*M. Alamgir, K.A.B.M. Mohiuddin, S.M.T. Islam, and M.H. Hasan (Eds.)*
*ISBN: 978-984-33-8695-3, PI.149 (1-10)*

*Proceedings of the WasteSafe 2015 – 4th International Conference on Solid Waste Management in the Developing Countries*
*15-17 February 2015, Khulna, Bangladesh*

# Design of Integrated Solid Waste Management System of Kakonhat Municipality

**Md. Noman Parvez[1], Md. Niamul Bari[2] and Md. Shahin[3]**
[1]*Executive Engineering, Kakonhat Municipality, Godagari, Rajshahi.*
[2] *Professor, Department of Civil Engineering, Rajshahi University of Engineering & Technology*
[3]*Lecturer, Department of Resource Management, Faculty of Disaster Management, Potuakhali Science and Technology University*

## Abstract

*A study is carried out for the design of municipal solid waste management system of Kakonhat municipal area considering integrated approach. Kakonhat is in the Barind tract under Godagari Upazila of Rajshahi district. The existing information is collected and used to design the system. Integrated approach of solid waste management comprises wastes sorting, resource recovery by reusing, recycling and bioconversion and finally sanitary landfill is designed in this study. Landfill liner, cover material, leachate management and landfill gas management are not required in this system because of only inert waste materials are disposed in landfill. Total land area required for sanitary landfill in integrated approach is 1279 $m^2$. The total requirement of manpower, waste collection van and compaction equipment for waste management are of 44 people, 13 numbers and 1 number, respectively. Eventually, the design of solid waste management system will be helpful to develop the Kakonhat municipal area providing the modern facilities to their local people.*

***Keywords:*** *Solid wastes management, integrated approach, composting, landfilling*

## Introduction

Kakonhat Municipality is newly established in the year of 2002 at the northern part of Bangladesh in the Godagari Thana under Rajshahi district. It is a “B” category municipality having population of about 13,000 covering an area of 20.05 sq. km. As it is a new municipality physical infrastructure is not yet developed. It is necessary to mentioned that this area is situated in Barind tract, a very high and flood free area which is under the arid and draught region of northern part of the Bangladesh (BMDA, 2003). The area has economic importance because of large quantity of paddy crop is produced in this region and meets up a part of food demand of Bangladesh as well as large scales of cattle and dairy firms have developed to contribute to the national economy.

It is revealed from the field observation that the existing environmental condition of the municipal area is very poor. Most of dwellers of the municipal area used to dispose solid waste in the vicinity of the household, nearby ditches, canals, drains and vacant places which can adversely impact on environment (Enayetullah, 1994). Solid wastes are mainly produced in household, market place, crop production field, small industries and streets. Loading and unloading and carrying of soils and sand without any dust preventing measures are also found within the municipality. As a result, the roads within the municipal area are very dirty. The area around the poultry markets are also found very nuisance having rotten waste and are spreading bad smell. Inadequate management of municipal solid wastes creates serious environmental degradation within the municipal area.

It appears that planned development of Kakonhat Municipality is very important for the development of this Municipality as Model Town (BKH, 1986; DMDP, 1992). At present, there is no proper planned solid waste disposal system for the development of Kakonhat Municipality as a Model Town. In the absence of proper planned solid waste disposal system the program related to above work is going on in an unplanned way. This situation is creating an adverse effect on the original landscape and thereby creating environmental hazards. The aim of this study is to develop a system of solid waste management for the development of Kakonhat Municipality as a Model Town.

## Methodology

To fulfil the objectives of the study, following activities are considered under the scope of the study those are sequentially and briefly described as below:

The background information of Kakonhat municipality like jurisdiction area, population, trend of infrastructural development, exiting resources, environmental conditions, etc. are collected and studied for the better understanding about the existing situation and future necessity.

An integrated solid waste management system is designed comprising, waste sorting for recycling, reuse, composting and sanitary disposal. A sanitary landfill site is also designed for ten years of design period for non bio-degradable and non-recyclable as well as non-reusable wastes. The municipal area is divided into two zones comprising ward no. 1, 2, 8 and 9 at northern part and ward no. 3 to 7 at southern part for efficient management system.

## Results and Discussions

Integrated solid wastes management can be employed by introducing the all possible option of solid waste utilization and disposal. Solid waste collection from the generation points and transfer and transport to the processing station or disposal point was followed by conventional method. Mainly three options vide selling of saleable portion, composting of the biodegradable portion and ultimate disposal of non-biodegradable inert and non-saleable portion by following conventional sanitary landfill were employed. Sorting operation was conducted for segregating the wastes into three major categories (Sinha, 1993). Sorting operation, composting and sanitary land filling were designed by employing standard methods at disposal site. A flow diagram of integrated approach of solid waste management in Kakonhat municipality is shown in Figure 1.

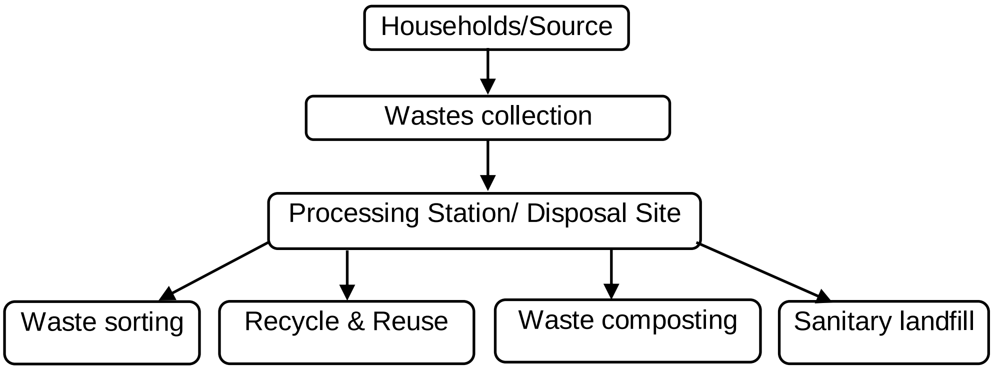


Figure 1: Flow diagram of Integrated Approach for Solid Waste Management

**Rate of Generation of Solid Waste**

Solid waste generation of Kakonhat municipality was estimated on the basis of total population of the study area and waste generation rate. Waste generation rate may vary place to place and season to season. To determine the possible maximum generation of wastes, field investigation was conducted in the study area. The generated wastes were collected with a rickshaw van from 62 houses. The daily average generated waste of 152.67 kg was collected from 252 people of 62 houses. The average population in each household was observed to be 4.1. The volume and weight of the collected wastes were measured to estimate the rate of generation of wastes and density of waste. The rate of generation of wastes was estimated to be 0.605 kg/capita/day. The size of the waste collected van is (1.22m×0.686m×0.838m) 0.70 $m^3$. The density of wastes as discarded basis was estimated to be 218 kg/ $m^3$.

**Composition of Generated Solid Waste**

The composition of generated wastes was determined by manual sorting. The result is expressed in percentage of weight. The ward wise total generated wastes according to the estimated rate of generation and their compositions are presented in Table 1 and 2. The Table 1 shows that the daily total generated wastes is 7711 kg and volume is around 35.4 $m^3$. The different constituents of wastes are paper, rag, plastic, leaf, vegetable, ash, polythene, rubber, glass, bricks, tin can, egg shell and wood (Table 2). The total generated solid waste can be classified into three major categories, such as reusable or recyclable, biodegradable or decomposable and non-reusable, non-biodegradable and inert. The composition analysis of collected wastes by sorting is presented in Plate 1. Figure 2 shows that about 68% of the total generated solid waste is biodegradable which can be used as raw material for the production of value added product through solid state bioconversion. The most common and easy option is production of compost. The second highest portion of 24% is usable, recyclable which can be sold to get back some money from waste material. The remaining part of 8% is non-usable and non-biodegradable that should be disposed of ultimately by any means. The easy way of disposal is the use of this material for filling the low laying land or dispose of by conventional landfill. The percentages of major categories of the generated wastes are presented in Figure 2.

Table 1 Ward wise generated wastes

| Ward No. | Household | Population | Population per Household | Generation Rate (kg/cap/day) | Generated Waste (kg) |
|---|---|---|---|---|---|
| 1 | 503 | 2054 | 4.08 | 0.605 | 1243 |
| 2 | 386 | 1669 | 4.32 | 0.605 | 1010 |
| 3 | 342 | 1342 | 3.92 | 0.605 | 812 |
| 4 | 291 | 1115 | 3.83 | 0.605 | 675 |
| 5 | 297 | 1259 | 4.24 | 0.605 | 762 |
| 6 | 334 | 1360 | 4.07 | 0.605 | 823 |
| 7 | 284 | 779 | 2.74 | 0.605 | 471 |
| 8 | 397 | 1733 | 4.37 | 0.605 | 1049 |
| 9 | 300 | 1431 | 4.77 | 0.605 | 866 |
| Total | 3134 | 12742 | 4.07 | 0.605 | 7711 |

Plate 1: Composition analysis of collected wastes by sorting

Table 2 Compositions of generated wastes in Kakonhat Municipality

<table>
<tr><th>Composition</th><th>weight (kg)</th><th>Composition</th><th>weight (kg)</th></tr>
<tr><td>Plastic</td><td>1.125</td><td rowspan="9">Reusable & Recyclable</td><td rowspan="9">37.08</td></tr>
<tr><td>Polythene</td><td>4.175</td></tr>
<tr><td>Rubber</td><td>1.1</td></tr>
<tr><td>Glass</td><td>12.7</td></tr>
<tr><td>Bricks</td><td>8.125</td></tr>
<tr><td>Tin can</td><td>2.9</td></tr>
<tr><td>Iron</td><td>0</td></tr>
<tr><td>Paper</td><td>5.175</td></tr>
<tr><td>Rag</td><td>1.775</td></tr>
<tr><td>Leaf</td><td>12.1</td><td rowspan="3">Biodegradable</td><td rowspan="3">102.64</td></tr>
<tr><td>Vegetable</td><td>90.3</td></tr>
<tr><td>Wood</td><td>0.24</td></tr>
<tr><td>Egg Shell</td><td>0.0515</td><td rowspan="2">Non-biodegradable & Inert</td><td rowspan="2">12.95</td></tr>
<tr><td>Ash</td><td>12.9</td></tr>
<tr><td>Total</td><td>152.6665</td><td>Total</td><td>152.67</td></tr>
</table>

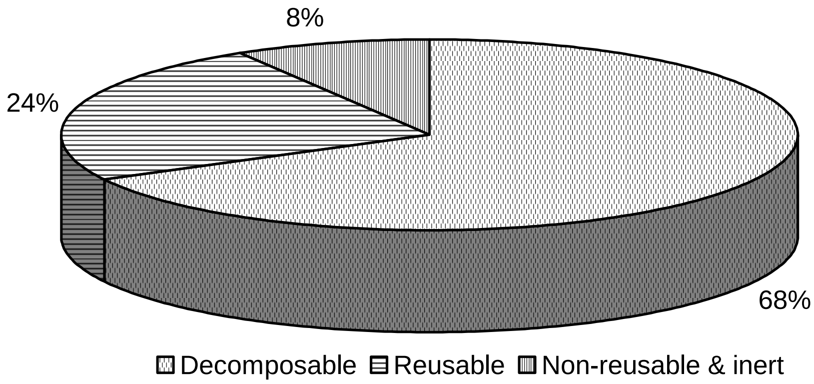


Figure 2: Major composition of generated wastes

The total volume of biodegradable (organic) wastes for site 1 is estimated to be 13 $m^3$ and for site 2 is 11 $m^3$ on the basis of 68% of total wastes.

**Collection of Solid Wastes**

Solid wastes collection would be conducted by Rickshaw Van and delivered to the waste processing station. The volume of collection rickshaw van is 0.70 $m^3$. One processing station should be constructed in each northern and southern part of area. Hence, the maximum travel distance for van during collection and transportation is around to be 2 km. The possible trip per day is considered based on the experience of field investigation is to be four. Detail estimation of ward wise requirements of rickshaw vans and waste collectors for the collection of waste is shown in Table 3. Total 13 nos. of rickshaw van and collectors are required for 9 nos. of wards. Plate 2 shows the collection of wastes with Rickshaw Van.

Plate 2: Collection of Wastes with Rickshaw Van

Table 3 Requirement of rickshaw van and collector

| Wards | Generated Waste (kg) | Volume of waste (m3) | Volume of van (m3) | No. of trip/day | No. of van | No. of collector |
|---|---|---|---|---|---|---|
| 1 | 1243 | 5.70 | 0.70 | 4 | 2 | 2 |
| 2 | 1010 | 4.63 | 0.70 | 4 | 2 | 2 |
| 3 | 812 | 3.72 | 0.70 | 4 | 1 | 1 |
| 4 | 675 | 3.10 | 0.70 | 4 | 1 | 1 |
| 5 | 762 | 3.50 | 0.70 | 4 | 1 | 1 |
| 6 | 823 | 3.78 | 0.70 | 4 | 1 | 1 |
| 7 | 471 | 2.16 | 0.70 | 4 | 1 | 1 |
| 8 | 1049 | 4.81 | 0.70 | 4 | 2 | 2 |
| 9 | 866 | 3.97 | 0.70 | 4 | 2 | 2 |
| Total | 7711 | 35.37 | 0.70 | 4 | 13 | 13 |

**Design of Integrated Approach**

An integrated approach has been designed by employing standard methods of sorting of wastes, composting and sanitary landfill at disposal site. Sorting of waste for recycling, composting of the organic fraction of the waste, and sanitary landfill of inorganic non-recyclable inert material and residue from compost plant at the ultimate disposal site. A flow diagram of Integrated Approach is shown in Figure 3 and in Figure 4 a layout plan of an integrated solid waste management site is shown also shown.

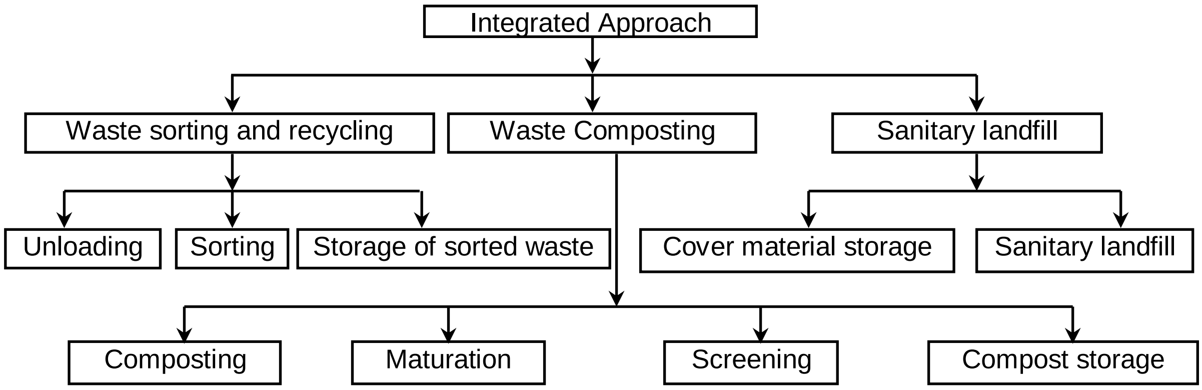


Figure 3: Flow diagram of total work execution at the disposal site employing Integrated Approach

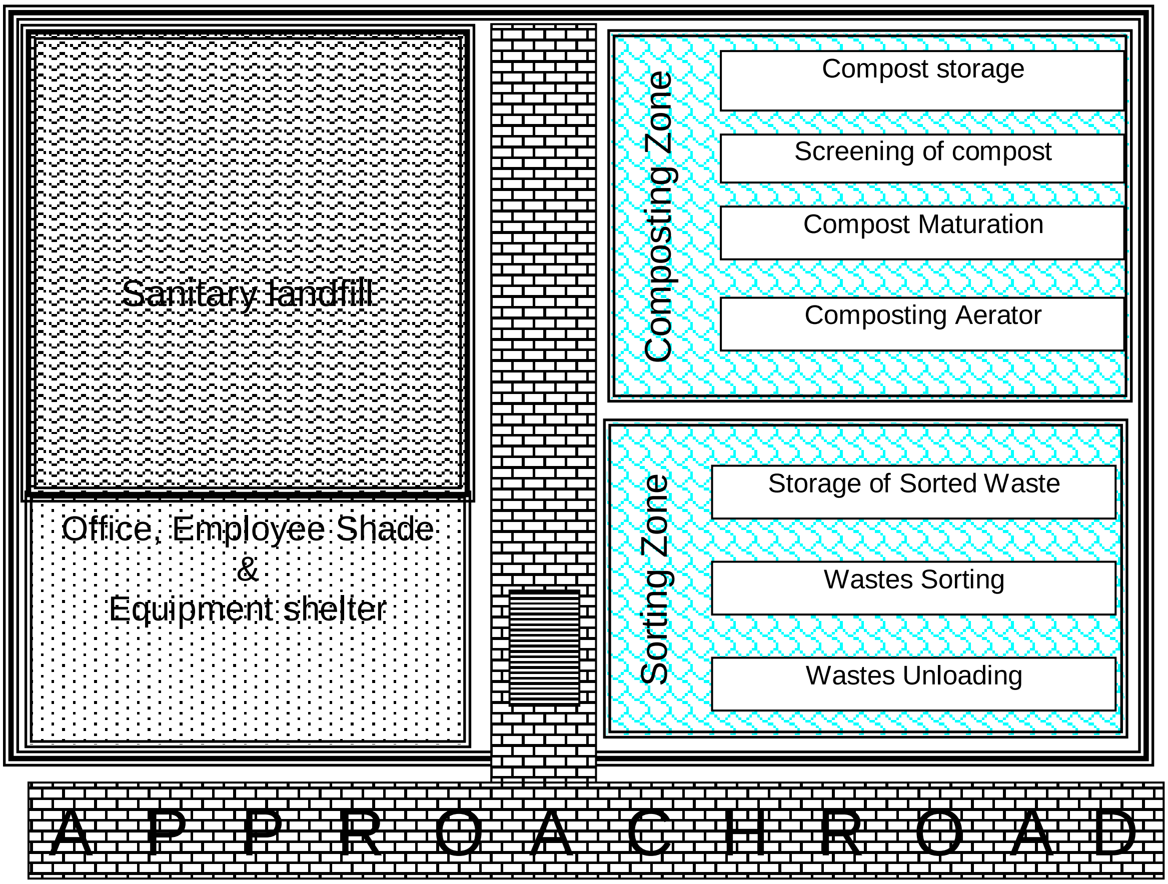


Figure 4: Typical layout plan of an integrated solid waste management site

The total site is divided into wastes sorting and recycling zone including waste unloading, sorting and storage of sorted wastes, composting zone including wastes composting, compost maturation, compost screening and compost storage, sanitary landfill zone including cover material storage and landfill and office zone including office, employee shade and equipment shelter. A platform scale for taking weight of wastes also present on the way of approach road.

The access road, drainage system, boundary wall are considered inside the processing and disposal site. Two processing and disposal sites are designed in the northern and southern part of municipal office considering at the centre point. The detail design of each component is shown below.

Sorting and Recycling Zone

Wastes sorting area is required for wastes unloading and sorting operation, and storage of sorted wastes. Unloading area would be equal to the area covered by number of rickshaw van, which unloaded at a time and area occupied by the unloaded wastes. Unloading area was accommodated for three rickshaw van at a time. Each rickshaw van occupies (2.14×0.7m) 1.5 $m^2$ and area required for three vans is 4.5 $m^2$. Height of the unloaded waste and sorted waste stack were considered 1 and 2.5m, respectively. The total waste sorting area is covered with shade. The requirement of total area for sorting operation and area of sorting shade are estimated in Table 4. Total area required for waste sorting shade is 31.27 $m^2$ at site 1 and 27.23 $m^2$ at site 2.

Table 4 Area requirement for waste unloading and sorting shade

| Site | Total waste | | Unloading area ($m^2$) | | Sorting area ($m^2$) | | | Total area ($m^2$) |
|---|---|---|---|---|---|---|---|---|
| | (kg/day) | ($m^3$/day) | Waste | Van | Organic | Reusable | Inorganic | |
| 1 | 4168 | 19.12 | 19.12 | 4.50 | 5.20 | 1.84 | 0.61 | 31.27 |
| 2 | 3543 | 16.25 | 16.25 | 4.50 | 4.40 | 1.56 | 0.52 | 27.23 |

Design of Compost Plant

In Integrated Approach composting operation would perform aerobically with natural microbial consortium. The organic waste would be pilled in box type aerator manually. The design of aerator would be followed as described by Bari (2003) which is used at Dhalpur composting plant of Waste Concern, Dhaka. The design of compost plant is associated with aerator, composting, maturation, screening and storage. The steps of composting activities are shown as a flow diagram in Figure 5.

Waste unloading → Sorting → Composting → Maturation → Screening → Storage

Figure 5: Flow diagram of composting

Design of Aerator

At Dhalpur site Waste Concern used box type composting system. Here a rectangular box has construct by brickwork. There are some regular openings in the wall. A mesh, made of M.S. rod, is placed at 150 mm above from bottom. Perforated PVC pipe of 100 mm diameter was placed vertically at some spacing in the piled wastes. Air would flow through the opening on wall, bottom of mesh and perforated pipe. Organic wastes were pile in this box. The length of aerator box is 3.00m, width is 1.22 m and height is 1.32 m. Volume of box is 4.83 $m^3$ and plan area is 3.66 $m^2$. Additional space will be provided surrounding the aerator box for comfortable work. The width of the working space around the box is assumed to be 1 m. Therefore, area required for each aerator box is 8.88 (4 x 2.22) $m^2$. Figure 6 shows the box type composting plant.

The sorted organic wastes will be placed into the aerator. Wastes then start to decompose aerobically with the help of bacteria. The decomposition period of organic wastes is in this case 25 days. To control moisture content and temperature water also added. After 25 days decomposed wastes is unloaded from aerator and stack for maturation on maturation place. Here decomposed waste is matured in 15 days to compost. Then the matured compost is screened and graded as finish produce. This finish compost is stored for sale.

The requirement of land area for composting shade is based on the volume of organic wastes that to be decomposed in aerator box. The volume of waste to be filled in each aerator box is considered as per design detail shown in Figure 6.7. The total number of boxes for maturation period of 15 days and required land area for composting is estimated as well. The result of estimation is presented in Table 5.

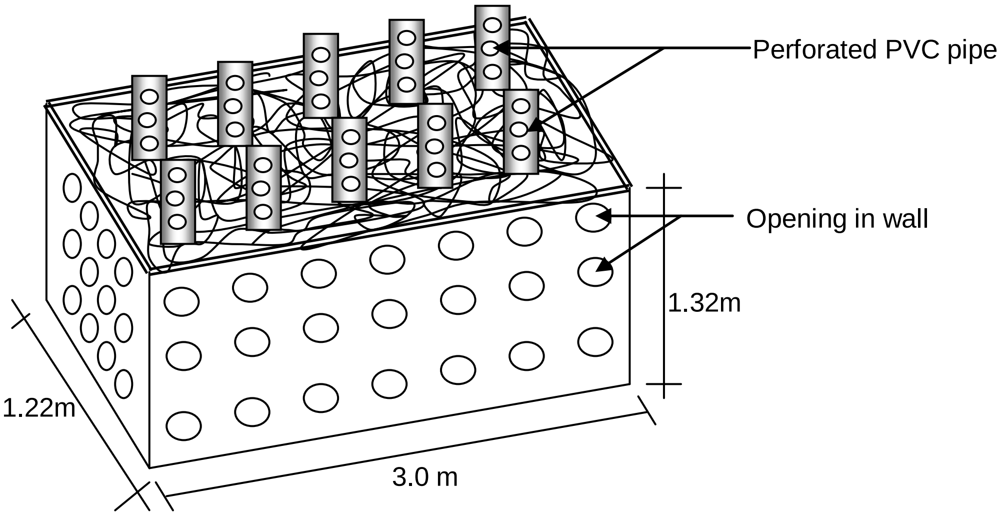


Figure 6: Box Type Composting Aerator

Table 5 shows that total 75 numbers of aerator boxes are required for the composting period of 25 days in each composting site. The land area required for composting operation is to be 666 $m^2$ for site 1 and site 2.

Table 5 Requirement of area for composting shade

| Site | Volume of waste ($m^3$) | Volume of aerator box ($m^3$) | No. of box | | Area for composting | |
|---|---|---|---|---|---|---|
| | | | Per day | 25 day | Single box ($m^2$) | Total ($m^2$) |
| 1 | 13 | 4.83 | 3 | 75 | 8.88 | 666 |
| 2 | 11 | 4.83 | 3 | 75 | 8.88 | 666 |

The field study conducted by Bari (2003) at Dhalpur composting plant showed that 11.67% volume of organic waste would be reduced due to the decomposition while it become compost. It is meaning that the volume of compost will be reduced to only 88.33% of the initial volume of organic wastes. Bari (2003) also conducted study on the density of compost as well as compost production rate and found to be 625 kg/$m^3$ and 22.5%, respectively. The stack pile height of decomposed wastes (compost before maturation) is considered to be 2.5 m for maturation operation for 15 days. On the basis of this study, the requirement of land area for maturation of compost is estimated and presented in Table 6. Table 6 shows that the land area required for site 1 and site 2 are 4.60 $m^2$ and 3.88 $m^2$, respectively. The quantities of compost are produced in site 1 and site 2 of 637.7 kg/day (1.02 $m^3$/day) and 542.1 kg/day (0.87 $m^3$/day), respectively are presented in Table 7.

Table 6 Area requirement for compost maturation (Maturation period 15 days)

| Site | Waste Volume | Reduced volume (%) | Compost volume for Maturation ($m^3$) | Stack pile height (m) | Area for Maturation ($m^2$) |
|---|---|---|---|---|---|
| 1 | 13 | 88.33 | 11.50 | 2.5 | 4.60 |
| 2 | 11 | 88.33 | 9.70 | 2.5 | 3.88 |

Table 7 Production of compost

| Site | Waste (kg/day) | Compost production rate (kg/kg waste/day) | Compost density (kg/$m^3$/day) | Compost Production | |
|---|---|---|---|---|---|
| | | | | (kg/day) | ($m^3$/day) |
| 1 | 2834.24 | 0.225 | 625 | 637.70 | 1.02 |
| 2 | 2409.24 | 0.225 | 625 | 542.10 | 0.87 |
| | | | Total | 1179.80 | 1.89 |

The matured compost is needed to be screened for grading of classes as per requirement of the farmers. Table 7 shows that the produced compost in site 1 and site 2 are only of 1.02 $m^3$/day and 0.87 $m^3$/day, respectively. From the experience it can be noted that 10 $m^2$ areas would be enough for screening operation in each composting site. After screening of compost, it needs to be store for some times up to selling to the consumers. The storage duration is assumed to be of 60 days and storage pile height is assumed to be 3 m. Accordingly the requirement of screening area and storage area are estimated and presented in Table 8. The required area for storage at site 1 and site 2 are 20.40 $m^2$ and 17.40 $m^2$, respectively. An office room is essential in each site for management and keeping the instrument. The space required for office room is assumed to be 14 $m^2$ in each site. The total requirement of land area for whole operation from wastes unloading to compost storage is presented in Table 9.

Table 8 Area requirement for compost screening and storage shade

| Site | Volume of Compost | | Storage Height (m) | Screening Area ($m^2$) | Storage Area ($m^2$) | Total Area ($m^2$) |
|---|---|---|---|---|---|---|
| | ($m^3$/day) | ($m^3$ / 60 day) | | | | |
| 1 | 1.02 | 61.20 | 3.00 | 10 | 20.40 | 30.40 |
| 2 | 0.87 | 52.20 | 3.00 | 10 | 17.40 | 27.40 |

Table 9 Total requirement of shade for compost plant

| Site | Waste unloading & sorting ($m^2$) | Composting ($m^2$) | Maturation ($m^2$) | Screening & storage ($m^2$) | Office ($m^2$) | Total area ($m^2$) |
|---|---|---|---|---|---|---|
| 1 | 31.27 | 666 | 4.60 | 30.40 | 14 | 746.27 |
| 2 | 27.23 | 666 | 3.88 | 27.40 | 14 | 738.51 |

**Estimation for Manpower Requirement**

Bari (2003) shows that a person is capable to sort the wastes is 80 kg/hr., pile wastes in the composting box is 110 kg/hr., unloading of compost from composting box is 140 kg/hr. and screening of compost is 56.25 kg/hr. while six persons worked together. Manpower requirement for composting operation is estimated on the basis of performance analysis of worker in composting work by Bari (2003) in the Table 10. Total working hour is considered to be 8 hours and working efficiency is 80%.

Table 10 Manpower requirement for composting

| Site | Raw waste (kg/day) | Organic waste (kg/day) | Compost (kg/day) | Sorting | Piling | Compost unloading | Compost screening | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | 4168 | 2834.24 | 637.7 | 8 | 4 | 1 | 2 | 15 |
| 2 | 3543 | 2409.24 | 542.1 | 7 | 4 | 1 | 2 | 14 |

According to the performance of the workers in different works the number of people required for different functions of composting operation is estimated. Table 10 shows that the total manpower for waste sorting, waste piling in the aerator, compost unloading and compost screening for site 1 and site 2 is 15 and 14 person per day, respectively.

**Sanitary Landfill Design in Integrated Approach**

The disposable waste is 8% of the total collected wastes which is inert material and no resale value. The density of compacted landfill should be from 300 to 700 kg/$m^3$ while for this calculation of requirement of landfill site is considered to be 600 kg/$m^3$ (Davis and Cornwell, 1998). The effective land area should be 90% of gross area of landfill site. The design period is considered of 10 years. The requirement of land area for landfill site is presented in Table 11. From the design calculation, it is found that total land area required for 10 years of landfill at site 1 and site 2 are 322 $m^2$ and 275 $m^2$, respectively.

Table 11 Total land area requirement for 10 years landfill

| Site | Generated waste (ton/day) | Disposable waste for 10 years | | | Depth of landfill (m) | Effective area ($m^2$) | Gross area ($m^2$) |
|---|---|---|---|---|---|---|---|
| | | (ton) | Density (ton/$m^3$) | Volume (m3) | | | |
| 1 | 4.168 | 1217 | 0.60 | 2028 | 7.0 | 290 | 322 |
| 2 | 3.543 | 1035 | 0.60 | 1725 | 7.0 | 247 | 275 |

Since the quantity of non-usable and non-sellable wastes are very less (8% of total waste) the land filling operation would be performed monthly. Although the wastes will be stored for one month in the landfill site for one month, there is no chance of spreading of odor or nuisance and pollution of environment because of inorganic and inert in nature of the wastes. The cell of the landfill is designed considering the cell height of 1.75 m. Single lane waste spreading and compaction equipment is to be 1.83 m as standard width of the equipment. Design of cell of landfill is shown in Table 12.

Table 12 Design of cell of landfill

| Site | Waste volume ($m^3$) | | Cell height (m) | Area of cell ($m^2$) | Width of cell (m) | Length of cell (m) |
|---|---|---|---|---|---|---|
| | For 10 years | Monthly | | | | |
| 1 | 2028 | 16.50 | 1.75 | 9.43 | 1.83 | 5.15 |
| 2 | 1725 | 14.10 | 1.75 | 8.06 | 1.83 | 4.40 |

One complete compaction required 4 (four) passes by single equipment. Running speed of equipment is assumed to be 1 km/hr. Working time per day is 8.0 hrs. and working efficiency is 80%. Thickness of each layer spreading solid waste is 0.6 m. Width of equipment is 1.83 m. Compaction operation is to be performed in single lane. Time required for 1m running = 60/1000 = 0.06 min. Pay-loader type compaction equipment could be used for waste carrying, spreading and compaction since the quantity of waste to be disposed off is very less. The requirement of compaction equipment is presented in Table 13. It is found that only one equipment is more than sufficient and even same equipment can be used in both sites considering morning and noon shift.

Table 13 Requirement of compaction equipment

| Site | Cell height (m) | Compaction layer | Total pass/day | Time for one pass (min) | Total time (min) | Requirement of equipment |
|---|---|---|---|---|---|---|
| 1 | 1.75 | 3 | 12 | 0.31 | 3.71 | 1.0 |
| 2 | 1.75 | 3 | 12 | 0.26 | 3.17 | 1.0 |

**Manpower Requirement for Sanitary Landfill**

Since the quantity of waste that to be disposed off by sanitary landfill is very less, land filling operation will be performed once a month. Pay-loader type compaction equipment will be used for waste carrying, spreading and compaction. Therefore the driver of equipment can be worked as landfill site in-charge.

**Summary of Design**

Finally, as per the design and estimation of all requirements for integrated waste management are now summarized in Table 14. From Table 6.14 it is observed that the total land area required for integrated solid waste management at site 1 and site 2 are 667 $m^2$ and 612 $m^2$. Total manpower required is 24 people and 20 people for northern part and southern part of the municipal area, respectively. The number of waste collection vans required are 8 and 5 or northern part and southern part of the municipal area, respectively. There is only one equipment is enough for waste carrying at the landfill site, waste spreading and compaction in fill for making the landfill cell.

Table 14 Total requirement of integrated solid waste management system

| Site | Land Area ($m^2$) | | | Manpower | | | | Collection Van | Equipment |
|---|---|---|---|---|---|---|---|---|---|
| | Compost | Landfill | Total | Collection | Compost | Landfill | Total | | |
| 1 | 345 | 322 | 667 | 8 | 15 | 1 | 24 | 8 | 1 |
| 2 | 337 | 275 | 612 | 5 | 14 | 1 | 20 | 5 | 1 |

It can be mentioned as the advantages of integrated solid waste management system that the landfill requires no landfill liner, cover material, leachate management system and landfill gas management system those are essential and expansive component of the conventional sanitary landfill system. Furthermore, financial return can be achieved by selling the sellable and recyclable material and selling the produced compost that can be used as organic fertilizer and soil conditioner. As a result it can be claimed that the proposed and designed integrated solid waste management system would be economical and beneficial for the Kakonhat municipality.

## Conclusions

Solid wastes management systems are designed for Kakonhat municipality according to the existing information and standard methods. The following conclusions are drawn on the basis of results obtained from this study and field investigation:

i. Cent percent wastes may be collected by house-to-house wastes collection system in Integrated Approach.
ii. Total generated waste is 7711 kg/day with generation rate of 0.605 kg/cap/day.
iii. Total organic wastes (biodegradable waste 68%) are converted into compost (an organic fertilizer).
iv. Total reusable waste of 24% is to be sale directly after sorting.
v. Only the inorganic non-reusable wastes (8% of total waste) are to be disposed of by sanitary landfill in Integrated Approach.
vi. Total land areas required for sanitary landfill in integrated approach are 667 $m^2$ and 612 $m^2$ at site 1 and 2 respectively.
vii. The total requirement of manpower, waste collection van and compaction equipment for waste management are of 44 people, 13 numbers and 1 number, respectively.
viii. Total compost to be produced is 1179.80 kg/day

All these analyses performed in the present study lead to the conclusion that the design of solid waste management system will help to develop the Kakonhat as clean municipality through proper solid wastes management.

## References

*Bari, M.N. (2003); 'An Integrated Approach for Ultimate Disposal of Municipal Solid Wastes' M.Sc.Engg. Thesis, Bangladesh University of Engineering and Technology, Dhaka.*

*BKH, (1986); 'Solid Waste Management, Housing Development Project', UNDP/UNCHS (Habitat), Bangladesh.*

*BMDA, (2003); 'Final Report on Barind Environmental Action Plan (BEAP)', BMDA-SEMP (MoEF) Initiative Assisted by UNDP, Barind Multipurpose Development Authority, Rajshahi, Bangladesh.*

*Davis, M.L & Cornwell, D.A, (1998); 'Introduction to Environmental Engineering" Third edition, Mc Graw-Hill publications company.*

*DMDP, (1992); 'Dhaka Metropolitan Development Planning Waste Management Report', Presented by Mott. Macdonald International limited, Engineering and planning consultant GOB, RAJUK.*

*Enayetullah,I. (1994); 'A Study of Solid Waste Management for Environmental Improvement of Dhaka City', M.Engg. Thesis, Department of URP, Bangladesh University of Engineering and Technology, Dhaka.*

*Sinha, A.H.M.M. (1993); 'Solid Waste Management and Recycling in Dhaka; Problem and prospects', A paper published in 'EARTH Magazine' issues No. 4, 1995 and 'Recycling potentials of organic waste in Dhaka' issues No.5.*