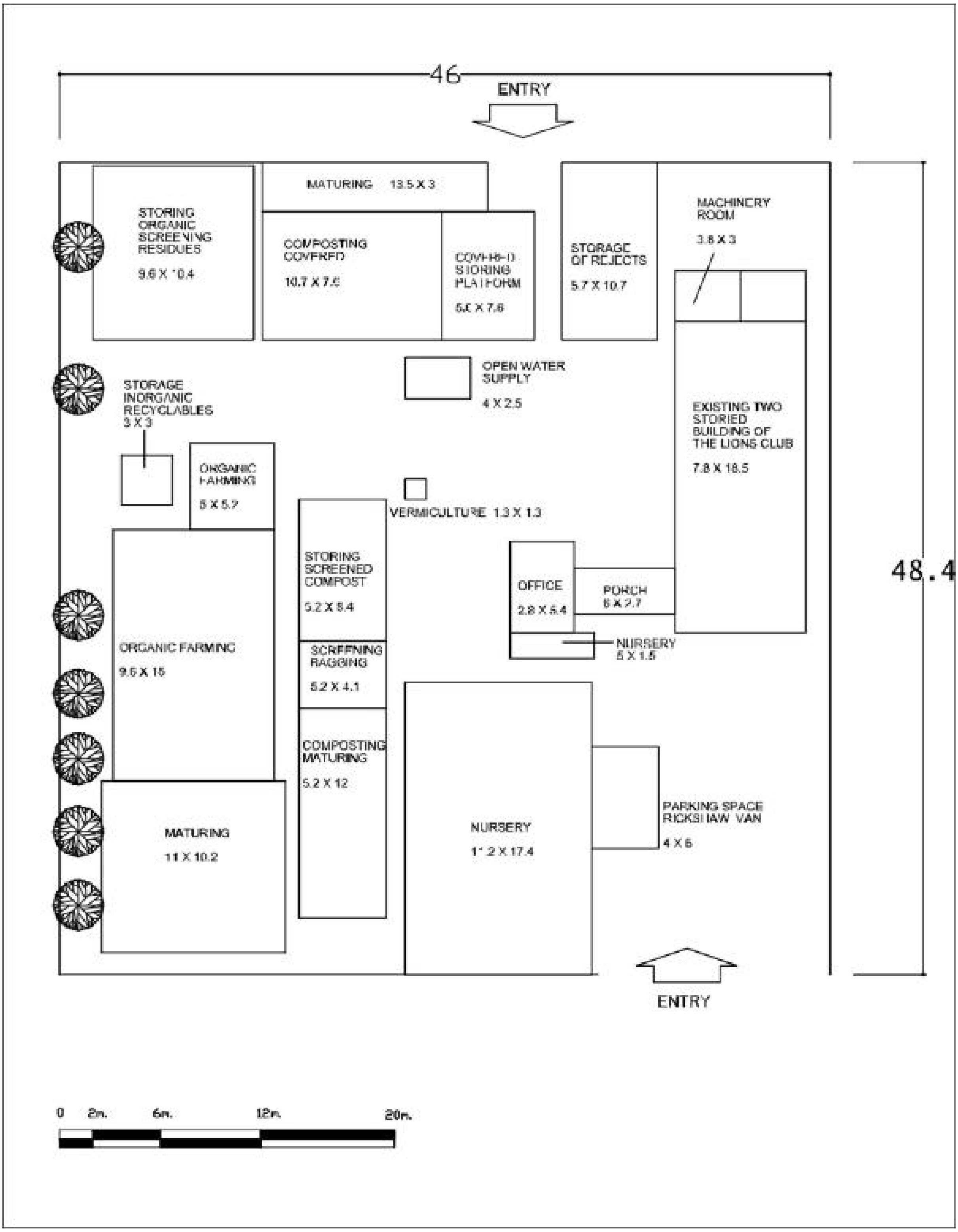

FIGURE 1 LAYOUT OF THE COMPOSTING PLANT

TABLE 1 SPACE REQUIREMENTS FOR DIFFERENT PROCESS STEPS OF THE COMPOSTING ACTIVITY

	measurements	area				roofed?
		actual		minimum required for 3 tons capacity plant		
	[m x m]	[m2]	[%]	[m2]	[%]	
parking space for rickshaw vans	4.0 x 6.0	24	2	24	6	no
sorting	4.6 x 7.6	35	3	35	9	yes
storage inorganic recyclables	3.0 x 3.0	9	1	9	2	no
storage of rejects	5.7 x 10.7	61	6	30 1)	8	no
composting	10.7 x 7.6 + 5.2 x 6.2	114	11	114	30	yes
maturation/curing	5.2 x 6.2 + 13.5 x 3.0 +11x10.2	185	18	92.5 2)	24	3)
storing organic screening residues	9.6 x 10.4	100	10	0 4)		no
screening & bagging	5.2 x 4.1	35	3	35	9	yes
storage compost	5.2 x 8.1	42	4	20 2)	5	yes
open water supply	4 x 2.5	10	1	10	3	no
toilet	1.3 x 1.3	4	0	4	1	yes
office	2.8 x 5.4	15	1	7 5)	2	yes
machinery room	3.8 x 3.0	11	1			yes
nursery	1.5 x 5.0 + 11.2 x 17.4	202	20			no
farming demonstration	9.6 x 15 + 5.0 x 5.2	170	17			no
actual area of the plant	46.0 x 48.4	2227				
total area needed for composting activity 6)		**1017**	**100**	**380**	**100**	

Explanations:
1) on the presumption that the rejects are collected regularly (at least one three-tons-truck/week) from the site
2) space required on the presumption that the compost can regularly be marketed
3) in the rainy season the maturing should be done in the roofed area
4) if organic screening residues are immediately added to a new pile
5) the present office accommodates also two persons working in the slums
6) excluding pathways

4.1.2 Process steps of the composting system

The process steps of the composting scheme are visualised in Figure 2. Table 2 describes various actors and stakeholders involved in the composting scheme.

TABLE 2 ACTORS OF THE DECENTRALISED COMPOSTING SCHEME

Actor/Stakeholders	Actions
WASTE GENERATORS	
• Households →	give their solid waste to WC and pay for the collection service
• (Vegetable) Markets →	give their solid waste to WC
WASTE OPERATORS	
• Waste Concern →	collects the solid waste from households and markets, sorts it into different fractions and converts the organic waste fraction into compost
• DCC →	collects the inorganic rejects (after sorting) from the composting site of WC
COMPOST BUYERS/USERS	
• M/S. MAP Agro Industries →	buy and enrich compost on behalf of Alpha Agro Ltd.
• Retailers →	buy (enriched) compost from Alpha Agro Ltd. and sell it to the farmers
• Nurseries →	buy compost from WC and use it for plant cultivation
• Farmers →	buy compost from retailers and apply it on their fields
• Waste Concern →	use their compost (raw and enriched) for their nursery and farming demonstration

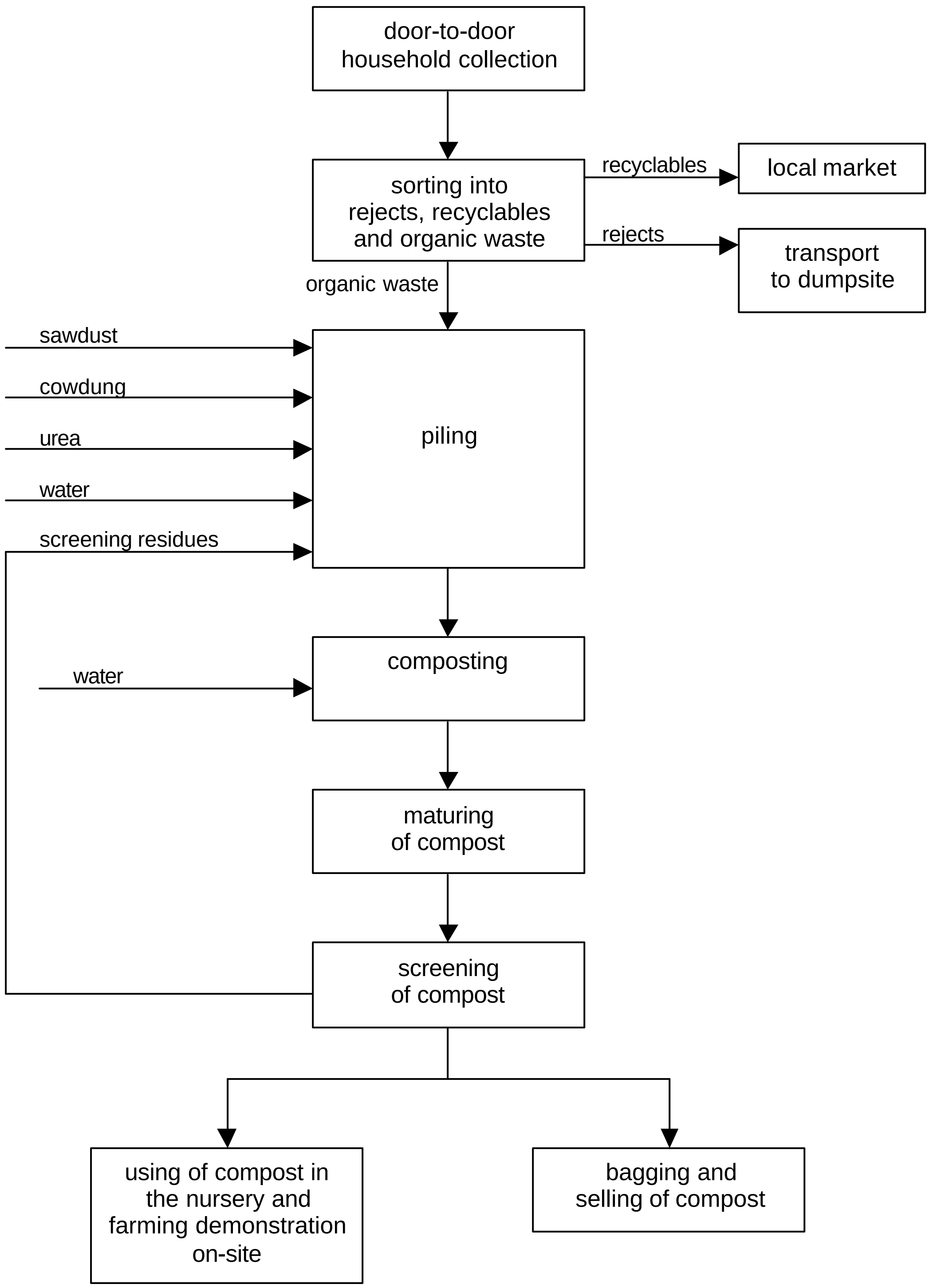

FIGURE 2 FLOW CHART OF THE COMPOSTING PROCESS

4.1.2.1 Waste Collection

A door-to-door solid waste collection system was introduced in the project area. Six collectors collect the domestic solid waste from at currently 790 households. They use modified rickshaw vans with a body volume of 1.18 m^3 (87 x 137 x 99 cm) to transport the waste.
The households pay a monthly charge of Tk. 10 to 20[1] per household (according to their financial situation) for the door-to-door collection service.
The collected waste is taken to the composting unit which is located within the serviced area.

PICTURE 2 WASTE COLLECTION BY RICKSHAW VAN

4.1.2.2 Sorting

The collected miscellaneous waste is manually separated and sorted into the fractions organic easily degradable material, other recyclable materials and rejects (mainly inorganic). The recyclables are either sold at the local market (cardboard, glass, hard plastic, metal), thus providing the plant-workers with some extra income, or used as fuel (coconut) by the plant-workers. The rejects, which consist mainly of polyethylene bags, are piled up in one corner of the site. They are collected weekly by a van (about three tons per load) of the DCC which takes them to a dumpsite outside Dhaka (secondary collection).

PICTURE 3 SORTING OF THE WASTE

[1] 1 US $ = Tk. 50

4.1.2.3 Piling

An efficient composting process needs a C:N-ratio within the range of 25:1 to 40:1. When the C:N-ratio is too high, nitrogen will become the limiting nutrient and decomposition will slow down. When the C:N-ratio is too low, there is too much nitrogen and it will likely be lost to the atmosphere in the form of ammonia gas. As most of the materials used for composting do not have the ideal ratio, different materials can be blended to reach the required ratio.

A good aeration is also essential for the process, as it provides the micro-organisms of the composting pile with the oxygen that they require for the decomposition. If the process becomes anaerobic, decomposition will slow down and odor problems will be created through the release of ammonia gas. Additives such as sawdust can be added to increase the pile porosity, thus enabling the required aeration.

Out of these reasons, different additional feedstocks are mixed with the organic waste before piling it into windrows in the Mirpur Composting Scheme.

- *C:N-ratio:*

The C:N-ratio of the waste in Dhaka is around 56:1 [Hoq, & Lechner 1994]. Therefore, urea (300 g/pile) and cowdung (ratio cowdung:organic waste = 1:20, cowdung then mixed 1:1 with water) are mixed with the organic material to optimise the ratio.

- *Increase of porosity/better aeration:*

Mixing of sawdust (1.5 w% of the organic waste) and organic screening residues from a previous pile (currently 30 kg/pile)

As the screening residues already contain micro-organisms, they also accelerate the composting process in an initial phase.

PICTURE 4 ADDING OF SAWDUST

The material then is piled around a bamboo aerator (length 2.4 m; max. height 0.53 m) which enables a better aeration. One pile consists of two to three day's waste (around 3 tons, height 1.3 m, width 1.7 m, length 2.4 m). The piles are covered by a shed with steel angle posts and asbestos roofing, which protects the organic matter as well as the workers from rain and direct sunlight (prevents drying out of the material).

PICTURE 5 BAMBOO AERATOR

PICTURE 6 PILING OF ORGANIC MATERIAL

4.1.2.4 Turning, watering and temperature monitoring

After piling the material, a period of decomposition follows. To ensure a fast decomposition, two major parameters have to be taken care of:

1. *Pile temperature*
   The decomposer organisms work most efficiently between 55 and 65°C. Extremely high temperature (over 70°C) can kill these beneficial organisms. The heat that is generated by the micro-organisms while decomposing increases the pile temperature, therefore measures to drop temperature have to be taken. But in an initial phase high temperature (70°C during at least 30 minutes in the whole pile or 65°C during several hours [Bertoldi et al.,1983]) should be reached as this kills major disease organisms and fly larvae and helps killing weed seeds.
2. *Moisture content*
   Optimal is a content of 40-60% as this is enough moisture for the bacteria without limiting aeration. If the moisture content is below 40 %, the nutrients are no longer in an aqueous medium and easily available for the micro-organisms [USEPA, 1994].

In Mirpur, the period of decomposition through micro-organisms lasts 40 days.
To control the temperature of the pile, temperature is recorded daily and the pile is turned when the average pile-temperature (measured at a depth of one feet[2] at the top, middle and bottom of the pile) approaches 60 to 70°C. When the temperature starts to drop, the pile still is turned occasionally (all together 5 to 7 turnings within 40 days).

PICTURE 7 TURNING OF DECOMPOSING ORGANIC MATERIAL

[2] 1 feet = 30.48 cm

The moisture content is controlled during turning through its determination with the squeeze test[3], and if necessary, water is added (10 l per turning). Before repiling, the material is laid spread out for about fifteen minutes to release excessive heat. If any leachate is produced during this process step, it is remixed with the organic material.

In addition, the turning allows to reach an equal decomposition level throughout the pile as well as to fasten the decomposition as non-decomposed material is moved from the exterior to the interior and provides new food sources to the micro-organisms. It also facilitates the aeration of the pile (oxygen supply).

PICTURE 8 (LEFT) HEAP OF ORGANIC WASTE JUST AFTER PILING
PICTURE 9 (RIGHT) THE SAME HEAP AS IN PICTURE 7 AFTER 40 DAYS OF DECOMPOSITION

4.1.2.5 Maturing

Mature compost should have an earthy odor as well as be dark and crumbly. The pile temperature should be near the ambient temperature.

During the 40 days of decomposition, the material changes its colour to dark-brown. To ensure that the compost is really mature and thus safe for use, another two weeks for maturing are needed: The material is kept in piles without turning or watering it any further. In the rainy season the maturing is done under a roofed shed to avoid a too high moisture content.

PICTURE 10 MATURING OF ORGANIC MATERIAL

[3] This moisture test is done through hand-squeezing of the compost: If no water is squeezed out, the compost is too dry; if many drops can be squeezed out, the compost is too wet; if a few drops can be squeezed out, the moisture content is ideal [CPIS, 1992].

4.1.2.6 Screening

The compost that can be produced through the described process has a rather coarse quality (depending on the size and composition of the original material and the process parameters). If a finer quality is required, the compost product can be screened. Through screening two main fractions can be gained:

- a fine compost
- screening residues, consisting of:
  - small inorganic particles which were missed during the initial sorting (they are sent to the disposal site together with the other residues)
  - larger pieces of organic material which had not enough time to decompose completely and can be added to a new pile to allow a further decomposition.

PICTURE 11 SCREENING OF COMPOST

In Mirpur, the matured compost is screened by a wiremesh screen (opening size 4 mm, wooden framework 0.8 x 1.4 m). The wooden framework is held up sloping by two persons on either side. The same persons can treat the material, that is added with a bucket on the wiremesh screen through a third person (see picture 11). As the fine material falls through the wiremesh, it can be separated from inorganic particles and coarse organic material.

Screening is the last step of the compost production – the compost now is ready for its use.

PICTURE 12 SCREENED COMPOST (READY FOR BAGGING)

The inorganic rejects are sent to the disposal site together with the rejects from the initial sorting while the large pieces of organic material are added to a new pile to allow further decomposition.

4.1.2.7 Grinding, enrichment and marketing

The screened compost is bagged in 50 kg bags and most of it is at present sold for Tk. 2.5 per kg to M/S. MAP Agro Industries, Utter. M/S. MAP Agro Industries, which act on behalf of Alpha Agro Ltd., a fertiliser trading company, occasionally collect compost in Mirpur and take it to their mixing factory in Uttara.

PICTURE 13 BAGGING OF THE COMPOST PRODUCT

There, M/S. MAP Agro Industries grind the compost with a machine and then screen it again with a 4 mm-sieve to get a finer quality.

PICTURE 14 GRINDING OF COMPOST (M/S. MAP AGRO INDUSTRIES)

They then enrich the compost with further nutrients. Example of the brands of enriched compost are shown in Table 3.

TABLE 3 COMPOST BRANDS OF M/S. MAP AGRO INDUSTRIES

Brand	Grade						
	N [%]	P [%]	K [%]	S [%]	Zn [%]	B [%]	OM [%]
Vegetable	1.5	15	10	2.5	0.4	0.15	30
Potato	7	7	14	2	0.5	0.15	30

The enriched compost is bagged (40 kg/bag), picked up by Alpha Agro Ltd. and sold to the retailers at Tk. 6 per kg all over the country. Farmers then buy the compost at Tk. 7 per kg from the retailers.
Waste Concern is planning to do the enrichment themselves which would allow them to sell the compost for Tk. 7-8 per kg.

4.1.3 Farming demonstration and nursery

To show the positive effect of compost, Waste Concern runs both a small nursery and a farming plot in Mirpur. In the nursery, compost is mixed with soil in a ratio of 1:3. In the farming section, experiments with compost, enriched compost and chemical fertiliser (NPK) are carried out to demonstrate the different effects on the plant growth.

PICTURE 15 (LEFT) NURSERY OF WASTE CONCERN ON THE MIRPUR COMPOSTING SITE
PICTURE 16 (RIGHT) FARMING DEMONSTRATION OF WASTE CONCERN (COMPOST AND NPK, COMPOST , COMPOST AND NUTRIENT ENRICHED COMPOST

4.2 Alternative composting system: Barrel-type Composting System

An alternative way of composting to the Indonesian Windrow Technique is the barrel-type composting system.

4.2.1 Description of the process

In the area of Baily Road, Ramona (Dhaka City) a barrel-type composting plant has been installed. Two persons are in charge of this plant. They daily collect the mixed domestic waste from about 300 households which pay in return Tk. 15 a month for the collection. The workers sort the waste into the fractions organic easily degradable material, other recyclable materials and rejects (mainly inorganic). The recyclables are sold at the local market while the rejects are placed in a container of the DCC.
The degradable fraction is placed in a 200 litres perforated green barrel with a lid.

P

The barrel is placed on a mobile raised base with a concrete ring. This is needed because of the rainy season - thanks to the base, the rain water drains off fast and can not percolate in the composting barrel, which would lead to anaerobic conditions and odor problems. The lid also protects the organic material from rainwater and prevents animals and birds entering the barrel.

After filling up of one barrel which has a capacity of 160 kg of raw organic material, a semi-aerobic composting period of about 45 days follows before the compost is removed and piled on the floor of a shed (covering needed for rainy days) for another 15 days of maturing. The compost then is screened (opening size of the meshwire: 4 mm).

PICTURE 18 REMOVING OF ORGANIC MATERIAL FROM BARREL AFTER 40 DAYS OF DECOMPOSITION

The finished compost is bought from the workers by Waste Concern for Tk. 1 per kg. This encourages them to carry on. Finally, this barrel type compost is sold to nurseries or Alpha Agro Ltd., together with the compost from the Mirpur plant.
Till now five barrels have been installed but once the plant is in full operation, more barrels will be needed.

4.2.2 Space requirements

One barrel needs an area of about 1.5 m^2 (including distance to the next barrel). According to the expected amount of collected waste and the barrel capacity, the required space can be calculated. In addition, the sorting, maturing, screening and storing needs a shed of approximately 15 m^2.

4.2.3 Problems and advantages when using barrels for composting

4.2.3.1 Advantages

1. Odor

The main source of odor in the Aerobic Windrow System is the turning. With the barrel, no turning is needed and the decomposing material is covered with a lid what prevents the release of odor. Thanks to that, a Barrel-type Composting System can be located nearer to the houses of the residents than a Windrow Technique System.

2. Labour intensity

With the barrel system, less working hours are needed, as no turning and watering has to be done.

4.2.3.2 Problem: Corrosion

Although both sides of the barrel are painted with a layer of anticorrosive paint, the material shows signs of corrosion after a certain operating time due to the acids produced through decomposition. Waste Concern plans therefore to replace the barrel through a container out of concrete.

5. Evaluation of the Composting Process

5.1 Methodology

To gather information on different parameters of the composting process, one pile was closely followed through all the process steps. The pile, that was piled on the 15., 16. and 17. January 2001 was chosen for this study. Its decomposition time was 40 days from the 15th to the 23rd February 2001, its maturing time 15 days from the 24th February to the 11th March 2001; first screening was done on the 11th, the second screening on the 15th of March. One pile can not be considered as representative, therefore major parameters of other piles and already existing data had also to be included.

5.1.1 Mass flow

The weight of the material involved in the process was measured at different stages: after sorting, after 40 days of composting, after maturing and after screening.

PICTURE 19 WEIGHING OF MASS

5.1.2 Temperature

Temperature in the pile was determined with an alcohol thermometer three times a day. As temperature can vary throughout the pile, measurements were taken at six different points of the pile (depth: one feet, two points at the top, middle and bottom of the pile).

5.1.3 Determination of the development of various parameters during the composting process

5.1.3.1 Collecting of samples and determination of the moisture content

When collecting a sample from a decomposing pile, one has to take into account that the material is heterogeneous, especially at the beginning of the composting process. Therefore, a good handful of material was taken from different places of the pile and these samples were mixed again. In this way, one kilogram of material was collected every time. The samples of the turning stage were taken while the material was spread out and after the watering (if needed).

Two different methods were used to determine the water content:

1) The moisture content of the samples after sorting and after piling was determined by the gravimetric method (drying of the sample in an electric oven at 105°C until

constant weight) in the SRDI laboratory.

2) The moisture content of the samples from the 2nd turning on was determined as described bellow (the used method had to be changed as the odor during the drying of the decomposing matter was that strong that the laboratory refused to accept fresh samples):
   a) The sample of compost was weighted just after sampling on a balance and spread out in a basket for several days. In this way, part of the water could evaporate what helped to decrease the odor of the sample released during the drying in the electric oven. The sample was weighted again after seven to fifteen days and the loss of weight (= loss of water) was recorded.
   b) The remaining moisture content was determined by the gravimetric method.
   c) The real moisture content was finally received through adding of both results.

5.1.3.2 Sample preparation

The chemical and physical analysis, except for the tests on maturity and helminth eggs pathogen, was done at the Soil Resource Development Institute (SRDI) in Dhaka. The preparation of the dried sample for the analysis of all parameters except nitrogen and carbon followed the wet digestion procedure (HNO_3 + 30% H_20_2).

Wet digestion procedure:

1. Put 0.5 g sample into the digestion tube
2. Add 5 ml conc. HNO_3 and cover with funnel
3. Let it stand over night
4. Heat at 125°C for one hour
5. Cool it at room temperature
6. Add 5 ml 30% H_20_2 and heat it until the digest is clear
7. Add as much HNO_3 as needed to keep the digest from going dry
8. When the digest is colourless, reduce the temperature of the digestion block to 80°C
9. Remove the funnel from the digestion tube and let the digest almost go to dryness
10. Add 10 ml 1:10 HNO_3
11. Add 30-50 ml water and transfer the solution into a 100 ml volumetric flask (filter it if necessary)
12. Fill the flask up to the mark
13. The solution is ready for the elemental analysis

5.1.3.3 Analysis of elements, helminth eggs pathogen and maturity

The determination of the pH and the chemical elements was done with following methods:

- PH: The pH was determined by the glass electrode method.
- C: Organic carbon was determined by using the dry combustion method.
- N: Total nitrogen was determined by using the micro kjeldal method.
- P: Phosphorus was determined on a spectrometer by using ammonium molybdate in ascorbic acid.
- K, Zn, Pb, Cd, Cu :Potassium, zinc, lead, cadmium and copper were determined by an atomic absorption spectrometer.

The detection and quantification of total and viable helminth egg pathogens was done in the laboratories for physical chemistry of the environment (Laboratoire de Chimie Physique pour l'Environment (LCPE)) of the University Henri Poincaré in Nancy, France. They used the method EPA/625/R-92/013.

To determine the maturity of the compost, different tests can be done:

- Temperature test: The temperature of piles of mature compost should be near to the ambient air temperature.
- Visual test: The colour of the compost should be brown to dark-brown.
- Odor test: The compost should have an earthy odor.
- Determination of the Maturity Index of the compost with the Solvita® test kit (Wood End Research Laboratory, Inc., P.O. Box 297, Mt. Vernon, ME 04352, USA), a test based on measuring carbon-dioxide respiration and ammonia content simultaneously (Appendix C).

5.1.4 Man-hour monitoring

The man-hours needed for the different process steps were monitored daily between the 13. and 26. February 2001 through filling out of a table by the plant manager (Table see Appendix D).

5.1.5 Household survey

A survey among the residents of the community of Mirpur-2 was conducted to gain information on following issues:

- Are there any annoyances because of the waste recovery plant?
- Do the residents participate in the waste recovery activity?
- Are they satisfied with the service of Waste Concern? Do they suggest any improvements?
- What improvements have taken place since the door-to-door waste collection started?

As one of the main questions was, if there is any impact of the plant on the immediate neighbourhood, the survey was confined to the residents living within about 125 m distance from the wall of the composting plant (Block-D, Road 1,2 & 3, Section-2, Mirpur Housing Estate, Dhaka (area covers about 21% of the collection area and an estimated number of 170 households live in it).

It was estimated that 30 households (18%) can be considered as representative for this area and the survey was done through random sampling. If a resident was not at home or refused to answer, his next-door neighbour was chosen (Appendix E includes a full print out of the questionnaire).

5.2 Results and discussion

5.2.1 Collection

Table 4, 5 and 6 and Figure 3 show the amount and the physical composition of the waste collected in different times of the year:

TABLE 4 MONTHLY COLLECTED WASTE IN THE PROJECT AREA
(DATA PROVIDED BY WASTE CONCERN)

month	total waste [ton]	organic waste [ton]	number of households	number of residents 1)	waste generation per capita [kg/cap/day]	organic waste per capita [kg/cap/day]	average organic fraction [%]
Jan 00	40.44	32.86	672	3763	0.347	0.282	81.26
Feb 00	42.00	34.90	672	3763	0.385	0.299	77.73
Mrz 00	39.55	31.24	672	3763	0.339	0.268	78.99
Apr 00	47.10	36.73	672	3763	0.417	0.315	75.47
Mai 00	47.40	37.82	672	3763	0.406	0.324	79.79
Jun 00	46.95	37.80	700	3920	0.399	0.311	77.91
Jul 00	45.21	35.86	700	3920	0.372	0.295	79.32
Aug 00	51.75	41.40	700	3920	0.426	0.341	80.00
Sep 00	48.10	37.90	780	4368	0.367	0.280	76.25
Okt 00	46.90	36.50	780	4368	0.346	0.270	77.83
Nov 00	45.80	37.50	780	4368	0.350	0.277	79.24
Dez 00	46.50	38.10	780	4368	0.343	0.281	81.94
average					0.375	0.295	78.81

1) AN AVERAGE OF 5.6 PERSONS LIVE IN ONE HOUSEHOLD

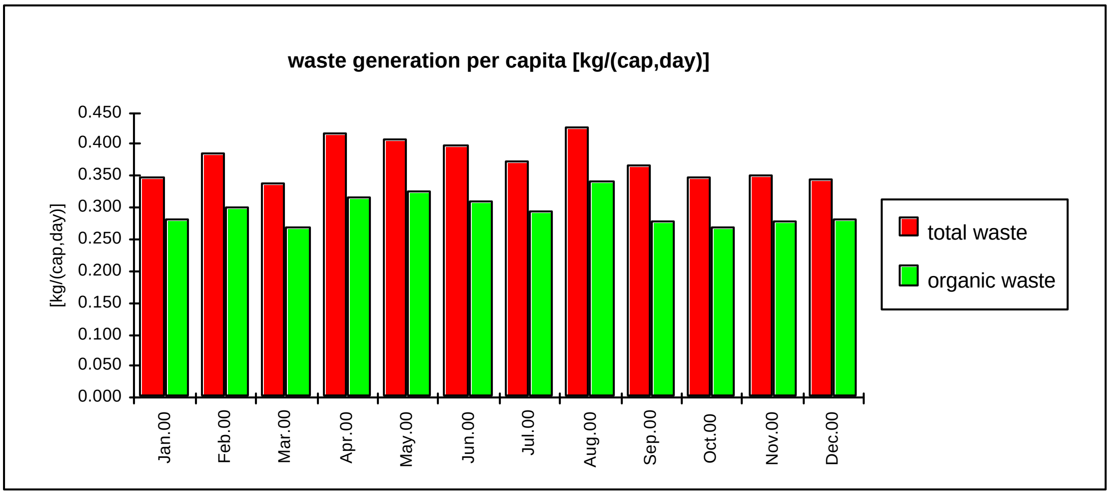

FIGURE 3 VARIATION IN THE WASTE GENERATION PER CAPITA

The average solid waste generation rate is 0.375 kg/(cap,day) in the Mirpur residential area. In the whole of Dhaka city, the solid waste generation rate is 0.245 kg/(cap,day) [Bhuiyan, 1999]. The difference is consistent with other studies that showed that the waste generation rate of a higher income class is higher [CREPA, 1996].

TABLE 5 PHYSICAL COMPOSITION OF THREE DAYS HOUSEHOLD WASTE (NUMBER OF HOUSEHOLDS: 790)

	15/01/01		16/01/01		17/01/01		average 15-17/01/01	
Name of waste	[kg]	[%]	[kg]	[%]	[kg]	[%]	[kg]	[%]
vegetable waste	1400	80.77	1050	82.99	1300	86.20	1250	83.32
poly bags	205	11.83	98	7.75	96	6.37	133	8.65
mud deck	15	0.87	22	1.74	14	0.93	17	1.18
coconut shell	39	2.25	35	2.77	33.5	2.22	35.83	2.41
bone	-	-	1	0.08	3	0.20	1.33	2.73
textile	12	0.69	11	0.87	11	0.73	11.33	0.76
hard plastic	5.8	0.33	3	0.24	4.5	0.30	4.43	0.29
glass	8.2	0.47	7	0.55	8	0.53	7.73	0.52
metals	2.7	0.16	3	0.24	2.5	0.17	2.73	0.19
cardboard	30	1.73	21	1.66	22	1.46	24.33	1.62
sanitary napkins	5	0.29	7	0.55	10	0.66	7.33	0.50
jute bags	5	0.29	0.5	0.04	1	0.07	2.17	0.13
plastic cane	2	0.12	1.2	0.09	1.1	0.07	1.43	0.09
cork	0.7	0.04	0.3	0.02	0.5	0.03	0.50	0.03
sweeping brush	2.2	0.13	1	0.08	1	0.07	1.40	0.09
leather	-	-	4.2	0.33	-	-	1.40	0.11
animal waste	0.7	0.04	-	-	-	-	0.23	0.01
Total waste collected	**1733.3**	**100**	**1265.2**	**100**	**1508.1**	**100.00**	**1502.2**	**100.00**
decompososable material	1400	80.77	1050	82.99	1300	86.20	1250	83.32
rejects	248	14.28	146	11.56	138	9.12	177	11.65
recyclables	85.70	4.94	69.00	5.45	70.50	4.67	75.07	5.02

TABLE 6 PHYSICAL COMPOSITION OF THE WASTE (PERCENTAGE)

	Date					
Name of waste	2-7/04/00	4-9/06/00	4-9/07/00	24-29/10/00	15-17/01/01	average
vegetable waste	77.8	80.51	79.34	76.2	83.32	79.43
coconut shell	5.4	4.6	4.26	4.5	2.42	4.24
cardboard	1.03	0.83	0.92	1.23	1.62	1.13
glass	0.51	0.38	0.4	0.41	0.52	0.44
hard plastic	0.22	0.26	0.23	0.23	0.29	0.25
metals	0.16	0.19	0.19	0.16	0.19	0.18
poly bags	12.57	12.01	13.18	15.06	8.65	12.29
mud deck	1.03	0.38	0.38	0.9	1.18	0.77
textile	0.84	0.38	0.69	0.91	0.76	0.72
sanitary napkins	0.22	0.33	0.33	0.3	0.50	0.34
bone	0.22	0.13	0.08	0.03	0.09	0.11
jute bags	-	-	-	-	0.13	0.02
leather	-	-	-	0.07	0.11	0.04
plastic cans	-	-	-	-	0.09	0.02
sweeping brush	-	-	-	-	0.09	0.02
cork	-	-	-	-	0.03	0.01
animal waste	-	-	-	-	0.01	0.00
Total	100	100	100	100	100	100
decomposable material	77.80	80.51	79.34	76.20	83.32	79.43
rejects	14.88	13.23	14.66	17.27	11.64	14.34
recyclables	7.32	6.26	6.00	6.53	5.04	6.23
Total	100	100	100	100	100	100

The generation and composition of the waste shows some fluctuations both during the week and the different seasons. The weekly fluctuation is mainly due to the weekend, when people go shopping (more polyethylene bags) and have bigger meals.
Reasons for the yearly fluctuation can be:

- change in the weather condition (the moisture content of the waste during the rainy season is higher, thus leading to a higher weight)
- dominating of different fruits and vegetables during different seasons (e.g. heavy jackfruit in July and August, vegetables in winter (January, February))

The data show that the organic compostable fraction of the collected waste is around 80 %, while 15 % of the waste are rejects and have to be taken to the dumpsite. The density of the collected mixed waste is about 300 kg/m^3 (January 2001).

5.2.2 Mass flow

Figure 4 and Table 7 show the mass flow of the chosen pile (in kg). The amount of water required during the composting process depends on the humidity and the temperature of the ambient air.

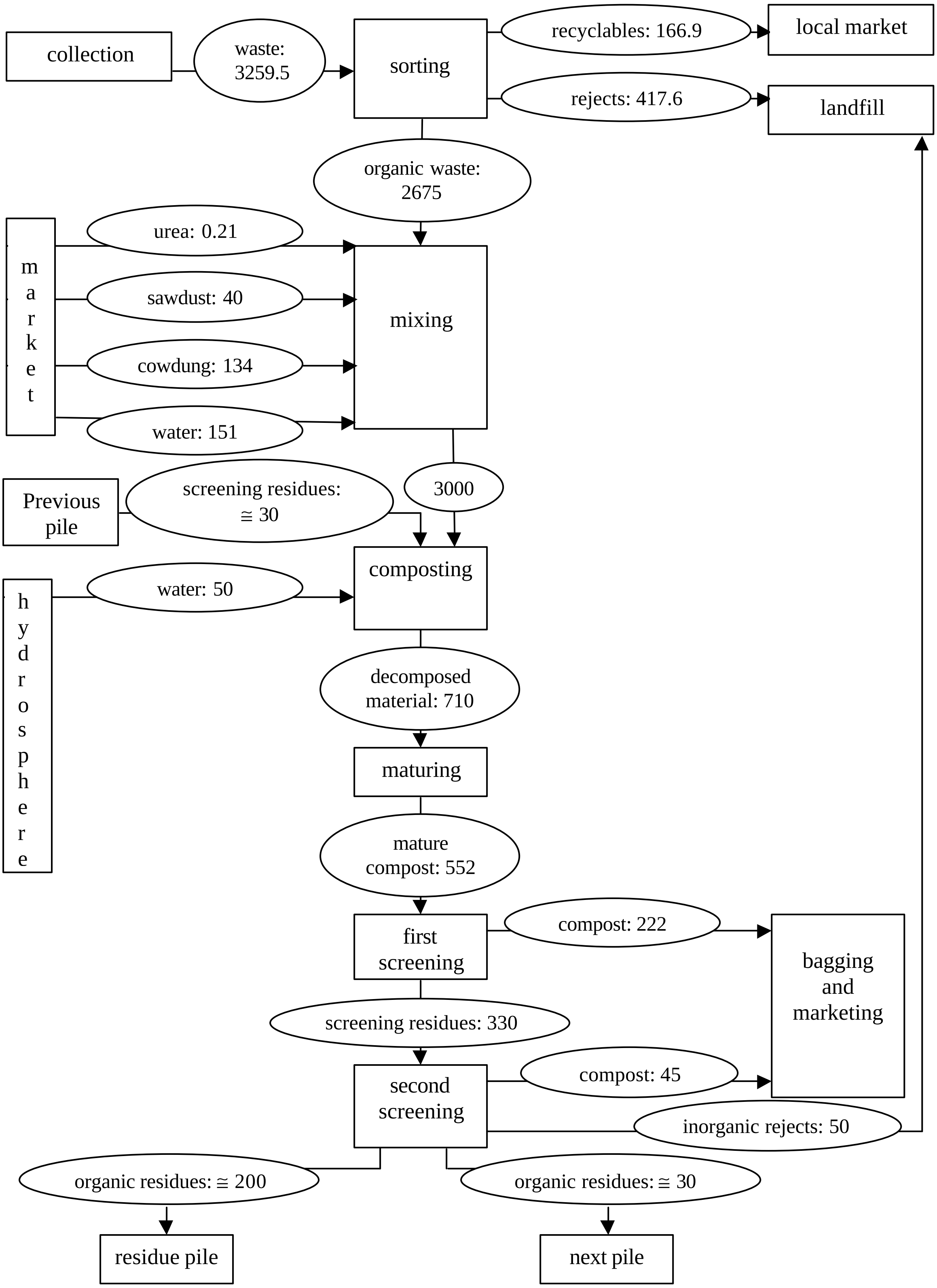

FIGURE 4 MASS FLOW OF ONE PILE (IN KG)

TABLE 7 MASS FLOW OF RECYCLABLES AND REJECTS

category	material	kg/ pile
rejects	poly bags	319.6
	mud deck	39.4
	textile	24.9
	sanitary napkins	13.7
	jute bags	5.7
	leather	4.2
	plastic cane	3.4
	sweeping brush	3.4
	bone	1.5
	cork	1.1
	animal waste	0.7
total rejects		**417.6**
recyclables	coconut shell	79.8
	cardboard	54.8
	glass	16.6
	hard plastic	9.6
	metals	6.1
total recyclables		**166.9**

5.2.3 Composting process

5.2.4 Temperature curve

Figure 5 shows the average pile temperature compared with the maximal and minimal air temperatures in Dhaka city. The drops in the pile-temperature are caused by the turnings of the pile (release of heat during turning).

The duration of the thermophilic phase (40-70°C) is 27 days and the mesophilic phase (20-40°C) then lasts for another 26 days. After 45 days, the pile temperature drops under the maximal ambient air temperature. Different standards mention the required temperature for the killing of pathogenic organisms:

- Standards of New York, USA [Dorau, 1992]: 15 days above 55°C with a turning every three days
- 70°C during at least 30 minutes in the whole pile or 65°C during several hours [Bertoldi et al.]

The temperature curve of the observed pile indicates that the necessary temperature is reached and that pathogenic organisms do not survive.

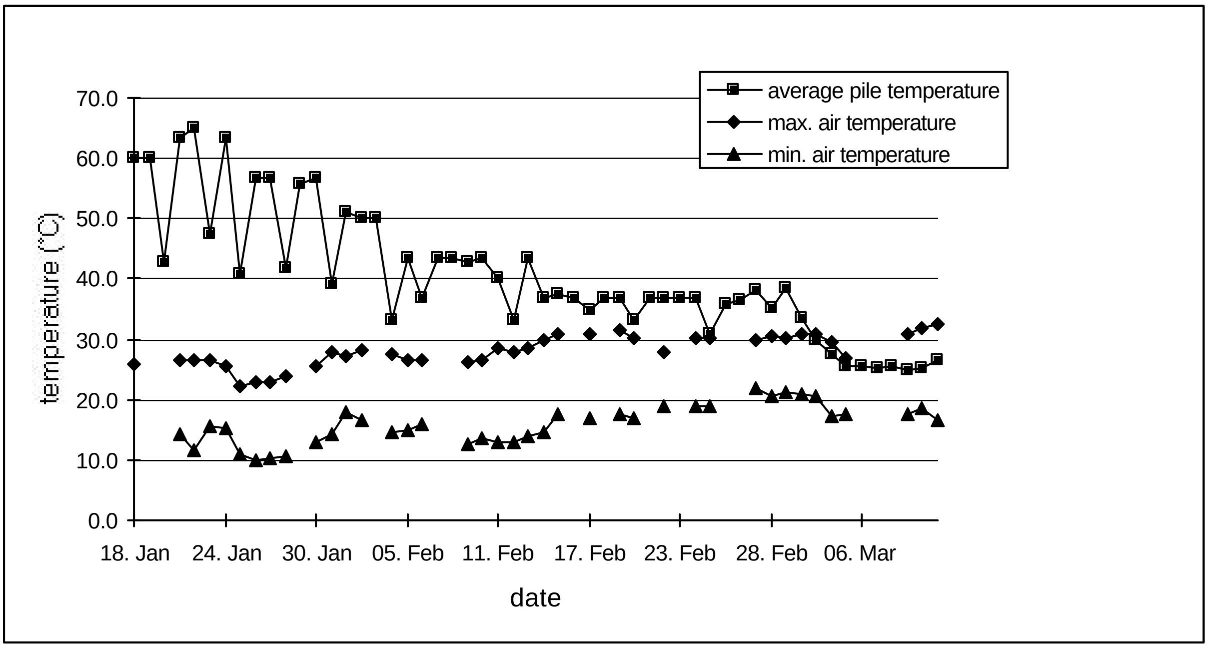

FIGURE 5 TEMPERATURE CURVE OF THE COMPOSTING PILE

5.2.5 Helminth eggs pathogen

Table 8 shows the results of the parasitological analysis of total and viable helminth eggs pathogen:

TABLE 8 RESULT OF THE ANALYSIS OF HELMINTH EGGS PATHOGEN

Family	Genus	Numeration total [eggs/10g dry matter]	Numeration viable eggs [eggs/10g dry matter]
Nematodes	*Ascaris*	2	0
	Trichuris	8	0
	Capillaria	n.d.	n.d.
	Toxocara	n.d.	n.d.
	Enterobius	n.d.	n.d.
Cestodes	*Taenia*	n.d.	
	Hymenolepis	n.d.	
Trematodes	*Fasciola*	n.d.	

n.d.: not detected

The results show that the compost is free of viable helminth eggs. The eggs that were found in the compost (10 eggs / 10 g dry matter) were not viable after an incubation at 26°C during three weeks. This shows that the hygienisation of the organic material through the composting process is very efficient and that there is no risk for public health (illnesses caused by pathogenic organisms) through the use of the compost [written statement of Prof. J. Schwartzbrod, LCPE, Nancy].

The origin of the eggs probably are human faeces that were somehow mixed with the organic material.

5.2.6 Compost production

When talking about the compost production, one has to differ between two things:

A. The output after screening of one single pile in relation to its input (conversion rate of one cycle)
B. The final conversion rate of raw organic material into compost after several cycles of decomposition (organic particles, that need more than 55 days to decompose or are too big to pass through the sieve (screening residues) are added to new piles till they finally become fine compost).

The output in case A depends on the sieve size[4] while case B is independent from the sieve, it only takes longer to reach the final stage with a smaller sieve size.
The final conversion rate (total compost/input[5]) lies between 17 and 25 %, according to the water content, which can fluctuate between 25 and 40 %. For the following calculations, a final output of 20 % of the raw organic input material was used as the actual contract with M/S. MAP Agro Industries demands a low water content (12%).

An other ratio that was calculated is 40 days weight/input which was around 39% during the year 2000 and decreased to 25% in spring 2001, due to the decreasing water content.
The changing water content makes it difficult to compare different outputs when the water content is not determined. Therefore, some assumptions about the actual loss of the dry matter have been made: A ratio 'material weight after 40 days/input' was calculated with the dry matter, for what following assumption had to be made:

1. The water content decreased from 75% (input) to 50% (after 40 days) during 40 days of composting in the year 2000
2. The water content decreased from 75% to 30% in spring 2001 (reason for the lower water content is the contract with M/S. MAP Agro Industries which demands a final content of 12% of water - to reach this target, less water was added in the composting process).

The average ratio is about 76% what means that the loss of dry organic matter through decomposition (volatilisation) is around 24 % (loss of dry organic matter during maturing can be neglected), for details see Appendix G.

TABLE 9 AVERAGE COMPOST PRODUCTION

Item	[wet weight]	at present	max. capacity
average waste collected	[kg/day]	1659	3000
organic fraction	[kg/day]	1318	2383
additives	[kg/day]	160	282
average compost produced	[kg/day]	295	533
	[tons/year]	108	195

The density of the finished compost was 417 kg/m^3 on the 11th March 2001. But the density is dependent on the water content of the compost which may change according to the season.

[4] Experiments showed that the output with a 2 mm-sieve is about 65% of the output with a 4 mm-sieve.
[5] The amount of total compost is nearly equal to the amount of organic matter of a pile before screening.

5.2.7 The development of various parameters during the composting process

5.2.7.1 Overview of the lab results

Table 10 and 11 show an overview of the parameters of the observed pile.

5.2.7.2 The development of physical and chemical parameters through composting

5.2.7.2.1 Water content

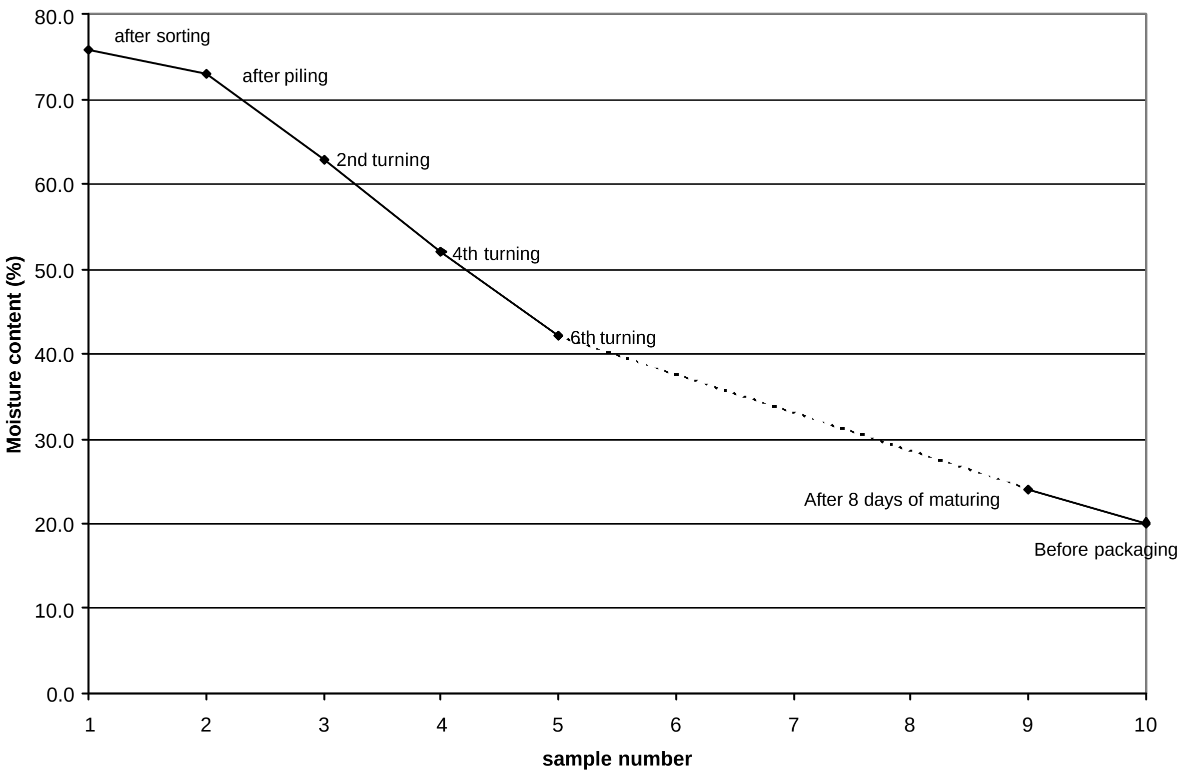

FIGURE 6 THE CHANGE OF THE WATER CONTENT

The result shows that the water content constantly decreased although water was added during the 1st, 2nd, 3rd, 4th and 8th turning (some problems with the measurement were faced at the 8th and 10th turning and after 40 days of composting, but it can be assumed that the water content does not increase).

The water content during the composting stage should not fall below of 40% (optimal around 50%) [NRAES], otherwise it hampers the biological activity in the heap, resulting in an insufficient decomposition (compost not mature). The water content after the 6th turning is therefore too low. The contract with M/S. MAP Agro Industries demands a low water content (12 %) - the idea arose that this can be reached easier when adding less water, without considering that it can hamper the decomposition. The importance of adding water has now been realised and more attention will be given to carry out the squeeze test properly so that the optimal environment for the micro-organisms can be reached.

TABLE 10 OVERVIEW OF LAB RESULTS 1

Process steps and samples		sample number	Date	pH	Moisture [%]	Carbon [g/kg]	Total N [g/kg]	P [g/kg]	K [g/kg]	S [g/kg]	C/N-ratio [-]
Mixed sample of organic waste after sorting			15. Jan 01	5.7	75.1	282.5	22.00	7.29	10.92	10.00	12.8
			16. Jan 01	6.1	74.6	311.1	15.90	5.37	10.92	9.00	19.6
			17. Jan 01	5.8	78.1	316.9	20.10	8.43	10.92	8.90	15.8
	average	1	17. Jan 01	5.9	75.9	303.5	19.33	7.03	10.92	9.30	15.7
Mixed sample of organic waste after piling (watered)	top		17. Jan 01	5.7	77.0	330.4	18.70	8.47	11.75	6.00	17.7
	middle		17. Jan 01	5.7	70.1	351.2	20.10	7.47	10.92	5.80	17.5
	bottom		17. Jan 01	6.1	72.2	316.6	14.20	17.95	22.17	4.00	22.3
	average	2	17. Jan 01	5.8	73.1	332.7	17.67	11.30	14.94	5.27	18.8
Turning stage	2nd turning	3	23. Jan 01	6.6	62.9	244.6	14.30	10.44	11.75	4.00	17.1
	4th turning	4	28. Jan 01	7.2	52.0	246.0	18.20	12.23	14.33	4.00	13.5
	6th turning	5	04. Feb 01	7.3	42.1	241.8	8.90	12.66	16.92	5.80	27.2
	8th turning	6	12. Feb 01	7.7		214.3	6.00	14.93	15.67	4.00	35.7
	10th turning	7	20. Feb 01	7.7		200.2	6.00	15.41	16.92	5.30	33.4
Beginning of maturing		8	24. Feb 02	7.6		238.1	26.30	14.54	16.92	4.40	9.1
After 8 days of maturing		9	04. Mar 01	7.5	24.1	186.7	26.60	15.37	16.92	4.50	7.0
Before packaging		10	11. Mar 01	7.7	20.1	190.6	23.80	12.40	16.92	4.50	8.0
Water (used for watering)			11. Mar 01	8.0				0.00		0.40	

TABLE 11 OVERVIEW OF LAB RESULTS 2

Process steps and samples		sample number	Date	Parameters							
				Zn	B	Cu	Pb	Cd	Maturity index		
				ppm	ppm	ppm	ppm	ppm	CO2	NH3	Final Index
Mixed sample of organic waste after sorting			15. Jan 01	256	168	18	n.d.	4			
			16. Jan 01	224	180	14	n.d.	6			
			17. Jan 01	198	83	14	n.d.	4			
	average	1	17. Jan 01	226	144	15	n.d.	5			
Mixed sample of organic waste after piling (watered)	top		17. Jan 01	216	212	20	n.d.	4			
	middle		17. Jan 01	236	224	18	n.d.	4			
	bottom		17. Jan 01	420	268	42	n.d.	6			
	average	2	17. Jan 01	291	235	27	n.d.	5			
Turning stage	2nd turning	3	23. Jan 01	226	132	36	n.d.	6			
	4th turning	4	28. Jan 01	278	134	58	n.d.	6			
	6th turning	5	04. Feb 01	334	124	62	n.d.	6			
	8th turning	6	12. Feb 01	332	107	72	n.d.	8	5 - 6	3 (- 4)	(4 -) 5
	10th turning	7	20. Feb 01	392	179	70	n.d.	6			
Beginning of maturing		8	24. Feb 01	358	282	94	n.d.	8	5 - 6	4 (- 5)	5 - 6
After 8 days of maturing		9	04. Mar 01	480	242	87	n.d.	6	6	3	5
Before packaging		10	11. Mar 01	470	278	86	n.d.	6	6	4 - 5	6

5.2.7.2.2 pH

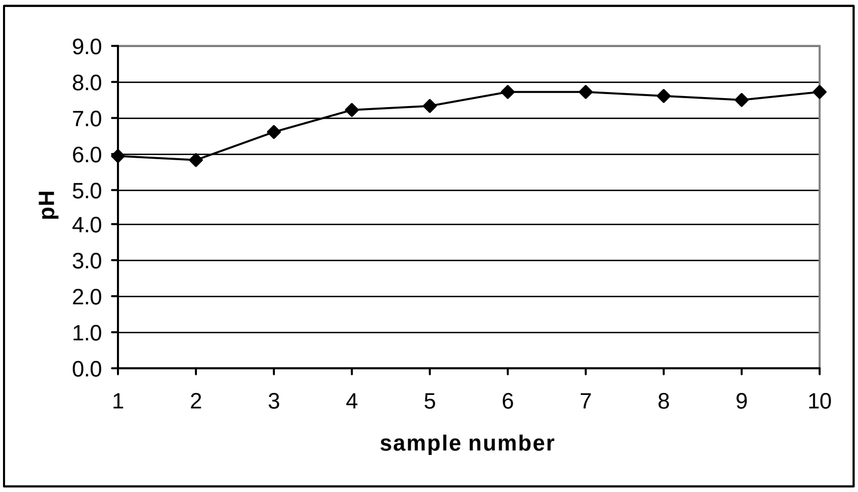

FIGURE 7 THE CHANGE OF THE PH

The pH remains in the optimal range of 5.5 to 8 during all the process. The pH increases during the thermophilic phase (till about the 8th turning) due to the consumption of the organic acids through the micro-organisms.

5.2.7.2.3 Carbon, Nitrogen and C/N-ratio

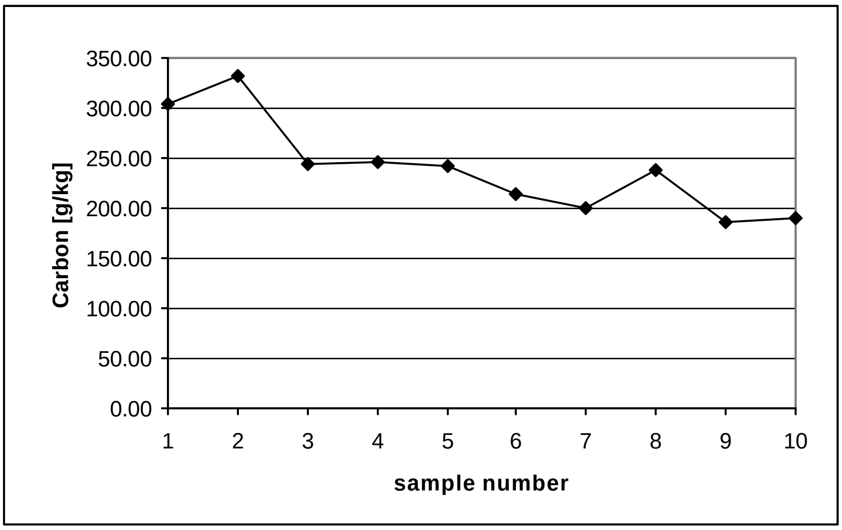

FIGURE 8 THE CHANGE OF CARBON

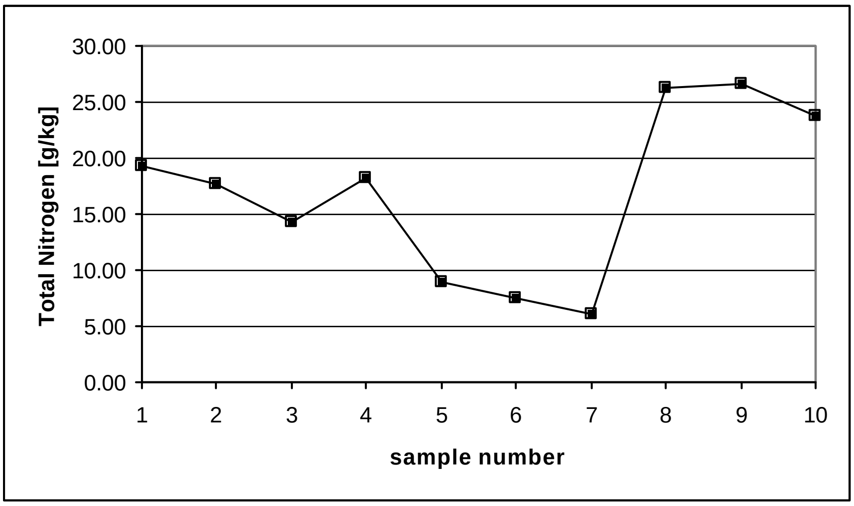

FIGURE 9 THE CHANGE OF TOTAL NITROGEN

The carbon content decreases during the whole process because the micro-organisms use it for their metabolism. The metabolism rate shows a peak at the beginning of the process and after the replacing of the pile (probably due to the high oxygen supply through the replacing).

The total nitrogen is rather high in relation to the carbon content. The reason might be that additives (cowdung and urea) are added at the beginning of the composting process. The reason for the dropping between the 8th and 10th turning are not clear. The high nitrogen content is responsible for the low C/N-ratio – it is beneath the optimal range of 25 – 35. A low C/N-ratio initially accelerates microbiological growth and decomposition and the temperature therefore rises fast (as seen in the observed pile). But the acceleration also leads to a rapid oxygen consumption and after the use-up of the available oxygen, the conditions can become anaerobic if the pile is not aerated enough. Anaerobic conditions result in bad odor (ammonia) and a loss of the excess nitrogen as ammonia gas (especially if pH and temperature are high) [USEPA, 1994].

The nitrogen content of the organic waste might be higher than generally in Bangladesh, because the organic material consists mainly of vegetable residues which contain more nitrogen than other organic waste [personal statement of Dr. Zainal Abedin, SRDI, April 2001].

5.2.7.2.4 Phosphorus

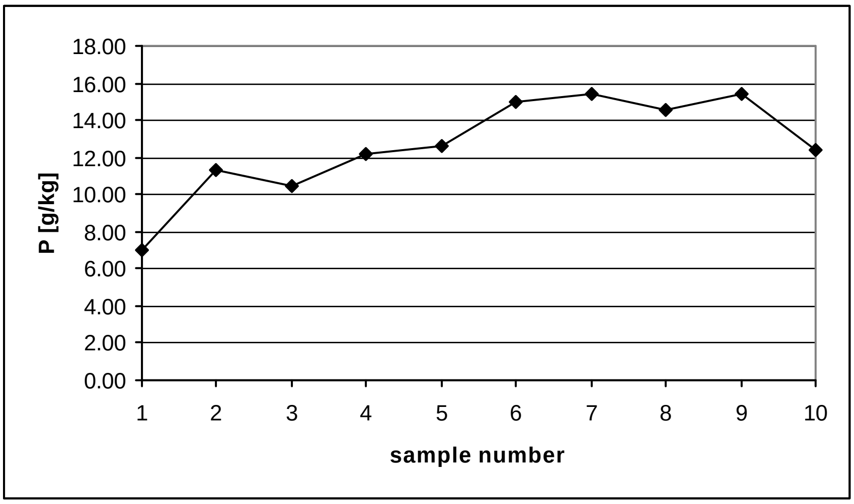

FIGURE 10 THE CHANGE OF PHOSPHORUS

The content is increasing during the composting process. No losses of phosphorus (volatilisation or leachate) together with decomposition of the organic matter (carbon) are responsible for it. The break after the screening might indicate that the screening residues contain more phosphorus than the screened compost.

5.2.7.2.5 Potassium (K)

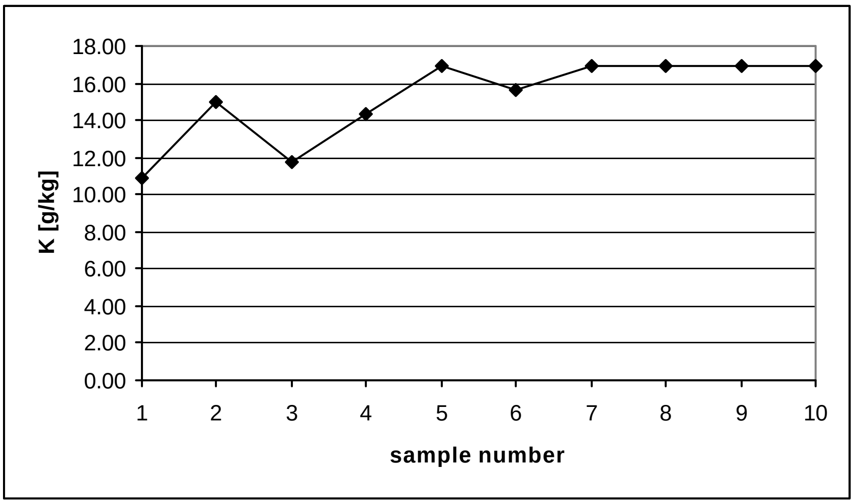

FIGURE 11 THE CHANGE OF POTASSIUM

The concentration of potassium is increasing during the first 19 days to become stable for the remaining time of the composting process. The increasing can be explained with the loss of organic matter.

5.2.7.2.6 Heavy metals (Zn, Cd, Cu)

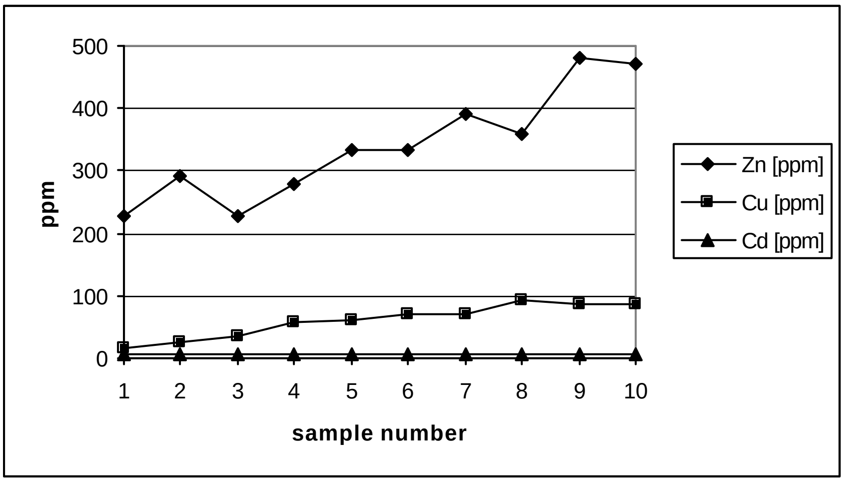

FIGURE 12 THE CHANGE OF HEAVY METALS

The concentrations of zinc and copper are increasing during the composting process as there exists no possibility of degradation for them while the organic matter decomposes. Cadmium shows no changes.

5.2.7.3 Maturity and Maturity Index

The Maturity Index does not change much during the last four weeks of the composting process. This shows that either the maximal possible maturity has already been reached or that the decomposition can not go on because of the low moisture content. But a Maturity Index of 6 already allows a broad use (General Gardening, Field Cultivation [Woods End Research], Appendix C).
A control with a later pile showed a Maturity Index of only 3-4 (ideal active compost, needs on-going management [Woods End Research]).). This is not sufficient considering the length of the composting process. It can strongly be assumed that the low moisture content (together with fewer turnings than the observed pile) are responsible for this fact.
The other tests indicate a mature compost as the colour was dark-brown, the odor earthy and the temperature of the pile dropped to the ambient air temperature during the last weeks. But it also must be considered that the temperature can not be high if microbiological activity is hampered because of lack of water.

5.2.7.4 Water for watering

The analysis shows that the nutrients of the water used in the process can be neglected.

5.2.8 Man-hour monitoring

5.2.8.1 Results from Mirpur plant

In the Mirpur Composting Scheme 16 workers are needed to run the plant: six collectors (five boys, one man) and ten workers on the plant (9 females, one male). In addition, a plant manager (about 48 working-hours/week) is needed to run the plant and supervise the actions of the workers.
Table 12 shows the results from the man-hour monitoring carried out in Mirpur.

TABLE 12 WEEKLY MAN-HOURS FOR DIFFERENT PROCESS STEPS OF THE COMPOSTING ACTIVITY

	Date		average		
	13.-19.02.2001	20.-26.02.2001			
process step	manhours/week	manhours/week	manhours/week	[%] (without collection)	[%]
collecting	172h 5 min	175h	173h 33min		26.55
sorting	134h 10min	150h	142h 5min	29.60	21.74
piling	34h 10min	49h 10min	41h 40min	8.68	6.38
turning	104h 10min	113h 20 min	108h 45min	22.66	16.64
screening	132h 30min	167h 30min	150h	31.25	22.95
bagging	75h	-	37h 30min	7.81	5.74
total	652h 5min	655h	653h 33min	100	100

Based on this man-hour monitoring and an amount of 11.63 tons of waste treated and 2.07 tons of compost produced per week, specific man-hours can be calculated:

Man-hours for collection/waste collected	14.9 hours/ton
Man-hours for processing/waste collected	41.3 hours/ton
Total man-hours/waste processed	56.2 hours/ton
Man-hours for processing/compost produced	231.9 hours/ton
Total man-hours/compost produced	315.7 hours/ton

5.2.8.2 Comparison with Yogyakarta, Indonesia

Table 13 shows a comparison of the allocation of the working hours on the different process steps between the Mirpur Composting Scheme and a Composting Unit in Yogyakarta, Indonesia (Indonesian Windrow Technique; average amount of raw waste processed per day is 2.4 tons) [Zurbrügg and Aristanti, 2000].

TABLE 13 COMPARISON OF THE ALLOCATION OF THE WORKING HOURS ON THE PROCESS STEPS OF MIRPUR AND YOGYAKARTA

	Mirpur plant	Yogyakarta plant
process step	[%]	[%]
sorting	29.60	52.87
piling/turning	31.34	26.44
screening	31.25	13.79
bagging	7.81	6.90
total	100.0	100.0

The comparison shows big differences between the allocation of the working hours on the different process steps. The sorting needs more than half of the time in Yogyakarta while the different steps need similar amounts of the working time in Mirpur (except for bagging). The screening in Mirpur needs more than twice the time that it needs in Yogyakarta. Reasons for the differences might be the composition of the raw waste and the sieve size for screening.

5.2.9 Household survey

The household survey was conducted in one fifth of the collection area of Section-2, Mirpur Housing Estate, Dhaka (estimated number of households 170). 30 households were sampled by questionnaire (see chapter 5.1.5).

The survey revealed that 80% of the households in the area make use of the service of Waste Concern while 20% prefer to give their waste to their servants to place it in the dustbin or dump it onto the street. They do not want to pay for their waste.

The following analysis was done only with the households that participate in the collection.

Asked about the service charge they have to pay, 75% (18) of the participating residents said that the amount is okay for them and 12 of them are even prepared to pay between Tk.5 - 30 more (weighted average: Tk. 11.5/month) if further improvements of the collection, composting process or general cleanliness of the area are tackled in exchange. The other 25% think that the charge is too high, either because they are not satisfied with the service or because they heard that others pay less. But even then, half of them are prepared to pay more as they do not want to dump their waste themselves and on the condition that the service is improved.

5.2.9.1 Views of the households

80% of the residents are satisfied with the work of Waste Concern (Figure 13), but some complaints have also been expressed (see Table 14). The residents then also suggested some improvements (Table 15).

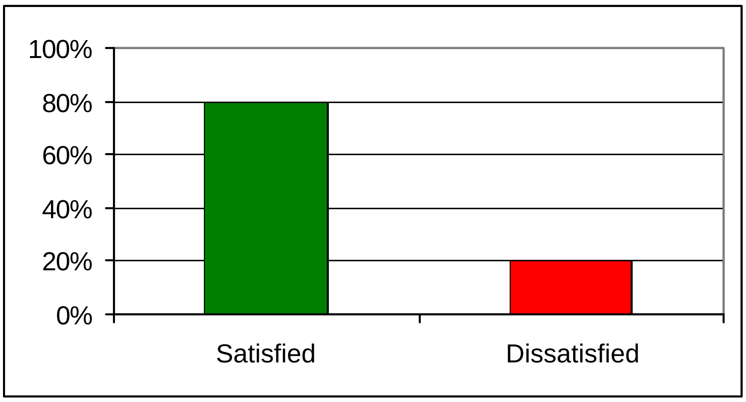

FIGURE 13 SATISFACTION OF THE RESIDENTS

TABLE 14 COMPLAINTS OF THE HOUSEHOLDS

Response		Frequency of response 1)	% of all participating residents	Reasons for complaints
Unsatisfactory collection system		*6*	*25.0*	
Reasons 2)	No fixed collection time	5	20.8	Residents have to wait for the collectors or are disturbed in their work
	The collectors sometimes do not wait long enough	2	8.3	
	Waste falls down from the rickshaw van	1	4.2	
	The collection vehicle makes noise	1	4.2	
Odor		*6*	*25.0*	
Reasons 2)	Odor is emitted from open rickshaw vans during collection	3	12.5	
	Odor is emitted from the composting site (especially during turning) 3)	3	12.5	
Location of the site		*1*	*4.2*	*Site should not be located in a residental area*

1) Several households had more than one complaint
2) Several households mentioned more than one reason
3) The survey showed that the odour during turning is confined to a radius of 25 m from the site's boundaries

TABLE 15 SUGGESTIONS OF THE HOUSEHOLDS

Suggested improvements	Frequency of responses 1)	% of all residents	Reasons for suggestion
Fixed collection time	6	25.0	Allows the residents to be ready by that time and reduces waiting time on either side
Covered instead of open vehicle	4	16.7	Minimises odor and falling down of waste
Improvement of the composting process to reduce odor	2	8.3	
Introduction of a regular street sweeping through Waste Concern	2	8.3	Allows further improvement of the environment through removing of waste

1) out of 24 responding residents, several residents mentioned more than one improvement

5.2.9.2 Conclusion

The survey showed that the composting activity is widely accepted and appreciated by the residents. They are happy about the improvement of the environment that could be achieved through the service of Waste Concern (the environment is much cleaner since the door-to-door waste collection has been introduced; less waste is lying around on the streets, no overfilled dustbins can be seen and as a result, less flies and mosquitoes can be observed). The residents are glad that they have not to care about what to do with their waste any more and that they can give it to the collectors instead of carrying it themselves to the dustbin.

Several complaints have been expressed and suggestions to improve the situation further have been made. Some of them, like the fixed collection time or the minimisation of odor should be taken seriously to keep the positive attitude of the residents in future. To meet the higher costs of further improvements, the collection costs might be slightly increased - but it is important to explain to the residents what this money is used for.

6. Financial evaluation of the Mirpur collection and composting scheme

The plant in Mirpur was started as a demonstration project and not run at full capacity till spring 2001. Therefore, two cases were distinguished in the financial evaluation:

1. Financial situation with the present production level (1.66 tons of collected waste/day)
2. Financial situation in case of running with full capacity (3 tons of collected waste/day; if necessary, costs and revenues were proportionally increased)

6.1 Costs

Two types of costs are involved in the setting up and running of a composting plant:

- Investment costs, which mainly arise at the start of the activity (see Table 16). Investment costs include also costs for purchasing or renting of land. This type of costs are separately looked at in Chapter 6.1.1.
- Operation costs, which arise every year (see Table 18)

In addition, two main hidden costs have to be mentioned:

- Know how about the process of the introduction and installation of a composting plant
- Experience of the workers of a composting plant

6.1.1 Investment costs

TABLE 16 INVESTMENT COSTS

Investment costs	Depreciation period (life time) in years	Investment costs present situation				Investment costs maximal capacity			
	years	costs of unit		no. of units	total (US$)	costs of unit		no. of units	total (US$)
collection									
purchase of rickshaw vans	5	300	US$/van	3 vans	900	300	US$/van	5 vans	1500
Total collection					900				1500
general site development costs									
construction cost of office	10				1000				1000
water and electricity connection	10				1000				1000
sorting									
construction of sorting platform with shed	10	25.71	US$/m2	35.0 m2	900	25.71	US$/m2	35.0 m2	900
composting									
construction of composting shed	10	25.63	US$/m2	113.7 m2	2914	25.63	US$/m2	113.7 m2	2914
maturing									
construction of shed	10	25.63	US$/m2	32.4 m2	830	25.63	US$/m2	32.4 m2	830
screening/bagging									
construction of platform with shed	10	25.63	US$/m2	21.2 m2	543	25.63	US$/m2	21.2 m2	543
storing									
construction of shed	10	25.63	US$/m2	42.0 m2	1076	25.63	US$/m2	42.0 m2	1076
Total composting site					8264				8264
Total for collection and composting activity					9164				9764

6.1.1.1 Land costs

The costs for the purchasing or renting of land are a main cost factor. Land prices in Bangladesh have a wide range as shown in Table 17.
The purchasing costs have been calculated with the minimum space required for a composting plant (380m^2). The land prices in Dhaka are extremely high due to a high population density and lack of vacant land.

TABLE 17 LAND COSTS IN DHAKA AND KHULNA CITY

Region	Land price US$/m2	Costs for land purchasing US$
Dhaka		
High-income areas (Gulshan, Banani)	500	190000
Middle-income areas (Dhamondi)	400	152000
Other Dhaka	320	121600
Mirpur/suburban areas	300	114000
Khulna		
Inner city	44.8	17024
Fringe areas	9	3420

Source: Dhaka: World Bank 2000, Khulna: Sinha & Enayetullah, 2000B

6.1.2 Operation costs

TABLE 18 OPERATION COSTS

Process	Operation and maintenance costs (per year)				
		present situation		maximal capacity	
	Costs of unit	no. of units	total [US$]	no. of units	total [US$]
Collection					
salary 1)			1560		2821
uniforms	9 US$/uniform	5 uniforms/year	45	9 uniforms/year	81
rickshaw van repair			120		217
Total collection costs			1725		3119
general costs for site-running					
salary for manager			1560		1560
costs for equipment 2)			155		155
electricity bill			240		240
water bill			48		48
transport of rejects to landfill	10 US$/trip	52 trips/year	520	94 trips/year	940
total general costs			2523		2943
sorting					
salary 1)			675		675
total sorting costs			675		675
composting					
raw material:					
sawdust	0.04 US$/kg	6000 kg/year	240	10850 kg/year	434
cow dung	0.02 US$/kg	21000 kg/year	420	37975 kg/year	759
urea	0.2 US$/kg	60 kg/year	12	108 kg/year	22
salary for piling 1)			198		198
salary for turning 1)			517		517
total composting costs			1387		1930
screening					
salary 1)			713		713
total screening costs			713		713
bagging					
salary 1)			178		178
total bagging costs			178		178
salary for extra work (screening/bagging) during marketing period 3)					1073
Total costs of composting site			5475		7511
Total collection and composting			7200		10631

1) salary calculated based on man-hour monitoring
2) equipment includes uniforms, gloves, buckets, pitchforks, shovels, aerators
3) extra salary needed is Tk. 268.3 per ton = 5.37 US$/ton

6.1.3 Specific costs of the Composting Project

Based on 11.613 tons of waste collected and 2.07 tons of compost produced per week and the running costs, specific costs can be calculated:

1. Running Costs

1.1. Salary costs

Salary costs for collection	1560 US$/year
Salary costs for processing of waste to compost	3840 US$/year
Total salary costs	5400 US$/year

1.2. Operation costs (including salary costs)

Operation costs for collection	1725 US$/year
Operation costs for processing of waste to compost	5475 US$/year
Total operation costs	7200 US$/year

1.3. Total costs (operation and depreciation[6])

Total costs for collection	1994 US$/year
Total costs for processing of waste to compost	7122 US$/year
Total yearly site costs	9116 US$/year

2. Specific costs

2.1. Specific labour costs

Salary costs for collection/waste collected	2.58 US$/ton
Salary costs for processing/waste processed	6.34 US$/ton
Total salary costs/waste processed	8.92 US$/ton
Salary costs for processing/compost produced	35.6 US$/ton
Total salary costs/compost produced	50 US$/ton

2.2. Specific operation costs (including salary costs)

Operation costs for collection/waste collected	2.84 US$/ton
Processing cost/waste collected	9.04 US$/ton
Total operation costs/waste collected	11.88 US$/ton
Processing costs/compost produced	50.7 US$/ton
Total operation costs/compost produced	66.7 US$/ton

2.3. Specific total costs

Total collection costs/waste collected	3.3 US$/ton
Total processing costs/waste collected	11.8 US$/ton
Total yearly site costs/waste collected	15.1 US$/ton
Total processing costs/compost produced	66.0 US$/ton
Total yearly site costs/compost produced	84.5 US$/ton

[6] Depreciation costs are calculated with the formula below where DC = Depreciation costs, C = Investment costs, i = interest rate (here i = 0.15), n = Depreciation period (life time in years), see also chapter six

$$DC = C * \frac{i}{1 - \frac{1}{(1+i)^n}}$$

6.2 Revenues

6.2.1 Revenues from the composting activity

Three types of revenues from the composting project can be distinguished:

1. Income from the collection fees
   The households pay a collection fee between Tk.10 and Tk.20 according to their financial situation. At present, 790 households participate in giving their waste while about 1430 are needed to reach full capacity (with an average per capita waste generation of 0.375 kg/day).
2. Proceeds from the compost sale
   The compost presently is sold for Tk.2.5/kg.
3. Proceeds from the sale of recyclables [Table 19 and 20]
   Recyclables are hard plastic, cardboard, glass and metal. At Mirpur, they are sold by the plant workers which provides them with extra money. Nevertheless, they were included in part of the economic evaluation to gain an overall picture.

Table 21 shows the total income from the Mirpur Composting Scheme.

TABLE 19 PROCEEDS FROM THE SALE OF RECYCLABLES AT PRESENT

Item	average amount	selling price	revenue		
	[kg/month]	[Tk./kg]	[Tk./month]	[Tk./year]	[US$/year]
hard plastic	80	8	640	7680	153.6
cardboard	300	1.5	450	5400	108
glass	150	2	300	3600	72
metals	60	2	120	1440	28.8
Total			1510	18120	362.4

TABLE 20 PROCEEDS FROM THE SALE OF RECYCLABLES IN CASE OF FULL CAPACITY

Item	average amount	selling price	revenue		
	[kg/month]	[Tk./kg]	[Tk./month]	[Tk./year]	[US$/year]
hard plastic	145	8	1157	13888	278
cardboard	542	1.5	814	9765	195
glass	271	2	542	6510	130
metals	108	2	217	2604	52
Total			2731	32767	655

TABLE 21 EARNINGS OF THE COMPOSTING PROJECT

Item	present situation	max. capacity
	[US$/year]	[US$/year]
sale of compost (Tk. 2.5/kg)	5393	9728
household collection fee	3366	6087
selling of recyclables	362	655
total without recyclables	8759	15815
total with recyclables	9121	16470

6.2.2 Cost reduction for transport and dumping

Community based composting activities reduce the amount of waste to be collected and disposed of by the municipality, thus reducing several types of costs:

1. Costs for collection and transport of waste
2. Costs for the purchase of landfill areas
3. Costs for the running of the landfill (wastewater and gas treatment)

The reduction of the waste to be disposed of can be calculated as followed:

reduction = organic fraction + recyclables - screening rejects

6.2.2.1 Reduction of transport costs

To calculate the reduction of the transport costs it had to be assumed that the average costs of the DCC for the transport of a ton of waste does not change with the introduction of composting activities. The data used for the calculation date from 1998 - nowadays (2001), transport costs might be even higher.

TABLE 22 REDUCTION OF TRANSPORT COSTS

Item		actual amount	max. capacity
waste collected by Waste Concern	[tons/day]	1.66	3.00
organic fraction	[tons/day]	1.32	2.38
recyclables	[tons/day]	0.10	0.19
rejects	[tons/day]	0.24	0.43
rejects after screening	[tons/day]	0.02	0.04
reduction of waste to be transported and dumped	[tons/day]	1.39	2.52
	[tons/year]	508.89	920.75
costs of the DCC for waste collection and transport 1)	[US$/ton]	16.40	16.40
transport cost reduction for DCC	**[US$/year]**	**8346**	**15100**

1) Source: World Bank, 1998

6.2.2.2 Reduction of landfill costs

To calculate the reduced landfill costs, several assumptions had to be made:

- All collected waste is going to the official dumpsite (in reality part of the waste is dumped in unofficial dumpsites (filling up of low-lying areas for building construction purpose which is free of costs)).
- The average height of the dumped waste in a dumpsite is 6 m (e.g. 6 m^3 waste per m^2 area).
- The density of the waste six months after disposing is 1.1 t/m^3.

The dumpsites in Dhaka are not sanitary run, therefore no cost savings for wastewater and gas treatment can be calculated.

TABLE 23 REDUCTION OF LANDFILL COSTS

Item		actual amount	max. capacity
reduction of waste to be dumped	[tons/day]	1.39	2.52
volume of waste saved per day	[m3/day]	1.27	2.29
dumping area safed per day	[m2/day]	0.21	0.38
dumping area safed per year	[m2/year]	77	140
costs for purchasing new dumping area 1)	[US$/m2]	24.5	24.5
cost reduction per year	**[US$/year]**	**1889**	**3418**

1) Personal information Tariq Bin Yousuf, DCC (land prices for Amin Bazar, Dhaka)

6.2.2.3 Total cost reduction for the municipality

Table 24 shows the total cost reduction for the municipality through the Mirpur Composting Scheme.

TABLE 24 TOTAL COST REDUCTION FOR THE MUNICIPALITY THROUGH A COMPOSTING PROJECT

Item		actual amount	max. capacity
reduced collection and transport costs	[US$/year]	8346	15100
reduced purchase costs	[US$/year]	1889	3418
total cost reduction	**[US$/year]**	**10235**	**18518**

This means that 16.9 US$ per ton of treated waste can be saved through the composting activity (based on the treatment of 605.5 tons of waste per year).

6.3 Commercial appraisal of the project

6.3.1 Discounting method: Net Present Value (NPV)

Investment in general involves expenditure today which will produce benefits (income) in the longer-term future. The NPV method takes into account both the size and the timing of the return on the investments (earnings). A return in early years is weighted greater than one in later years - this can be done trough discounting of the future income.

The Present Value which represents the value of a future payment at the time of investing, has to be calculated for every year ((revenues - operation costs) * discount factor). The discount factor (df) can be calculated with following formula:

$$df = \frac{1}{(1+n)^n}$$

$$i = discountrate$$

$$n = year$$

The discount rate, which should reflect the interest rates of the market, was chosen as 15 %. The Net Present Value is the sum of the discounted future incomes minus the investment costs. If the NPV is positive, the project can be considered commercially viable.

6.3.2 Net Present Value of the Mirpur Composting Scheme

The Net Present Value has been calculated for different cases in the present and full capacity situation:

- NPV with and without the selling of recyclables
- NPV with and without the cost savings of DCC

The lifetime of the installation was considered to be 10 years. The rickshaw vans have to be replaced after a time of 5 years.

Land costs are not included in the calculations as no information on the rent for land could be collected and it can not be foreseen how land purchasing prices will develop in the next ten years (land in Dhaka is scarce, so it is likely that prices will rise; it is not possible to discount a value that might be higher in the future). Figure14 shows the Net Present Value for the different cases (for details see Appendix H).

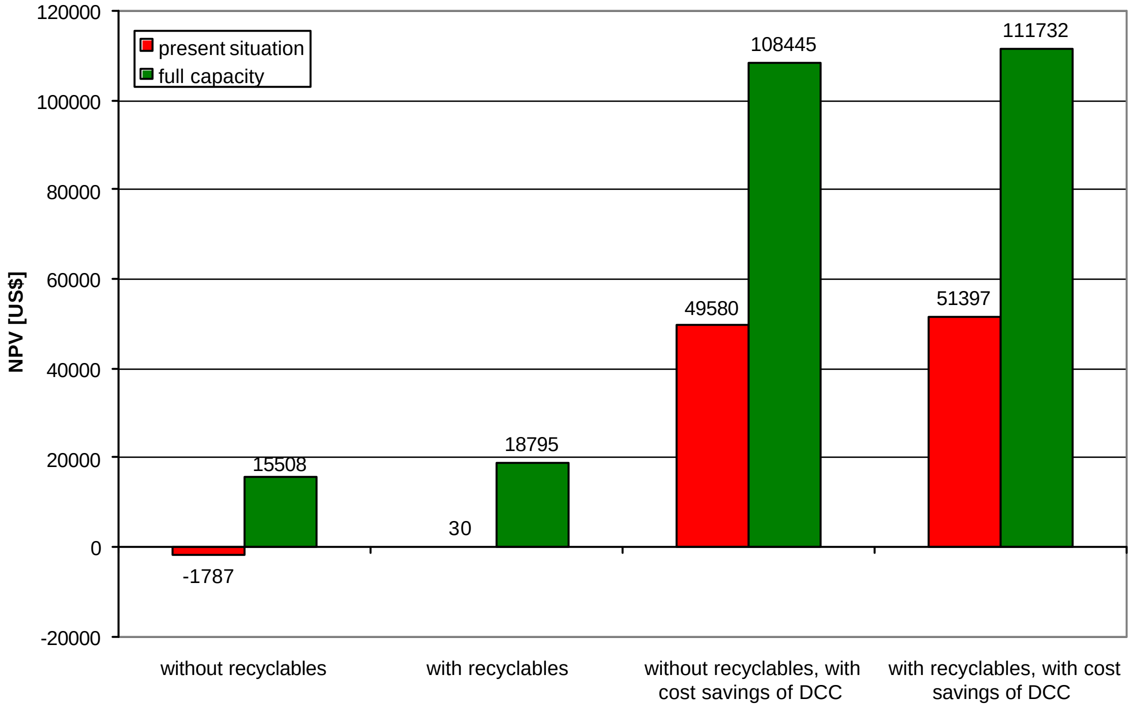

FIGURE 14 NET PRESENT VALUE IN US$

6.3.3 Discussion

The financial evaluation shows that the Mirpur project is not viable at present. It was started as a demonstration project without the aim of gaining profit and now (2001)gradually is approaching economical viability. Once the full capacity is reached in future, the project will become economically viable. To realise composting activities in Dhaka, the land has to be provided free of charge as the purchasing of land would be a too high investment (although one could consider the purchasing and composting as a capital investment with a profit). The case of Dhaka with such high prices is not representative for the whole country of Bangladesh: in other areas, where more vacant land is available and prices therefore lower, a project can be viable in spite of the land costs [Sinha & Enayetullah, 2000B].

If the cost savings of DCC are included, it can be shown that such a project is worthwhile in every case. The entrepreneur that invests mostly does not profit from this cost savings himself, but it shows that the municipalities should support such activities as it helps them to overcome their capacity and/or financial problems.

In addition it has to be said, that such an evaluation only considers the tangible costs and benefits of a project. But the project or, in general, solid waste management, must also be considered in the light of a sustainable environment management - various benefits of a composting project that can not be measured in monetary terms (intangible benefits) are:

- cleaner environment in the community (no waste on the streets, in the drains or vacant lots)
- increasing awareness concerning environmental issues under the residents
- creation of working opportunities for the lower class
- resource recovery

This increase of the welfare of the population should never be forgotten when discussing about the introduction of a composting plant.

6.3.4 Commercial value of the compost [after CREPA].

An approach to control the commercial value of compost is to determine the value of substitutes. This value can be calculated through adding of the substitute prices of different fertilising elements of the compost (Example: Urea is a mineral fertiliser which contains 46% of nitrogen. The price is Tk.5/kg. One kilogram of pure nitrogen therefore costs Tk.10.87 (this is the substitute price)). After the lab analysis of the compost, its value can be found with the help of the quantity found and the substitute price of every element.
Only nitrogen (N), phosphorus (P) and potassium (K) were taken into account as the other elements do not significantly influence the commercial value. The value of the organic matter can not be properly evaluated as no amendments exist for comparison.
The chemical fertilisers that were chosen as reference - urea, TSP (Triple Super Phosphate) and MP (Muriate of Potash) are the ones most commonly used by the farmers in Bangladesh.

TABLE 25 DETERMINATION OF THE SUBSTITUTE VALUE

fertilizer	urea (N)	TSP (P2O5)	MP (K2O)
price (Tk./kg)1)	5	11	8
content	46 % N	46 % P2O5	60 % K2O
price of one kilogram (N, P2O5 resp. K2O) (Tk.)	10.87	23.91	13.33

1) Governmental rates

TABLE 26 SUBSTITUTE VALUE OF COMPOST

Parameter	content (g/kg)	value (Tk./kg)
Nitrogen (N)	22.4	0.24
Phosphor (P2O5)	14.9	0.36
Potassium (K2O)	19.1	0.25
Total		0.85

Table 26 shows that the resulting commercial value does only reach 34 % of the selling price (Tk. 2.5/kg). But the further benefits of compost (see chapter 3.2) weigh certainly higher than the missing Tk.1.6, especially when seen in the long run.

6.4 Financial aspects of barrel-type composting

In this study, no detailed evaluation of the financial situation was done. But it can be said that the main expenditures are for the purchase of land, the construction of a shed, the purchase of the barrels (app. 50 US$/barrel, including civil work) and the workers. The lifetime of a barrel is about five years. Revenues are the collection fees of the households and the proceeds from the sale of compost. If no land costs have to be paid, it should be possible to run the composting site economically.

7. Health aspects of the production and use of compost

The health and welfare of different groups of individuals may be affected by the composting activity and the use of compost [CREPA, 1994, p.20f]

- the people working in the composting plant
- the inhabitants of the neighbourhood of the composting site
- the users of the compost (farmers, nurseries)
- the consumers of the product grown on soils enriched with compost

Following chapters first highlight the general health risks associated with compost production and use and then focuses on the Mirpur composting plant.

7.1 Health of the plant workers

When working with miscellaneous solid waste there is a high risk of injuries and infections caused by objects as fragments of broken glass, syringes or sharp pieces of metal. Urban solid waste can contain different pathogenic micro-organisms (virus, bacteria, protozoa, helminth eggs) which may cause severe diseases like typhoid fever or diarrhoea - mostly through faecal-oral transmission routes. Primary pathogens exist in the collected waste while the secondary pathogens grow during the composting process. The workers of a composting plant are exposed to higher concentrations of this pathogens than the normal people. The risk of inhalation of such pathogens may be increased during the dry season when air movement whirls up dust which can carry germs. In addition, the decomposing organic matter, especially in the early stage while turning, emits a strong odor, which can, although not being harmful, be rather annoying for the plant-workers.

For these reasons, the workers in the composting plant in Mirpur are provided with boots, gloves, a mouth mask and long working clothes. But although the workers have this equipment, they do not wear it all the time - it is therefore very important that they are repeatedly made aware of the reasons for these precautions.

Another potential source of nuisance is the proximity of the open water supply to the composting piles. This bears the risk of a contamination of the water with pathogens from the fresh organic matter. The water then is used to clean the hand, the face and occasionally even to clean the mouth.

A problem that goes together with composting is the high abundance of mosquitoes within the plant area because the decomposing matter is an excellent breeding environment for these insects. They may transmit diseases like malaria and dengue fever. But although the abundance of mosquitoes is quite high within the plant area, no plant-workers complained about an increase of insect-transmitted diseases because of working there (one reason might be, that the situation only becomes worse after dusk when the workers have already left the plant). In addition they do not face any other diseases or skin problems because of working there. It seems that they are accustomed to any germs present in the collected waste.

7.2 Health risk for the neighbourhood of the plant

The abundance of mosquitoes, which can be the transmitter of diseases, might be changed through the composting activity. Their number in the very proximity of the plant might be increased while a decrease can be expected in the remaining area of the community as less waste is lying on the street. But the real scenario is difficult to judge as other reasons like drains, dustbins, slums and nurseries have been mentioned by the residents.

Based on the household survey it can be said that the probability of a correlation between health issues and the composting activity is very low: None of the residents was able to judge if there has been an increase or decrease in health problems since the composting activity was started.

7.3 Health risk for users and consumers of compost

Compost can contain traces of heavy metals and persistent organic compounds. When applicated on the soil, this can increase their concentration in the soil. Important heavy metals in solid waste are boron (B), cadmium (Cd), copper (Cu), mercury (Hg) and zinc (Zn). Depending on the condition of the soil (pH, organic matter content, cation exchange capacity), the actual concentration of the element in the soil and the crop itself (certain plants are more likely to take up heavy metals), the plants take up more or less heavy metals from the soil. This can either lead to the death of the plant itself or, if the plant is tolerant enough, start an accumulation in the food chain. Low concentrations of certain heavy metals can already cause severe diseases in humans (mostly chronic effects) [Wenger, 2000]. The health effects of the various metals differ and depend upon the concentrations.

The amounts of metals that remain in the end product of the composting process can fluctuate strongly, depending on the origin of the raw material. Organic waste material may contain high concentrations of heavy metals due to contact with, for example, batteries of newspaper ink, during storage and transportation [Lardinois, 1993]. Standards for compost have been formulated to meet the dependence from the origin and composition of raw organic material (Chapter 7.3.1).

If the composting is done properly (careful sorting out of harmful objects before piling, necessary pile temperature reached to kill pathogenic micro-organisms, screening with a tight wiremesh), there should be no acute health risk for the users and consumers of compost.

In Mirpur, the temperature curve of the observed pile and the test of helminth eggs pathogen show that the compost is sufficiently hygienised. Possibly existing organic substances are also degraded by the high temperature.

The contents of heavy metals of the compost produced by Waste Concern are discussed in Chapter 8.

7.3.1 Quality standards for compost

To ensure that the application of compost does not affect the health and growth of plants as well as the health of animals and human beings, quality standards for compost have been introduced. Following chart shows the legislative standards in different countries:

TABLE 27 STANDARDS FOR COMPOST

Parameter		Switzerland[7]	Netherlands[8]	Canada[9],	India[10]
Organic material	% dry weight		>= 20		
Pb	g/t dry weight	120	100	150	500
Cd	g/t dry weight	1	1	3	20
Cr	g/t dry weight	100	50	210	20
Co	g/t dry weight			34	
Cu	g/t dry weight	100	60	100	500
Mo	g/t dry weight			5	
Ni	g/t dry weight	30	20	62	100
Hg	g/t dry weight	1	0.3	0.8	10
Zn	g/t dry weight	400	200	500	2500
As	g/t dry weight		15	13	20
Se	g/t dry weight			2	
Foreign matter	% of dry weight maximal size [mm]			< 0.5 12.5	
Maturity	C/N			< 25	< 20

The two West European countries have the strictest standards while the standards of India are one to twenty times higher. Canadian standards are somewhere in between. Bangladesh itself has no quality standards for compost.

7.4 Odor problems

Aerobic decomposition should not produce any bad smell. But if the decomposition becomes partly anaerobic, odor (caused by CH_4 and ammonia) is produced. In the Mirpur plant, strong odor is sometimes emitted during turning (especially in the early stage of composting), which indicates that the system is partly in an anaerobic state. Although the odor is not harmful, it can be a nuisance for the neighbourhood and can create public opposition against a composting site. The household survey showed that the impact of odor is limited to a radius of 25 m from the border of the plant.

The screened organic residues, added to a new pile, help controlling odor, because they act as a biofilter (the already present organisms absorb and decompose the malodorous components [Lardinois, 1993]).

[7] Swiss Ordinance on Hazardous Substances, 16.9.1992
[8] The Netherlands Standards since January 1995
[9] Canadian National Compost Standards, Standards Council of Canada, Category A compost
[10] Government of India, SWM rules, 1999

8. Quality and Quality control

Table 28 shows a comparison between compost produced by Waste Concern, typical values in other countries and Swiss and Indian Standards.
The comparison shows that the compost of Waste Concern has a high nutrient content (N, P, K) and therefore has a good soil fertilising value. The concentrations of zinc and cadmium exceed the Swiss Standards but not the Indian Standards. Cadmium concentration is five to six times higher than the Swiss Standards. But one also has to consider that the farmers of Bangladesh apply only a small amount of compost compared to Swiss farmers [personal communication with I. Enayetullah, April 2001]. This is due to the limited financial resources of Bangladesh farmers. So any accumulation in the soil will take a long time. But as both the amount of applicated compost and the concentration of the heavy metals may rise in future, the development of these parameters should be followed to detect an increase in their concentration early (allows to take measures).
In the case of Mirpur, the compost quality is measured regularly: As the agreement with M/S. MAP Agro Industries demands a minimum amount of NPKS and a maximal water content (N-1.2%, P-0.9%, K-1.5%, S-0.4%, H_2O < 12%), physical and chemical analysis are done every month at the SRDI where the pH, organic carbon, total nitrogen (N), phosphor (P_2O_5), potassium (K_2O), sulphur (S), boron (B), zinc (Zn), lead (Pb) and cadmium(Cd) are determined.
But not only the chemical analysis plays a role in quality control - the users of compost also have a control function: If the result (crop yield) does not meet the expectations or the price is too high, they will not buy the compost. It is therefore advisable that the producer does some (demonstration) farming himself so that he can locate any problems in an early stage.

TABLE 28 COMPARISON OF PARAMETERS OF WASTE CONCERN COMPOST WITH OTHER COMPOSTS AND STANDARDS

Parameter		Windrow Technique 28. Feb 01 1)	Windrow Technique 11. Mar 01	municipal waste compost 1)	composted material 2)	Switzerland 3) range	Swiss Standards	Indian Standards
TS	[%]		75.90			35-60		
OS	[% TS]	31.03	32.86	22-25		20-50		
Ntot	[g/kg TS]	21.00	23.80	13	4-35	6-16		
P	[g/kg TS]	17.47	12.40	8	1.3-15.3	1-4		
K	[g/kg TS]	21.57	16.92	9	4.1-14.9	3-15		
Zn	[mg/kg TS]	400	470			100-400	400	2500
S	[g/kg TS]	3.9	4.5					
B	[mg/kg TS]	300	278					
Pb	[mg/kg TS]	4	0				120	500
Cd	[mg/kg TS]	5	6				1	20

1) Source: EQI
2) Source: Cross and Strauss, 1985
3) from CARDINAS et al., 1989

9. Marketing of compost

9.1 General comments

One of the crucial points which decides about the financial viability of a composting activity is the marketing of the compost. Only if this aspect can be solved satisfactory, a composting plant can be run commercially.
A market for compost can not be created from one day to another as it is a new product. Most of its potential users are not aware of its benefits. They therefore have to be informed through written documents like leaflets and advertisements as well as through discussions and demonstration projects. The last part is especially important in Bangladesh as many farmers are illiterate. But even if the farmers know the benefits, they will only buy compost if they consider the price as reasonable compared to the price of chemical fertilisers.
It is advisable to make use of private specialised marketing companies as their network (transport and distribution) and experience can be used. If the marketing is done through the community itself, the market radius is usually limited because of the increasing transport costs (these costs usually are added to the market price). In addition, investment costs to build a new network are quite high and it needs too much time.

9.2 Transport costs

As mentioned above, the transport costs have to be added to a basic price (= price if compost is sold directly at the composting site). Transport costs in Bangladesh are about Tk.0.0045/(kg,km) respectively Tk.0.45/(kg,100 km) [personal information from M/S. MAP Agro Industries, April 2001].
If Waste Concern marketed and sold their compost themselves, they would have to increase their selling price from Tk.2.5/kg (basic price) according to the transport distance (if a coverage of the transport costs is required). After a certain distance, compost would no longer be competitive because of the higher price.

9.3 Marketing of the compost of Waste Concern

In the case of Waste Concern, the compost is sold to M/S. MAP Agro Industries which acts on behalf of Alpha Agro Ltd.. Alpha Agro Ltd. is one of the biggest fertiliser trading companies in Bangladesh and covers 64 districts. The transport distance to the users is between 64 and 480 km. Alpha Agro calculated the average transport costs as Tk.1.1/kg, what is included in their selling price of Tk.6/kg (retail price). The addition of the average costs allows them to sell the compost at the same price throughout the country. The company has their marketing officer in every district who is responsible to inform the farmers about their products (chemical fertiliser, enriched compost, pesticides) through leaflets, advertisements and discussions.
A detailed analysis of the marketing situation can be read in [Qaiyyum, 2001].

The example of Alpha Agro Ltd. shows, that it is possible to market compost within a large radius - this finding stands in contrast to other examples in Asia which suggest that the market radius of compost is limited to 25 km from the plant because of a lack of competitiveness [Lardinois, 1993].

10. Recommended steps for the implementation of a composting plant

Community based composting projects are based on the idea that households, who generate the waste, should bear part of the responsibility for its proper disposal. It needs time to change the behaviour of households and communities, but once on the right way, they can play an important role in reducing the volume of the waste stream.

10.1 Necessary steps for the introduction

When planning to introduce a composting activity, one has to be aware that finding a suitable location and starting the composting does not guarantee a success as it needs also a market for compost or at least the prospect of building a market in the near future. Therefore the first step is to conduct a market study which gives answer to following questions:

- Who are the potential users? (⇒ required quality of end product (screening necessary?))
- Where are the potential users? (⇒ preferable location of the site (short transport distance of compost))
- What is their potential demand? (⇒ required capacity of the composting plant)

Only if the market study shows, that there is a (potential) market, following steps can be undertaken (step 1&2 should be tackled simultaneously):

1. *Identification of a community with a potential interest in the introduction of a door-to-door waste collection system and a composting site*
   First of all, the households have to be informed what the idea of a community based composting project is and what would be expected from them, if the activity was introduced. Then a questionnaire survey among the households can be undertaken to find out if they have any interest - emphasis should be laid on following questions:
   a) Do the households approve of introducing a collection and composting system?
   b) Are they willing to participate through:
      - giving their waste to the collectors?
      - paying a monthly service charge for the collection and the cleaner environment? Which amount are they ready to pay?

   If the survey shows that the community has an interest, the next steps can follow.

2. *Identification of the location of the composting site*
   Potential locations within the community and their owners have to be found out. Whenever possible, the land should be provided free of charge as it is difficult to run a site economically if a site rent has to be paid.
   When choosing the optimal location out of the potentials, it is best to do that with the participation of the inhabitants as they know their area, problems and preferences best.

3. *Application and agreement with the landowner*
   An agreement that includes the planned duration of the project, financial aspects and other conditions has to be signed.

4. *Arrangement of loan facilities for the initial phase of the project*

5. *Construction of the composting site, identification and instruction of plant-workers*
The workers, which will rule the plant, should carefully be chosen as the success of the composting process mainly depends on them. They have to be introduced with the composting system - either through training on an existing composting plant or through an instruction on the new plant itself through trained people.
When developing the design of the site, enough space for future expansion possibilities should be calculated.

6. *Introduction of the door-to-door waste collection*
To persuade the households of the improvements that can be reached through the new system and that these are worth paying a fee, the collection should be free of charge during an initial phase of one to three months.

7. *Starting of the composting process and finding of a market for the compost*
The marketing is favourably solved through an agreement with a marketing company, so that the responsibility for the marketing does not lie on the community. If a direct link with a marketing company is not possible because some may refuse to negotiate with small producers, several communities should work together in their marketing.

During all these steps, some time has also to be spent for building awareness among the citizens regarding source separation, recycling and resource recovery of solid waste. This can be done through posters and leaflets, discussions, training courses and demonstration projects.

If the target is that the plant is independently run by the community after a certain time, following steps are recommended:

- Building of a Green Force with interested members of the community - through an awareness program including training and workshops, the future motivation can be ensured.

PICTURE 20 COMMUNITY MOBILISATION

- Identification of Group leaders within the community: the inhabitants can talk with them about their problems and complaints and these can be solved (if needed with the help of Waste Concern).
- Monitoring activity of Waste Concern after handing over the project to the community: this helps preventing any decrease of quality and advise can be given if new (technical) problems arise.

10.2 Recent development in Dhaka city concerning community based composting

In Dhaka, different organisations have recently shown interest in composting activities and are willing to support the idea through providing land to Waste Concern. Recently, agreements have been signed with following organisations:

- The Public Works Department (PWD) of the Government: they gave permission for the use of land at six different Governmental Colonies (Baily Road, Azimpur, Jigatola, Green Road, Mirpur, Motijheel). The composting plants in Baily and Green Road are already in use and Baily Road was already handed over to the community.
- DCC: They give their land for the Dhollpur plant and it is planned to hand over the plant to DCC after one year (according to Art. 140, DCC Ordinance, DCC can sponsor or promote community development projects for the city).
- Dhaka University (Shahidullah Hall)

The money for the construction is given by the UNDP under the Ministry of Environment and Forest. They initiate the replication of the decentralised composting project under their Sustainable Environmental Management Program (SEMP).

11. Final comments

1. Recent development in Bangladesh

In the last months, the awareness building programs among users started to show effects - the demand for normal and enriched compost is rapidly increasing. Farmers start using compost for horticulture, especially vegetable crops, and seeing the benefits of compost, they demand more. Besides of Alpha Agro Ltd., two other companies have shown interest in compost of Waste Concern:

- A Memorandum On Understanding (MOU) has been signed with Proshika (organisation with the aim to develop sustainable agriculture) - they are planning to apply raw compost[11] on 12000 acres of land[12].
- Duncan Brothers, a Tea Company, wants to try out the compost of Waste Concern.

As the demand is rising, the production level of Mirpur-2 should be increased towards full capacity (meanwhile, six more bamboo aerators have already been bought) and more composting projects should be introduced all over the country.

2. Support of the Municipality

The municipalities should support every effort to introduce composting activities as it saves them costs and/or increases their capacity in solid waste management. The lifetime of their landfills can be extended and they are able to meet the increasing waste generation in future. It is important to seek contact with them to make them aware of the advantages that result for them.

3. Quality of compost

The quality of the compost produced by Waste Concern is satisfactory - high nutrient contents and at present acceptable levels of heavy metals. The temperature curve and the helminth eggs test show that pathogenic micro-organism are killed initially. The compost can help to increase the soil fertility and the crop yield. Some problems have been found concerning the maturity of the compost - raw compost can hamper the plant grow [Dorau, 1992]. This issue therefore should not be neglected.

The quality should be controlled regularly so that problems can be detected early. It is to be feared that contents of heavy metals might rise with the rising living standards in developing countries as the quantity of inorganic and toxic elements might rise due to new consuming habits [CREPA, 1996]. The problem of the contamination with heavy metals through these elements could be solved through the introduction of an initial household separation of organic and inorganic material.

4. Composting potential in Dhaka

Around 63% (2205 tons) of the daily generated solid waste in Dhaka is compostable [see Appendix A]. According to a recent study by Waste Concern [Potential Sites for Decentralised Composting], enough space is available to convert this organic fraction into compost. 400 tons of the remaining amount of waste are recyclables, so that only 925 tons have to be dumped every day. Although all waste then could be collected, the reduced waste stream would still save transport costs and dumpsite area compared with the present situation.

[11] raw compost = decomposed material without screening
[12] 1 acre = 4047 m^2

12. Future research recommendations

In future research work, attention should be given to following subjects:

1. Change in process through different seasons
This study was carried out during the dry seasons (January to April 2001). Except for one event, no rainfall was recorded and the humidity was relatively low. To get a real picture of the composting process, similar data should be collected in different seasons (focus on output of compost (also the dependency on water content) and some chemical parameters (C, N, P, K)). The C/N-ratio should be checked – if the data show, that it is always that low, less additives should be added - this will also save costs. If a high nitrogen content is desired for the agricultural use, this nutrient can be added to the finished compost, it then does not influence the composting process any more. The maturity of the compost should be observed through temperature monitoring and maturity tests as some problems were detected here. Efforts should be made to find out if the maturity can be increased with a proper handling of the water content and turnings or if other changes in the process should be made. The maturity is important for the recommended use.

2. Optimal procedure and quality when using vegetable waste from the market
Recently, Waste Concern started to collect vegetable waste from a local market in Mirpur-1, Dhaka, to increase their production level. Vegetable waste has a higher water content than household waste (=> leachate) and might have a different composition. Experiments should be carried out to find out which procedure leads to the best results (chemical parameters and output):

- piling of vegetable waste alone
- mixing of vegetable waste with household waste (optimal percentage)
- optimal turning and decomposition time

3. Effect of the application of Effective Micro-organisms (EM) and BAT 506
Waste Concern and Proshika plan to experiment with Effective Micro-organisms and Waste Concern recently imported BAT 506 from the USA. These micro-organisms are said to accelerate the composting process (BAT 506: 28 instead of 40 days for composting) and to reduce the odor. Parallel studies with and without these micro-organisms should be conducted to answer questions about the effect on the duration of the process, the quality, the odor and the efficiency.

4. Information about barrel-type composting
Following data should be collected:

- Input vs Output (efficiency of the process)
- Financial situation
- Temperature curve (important for the killing of pathogens - if only small amounts of raw material are composted at a time, temperature may not rise enough to reach the necessary temperature to kill pathogenic organisms)
- Chemical parameters (nutrients and heavy metals)

13. Literature

ALTER AGO, CREPA, IAGU, SANDEC (1996), Giving value to organic wastes in low-income areas of African towns(in French), Project FNRS No. 5001-038104, Module 7, Développement et Environnement, Program Prioritaire Environnement, Fonds National Suisse de la Recherche Scientifique, Swiss Center for Development Co-operation in Technology and Management, SKAT, ST. Gallen, Switzerland

BERTOLDI DE, M., Vallini, G. and Pera, A. (1983). The Biology of Composting: A Review, Waste Management & Research, Vol. 1, p. 157-176

BERTOLDI, M. et al, The Science of Composting, European Commission International Symposium, p. 247 - 254

BHUIYAN, MD.S.H. (1999), Solid Waste Management in Dhaka City, Dhaka City Corporation

CARDINAS, T., BESSON, J.-M. AND HUMBEL, S. (1989), Inquiry on the quality of compost gained from separately collected domestic waste (in German), Sonderdruck aus dem Tätigkeitsbereich FAC 1987-1988, Landw. Jahrbuch Schweiz, 103.pp.445-470

CPIS (1992), Panduan Praktis Pembuatan Kompos (Practical Handbook on Composting), Center for Policy and Implementation Studies (CPIS) and Harvard Institute for International Development (HIID), Jakarta, Indonesia

COINTREAU, SANDRA J., Environmental Management of Urban Solid Wastes in Developing Countries, A Project Guide, p. 11-13

CROSS, P AND STRAUSS, M., Health aspects of nightsoil and sludge use in agriculture and aquaculture, IRCDW Report No, 04/85, Duebendorf, Switzerland

DORAU, D.A. (1992), Solid Waste Compost Standards, Air &Waste Management Association, Black & Veatch, Kansas City, Missouri

EQI (Environmental Quality International), unpublished paper, 1989

GOVERNMENT OF BANGLADESH, Ministry of law, justice and parliamentary affairs, The Dhaka City Corporation Ordinance, 1983

GOVERNMENT OF BANGLADESH, Environmental Policy 1992 and implementation work

GOVERNMENT OF BANGLADESH (1998), National Policy for Safe Water and Sanitation, Local Government Division, Ministry of Local Government, Rural Development and Co-operatives, Dhaka

GOVERNMENT OF BANGLADESH (GoB), THE WORLD BANK (1998), Refuse Quality Assessment of the Dhaka City Corporation Waste to Electrical Energy Project, a report prepared by the Institute of Fuel Research and Development, Bangladesh Council of Scientific and Industrial Research

GOVERNMENT OF BANGLADESH (GoB), World Bank (1998), Refuse Quality Assessment of Dhaka City Corporation Waste to Electrical Energy Project, prepared by the Institute of Fuel Research and Development, Bangladesh Council of Scientific and Industrial Research

GOVERNMENT OF SWITZERLAND (1986), Swiss Ordinance on Hazardous Substances

HOQ, M., LECHNER, H. (1994), Aspects of solid waste management: Bangladesh context, German Cultural Centre, Goethe Institute Dhaka, p.113-119

KUPPER, T. (1995), Sampling of compost (in German), FAC, Liebefeld-Bern, Switzerland

LARDINOIS, I., KLUNDERT, A.V. (1993), Organic Waste: Options for Small-Scale Resource Recovery, TOOL, Amsterdam, The Netherlands

LIEROP, VAN W. et al.(1992), Handbook on composting and digestion of GFT-waste Ministerie van Volkshuisvesting, Ruimteliijke Ordening en Milieubeheer, Nederland

NRAES (Northeast Regional Agricultural Engineering Service), Composting to reduce the waste stream, Co-operative extension

POTENTIAL SITES FOR DECENTRALIZED COMPOSTING: A Spatial Analysis for Dhaka City (1999), carried out by Waste Concern with support from Regional Urban Development Office (RUDO), South Asia, USAID

QAIYYUM, N. (2001), Study on marketing aspects of various fertilisers (especially organic fertiliser) in Bangladesh, in print

SINHA, A.H. M.M., ENAYETULLAH, I. (1999), Community based decentralised composting, Experience of Waste Concern in Dhaka, Urban Management h-novation, Case Study No.3

SINHA, A.H. M.M., ENAYETULLAH, I. (2000A), Community based solid waste management: The Asian Experience, Waste Concern, Bangladesh

SINHA, A.H. M.M., ENAYETULLAH, I. (2000B), Study on resource recovery from Solid Waste in Khulna City, Waste Concern, Water and sanitation program - South Asia

SULTANA, S. (2001), Study on technical aspects of organic waste recovery in Dhaka city, unpublished report of the Composting project

THE DAILY STAR (2001), Dhaka: challenges of a mega-city, 30.January

T'HART, D., PLUILMERS, J. (1996), Wasted Agriculture: The use of compost in urban agriculture, Urban Waste Expertise Programme, WASTE, Gouda, The Netherlands

THE WORLD BANK (1998), Sectoral Analysis in Bangladesh, Draft report, p. 4-4 - 4-7

THE WORLD BANK (2000), Urban Development Strategy and City Assistance Program in South Asia, Interim Report, p.2-30

USEPA (United States Environmental Protection Agency) (1994), Composting Yard Trimming and Municipal Solid Waste, Office of Solid Waste and Emergency Response, Washington

WASTE CONCERN, Aborjona o Paribesh, a newsletter on waste management and recycling in Bangladesh, No. 1-4

WENGER, K. (2000), Ligand-Assisted Phytoextraction of Heavy Metals from Contaminated Soils Using Common Crop Plants, Diss. ETH No. 13900, Zurich, Switzerland

WOODS END® RESEARCH, Guide to Solvita®Testing for Compost Maturity Index, Woods End Research Laboratory, Inc., Mt. Vernon, USA

ZURBRÜGG, CH., ARISTANTI, CH. (2000), Waste collectors are operating a composting unit on neighbourhood level: An Indonesian example in Sinha, A.H. M.M., Enayetullah, I. (Community based solid waste management: The Asian Experience, Waste Concern, Bangladesh

Appendix A: Organic fraction of the solid waste in Dhaka City

Source of waste generation	total waste generation	compostable waste	
	[tons/day]	[%]	[tons/day]
Residental	1715	85.17	1460.7
Commercial	735	71.19	523.2
Industrial	840	26.37	221.5
Hospital/Clinical	210	mainly hazardeous	
Total	3500	63.01	2205.4

Appendix B: About Standards of compost (BARC)

Bangladesh Agricultural Research Council

To
Mr. Maqsood Sinha
Waste Concern
House-21, Side-B, Road-7
Block-G, Banani Model Town
Dhaka-1213

5th February 2001

About Standards for Compost

It is in return of your application about the above topic that there is no need to fix a standard for organic fertiliser as it was decided by the National Technical Committee for fertiliser held at the Ministry of Agriculture (Memorandum No.6/fertiliser - 32/97 (Part.-I)/132; 16.6.2000). But nutrient concentration and other ingredients of the compost mentioned in your application should always maintain the right quality (N-1.44%, P-0.96%, K-1.6%, organic material-15.23%, moisture content-22.59%). The committee may visit your factory in case of necessity and analyse the compost to make sure that the compost reaches your standards.

Dr. Md. Shahidul Islam
Member - Director (Soil) and Addresser,
Mechanical sub-committee for fertiliser

translated from Bangla by Sharmin Sultana, Dhaka

Appendix C: Solvita Maturity Test [Wood End Research]

The Solvita®test kit allows to calculate a Maturity Index based on a simultaneous measurement of carbon-dioxide respiration and ammonia content of any sample of active or aged compost. The Index gives information about the momentary maturity of the sample and its recommended uses. As compost ages, it normally goes from a fresh condition (Solvita Index #1-2) to a mature state (Solvita Index #7-8).
Following Tables show the conclusions which can be drawn from the Maturity Index.

Table 1: Solvita® Compost Maturity Index and other Indexes

IF SOLVITA MATURITY INDEX IS:	THE STAGE OF THE COMPOSTING PROCESS IS:		Correlation with other maturity indicators[a]		
			DEWAR[(b)]	CO_2 Rate[(c)]	O_2-Rate[(d)]
8.	Inactive, highly matured compost, very well aged, possibly over-aged, like soil; no limitations for usage	"FINISHED" COMPOST	V	1	<3
7.	Well matured, aged compost, cured; few limitations for usage			2	5
6.	Curing; aeration requirement reduced; compost ready for piling; significantly reduced management requirements	"ACTIVE" COMPOST		4	11
5.	Compost is moving past the active phase of decomposition and ready for curing; reduced need for intensive handling		IV	6	16
4.	Compost in medium or moderately active stage of decomposition; needs on-going management		III	8	21
3.	Active compost; fresh ingredients, still needs intensive oversight and management		II	10	27
2.	Very active, putrescible fresh compost; high-respiration rate; needs very intensive aeration and/or turning	"RAW" COMPOST	I	12	32
1.	Fresh, raw compost; typical of new mixes; extremely high rate of decomposition; putrescible or very odorous material			>15	> 40

a. Approximate correspondence based on average organic matter and density.
b. DEWAR = Dewar self-heating test, a standard procedure in the U.S., Europe & Australia
c. CO_2 Rate = total mg CO_2-C evolved per g VS per day
d. O_2 Rate = mg oxygen (O_2) consumed per g VS per day

Table 2 Overview of Compost Conditions and Solvita Ratings

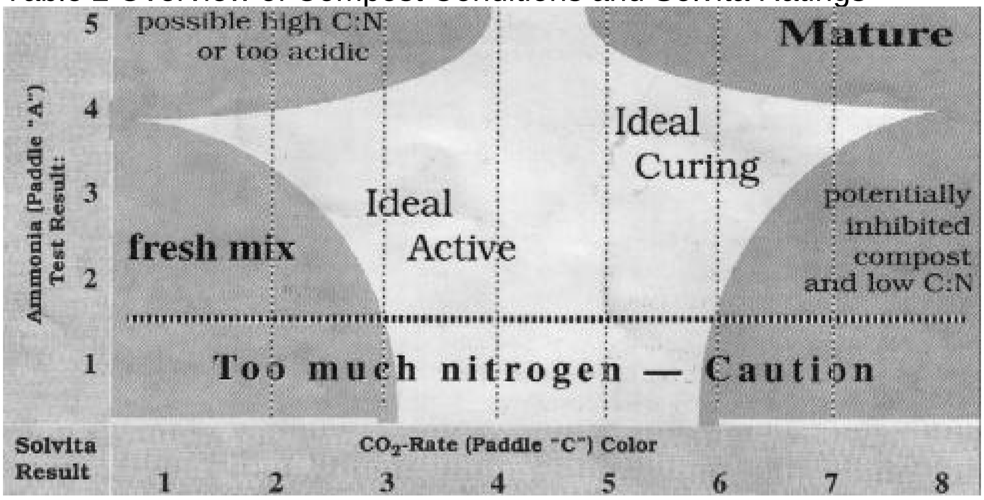

Table 3 Best Use of Compost

SOLVITA MATURITY INDEX	Raw Feedstock- Mushroom Compost	Landspreading on fallow soil; Mulch	Farm Row Crops, Field Cultivation	Hothouse Beds, Greenhouses	Orchards, Pastures, Hay Crops, Turf	Topsoil Substitute Blends	General Gardening	Bedding Plants, Container Media	Potting Mixes, Seedling Starters	Material in this class is comparable to:
8.					✔	✔	✔	✔	✔	soil & peat-based mixes
7.				✔	✔	✔	✔	✔	✔	soil mixes
6.				✔	✔	✔	✔			compost-soil blends
5.			✔	✔	✔					organic fertilizers
4.		✔	✔	✔						un-treated organic fertilizers
3.	✔	✔	✔							dehydrated manures
2.	✔	✔								raw-waste and most manures
1.	✔									raw-waste & some manures

Increase wait time prior to planting

Appendix D: Table for man-hour monitoring

	activity									
	collecting					sorting				
		time					time			
date	No. of workers	from	till	hours/worker	total hours/day	No. of workers	from	till	hours/worker	total hours/day

	activity									
	piling					turning				
		time					time			
date	No. of workers	from	till	hours/worker	total hours/day	No. of workers	from	till	hours/worker	total hours/day

	activity									
	screening					bagging				
		time					time			
date	No. of workers	from	till	hours/worker	total hours/day	No. of workers	from	till	hours/worker	total hours/day

Appendix E: Questionnaire for household survey

1. Name:
2. Age:
3. Education:
4. Occupation:
5. Number of Family Members:
6. Distance from the Site:

7. Since when have you been staying here?

8. Do you feel odor because of the site?

9. When do you feel the odor stronger?

Morning Afternoon Night

10. Which season do you feel the odor more?

Summer Rainy Winter

11. Do you have more mosquitoes because of the site?

Yes No

12. Can you say if there was a change in the frequency of diseases (indicate type) since the introduction of the composting plant?

Name of Diseases	Increasing	Decreasing
Stomach problem		
Fever		
Skin Diseases		
Malaria		
Dengue Fever		

13. Frequency of waste collection by Waste Concern?

Daily Once in every two days Once in a week

Twice in a week Thrice in a week

14. Which time of the day the wastes are collected?
Morning
Afternoon
Evening

15. Do you pay the collection fee?

Yes ... ... Taka / month

No

16. Is the amount that you pay ok for you?

Yes No

17. Do you find your area cleaner than before?

Yes No

18. Are you willing to pay more for a even cleaner environment?

Yes ... ... Taka / month

No

19. Are you satisfied with the service of Waste Concern?

20. Do you think improvement is needed? If yes, what kind of improvement is needed?

Appendix F: Temperature monitoring (in °C)

date	pile temperature				comments	weather in Dhaka city			
						air temperature		humidity [%]	
	top	middle	bottom	average		max.	min.	9 a.m.	6 p.m.
18-Jan	70	60	50	60.0		26.0			
19-Jan	70	60	50	60.0					
20-Jan	40	43.5	45	42.8	turning				
21-Jan	70	70	50	63.3		26.4	14.4	63	42
22-Jan	70	70	55	65.0		26.5	11.5	57	46
23-Jan	45	52.5	45	47.5	turning	26.7	15.7	69	61
24-Jan	70	70	50	63.3		25.7	15.4	59	25
25-Jan	40	42.5	40	40.8	turning	22.2	10.8	50	38
26-Jan	50	70	50	56.7		22.9	10.1	54	43
27-Jan	50	70	50	56.7		23.0	10.4	62	56
28-Jan	47.5	40	37.5	41.7	turning	24.0	10.7	68	53
29-Jan	47.5	70	50	55.8					
30-Jan	40	70	60	56.7		25.6	13.0	78	57
31-Jan	35	40	42.5	39.2	turning	27.8	14.4	81	59
01-Feb	43.5	60	50	51.2		27.3	17.8		
02-Feb	40	60	50	50.0		28.1	16.5	84	40
03-Feb	40	60	50	50.0					
04-Feb	30	30	40	33.3	turning	27.4	14.7	48	32
05-Feb	40	50	40	43.3		26.5	14.8	55	48
06-Feb	35	35	40	36.7	turning	26.6	16.0	60	43
07-Feb	40	40	50	43.3					
08-Feb	40	40	50	43.3					
09-Feb	39	39.5	50	42.8		26.3	12.7	52	36
10-Feb	40	40	50	43.3		26.4	13.5	67	36
11-Feb	30	40	50	40.0		28.5	12.8	51	38
12-Feb	30	30	40	33.3	turning	27.8	12.8	68	38
13-Feb	35	50	45	43.3		28.4	14.0	66	44
14-Feb	30	40	40	36.7		29.8	14.5	61	38
15-Feb	30	42	40	37.3		30.7	17.5	73	49
16-Feb	30	40	40	36.7					
17-Feb	30	35	40	35.0	turning	30.9	16.8	72	52
18-Feb	30	40	40	36.7					
19-Feb	30	40	40	36.7		31.4	17.7	55	56
20-Feb	30	30	40	33.3	turning	30.3	16.8	48	34
21-Feb	30	40	40	36.7					
22-Feb	30	40	40	36.7		28.0	18.8	79	56
23-Feb	30	40	40	36.7					
24-Feb	30	40	40	36.7	replacing of the pile	30.2	18.9	77	43
24-Feb	30.6		31.1	30.8	after replacing	30.2	18.9	77	43
25-Feb	38.6		33.0	35.8					
26-Feb	40.1		33.0	36.6					
27-Feb	40.3		36.2	38.3		30.0	22.0	77	30
28-Feb	38.1		32.3	35.2		30.5	20.7	79	53
01-Mar	42.7		34.3	38.5		30.2	21.2	68	56
02-Mar	35.4		31.7	33.5		31.0	21.0	59	44
03-Mar	30.6		29.3	30.0		30.7	20.5	32	30
04-Mar	28.0		27.3	27.7		29.6	17.2	36	29
05-Mar	26.0		25.0	25.5		26.8	17.5	33	62
06-Mar	26.0		25.0	25.5					
07-Mar	26.0		24.7	25.3					
08-Mar	26.1		24.7	25.4					
09-Mar	25.3		24.3	24.8		30.9	17.5	61	42
10-Mar	26.0		24.3	25.2		31.8	18.6	51	43
11-Mar	26.6		26.3	26.4	screening	32.6	16.6	40	29

Appendix G: Massflow through the composting system

1. Compost production with 8mm-sieve for screening

Date	organic waste*	weight after 40 days	compost production				ratio: 40 days/input	ratio: compost/40 days	ratio: 40 days/input assuming water content decrease from 75 to 50 %
			1st screening	2nd screening	total	% of input			
	[kg]	[kg]	[kg]	[kg]	[kg]	[%]			
Jan 00**	4000	1560	710	330	1040	26.0	0.39	0.67	0.78
Feb 00**	4000	1520	690	290	980	24.5	0.38	0.64	0.76
Mar 00**	4000	1580	750	330	1080	27.0	0.40	0.68	0.79
May 00**	4000	1550	700	220	920	23.0	0.39	0.59	0.78
Jul 00**	4000	1590	660	320	980	24.5	0.40	0.62	0.80
Aug 00**	4000	1570	760	300	1060	26.5	0.39	0.68	0.79
Sept 00**	3000	1200	450	300	750	25.0	0.40	0.63	0.80
Oct 00**	3000	1250	615	150	765	25.5	0.42	0.61	0.83
average						25.3	0.39	0.64	0.79

2. Compost production with 2mm-sieve for screening

Date	organic waste*	weight after 40 days	compost production				ratio: 40 days/input	ratio: compost/40 days	ratio: 40 days/input assuming water content decrease from 75 to 50 %
			1st screening	2nd screening	total	% of input			
	[kg]	[kg]	[kg]	[kg]	[kg]	[%]			
Nov 00**	3000	1230	330	260	590	19.7	0.41	0.48	0.82
Dez 00**	3000	1190	410	200	610	20.3	0.40	0.51	0.79
Jan 01**	3000	990	400	140	540	18.0	0.33	0.55	0.66
Jan 01	3000	1010	415	230	645	21.5	0.34	0.64	0.67
average		1105			596	19.9	0.37	0.54	0.74

2. Compost production with 4 mm-sieve for screening

Date	organic waste*	weight after 40 days	compost production				ratio: 40days/input	ratio: compost/40days	ratio: 40 days/input assuming water content decrease from 75 to 30 %
			1st screening	2nd screening	total	% of input			
	[kg]	[kg]	[kg]	[kg]	[kg]	[%]			
Mar 01	3000	710	342	69	411	13.7	0.24	0.58	0.66
Apr 01	3000	720	270	75	345	11.5	0.24	0.48	0.67
Apr 01	3000	870	300	80	380	12.7	0.29	0.44	0.81
Apr 01	3000	750	310	105	415	13.8	0.25	0.55	0.70
average		762.5				12.9	0.25	0.51	0.71

=> average ratio 40 days/input = 0.76

*measured by bucket (estimated weight of one bucket = 10 kg)
**data provided by Waste Concern

Appendix H: Net Present Value

1. present situation

a) without recyclables

	year										
	0	1	2	3	4	5	6	7	8	9	10
Investment (US$)	-9164					900					
Revenues (US$)		8759	8759	8759	8759	8759	8759	8759	8759	8759	8759
Operation Cost (US$)		7200	7200	7200	7200	7200	7200	7200	7200	7200	7200
Net Cash Flow (US$)	-9164	1559	1559	1559	1559	659	1559	1559	1559	1559	1559
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Present Value (US$)	-9164	1356	1179	1025	891	328	674	586	510	443	385
Net Present Value (US$)	-1787										

b) with recyclables

	year										
	0	1	2	3	4	5	6	7	8	9	10
Investment (US$)	-9164					900					
Revenues (US$)		9121	9121	9121	9121	9121	9121	9121	9121	9121	9121
Operation Cost (US$)		7200	7200	7200	7200	7200	7200	7200	7200	7200	7200
Net Cash Flow (US$)	-9164	1921	1921	1921	1921	1021	1921	1921	1921	1921	1921
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Present Value (US$)	-9164	1670	1453	1263	1098	508	831	722	628	546	475
Net Present Value (US$)	30										

2. situation when running with maximal capacity

a) without recyclables

	year										
	0	1	2	3	4	5	6	7	8	9	10
Investment (US$)	-9764					1500					
Revenues (US$)		15815	15815	15815	15815	15815	15815	15815	15815	15815	15815
Operation Cost (US$)		10631	10631	10631	10631	10631	10631	10631	10631	10631	10631
Net Cash Flow (US$)	-9764	5184	5184	5184	5184	3684	5184	5184	5184	5184	5184
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Present Value (US$)	-9764	4508	3920	3409	2964	1832	2241	1949	1695	1474	1281
Net Present Value (US$)	15508										

b) with recyclables

	year										
	0	1	2	3	4	5	6	7	8	9	10
Investment (US$)	-9764					1500					
Revenues (US$)		16470	16470	16470	16470	16470	16470	16470	16470	16470	16470
Operation Cost (US$)		10631	10631	10631	10631	10631	10631	10631	10631	10631	10631
Net Cash Flow (US$)	-9764	5839	5839	5839	5839	4339	5839	5839	5839	5839	5839
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Present Value (US$)	-9764	5077	4415	3839	3338	2157	2524	2195	1909	1660	1443
Net Present Value (US$)	18795										

1. present situation, including savings of DCC

a) without recyclables

	year										
	0	1	2	3	4	5	6	7	8	9	10
Investment (US$)	-9164					900					
Revenues (US$)		8759	8759	8759	8759	8759	8759	8759	8759	8759	8759
Cost reduction for DCC		10235	10235	10235	10235	10235	10235	10235	10235	10235	10235
Operation Cost (US$)		7200	7200	7200	7200	7200	7200	7200	7200	7200	7200
Net Cash Flow (US$)	-9164	11794	11794	11794	11794	10894	11794	11794	11794	11794	11794
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Present Value (US$)	-9164	10256	8918	7755	6743	5416	5099	4434	3855	3353	2915
Net Present Value (US$)	49580										

b) with recyclables

	year										
	0	1	2	3	4	5	6	7	8	9	10
Investment (US$)	-9164					900					
Revenues (US$)		9121	9121	9121	9121	9121	9121	9121	9121	9121	9121
Cost reduction for DCC		10235	10235	10235	10235	10235	10235	10235	10235	10235	10235
Operation Cost (US$)		7200	7200	7200	7200	7200	7200	7200	7200	7200	7200
Net Cash Flow (US$)	-9164	12156	12156	12156	12156	11256	12156	12156	12156	12156	12156
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Present Value (US$)	-9164	10570	9192	7993	6950	5596	5255	4570	3974	3455	3005
Net Present Value (US$)	51397										

2. situation when running with maximal capacity, including savings of DCC

a) without recyclables

	year										
	0	1	2	3	4	5	6	7	8	9	10
Investment (US$)	-9764					1500					
Revenues (US$)		15815	15815	15815	15815	15815	15815	15815	15815	15815	15815
Cost reduction for DCC		18518	18518	18518	18518	18518	18518	18518	18518	18518	18518
Operation Cost (US$)		10631	10631	10631	10631	10631	10631	10631	10631	10631	10631
Net Cash Flow (US$)	-9764	23702	23702	23702	23702	22202	23702	23702	23702	23702	23702
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Present Value (US$)	-9764	20610	17922	15584	13552	11038	10247	8910	7748	6738	5859
Net Present Value (US$)	108445										

b) with recyclables

	year										
	0	1	2	3	4	5	6	7	8	9	10
Investment (US$)	-9764					1500					
Revenues (US$)		16470	16470	16470	16470	16470	16470	16470	16470	16470	16470
Cost reduction for DCC		18518	18518	18518	18518	18518	18518	18518	18518	18518	18518
Operation Cost (US$)		10631	10631	10631	10631	10631	10631	10631	10631	10631	10631
Net Cash Flow (US$)	-9764	24357	24357	24357	24357	22857	24357	24357	24357	24357	24357
Discount Factor (15%)	1.0000	0.8696	0.7561	0.6575	0.5718	0.4972	0.4323	0.3759	0.3269	0.2843	0.2472
Present Value (US$)	-9764	21180	18417	16015	13926	11364	10530	9157	7962	6924	6021
Net Present Value (US$)	111732										

Appendix I: List of abbreviations

CBO	Community Based Organisations
DCC	Dhaka City Corporation
EAWAG	Swiss Federal Institute for Environmental Science and Technology
GoB	Government of Bangladesh
LCPE	Laboratoire de Chimie Physique pour l'Environment (laboratories for physical chemistry of the environment)
NGO	Non Government Organisation
NPK	Chemical fertiliser with nitrogen (N), phosphorus (P) and potassium (K)
PWD	Public Works Department
RUDO	Regional Urban Development Office
SANDEC	Swiss Institute for Environmental Science (Sanitation in Developing Countries)
SEMP	Sustainable Environmental Management Program
SRDI	Soil Resource Development Institute
SWM	Solid Waste Management
UNDP	United Nations Development Program
USAID	United States Agency for International Development
WC	Waste Concern