REPUBLIC OF RWANDA

RWANDA UTILITIES REGULATORY AGENCY

PROVISIONAL TECHNICAL GUIDELINES FOR BIOGAS PLANTS OPERATIONS

June 2012
LIST OF TABLES AND FIGURES

Table 4.2.1. Plant size & average daily feedstock........................................................................7

Figure 5. 2.1: Fixed Dome Biogas Plant Design........................................................................10

Table 5.2.1: Dimensions for the various plant sizes ..................................................................11

Table 6.1.1. Biogas Plant construction materials........................................................................12

Figure 6.4.1: Earth Base of excavation is compacted..................................................................16

Figure 6.5.1: Cobbles and Gravel placed on compacted earth floor..........................................16

Figure 6.5.2: Concrete foundation for digester, center guide pipe and horizontal cord............17

Figure 6.5.3: First Two Courses of Bricks Placed on Top of Foundation..................................18

Figure 6.5.4: View of manhole in main digester........................................................................19

Figure 6.6.1: Interior view of timber supporting earth mould for dome....................................20

Figure 6.6.2: Plywood frame supporting earth mould for dome..............................................21

Figure 6.6.3: Arch Guide, loop at right end for pivot on vertical central pipe...........................22

Figure 6.6.4: Earth mould with sand layer before Placing cast................................................23

Figure 6.6.5: Earth mould with sand layer before placing dome..............................................24

Figure 6.6.6: Completed dome with turret..............................................................................25

Figure 6.7.1: Outlet chamber foundation of brick with manhole adjacent to digester..............27

Figure 6.7.2: Outlet chamber slabs in casts..............................................................................28

Figure 6.7.3: Slabs in place on outlet chamber..........................................................................29

Figure 6.8.1: Inlet Tank during masonry construction.................................................................30

Figure 6.8.2: Complete inlet tank with mixer and ball valve on inlet tube..............................31
Figure 6.9.1: Schematic for condensate drain valve in gas line .............................................................. 33

Figure 6.9.1: Compost pits with brick walls for stability ................................................................. 34
1. PURPOSE OF THE DOCUMENT

These guidelines highlight the methods for selecting appropriate size and site for construction as well as steps of construction works related to the fixed dome biogas plant models for Rwanda. This document is prepared to assist the biogas plant operators to successfully carry out their anticipated roles in constructing good-quality biogas plants.

These guidelines include design and construction material quantities for the fixed-dome biogas plant models of 4, 6, 8, 10, 15 and 20 cubic meters capacity.

Design and size of a biogas plant other than those mentioned above is feasible and a skilled technical supervisor (National Domestic Biogas Program –NDBP/ EWSA) should be consulted for deviations from the provided designs.

2. INTRODUCTION

A biogas plant is an anaerobic digester of organic material for the purposes of treating waste and concurrently generating biogas fuel. The treated waste is a nutrient-rich, nitrogen-rich fertilizer while the biogas is mostly methane gas with inert gases including carbon dioxide and nitrogen. Biogas plants are a preferred alternative to burning dried animal dung as a fuel and can be used for the treatment of human waste.

Other feedstock which can be used includes plant material, non-meat or grease food-wastes, and most types of animal dung. Over a million biogas plants have been constructed in the developing world for treatment of organic wastes, alternative energy supply to direct burning in the home, and overall improvement of human health and the environment. Many factors for selection of feedstock and site location must be researched before deciding to install a biogas plant.

Successful construction of the biogas plant requires a proper design and adherence to follow correct construction methods. The success or failure of any biogas plant primarily depends upon the quality of construction work.

The advantages of the fixed dome plant include the simplicity of design, few moving parts, low cost to construct and low maintenance. The disadvantages when compared to a floating-dome digester
are primarily the inability to store gas for use on demand; gas from the fixed dome digester must be used as generated or expelled to avoid damaging the digester.

3. RESPONSIBILITIES OF A BIOGAS PLANT CONSTRUCTOR

The role of biogas plant constructor is vital in successful installation of biodigesters. The following are some of the major responsibilities of a biogas plant constructor:

- Provide necessary information on benefits of biodigester to the users and motivate them for bio-digester installation
- Select proper size of bio-digester based upon the availability of feeding materials
- Ensure that the quality standards of construction materials and appliances are properly complied with.
- Follow strictly the design and drawing as provided to them during construction of bio-digesters
- Comply with the Construction Manuals while installing the bio-digesters
- Provide the users with minimum requirement of knowledge and skill to operate various components of bio-digester
- Ensure timely completion of the work
- Report progress and difficulties, if any, to supervisors regularly
- Work as extension worker and promoter of the technology in their areas of influences
- Provide regular follow-up and after-sales services to the users to ensure trouble-free functioning of completed plants
4. **DETERMINING PLANT SIZE & AVERAGE DAILY FEEDSTOCK**

The size of the biogas plant depends on the quantity, quality & kind of available biomass, average daily feed stock and expected hydraulic retention time of the material in the biogas system. The following points should be considered.

### 4.1 Sizing the digester

- The size of the digester, i.e. the digester volume $V_d$, is determined on the basis of the chosen retention time $RT$ and the daily substrate input quantity $S_d$.

$$V_d = S_d \times RT \ [m^3 = m^3/day \times \text{number of days}]$$

- The retention time, in turn, is determined by the chosen/given digesting temperature. For an unheated biogas plant, the temperature prevailing in the digester can be assumed as 1-2 degree Kelvin above the soil temperature. For a plant of simple design, the retention time should amount to at least 35 days.

- Substrate input ($S_d$) = biomass ($B$) + water ($W$) [$m^3/d$]

- In most agricultural biogas plants, the mixing ratio for dung (cattle and/or pigs) and water ($B:W$) amounts to 1:1

### 4.2 Average daily feedstock

- Generally, 24 kilograms of feedstock complimented with 24 liters of water per day with a hydraulic retention time of 35 days will require a 4-cubic meter plant.

- Table 2.1 below gives some relevant data about the six different sizes of biogas plants presented in these guidelines.

<table>
<thead>
<tr>
<th>Plant Size (m3)</th>
<th>Daily Feedstock (kilogram)</th>
<th>Daily Water (liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>8</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>----</td>
<td>--------</td>
<td>----</td>
</tr>
<tr>
<td>15</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>20</td>
<td>120</td>
<td>120</td>
</tr>
</tbody>
</table>

Table 4.2.1. Plant size & average daily feedstock.

**Note:** Plant size is the sum of digester volume and gas storage based on a hydraulic retention time of 35 days

5 DESIGN OF BIOGAS PLANT

5.1 Main components of the biogas plant

The biogas plant detailed in these guidelines consists of five main structures or components:

- Inlet Tank;
- Digester Vessel;
- Dome;
- Outlet Chamber; and
- Compost Pits.
5.2 Production of biogas

- The required quantity of feedstock and water is mixed in the inlet tank and the slurry is discharged to the digester vessel for digestion. The gas produced through methanogenesis in the digester is collected in the dome. The digested slurry flows to the outlet tank through the manhole. The slurry then flows through the overflow opening in the outlet tank to the compost pit. The gas is supplied from the dome to the point of application through a pipeline.

- When a biogas plant is underfed the gas production will be low; in this case, the pressure of the gas might not be sufficient to fully displace the slurry in the outlet chamber. It is important to design the plant keeping hydrostatic pressure higher at the inlet tank than the outlet tank. The hydrostatic pressure from slurry in the inlet and outlet tanks will pressurize the biogas accumulated in the dome. If too much material is fed into the digester and the volume of gas is consumed, the slurry may enter the gas pipe and to the appliances.
Figure 5.2.1: fixed dome Biogas Plant Design
Table 5.2.1: Dimensions for the Various Plant Sizes

6 CONSTRUCTION OF BIOGAS PLANT

6.1 Selection of construction materials

- If the materials used in the plant construction such as cement, sand, aggregate etc. are not of good quality, the quality of the plant will be poor even if the design and workmanship are excellent.

- A brief description regarding the specifications for some of the construction materials is provided below to assist with selection of the best quality materials. The list of construction materials is given in Table 6.1.1.
12


6.1.1 Cement

The cement to use in the plant construction must be of high quality Portland cement from a brand with a known reputation. It must be fresh, without lumps and stored in a dry place. Bags of cement should never be stacked directly on the floor or against the walls to protect the cement from absorbing moisture before use.
6.1.2 Sand

- Sand for construction purpose must be clean. Dirty sand has a very negative effect on the strength of the structure.

- If the sand contains 3% or more impurities by volume, it must be washed. The quantity of impurities especially mud in the sand can be determined by a simple test using a bottle and clean water. For the test, the bottle is half-filled with sand, filled with clean water, and then stirred vigorously. Allow the bottle to sit stationary to allow the sand to settle. The particles of sand will settle first while mud particles will settle last. After 20-25 minutes, compare the thickness of the mud layer to the sand inside the bottle are; the percent of mud should be less than 3% of the overall volume. Course and granular sand can be used for concrete work however fine sand is necessary for plastering work.

6.1.3 Gravel

Gravel size should not be too big or too small. Individual gravel diameter should not be greater than 25% of the thickness of concrete product where it is used. As the slabs and the top of the dome are not greater than 8 cm thick, gravel should not be larger than 2 cm in size. Furthermore, the gravel must be clean. If it is dirty, it should be washed with clean water.

6.1.4 Water

Water is mainly used for preparing the mortar for masonry, concrete and plastering work. It is also used to soak bricks/stones before using them. Water is also used for washing sand and aggregates. It is advised not to use water from ponds and irrigation canals for these purposes, as it is usually too dirty. Dirty water has an adverse effect the strength of the structure; hence, water to be used must be clean.

6.1.5 Bricks

Bricks must be of the best quality locally available. When hitting two bricks together, the sound must be crisp or clean. They must be well baked and regular in shape. Before use, bricks must be soaked for few minutes in clean water. This will prevent the bricks from soaking moisture from the mortar after being laid in place.
6.1.6 Cobblestones

If cobble-sized stones, 7.5-30 cm (3-12”) in diameter are used for masonry work, they must be clean, solid and of good quality. Cobbles should be washed if they are dirty.

6.2 Selection of construction site

The following points should be kept in mind when deciding on a site for biogas plant construction.

- For proper function of the plant, the optimal temperature has to be maintained in the digester. Therefore, a sunny site should be selected to keep the digester near 35 degrees Celsius (95 degrees Fahrenheit).
- To make plant operation easier and to avoid wastage of raw feedstock the plant must be as close as possible to the feedstock supply (toilet, animal pen, compost pits, etc.) and water source. If a supply of feedstock or water or both is not available then the biogas plant should not be installed.
- Gas pipe length should be kept as short as possible. A longer pipe increases the risk of gas leaks because of the increased number of joints; the cost of a longer pipe is also a factor. The main gas valve should be opened and closed before and after each use, therefore the plant should be as close as possible to the point of use to facilitate proper operation.
- The edge of the foundation of the plant should be at least two meters away from any other structures to avoid risk of damage during construction.
- The plant should be at least 10 meters away from groundwater wells or surface water bodies to protect water from pollution.

6.3 Site layout

- After selection of the plant size and site location, the site layout is marked on the ground surface with wooden stakes, rocks, chalk or other materials.
- To mark the plant, a small peg is stuck in the ground at the planned center of the digester.
- A cord for the radius of the digester is attached to the peg (length indicated on the drawing under dimension „C“, Figure 5.2.1).
- The circumference can be marked by rotating the end of the cord in circular fashion.
• A suitable arrangement must then be marked for the inlet tank, inlet-pipe(s), outlet-chamber, compost-pits and gas piping.

• After the site layout is marked, the engineer should review the selected location again to ensure the best site has been chosen and will not interfere with other activities normally performed at the planned biogas plant.

6.4 Excavation

• The pit depth is indicated on Figure 5.2.1 under dimension 'E'.

• The excavation work should only be started after deciding the location of manhole and outlet tank.

• For safety, the pit walls should be vertical and stepped from the ground surface by one meter away from the center of the excavation for each meter in depth excavated.

• Excavated soil should be placed at least one meter away from the edge of the dig so it does not fall inside the pit during construction.

• The pit bottom must be leveled and the earth must be untouched.

• If the design depth cannot be achieved because of hard rock or high groundwater, the design will need to be modified to a smaller plant or wider digester or combination of both.

• It is not recommended to construct the biogas plant at or below the groundwater table elevation. The earth base of the excavation is then compacted using mechanical or manual tools.
Figure 6.4.1: Earth Base of Excavation is compacted

6.5 Construction of digester main chamber

The digester foundation is placed using cobbles and gravel as aggregate then filled with concrete. The foundation should be 15 cm thick and allowed.

Figure 6.5.1: Cobbles and Gravel placed on compacted earth floor.
• At the center of the pit, a straight rod or pipe (the 0.5" GI gas pipe\(^1\)) must be placed in an exact vertical position. The vertical pipe will be used during the construction as a field-expedient guide to ensure symmetry of the biogas plant.

• At ground level, a rigid pole, pipe or cord is placed horizontally across the diameter of the pit.

• The vertical pipe is secured to the horizontal pipe, pole or cord. After securing, the vertical pipe should be checked to ensure it is still in the plumb/vertical position.

• A string or wire is attached to the vertical pipe. The length of this wire can be found on Figure 2.1, dimension „F“.

• Add one cm length to this length to allow space for plastering. Every brick or stone that is laid in the round-wall will be exactly F+ 1 cm away from the vertical pipe.

---

\(^1\) The domestic gas supply pipe

Figure 6.5.2: Concrete Foundation for Digester, Center Guide Pipe and Horizontal Cord.
• After the Foundation has cured for at least two days, the round wall is constructed.

• The first two rows of bricks must be positioned side by side so that 23 cm (9") wide base is made. It is essential that first row be placed on a firm, untouched and level foundation. Subsequent rows of bricks are positioned on their lengths so that the wall thickness is maintained at 23 cm (9") wide.

Figure 6.5.3: First two courses of bricks placed on top of foundation

• It is not necessary to build in support columns or pillars in the wall however, the backfilling between wall and pit-side must be compacted with great care. Backfilling should be done no sooner than 12 hours following brick course placement to allow mortar to cure. Earth should be well compacted by adding water and gentle ramming along the circumference of the digester. Poor compaction will lead to cracks in round-wall and dome.

• The cement mortar used can be 1 part cement to 4 parts sand (1:4) up to 1 part cement-6 parts sand (1:6) depending on the quality of the sand. The height of the round-wall is detailed on the drawing in Figure 5.2.1 under dimension 'H' as measured from the finished floor.

• The feedstock inlet pipe (and toilet pipe, if installed) must be placed in position when the round-wall is 30-36 cm high.
• To reduce the risk of blockages, the inlet pipe(s) must be placed as vertical as practically possible.

• To the opposite of the main feedstock inlet pipe, a 60 cm wide opening must be left in the round-wall that serves as a manhole. The digested slurry will flow to the outlet tank through this opening.

• Additional inlet pipes should be placed as close as possible to the main feedstock inlet pipe with a maximum distance of 45 degrees from the inlet-center-manhole line. When the round-wall has reached the correct height, the inside must be plastered with a smooth layer of cement mortar with mix of 1:3 cement-sand.

Figure 6.5.4: View of Manhole in Main Digester
6.6 Dome construction

- When the round wall of the digester is complete, the dome is then constructed. Before filling the pit with earth to make the mould for dome, backside of the round wall should be filled with proper compacted back-fill. If this is not done, the pressure of earth for the mould can lead to cracks in the round-wall.

- The dome is constructed using a mould or cast technique. This can be accomplished by constructing a timber frame then placing the earth-cast atop for proper arch design. Once the dome is cast, the timber frame and earth will be removed through the outlet chamber manhole.

Figure 6.6.1: Interior view of timber supporting earth mould for dome
Figure 6.6.2: Plywood frame supporting earth mould for dome

- Mark on the vertical center pipe the distance „J“ from the finished floor noted on drawing in Figure 5.2.1. The vertical pipe should remain in place as the mould is constructed.

- The arch shaped should be an 80 to 90-degree arc from the Mark „J“ on the vertical pipe and interior edge of the completed digester wall. The mould is shaped rotating the guide around the central vertical pipe.

- The top of the round-wall must be clean when the guide is in use.
It is important that the earth of the mould is well compacted. If the earth is further compressed after casting the dome, by its own weight and that of the concrete, it can lead to cracks in the dome.

- When the earth mould has the exact shape of the guide, a thin layer of fine sand is spread on the mould-top by gently patting it on the surface. The sand layer will prevent the earth from adhering to the cast.

- The earth used for the mould needs to be damp to prevent dry earth from soaking up water from freshly casted concrete.
Before start of the cast work, sufficient labor and construction materials like sand, gravel, cement and water must be staged on the site and ready for use.

- The casting must be done as quickly as possible and without interruptions as this will negatively affect the quality of the cast.

- A constant, adequate supply of concrete (mix: 1 cement, 3 sand, 3 gravel – 1:3:3) must be made for the mason.

- No concrete older than 30 minutes should be used.

- Special care should be taken to maintain the thickness of the dome while casting, i.e. the thickness near the outer edge should be greater than the thickness at the center.

- For the 4, 6, 8 and 10 m3 plant, the thickness at the edge should be 25 cm (10”) whereas the thickness in the center should be 7 cm (2 ¾”).

Figure 6.6.4: Earth mould with sand layer before placing cast
• For 15 and 20 m³ plants, the thickness at the edge should be 25 cm (10”) and the thickness in the center should be 8 and 9 cm (3 and 3 ½”) respectively.

• An alternative to concrete cast construction technique is the use of baked clay brick in corbel-arch construction. The compression of the brick and mortar in a spherical shape will support the dome. The clay brick dome will have a near-uniform thickness compared to the cast-concrete dome that thins towards the center.

• A continuous application of mortar along the sand mould is necessary as the bricks are placed. The brick dome should be placed continuously and use a mortar mix of 1:4 cement to sand. Once the bricks for the dome have all been placed, the exterior is covered with 1:3 cement to sand plaster.

Figure 6.6.5: Earth mould with sand layer before placing dome
• During the casting, the concrete has to be protected against strong sunlight by covering it with wetted burlap, jute bags or straw mats. This protection has to be left in place for at least one week.

• The day after the casting, the turret must be made. The turret is made with brick, 36 cm square and 50 cm tall.

• The turret is plastered with 1:3 concrete. Any delays during dome construction can lead to leakage between main gas pipe and dome.

• Following completion of the dome, the structure must be sprinkled with water 3 to 4 times a day during the curing period (up to one week).

Figure 6.6.6: Completed dome with turret.
• After the dome has cured for approximately one week, the timbers and earth of the mould can be removed through the manhole.

• When all earth is removed, the inside of the dome has to be thoroughly cleaned with a stiff brush and clean water.

• On the clean surface of the dome interior, the following plaster coats must be applied to make the dome gas-tight from first to last coats:

  a) Cement and water wash (1:1)

  b) 10 mm layer: 1 part cement, 2 parts sand (1:2)

  c) 5 mm layer: 1:1

  d) Cement/acrylic emulsion paint coating: 1.5 parts paint, 20 parts cement

  e) Cement/acrylic emulsion paint coating: 1 part paint, 2 parts cement

• For proper insulation during the cold season and as counter weight against the gas pressure inside, a minimum top cover of 40 cm (16”) compacted earth is required on the dome.

• If the top cover will be prone to erosion due to wind and rain proper protection with gravel, circular wall, or straw matting should be applied.

6.7 Outlet Chamber Construction

• The Outlet Chamber excavation and manhole is completed concurrently with the digester vessel and the manhole shares a common foundation with the digester vessel.

• The manhole of the Outlet Chamber is near the digester wall.

• The depth of excavation is less than the digester vessel measured from the top of digester floor by taking the dimension "I" minus the thickness of the digester floor (will depend upon construction material used but generally "I" + 13 cm (5”).

• The earth behind the manhole and under the outlet floor must be well compacted to prevent cracks in Outlet Chamber walls.
The inside dimensions of the outlet can be found on the drawing under A, B and D.

The overflow level is at the top of dimension „D“ and top of the Outlet Chamber walls is dimension „D“ + 15 cm.

It is important to use the prescribed dimensions as they determine the useful capacity of the gasholder. For the same reason the outlet floor and the top of the walls must be level.

The walls will be vertical and finished with a smooth layer of cement plaster mix: 1 part cement, 3 parts sand.

Outside of the walls must be supported with sufficient compacted earth up to the overflow level to avoid cracks.
• The Outlet Chamber walls should slightly higher elevation than the surrounding ground to reduce chances of surface water entering the outlet during the rainy season

![Outlet chamber slabs in casts.](image)

**Figure 6.7.2: Outlet chamber slabs in casts.**

- The concrete slabs for the Outlet Chamber should be constructed at the same time of dome casting.
- It should be easy to make the additional concrete at this time and the slabs will be well cured before they are placed on the outlet.
- The slabs must be 8 cm (3") thick with proper reinforcement (re-bar) 3 cm (1") from the bottom side.
- The number of slabs should be designed that they can be handled by four men without great difficulty.
- Installing re-bar loop handles on the slabs may be useful for the occasional handling of the slabs.
Special care must be taken for the placement of the concrete to prevent small holes that can expose the steel reinforcement to corrosive vapor from the slurry in the Outlet Chamber which will cause corrosion and ultimately lead to the slab collapse.

If holes form in the slab these should be filled with plaster layer.

The Outlet cover slabs are essential to protect people and animals from falling inside and to avoid excessive evaporation of the slurry in dry season.

### 6.8 Construction of Inlet Tank

- The Inlet Tank is constructed to mix feedstock and water. This can be constructed with or without a mixing device. Installation of a mixing device is preferable because not only it makes plant operation easier but it also improves the quality of mix.

- When a mixer is installed, it has to be firmly attached to the structure, easy to operate, effective in the mixing process and the steel parts in contact with the feedstock should be galvanized.
- The top of the structure should not be more than one meter above ground level and both inside and outside of the tank must be covered with a smooth layer of plaster (Mix: 1:3 cement, sand).

- The finished bottom of the Inlet Tank must be at least 5 cm above the Outlet Chamber overflow level.

- The position of the inlet pipe must be such that a pole or rod can be inserted through it to the digester vessel without obstructions. This will allow the operator to clear blockages in the inlet pipe. For the same reason the inlet pipe must be without bends.

- Even if a mixing device is not installed, the inlet pit should be round in shape as this is a more economical use of material and easier for hand mixing.

Figure 6.8.1: Inlet Tank during masonry construction.
• For plants that receive feedstock from a toilet, construct a cleanout valve between the water-trap and digester.

• The toilet inlet pipe should enter the digester tank no more than 45 degrees from the centerline of the main inlet pipe.

• The toilet pan level should be at least 25 cm above the outlet overflow level.

Figure 6.8.2: Complete Inlet Tank with mixer and ball valve on inlet tube.

6.9 LAY-OUT OF PIPELINE

• The gas pipe conveying the gas from the plant to point of user is vulnerable to damages by people, domestic animals and rodents.

• Only light quality galvanized iron pipe should be used which must be, where possible, buried 30 cm (1 foot) below ground level.
• Fittings in the pipeline must be sealed with zinc putty, Teflon tape or jute and paint.

• Any other sealing agent, like grease, paint only, soap etc. must not be used.

• The use of fittings, especially unions, should be kept to a minimum to reduce the risk of leakage.

• No fittings should be placed between the main gas valve and the dome gas pipe.

• The pipe size, inside diameter should be between 6 and 1 Cm.

• Pipe size is determined by the size of the digester, (amount of gas produced) and amount of gas required in the house. (Are the stoves, heater lights going to be used simultaneously?)

• A water drain or trap is installed in the pipeline.

• The position of the water drain should be vertically below the lowest point of the pipeline so water will flow by gravity to the trap.

• The drain must be easily accessible and protected in a well-maintained drain pit since water will be removed periodically by opening the drain.
To connect burners to gas pipelines use of transparent polyethylene hose must be avoided.

Only the best quality neoprene, rubber hose should be used. Other biogas appliances should be mounted and connected to the galvanized iron pipe.

All joints and taps must be inspected for leakage by applying a thick soap solution and observing for foam movement.

**6.10 COMPOST PITS**

- Compost pits are an integral part of the biogas plant; no plant is complete without them.

- A minimum of two compost pits must be dug near to the Outlet Chamber overflow in such a way that the slurry can run freely into the pits.

- At least 1 meter, between the pits and the outlet chamber to avoid cracking of the chamber walls.

- The total volume of the compost pits must be at least equal to the plant volume.
The earth excavated from the compost pits is used for backfilling of the inlet and outlet chamber and for top filling on the dome.

Figure 6.9.1: Compost pits with brick walls for stability