WaterAid Ethiopia

National Health Institutions (Health Centre & Health Posts) WaSH Facilities Design and Implementation Manual

Final Report

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Acronyms

FMOH	Federal Ministry of Health
DW	Deep Well
HC	Health Centre
HDW	Hand Dug Well
HP	Health Post
HSDP IV	Health Sector Development Program
MDG 4	Millennium Development Goals of reducing child mortality
MDG 5	Millennium Development Goals of reducing maternal mortality
PV	Photo Voltic
RWH	Rain Water Harvesting
SD	Standard Deviation
SPD	Spring Development
SW	Shallow Well
VIP	Ventilated Improved Pit Latrine
WHO	World Health Organization

1. INTRODUCTION

1.1 Background

Health Center and Health Post refers to those institutions in charge of helping the community on health and sanitation issues to improve the health status. It also provides education and consultation on hygiene practices and support on the methods of improving the sanitation condition of the community. This brings the community to realize the importance of health through the use of sanitation facilities and appropriate hygiene practices so that they can practice themselves.

Health Center and Health Post sanitation is part of the major areas of the health services for visiting patients and as demonstration centers to communities. The aim of providing sanitation facilities to the Health Center and Health Post is to improve existing sanitation conditions at the Health Center and Health Post.

In order to effectively perform the activities, it is recommended to integrate the promotion of environmental health education along with the construction and/or maintenance of sanitary facilities.

The 4th Health Sector Development Plan aims at improving health infrastructure in the country through expanding, equipping and managing of health institutions and different facilities required at health institutions. Coupled with the ongoing health extension program, improving health infrastructure is anticipated to meet the Millennium Development Goals of reducing child mortality (MDG 4) and reducing maternal mortality (MDG 5). Towards this, FMOH is rapidly increasing the number of health institutions (especially health centers and health posts) all over the country. It had targeted to have 3,200 health centers and 11,440 health posts by the end of 2010, and reached over 2,689 health centers and 14,416 health posts[1]

According to the health service delivery arrangement indicated in HSDP IV, primary health care unit comprises of a heath center and five satellite health posts, which altogether provide services to 25,000 people. Health posts are the frontline health care providers and health centers are the next higher level health care providers, which serves as a referral center for health posts.

1.2 Project Objectives

Health Center and Health Post Water Supply , Sanitation and hygiene facilities design and implementation manual as the name implies is planned to give a working guideline for the construction or maintenance of water supply , sanitation and hygiene facilities in health centers and health posts. This will assist to increase the service coverage of water supply, sanitation and hygiene in the Health institutions through construction of water schemes, construction of pit latrines and disseminating information on hygiene and environmental sanitation.

[1] Source:-Health Sector Development Plan IV (2010/11-2014/15), Federal Ministry of Health

The major objective of the manual mainly emphasized:-

a) In designing safe and reliable water supply and sanitation facilities to the Health institutions, and
b) To provide guidelines to implement hygiene and environmental sanitation.

1.3 Purpose of the Manual

The provision of improved sanitation facilities will benefit mainly Health Centers and Health Posts that do not have any facilities or require maintenance and rehabilitation.

The neighboring communities will also benefit from the technical assistance that will be given in the design and construction of latrines, and in hygiene and environmental sanitation education.

1.4 Existing Water Supply, Sanitation and Hygiene facility Technology Options

According to Health Institutions WaSH assessment report February, 2012, 9 out of the 12 health centers have water supply facilities. Three of the health facilities have no water supply facilities at all from which two of them need different technology options. Most of the water supply facilities to the HCs assessed are connected to the community water supply system with the exception of one HC which has its own water source. Health centers having water from the community water supply system reduces the costs required to construct and/or maintain water supply schemes, as the community contributes its own resources during construction of the water facilities and covers much of the operation and maintenance expenses. Deep well, shallow well and developed springs are the sources of water supply for the health centers assessed.

The study also reveals that HDW, SPD, SW and DW are the sources of water supply for Health Posts (HPs) assessed as well as for community water supply systems that share water to the HPs.

The assessment has also tried to show the challenges that HPs are facing in availing water at all times. The main challenge in this regard is the location of HPs, as most of them have been constructed at elevated sites, where surface or ground water sources are not easily available. Shortage of water storage facilities, shortage of fuel for pumping and failure of pumps at some water points were the other challenges.

Assessment of the existing situation of latrines/toilet at the HCs assessed indicated that all of them have at least 4 rooms latrine/ cubicle. In addition to the number of rooms HCs have pour flash toilets with pedestal in maternity/delivery rooms. The latrines/toilets are cleaned by cleaners assigned for the purpose. Assessment of practical experiences of health centers indicated that they use either soak away pits or septic tanks to dispose wastewater. In rural health centers hand washing facilities in the rooms are constructed with an onsite drainage system that is connected to a soak away pit. Whereas in the health centers with pour flash toilets, wastewater from hand washing facilities, showers and pour flash toilets are connected to waste disposal Septic tanks.

Assessment of the existing situation of latrines at the HPs assessed indicated that all of them have at least 2 rooms latrine. The toilets have doors and separate rooms for male and female. But no clear signs to differentiate rooms for males and females. Latrines in all the HPs visited are not accessible to pregnant women, children, the old and persons with disabilities. Those toilets do not consider local cultural practices like anal cleansing with water. Functional hand washing facility is not available at all latrines of the HPs visited.

The findings of the field assessment indicated that, incinerator, placenta pit and solid waste disposal pit were provided to handle the solid waste generated at the HPs. Non-of the HPs have liquid waste disposal pits.

1.5 The Manual

In this manual the appropriate technology options for the construction of water supply, sanitation and hygiene facilities that can be used by the Health Institutions are described. The description for each appropriate technology option includes the type and purpose of the option, method of construction, operation and maintenance, cost implications and its implementation under different conditions.

Technical Drawing and Bill of Quantities for Construction is also prepared The drawing will show in detail the size or dimensions of the structures, type of construction materials and bill of quantities of the technology option under consideration.

2. Design Criteria for Water supply and Sanitation

The design criteria that are applicable for Health Posts and Health Centers water supply and sanitation planning and implementation are described in the following sections.

2.1 Water Demand

Water demand for the Health Institutions depends on the level of service to be provided and the amount of water required satisfying the demand of the different facilities of the Health institutions.

According to Health institutions WaSH Assessment report February, 2012, the actual quantities of water required will depend on several factors such as climate, availability and type of water-use facilities (including type of toilets), level of care and local water-use practices. WHO roughly estimates the minimum amount of water that a health center requires for every patient, for purposes of: hand washing, cleaning, laundry and drinking (Table2-1).

Table 2-1: Minimum water requirement at health centres

S/N	Purpose	Amount in liters
1	Outpatients	5 liters/consultation
2	Inpatients	40–60 liters/patient/day
3	Operating theatre/maternity	100 liters /intervention
4	Dry supplementary feeding centre (depending on waiting time)	0.5–5 liters/consultation
5	Wet supplementary feeding centre	15 liters/consultation
6	Inpatient therapeutic feeding centre	30 liters/patient/day

Source: Operation manual for staffs at primary health level, WHO, 2007

2.2 Consumption Patterns and Peak Factors

There is no information regarding the consumption patterns of water supply services on hourly, daily and annual basis. This is due to the fact that Health institutions (Health Posts & Health Centers) don't have adequate water supply facility and the available record of consumption or water bill is not reflecting the actual demand of these facilities. However, most of the Health Posts and health centers may have major water supply demand during the working hours with additional demand from neighboring community. In some localities it may not be possible to avoid this option due to the lack of water supply source.

2.3 Water Treatment

The prerequisite for the recommendation of water treatment is the water quality analysis. A representative sample shall be obtained from source for water quality analysis. The minimum requirement will be disinfection based on the selected water source.

2.4 Service Reservoirs

The volume of service reservoirs should be sufficient to guarantee adequate and reasonable supply during working hours which will have peak demand. The storage requirement is also dependent on the selected water source. Hand Dug wells may require smaller storage facility. On another hand, rain water harvesting may require relatively bigger storage facility.

Where the power supply is highly unreliable and expensive, for cost effective design, the need for some additional storage capacity should be considered in conjunction with the requirement for stand-by power generation facilities at pumping station.

2.5 Transmission Mains

The transmission line transports water from the source to the treatment (if there is one) and onwards to the distribution. The transmission line will be basically designed to serve the health institution.

If the water supply source is Hand Dug well or Borehole within the compound, either deep or shallow, the transmission line is simply from the borehole up to the elevated water tank

If spring is selected as a water supply source or if the location of a borehole is outside the compound of the Health institution, the transmission line will be designed from the source up to the health institution considering the water demand of the neighboring community. In such circumstances, the transmission line as well as the storage facility should consider all scenarios for a comprehensive design.

In cost effective design, where the minimum standards for clean water supply are not yet met, the service level in terms of quantity of flow would be the minimum standard value adjusted for the Maximum Day demand.

The sizing of all transmission mains shall take into consideration the minimum pressure specified. It is preferable that flow velocities remain in the range of 0.6 to 1.5 m/s although in exceptional conditions this can rise to approx. 2.0 m/s.

2.6 Distribution

Basically the distribution pipe will be within the compound of the Health Institutions and will be fed by gravity from the elevated tanker. The sizing of the pipes is basically dependent on the fixtures connected to the line. If the supply is from a rain water tanker, a rising main up to the elevated reservoir will be considered. Appropriate pump selection and power requirement will be considered.

2.7 Design Criteria for Solid and Liquid Waste Disposal

The health posts or health centre is a place where there are people in the for-front in terms of disseminating and controlling the health and hygiene improvement in the community. Of course there are also patients and caregivers who are the largest number using the health centre sanitation facilities that on the other hand may not have the awareness in the benefits of hygiene and sanitation. As a result health centre sanitation facilities must be clean, and exemplary to the community about clean and safe environment. In this way it will provide a variety of experiences to the visiting patients for the purpose of improving attitudes, knowledge and practices to health. Together with hygiene promotion at the health centers, it will bring the patients to gradually realize the importance of health and to act intelligently in community with this awareness.

The design will mainly concentrate on selection of appropriate latrine facilities for excreta disposal and hand washing facilities. Furthermore, special attention should be given to categorize the solid waste generated from health institutions and appropriate technology option should be selected to dispose the generated waste without affecting the environment.

3. Design of Water Supply system for Health Institutions

According to the Health Institutions WaSH Assessment Report conducted by Water Aid Ethiopia, the average monthly water consumption, estimated on water bills, of a Health Centre connected to a public water supply line ranges from 4.26 M^3 to 60 M^3, which is equivalent to 142 liters to 2000 liters per day. On another hand, the above mentioned report didn't disclose estimated figure regarding the water consumption of Health Posts.

3.1 Water Demand for Health Institutions

3.1.1 Water Demand for Health Centers

According to Healthcare waste generation and its management system: the case of health centers in West Gojjam Zone, Amhara Region, by Muluken Azage, Abera Kumie, published in Ethiopian Journal of Health Development, the mean ± SD (standard deviation) patient flow per day in all sections and outpatients in each health center was 185.8 ± 30.3 and 51.7 ± 11.6 patients, respectively. The above data is used to estimate the water requirement of a Health Centre.

Table 3-1: Estimation of average water demand of a Health Centre

S/N	Purpose	Consumption in liters	No. of users per day	Water demand per day
1	Staff	20liters per capita	20	400
2	Patient in all section	5 liters per capita	139	695
3	Outpatients consultation	5 liters/consultation	52	260
4	Outpatients for drinking & washing	2 liters per capita	52	104
4	Inpatients 5 beds	40–60 liters/patient/day	5	300
5	maternity	100 liters /intervention	2	200
6	Caregivers	2 liters per capita	186	372
			Total water required per day	2331

According to the above table, the average water requirement of a Health Center is 2.33m^3 per day. In addition to this, water is required for general janitorial service, laundry and lawn sprinkling if any. According to the Consultants estimate, these operations will consume a maximum of 5% of the average demand, which is 116.6 liters per day. Therefore, the total average water demand of the Health Centre is 2.45m^3 per day, or 13.16 liters per patient per day

In exceptional occasion, the number of patients at the Health centers will be excessive. Considering the upper limit of the above estimate of number of patients, the water demand is analyzed.

Table 3-2: Maximum water demand at Health centers

S/N	Purpose	Consumption in liters	No. of users per day	Water demand per day
1	Staff	20liters per capita	20	400
2	Patient	5 liters per capita	149	745
3	Outpatients	5 liters/consultation	64	320
4	Outpatients	2 liters per capita	64	128
4	Inpatients 5 beds	40–60 liters/patient/day	5	300
5	maternity	100 liters /intervention	4	400
6	Caregivers	2 liters per capita	216	432
			Total water required per day	**2725**

The work load in janitorial service will be also increased. According to the Consultant, 7% of the average demand, which is 191 liters, will be required for this service. Therefore, the maximum water requirement is 2.92m^3 per day, or 13.49 liters per patient per day.

If the health center is operating as a supplementary feeding centre or inpatient therapeutic feeding centre, additional water is required depending on the number of beneficiaries. On another hand, the water requirement of the neighboring community cannot be under estimated if adequate water supply is not available for the community.

3.1.2 Storage Requirement

The optimization of required storage reservoir can be analyzed based on the operation of the health center taking into consideration that storage will be required to continue the service of the health center during power interruption. The required capacity of the service reservoir, taking into account economical design approach, is 30% (8 hours) of the average day demand. The operation of a health center is mainly during the working hours. Due to this, the storage requirement should meet this demand. Therefore, the minimum storage requirement should be 2.45 m^3.

According to Public Health Engineering practice by L.B.Escritt, 1978, water storage capacity, besides being estimated on water demand, is sometimes estimated on the number of fixtures provided. The unit storage requirement of each fixture is estimated in the book. Based on the above reference, the following storage requirement is estimated for the daily operation of the health Centre.

Table 3-3: Storage requirement at Health Centres

Fixture	Storage requirement per fixtures (litters)	No of fixtures provided	Required storage (litters)
Water-closet	151.4	1	151.4
Lavatory	227.1	9	2043.9
Sink	151.4	4	605.6
Laundry	378.5	3	1135.5
		Total	**3936.4**

According to Table 3-3, the required storage based on the installed fixtures is 3.94m^3. Therefore, reservoir sizes having 5m^3 capacity will be adequate to sustain the service for one day. However, the risk of power interruption is another factor in determining the reservoir capacity. Due to this, a $10m^3$ reservoir capacity is recommended for Health Centers.

3.1.3 Water Demand for Health Posts

Health posts are designed to be operated by health extension workers. According to Health institutions WaSH Assessment report February, 2012, the assigned health extension workers are expected to spend less than 20% of their time in health posts, and more than 80% of their time is spent on community outreach program visitation to households, especially mothers and children. Due to this, the water requirement is very limited. However, the standard design of a health post incorporates one lavatory, one sink and four taps for hand washing at the toilets. The running water from elevated tanker will feed these fixtures.

3.1.4 Storage requirement

The storage requirement for the health post is estimated as shown in Table 3-4

Table 3-4: Storage requirement at health post

Fixture	Storage requirement per fixtures (litres)	No of fixtures provided	Required storage (litres)
Lavatory	227.1	1	227.1
Sink	151.4	1	151.4
Tap for hand washing	151.4	4	605.6
		Total	**984.1**

According to the above estimate, a minimum of 1000 litter of water storage is required for the daily operation at a health centre.

4. Water Sources

The location, topography, geology, and climate determine the water resources characteristics and water availability. There are several types of water sources such as wells, springs, rainwater, streams or rivers, lakes etc used for different purposes. Among these sources some are available throughout the year while some are seasonal; some are convenient or provide water that tastes better while some do not.

After assessing a number of factors among the available water supply technology options the selected options are discussed in this chapter.

4.1 Rainwater Harvesting

4.1.1 Introduction

Rain Water Harvesting (RWH) is an option which can be adopted to augment the water demand of the Health institutions during the dry season. Rain water harvesting is mainly used for the provision of drinking water, and when local water supply sources dry up for a part of the year or it is can be also used as the sole water source in an area where there is uniform and adequate rainfall pattern is observed.

Every rain water system consists of three basic components:

- Catchment surface,
- Storage reservoir and
- Delivery system.

Where there are two rainy seasons, rain water harvesting can be possible twice in a year and the storage, which is directly dependent on the demand and the available roof area, will be recharged during both wet seasons. However, in a single wet season the rain water harvesting can occur only once in a year and this will require a large storage capacity. The water demand and the required storage capacity may require a considerable capital cost. With such system a strict water management strategy is required to ensure that the water is used carefully and will last until next season or identify another source for sustainable supply.

4.1.2 Quantity of Roof top Catchment

Roof top rain water harvesting system gathers rainwater caught on the roof using gutters and down pipes and lead to one or more storage containers ranging from simple pots to large storage tanks.

The water collected from roofs is reasonably pure if the roofs are made of galvanized sheets or tiles. It may be helpful to arrange the down pipe by fitting a foul flush device or detachable down pipe so that the first water from each shower, which is mostly contaminated with dust, leafs, insects and bird droppings, can be diverted from clear water container and allowed to run to waste.

For effective delivery of the rain water from roof catchments into storage tanks proper construction of gutter with respect to size, slope etc. is essential. The rainwater can be stored in tanks made of Ferro cement, bricks/blocks, reinforced concrete, metal, plastic and fiberglass and can be constructed over ground or underground. The storage tank has to be water tight with solid and secure cover to avoid risks from pollution sources or damage by erosion and to avoid breeding ground for mosquitoes. Furthermore, the tank has to be provided with proper inlet, overflow, and outlet and ventilation system.

The quantity of rainwater that can be collected from roof catchment largely depends on the size of the roof, the intensity of rainfall, and the storage capacity. This system can be effectively used by the health institutions in the longest season which may pass without rainfall.

The amount of rainwater that can be harvested from roof top for different rainfall amount and roof area is shown in Table 4-1, which is a product of the surface area, amount of rainfall and run off coefficient i.e. 0.8.

$$V = K*I*A$$

Where:-

V = Volume of rain water harvested in M^3
K = Runoff coefficient which is usually 0.8 for corrugated iron roofs
I= Recorded daily, monthly or annual rainfall in meters
A = Surface area of the roof in M^2

4.1.3 Construction of roof catchment

4.1.3.1 Roofing Requirements

Materials commonly used in the construction of the roofs used for rainwater harvesting are corrugated galvanized iron, concrete, or tiles. The effective roof area and the material used in constructing the roof influence the collection efficiency and water quality.

4.1.3.2 Conveyance Requirements

Conveyance systems usually consist of gutters and drain pipes that deliver rainwater from the catchment area into the storage tanks. The conveyance systems should be of inert material to avoid adverse affects on water quality.

The roof guttering should slope evenly towards the down pipe, because if it sags, pools will form that can provide breeding place for mosquitoes.

Dust, dead leafs and bird droppings will accumulate on the roof during dry periods. These will be washed off by the first new rains. It may be helpful to arrange the down pipe so that the first water from each shower (the “foul flush”) can be diverted from the clear water container and allowed to run to the waste.

4.1.3.3 Storage requirements

The rainwater ultimately is stored in a storage tank, which should also be constructed of inert material. Reinforced concrete, ferrocement, fibreglass, polyethylene, or stainless steel have been found to be suitable.

Storage tanks can be above-ground or below ground. Whichever type of storage is selected, adequate enclosure should be provided to prevent any contamination from human or animals, leafs, dust or other pollutants entering the storage tank. A cover should ensure dark storage conditions so as to prevent algal growth and the breeding of mosquito larvae. Open containers or storage ponds are generally unsuitable as sources of drinking water.

Water is taken from the storage tank by tapping, pumping, or using bucket and rope. For reasons of hygiene, the first two methods are preferred. Just before the start of the rainy season, complete system has to be checked for holes and broken parts and repaired if necessary.

Important factors to incorporate into the design of a storage tank include

- adequate capacity;
- provision of a sloped bottom and provision for collection of settled grit and sediment;
- overflow protection;
- inclusion of a manhole for easy access for cleaning;
- provision of a vent for air circulation (often the overflow pipe); and,
- Protection against insects and rodents.

The basic requirements are:

- The tank should not have excessive lose through seepage or evaporation;
- The tank should be covered to prevent entry of light, and sealed against intrusion by mosquitoes and small creatures;
- The tank should be ventilated to prevent anaerobic decomposition of any washed matter
- To reduce guttering costs and complications, the tank should be sited as close to the house as possible without undermining the foundation of the dwelling. If an underground design is used it should be more than 15 m away from any pit latrine.

Figure 4-1 Rainwater tank at Health Post

4.1.3.4 Selection of tank size

The quantity of water available from a rainwater harvesting system depends mainly on the amount and intensity of rain. Furthermore, the size of the roof catchment surface, the percentage catchment surface area that is guttered, the efficiency of the gutters in transporting the water, and the size of the storage tank also contribute on the amount of rainwater abstraction.

In standard Health Center, the catchment surface area of the main block is about $650m^2$. This surface area is used to overview the possible rainwater abstraction volume at different climatic zones

There are three broad climatic zones in the country. These are Kolla or hot zone found below the altitude of 1,500 meters ASL, Woyna Dega zone between 1500 and 2400 meters ASL and Dega or highlands 2500 meters ASL and above. These climatic zones are further subdivided to see the rainfall distribution and the following graph is generated, using the monthly rainfall distribution. The maximum size of rainwater tank to be constructed and the number of days in a particular year that the rainwater serves a Health Centre is estimated based on the graph. Figure 4.1 clearly depicts that rainwater harvesting is not sustainable throughout the year even in Dega climate without additional water supply source.

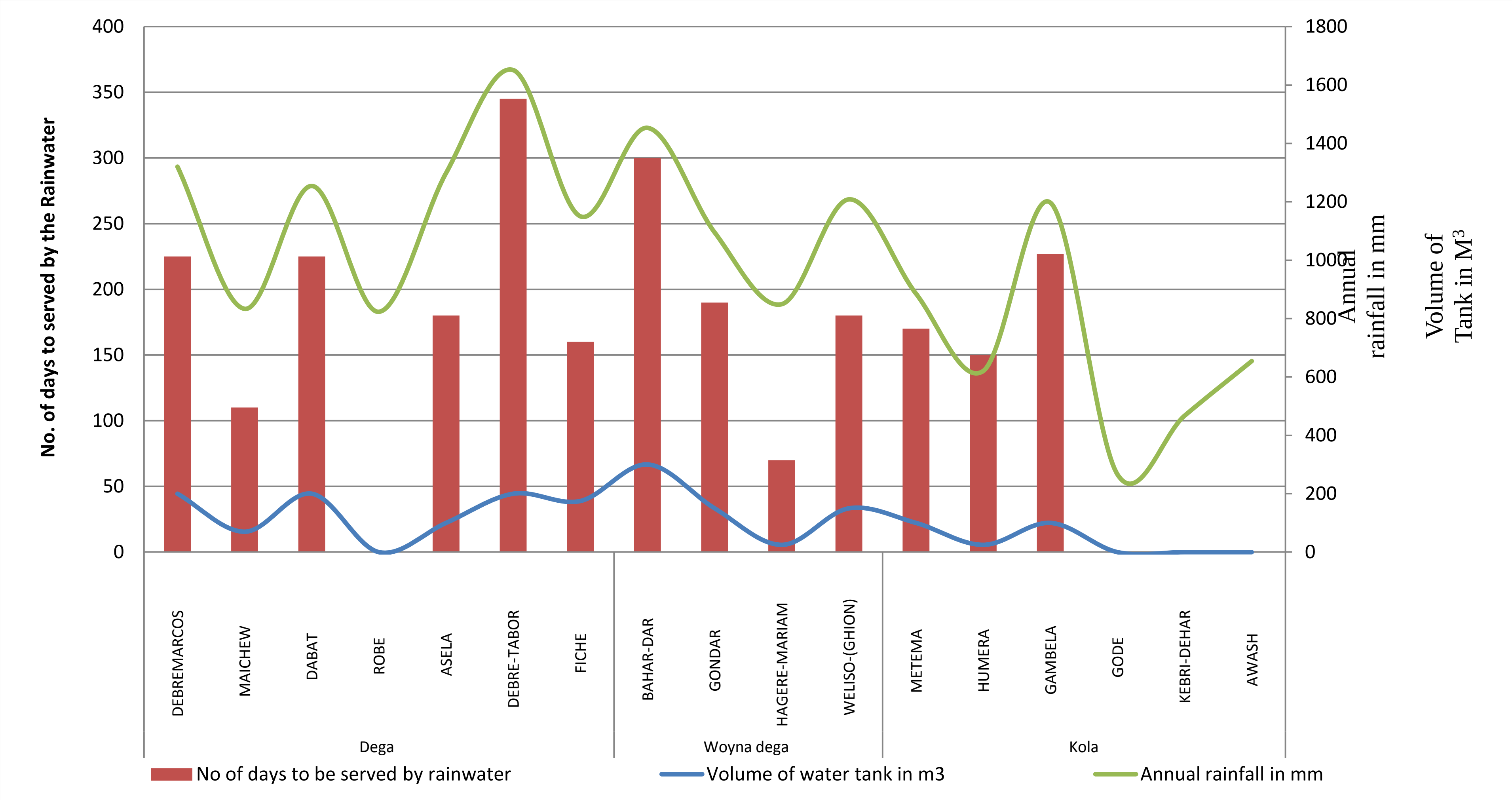

Figure **4-2** Volume of Rainwater Tank and duration of service of the Tank in a particular year **for HC**Rainwater abstraction from Health post roof

The available roof area at Health Post is about 65 m^2. The maximum tank size and volume of water which can be abstracted from the roof of a Health Post and the maximum duration of the service is shown in figure 4.3.

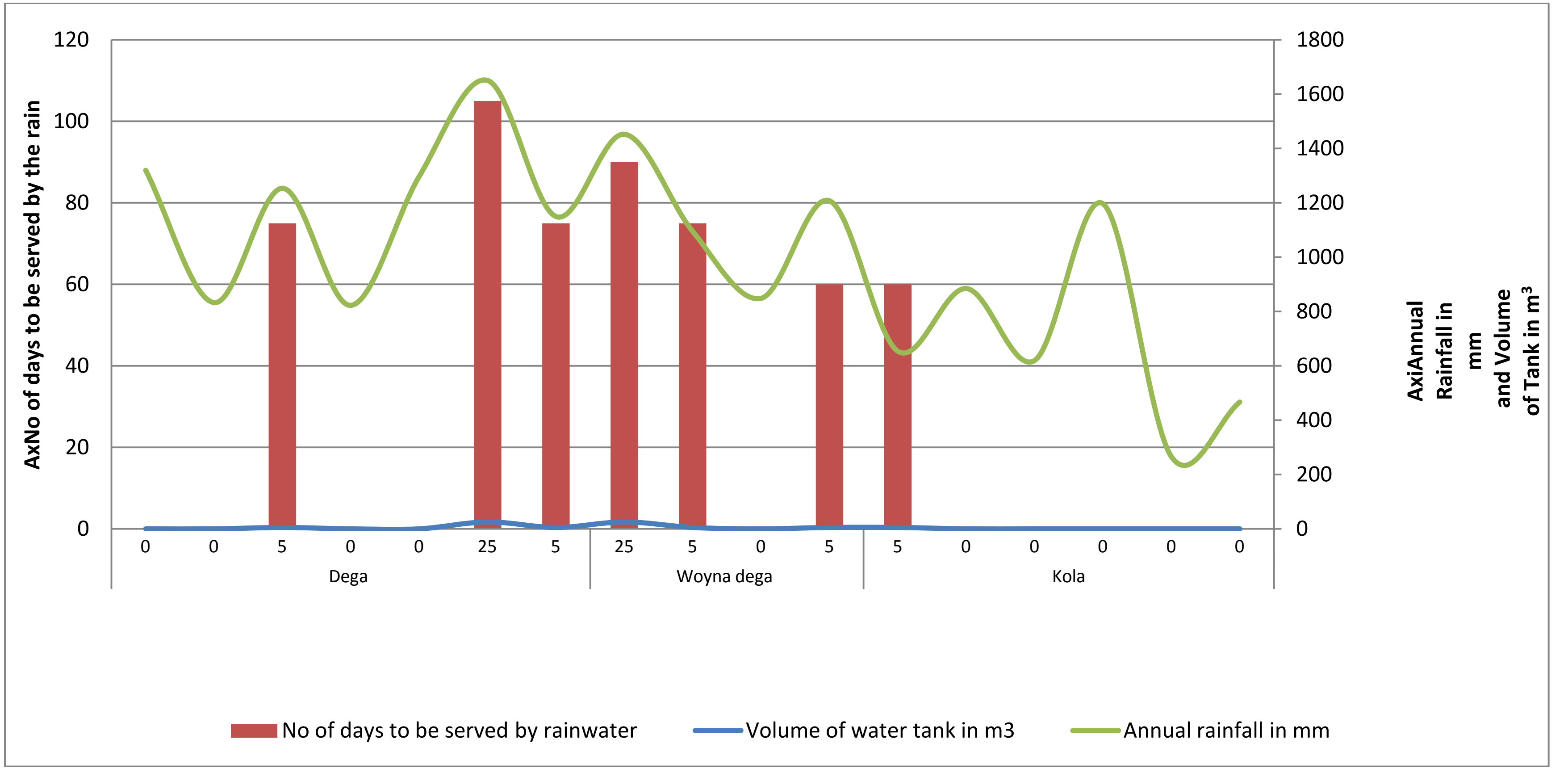

Figure 4-3 **Volume of Rainwater Tank and duration of service of the Tank in a particular year at Health Post**

According to the above figures, rainwater harvesting for Helath Post is not sestainable even in Dega climate due to limited roof area.

4.1.4 Cost Implications

The cost of this technology varies considerably depending on location, type of materials used, and level of implementation. The components that need cost estimate include roofing materials, gutters, conveyance pipes and storage tanks.

Thus, the main components of rooftop rainwater harvesting system which have initial investment costs are the following:

- Galvanized iron gutter
- Galvanized iron/ concrete/ ferrocement, etc. tank
- Down pipe
- Tap and filters
- Where the roof is not suitable for water harvesting, the cost of improving the roof and the gutters will have to be added to the cost of the tank

4.1.5 Operation and Maintenance

Rooftop rainwater harvesting systems require minimal attention with respect to their operation. The major concern is to prevent the entry of contaminants into the tank while it is being replenished during a rainstorm.

The main causes of bacterial pollution are from debris, bird and animal droppings, and insects that enter the tank.

The following maintenance guidelines should be considered in the operation of rooftop rainwater harvesting systems:

- Flush the rainwater to waste and away from the tank to avoid the entry of debris from the catchment area into the tank.
- Check and clean the storage tank periodically.
- Cover and ventilate the tank to avoid mosquito breeding, prevent insects and rodents from entering the tank, and minimize the growth of algae.
- Chlorinate the storage tanks as necessary if the stored water becomes contaminated. (Most times the rainwater is used without treatment.)
- Maintain gutters and down pipes. A good time to inspect gutters and down pipes is while it is raining, so that leaks can easily be detected. Regular cleaning is necessary to avoid contamination.
- If filter is provided, it should be cleaned every few months, filter sand should be washed at least every six months.
- Leaks have to be repaired throughout the year, especially leaking tanks and taps, as they present health risks.
- In some cases, where the water is pumped, periodic, preventive maintenance is required on the small pumps that lift water to selected areas of a house or building, or provide public supply from underground storage tanks;

Maintenance requirement and frequency of maintenance is summarized in Table

Table 4-1 Main activities involved and frequency of maintenance for a RWH system

Activity	Frequency	Materials and spare parts	Tools &equipment
Clean the system	1-3 times per year	Chlorine	Broom, brush, bucket
Divert foul flush	Every storm	-	-
Clean the filters	Twice a year	Sand, charcoal, plastic mesh	-
Disinfect the reservoir	Occasionally	Chlorine	Bucket
Repair roof, gutters and piping	Occasionally	Tiles, metal sheet, asbestos, cement sheet etc., bamboo or PVC pipes, nails, wire	Hammer, saw, pliers, tin cutter
Repair tap or pump	Occasionally	Washers, cup seals etc.	Spanner, Screw driver
Repair reservoir	Occasionally	Cement, sand, gravel, and bricks	Trowel, spade, bucket,

4.2 Spring Water Development

4.2.1 Introduction

A spring may be defined as a place where a natural outflow of groundwater occurs. Spring water is usually fed from a sand or gravel water-bearing ground formation (aquifer), or water flow through fissured rock. Where there are solid layers of block the underground flow of water is forced upward and can come to the surface. The water may emerge either in the open as spring, invisibly as an outflow into a river, stream, lake or the sea. Where the water emerges in the form of a spring, it can easily be tapped. If the collection point is protected with suitable structure, this will prevent contamination at the point of collection and provide the hydraulic conditions for distributing the water to points of use.

Springs are found mainly in mountainous or hilly terrains. Thus, the best places to look for springs are the slopes of hill sides and river valleys. Green vegetation at certain point in dry area may also indicate availability of spring water, or one may be found by following a stream up to its source. However, the local people are the best guides, as they usually know most springs in the area.

Spring water is safe and usually can be used without treatment, provided it is properly protected with a construction that prevents contamination of water from outside.

Springs can be exploited by developing at the spot or by a gravity-fed or pumped delivery system. Springs developed for a gravity-fed water supply should be at an elevation above the supply area.

4.2.2 Tapping of spring

Though, the type of construction to be adopted differs from each other due to spring type, size and location, a tapping structure for a gravity type delivery system emerging down the hillside is considered for further discussion.

Springs can be tapped with drains consisting of graded gravel pack with open joints placed over an impervious layer. The drain must be placed so deep that the saturated ground above them will act as storage reservoir compensating for fluctuation of the ground water table. The water collected by a drain discharges into a storage chamber which is mostly referred as the "spring box".

The drain system and the storage chamber should be so constructed that the contamination of the collected water is prevented. Before the back of the chamber is built, graded stones should be piled up. These serve to make a wall, and will prevent the washing away of soil. The chamber should be fitted with sealed and removable manhole cover for cleaning and access for maintenance work. Air vent, overflow pipe score drains must have screened openings. A diversion ditch should prevent surface runoff running down the hillside from entering the chamber to prevent contamination of the spring water.

4.2.3 Components of Spring Tapping Structure

The spring chosen for a water supply is to be enclosed in a structure from which a pipe leads down conveying the water to point of delivery. The structure can be constructed from concrete or masonry or brick. The spring box serves as storage and distribution for the spring water.

The spring box is usually built into hill side and deep enough to collect or access the spring – water source. This device allows water to enter from the bottom and fill up to a level established by an overflow or vent pipe. Hydraulic pressure then maintains the level in the spring box. The outflow pipe near the base of the device may be connected via pipe to a larger storage system (such as a tank) closer to the point of use or tapped directly at the location of the box.

Thus, the main parts of a spring water collection system are:

- a drain under the lowest natural water level,
- an outlet to tank or collection point
- an overflow pipe just below the roof
- a protective structure providing stability and
- a seal to prevent surface water from leaking back into the stored water.

The drain is usually placed at the lowest point and is provided with scour valve, while the outlet pipe is usually placed above the drain pipe preferably with a screen.

The protective structure may be made of concrete or masonry and the seal is usually made of puddle clay. A screened overflow pipe guarantees that the water can flow freely out of the spring at all times. To prevent contamination infiltrating from the surface, a ditch (known as interceptor drain) diverts surface water away from the spring box and a fence keeps animals out of the spring area. Usually spring water is of good quality, but this should be checked.

For low yield springs it would be advantageous to consider construction of a collection tank for night flow storage. Furthermore, when the terrain doesn't allow construction of spot supply withdrawal can be possible by constructing underground or over ground collection tank downstream at proper location.

4.2.4 Yield of spring

The Maximum day demand of a health center is 0.1 liters/second for eight hours. Due to this, a spring having a minimum discharge capacity of 0.1 liters per second can be selected as a source for health center if it is available within a reasonable distance from the health centre. The collection chamber will be additional storage to conserve the night discharge.

4.2.5 Cost Implications

There are different types of spring tapping structures, ranging from a simple weir structure (open) to more complex constructed (closed) systems. There is also a range of sizes depending on the flow and aerial extent of a given spring.

The main components of spring collection system which have initial investment costs implications are the following:

- Excavation and backfill
- Headwall or tapping box
- Pipe work
- Concrete work
- Masonry work.

4.2.6 Operation and Maintenance Requirements

The type of spring capping would generally require minimal intervention for operation and maintenance. Periodically, however, the chamber should be inspected and cleaned.

Thus, the main O&M activities are:

- Water should be permitted to flow out freely from the chamber at all the time so that it will not find another way out through the aquifer in different direction.
- Operation may include activities such as opening or closing of valves to divert the water to a reservoir, a conduit or a drain.
- The spring and surroundings must be kept clean.

Contamination should be prevented, both where the spring water infiltrates the ground (catchment area), if possible, and in area immediately surrounding the spring. Contamination can come from many sources, including from open defecation, latrines, cattle, pesticide and chemicals.

To avoid the contamination and deterioration of the source, the following points are anticipated to be checked at intervals and on regular basis:

- Check surface drains,
- Check and repair animal-proof fence and gate
- Check and protect the vegetative cover growth both in the area where the spring water infiltrates into the ground (if possible) and in the immediate surroundings of the spring (prevent clogging of the aquifer by growth of roots).
- Check the water flow from the spring box. If there is an increase in turbidity or flow after a rainstorm, surface run-off has to be identified and the protection of the spring improved. If the water flow decreases, it has to be suspected that the collection system is clogged. It may then be necessary to take out the gravel and replace with new gravel
- Regular water samples must be taken and analyzed to check for evidence of faecal contamination;
- the washout should be opened annually and the accumulate silt removed;

- screens should be checked and if they are damaged or blocked they should be cleaned (if dirty) or replaced with non-rusting materials (e.g. copper or plastic screening);
- After cleaning, the washout valve should be fully closed and the manhole covers to be sealed.
- The spring box should be disinfected each time a person enters to clean or repair it, or when there is a bacteriological contamination.
- Leaks in the protective seal, undermining of the headwall, and damaged caused by erosion or settlement of soil must be repaired.

Table 4-2 Main activities involved and frequency of maintenance

Activity	Frequency	Materials and spare parts	Tools and equipment
Clean the surroundings	Weekly	-	Broom, bucket, hoe, machete
Check the water quantity	Occasionally	-	Bucket, watch
Repair fence and clean surface drains	Occasionally	Wood, rope, wire	Machete, axe, knife, hoe, spade, pickaxe
Check the water quality	Regularly	Laboratory reagents	Laboratory equipment
Wash and disinfect the spring	Annually	Chlorine	Bucket, wrench, brush
Repair piping and valves	Occasionally	Spare pipes and valves, cement, sand, gravel	Bucket, trowel, wrench, flat spanners
Repair cracks	Annually	Cement, sand, gravel, clay	Bucket, trowel, hoe, spade, wheelbarrow
Check Turbidity	After every flood		

4.3 Hand Dug Wells

Hand dug wells may be defined as water points that tap water from shallow water tables. As the name suggests, these water points are constructed manually using hoes, picks and shovels. Usually, hand dug wells have a diameter of not less than 1.5 meters and a minimum water column of 3 meters. The wells are lined using bricks or concrete rings; and fitted with a pump.

4.3.1 Some Principles of Dug-Well Design

In principle, the hand dug well supplies water from storage. Where continuous pumping is planned, the rate of inflow to the well should be more than the rate at which the water is being pumped out. This will safeguard the pump from pumping the well dry.

The well storage acts as a "buffer" in providing water at peak pumping periods (such as early morning and late afternoon) when pump discharge can be higher than the rate of inflow to the well. For that reason a dug well is best sited in aquifers of very low permeability.

4.3.2 Well Yields

The storage requirement of the fixtures installed in health center is estimated to be 3.94m^3 per day. Therefore well storage of about this volume would be required and a total 24 hour inflow of this same volume would also be necessary.

Storage of the full daily requirement is not necessary but, the minimum storage should be more than half the daily pumping requirement. As a safety margin, an arbitrary figure of two-thirds of the full daily requirement should be allowed for. It is important to remember that rate of inflow is a function of "head" or drawdown and not dug-well diameter, unless the formation is fractured.

The dug-well diameter does not greatly affect the rate of inflow, but it does directly affect its storage. A dug-well of internal diameter of 1.0m after lining, has storage of about 786 liters for each meter dug.

The capacity of pump is also a critical factor to determine the yield of a shallow well. For hand pumps with piston diameters of 7.5-10 centimeters (3-4 inches) capacities of 1200 to 2000 l/h were found, based on one full stroke per second and an effective pumping time of 75%.

Therefore, the desired well depth can be calculated after determining the full daily required yield of 3940 litter per day. Applying the safety margin the health center would need a well that will store at least two thirds of this full daily requirement which is about 2626 liters. One meter depth of a 1.0 meter diameter well has storage of about 860 liters. To store 2626 liters, a water column of 3.0m is required in a 1.0m diameter well. The desired well depth will be 1.0m below the static water level.

With 1m high concrete rings, at least three porous concrete rings should be installed if possible, with the top of the highest one at least 1m below the static water level. The inflow into the drained hole over 12 hours should be adequate to fill at least to the top of the third ring (i.e. a height of 3m of water). If the pump suction is to be significantly above the bottom of the well, additional depth must be added accordingly.

4.3.3 Well Water Level

A fall in static water level could result in a major drop in both storage capacity and rates of inflow. In order to maintain acceptable water levels, the following should be observed:

- Construct wells in the dry season when water levels are at their lowest.
- Be aware of longer-term water-level fluctuations, if data is available, and dig to appropriate depths.
- Be able to deepen the well fairly easily after completion should there be drastic drops in water levels.

4.3.4 Design of Well Depth

The designed well depth should take into account both the average seasonal water level fluctuation and the desired storage as discussed in the last two sub sections. The time (season) of construction should also be taken into account:

- Dry Season: It is usually adequate to allow for the desired depth of water column (storage)
- Other Seasons: After allowing for the desired storage, add depth to allow for the seasonal water level fluctuation.

4.4 Deep Borehole Construction

A deep borehole is defined as a borehole that is greater than 25 meters in depth and minimum diameter of 110mm. These are normally constructed using mechanical methods.

Construction steps for boreholes

- Site selection,
- The actual drilling operation,
- Installation of casing , screen and gravel pack, to ensure sand-free operation at maximum yield,
- Well development and
- Construction of sanitary seal

Two more of these operations may be performed simultaneously, depending upon the borehole construction technique used.

4.4.1 Drilling Methods

Drilled wells can be constructed using the rotary method or cable tool percussion method. The method selected will depend primarily on nature of the aquifer, type of terrain and economic implications. Anticipated size and depth of well and the geologic formations to be penetrated may also dictate which method is preferable.

4.4.2 Selection of Drilling Methods

The location of the Health Institution and the geologic formations to be drilled dictate the drilling method best suited to the operation. In granular formations, such as in alluvial plains, the rotary method is usually preferred to cable tool because penetration is more rapid, a better well seal is obtained and maintaining a straight hole is easier. Hard sedimentary rock, such as limestone and dolomite, is more resistant to rotary drilling; the small rotary drill with a rock bit makes slow progress at the top of the hole where the weight of the drill pipe is not enough to force the rotating bit against the rock. Air rotary drilling is frequently used for drilling through metamorphic formations.

The cable tool method is preferred when drilling through cavernous rock or other highly permeable material, since all or most of the fluid used in the rotary method may disappear in this type formation, resulting in loss o the return flow or loss of circulation.

4.4.3 Well Completion

Well completion and development must follow the actual drilling to prepare a well for use. Elements of this process include:

- ♦ Installation of casing and screen
- ♦ Installation of gravel pack
- ♦ Development
- ♦ Test pumping
- ♦ Water sampling
- ♦ Cementing and grouting
- ♦ Sterilization

4.5 Water-lifting devices

Water-lifting devices are used to lift water to a height that allows users easy access to water. Lifting devices can be used to raise groundwater, rainwater stored in an underground reservoir, and river water. Communities should be able to choose from a range of water-lifting devices, and each option should be presented with its advantages, disadvantages and implications. For example, water lifting involves additional O&M activities and potential problems, compared to gravity systems, and the latter are often preferred if they are available and applicable to the situation.

The following water-lifting devices are described in this manual:

- Rope and bucket (loose through a pulley, or on a windlass);
- Bucket pump;
- Rope pump;
- Electrical submersible pump; etc.

4.5.1 Rope and bucket

This device is mainly used with hand-dug wells. A bucket on a rope is lowered into the water. When the bucket hits the water it dips and fills, and is pulled up with the rope. The rope may be held by hand, run through a pulley, or wound on a windlass. Sometimes, animal traction is used in combination with a pulley. Improved systems use a rope through a pulley, and two buckets – one on each end of the rope. For water less than 10 m deep, a windlass with a hose running from the bottom of the bucket to a spout at the side of the well can be used. However, the hygiene of this system is poorer, even if the well is protected.

4.5.2 Bucket pump

The bucket pump is mainly used in drilled wells. It consists of a windlass over a 125 mm PVC tube, down which a narrow bucket with a valve in the base is lowered into the water on a chain. When the bucket hits the water, the valve opens and the water flows in. When the bucket is raised, the valve closes and the water is retained in the bucket. To release the water, the pump operator rests the bucket on a water discharger, which opens the valve in the base. The windlass bearings are made of wood.

4.5.3 Rope pump

The basic parts of a rope pump are a pulley wheel above the well, a riser pipe from under the water level to an outlet just under the wheel, and a rope with rubber or plastic washers. The rope comes up through the pipe, over the wheel; back down into the well and into the bottom of the pipe, completing the loop. When the wheel is turned, the washers move upwards and lift water into the pipe towards the outflow. Other important parts are an underwater rope guide that directs the rope and washers back into the pipe, and a frame that holds the pulley wheel. The rope pump can be made at village level using wood, rope and PVC tubing (or bamboo canes with the centers bored out).

4.5.4 Deep-well piston hand pump

With a deep-well piston hand pump, the piston is placed in a cylinder below the water level, which is usually 15–45 m below the ground. The pumping motion by the user at the pump stand is transferred to the piston by a series of connected pumping rods inside the rising main. On the up-stroke, the plunger lifts water into the rising main, and replacement water is drawn into the cylinder through a foot valve. On the down-stroke, the foot valve closes, and water passes the plunger and is lifted on the next up-stroke. The pumping height is limited only by the effort needed to lift the water to the surface. Nowadays, most pump cylinders have an open top. This allows the piston and foot valve to be removed through the rising main for servicing and repairs, while the rising main and cylinder stay in place. The pump rods have special connectors that allow them to be assembled or dismantled without tools, or with only very simple ones. The connecting joints incorporate pump rod centralizers that prevent wear of the rising main. To a large extent, improved models can be maintained at village level.

4.5.5 Submersible pump

For deep-well applications, centrifugal pumps are housed with the electric engine in a single unit that is designed to be submerged. Usually, a multiple-stage pump is used. The multiple-stage pump is placed above a motor and under a check valve that leads to the rising main. Submersible pumps are self-priming, if they do not run dry. To prevent the pump from running dry, the water level in the well must be monitored, and pumping must be stopped if the water level drops to the intake of the pump. Power is delivered through a heavily insulated electricity cable connected to a switch panel at the side of the well. The power may come from an AC mains connection, a generator, or a solar power system.

4.6 Power systems

4.6.1 Introduction

The preferred energy sources for water-supply systems in poor communities are manual effort, animal traction and gravity. Solar power and windmills are attractive alternatives because there are no energy costs, but they require greater capital investment, greater organization and a higher level of technical capacity than traditional power sources.

Wind power may be a good option if there is wind throughout the year, with average monthly speeds exceeding 2.5 m/s. Solar power is a good alternative in areas with a lot of sunshine, where there is no electricity network, and where it is difficult to service internal combustion engines. Solar power is becoming more attractive as photovoltaic cells become more efficient.

If an engine-driven pump is chosen and there is a local electricity network, it is generally advisable to use an electric motor instead of an internal combustion engine, since the O&M of an electric motor is far less complicated.

The following power systems have been included in this manual, because they are of great interest in the sector today:

- windmill;
- solar systems;
- Diesel engine.

The windmill and solar power systems were chosen as examples of alternative power systems, and the diesel engine as a conventional system.

4.6.2 Windmills

The technology Windmills can provide the energy to move a pump. The most common models have a rotor fixed to a horizontal axis that is mounted on a steel tower. The tower of the windmill is usually 9–15 m high. Wind drives the rotor and this movement is transmitted to drive a pump (usually a piston type), either directly or via a gear box. A vane keeps the rotor facing the wind during normal wind speeds, but there is also a mechanism to position the rotor parallel to the wind to avoid damage to it from excessive wind.

Some windmills are fixed facing the wind, others are manually oriented, and some have a braking system. The right combination of pump, windmill and wind characteristic is important for the success of this technology. To be economically feasible, the average monthly wind speed at rotor level should be 2.5 m/s (or more) during the whole pumping season. Because wind can be unreliable, it is recommended that there be water-storage facilities with enough water to last for 3–4 days.

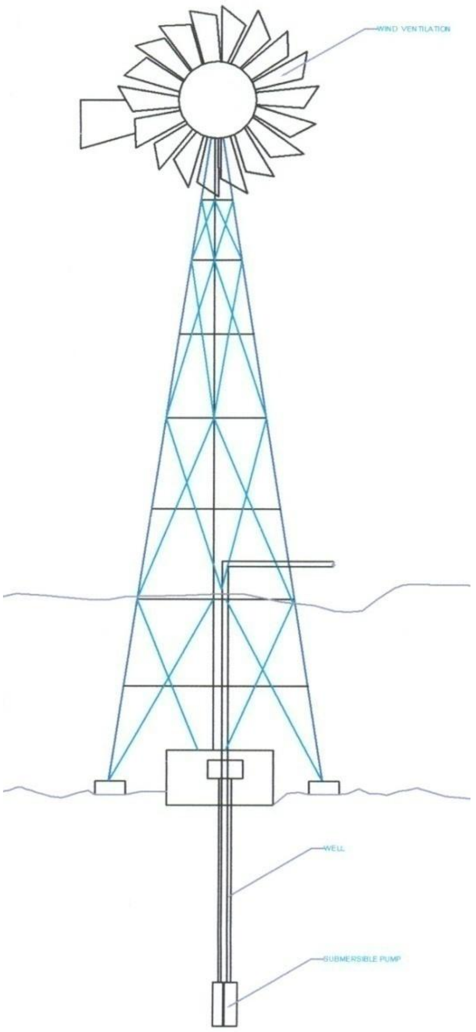

Figure 4-4 Typical windmill and elevated tank

In windy areas where fuel is expensive or the supply is unreliable, windmill pumps are a competitive alternative to diesel-driven pumps.

4.6.2.1 Main Operation & Maintenance activities

Operation is often automatic. Some windmills require manual release of the furling mechanism after excessive wind. When no pumping is needed, the windmill may be temporarily furled out of the wind by hand. Windmill and pump should be checked regularly and any abnormality corrected.

Every month, the windmill and pump must be checked visually. The bolts on the pumping rods tend to come loose, and loose nuts and bolts should be tightened and moving parts greased, as necessary. Paintwork should be maintained annually, and the lubrication oil changed in the gear box (if one is used). Poor maintenance will lead to the bearings wearing out rapidly and the wind will then damage the rotor and other pump parts. Maintenance for a windmill-driven piston pump is comparable to that for a heavily-used hand pump. Usually, one person is responsible for the windmill, pump and storage system. This person has to be trained for the job and may receive a caretaker's fee. Good preventive maintenance may extend the life of a windmill to well over 20 years, while bad maintenance may cause serious damage within a year.

4.6.2.2 Operation & Maintenance technical requirements

Activity and frequency Materials and spare parts Tools and equipment
Monthly

- visually check the pump and windmill;
- Tighten nuts and bolts; Spanners, wrench.
- Lubricate the moving parts. Oil or grease. Lubricator, funnel, container for used oil, spanners.

Occasionally

- Repair the furling mechanism; Special parts, nuts, bolts, rope. Spanners, wrench.
- Replace worn bearings. Bearing. Spanners, wrench, screwdriver.

Annually

- Paint the windmill. Anticorrosive paint. Steel brush, paintbrush.

4.6.2.3 Potential problems

Poorly-trained caretakers may accidentally block the furling mechanism, which can lead to the windmill being damaged in high winds;

- moving parts may wear out quickly, because they are inadequately lubricated;
- when wind speeds are lower than 2 m/s most windmills cannot pump, and many windmills are not economically viable when the average wind speed is below 3 m/s; to avoid problems with pump quality and performance, choose a local manufacturer or supplier with a proven track record, and who supplies a good-quality brand of windmill.

4.6.3 Solar power system

4.6.3.1 The technology

Photovoltaic (PV), or solar, cells convert the energy from light directly to electricity. The cells are shaped like thin squares, rectangles or circles, and are made from special materials such as silicon, germanium, selenium, etc. A number of solar cells wired together under a protective glass plate is called a module, which is the basic element a consumer can buy. Modules can be connected in parallel or series, according to the required voltage and current. A group of modules is called an array. It must be installed where it is completely exposed to sunlight and protected against damage by cattle or vandalism. The electricity produced by the modules may go directly to an engine or be stored in batteries. System performance can be improved in several ways, such as by having the provider design the system for a specific application.

To be economically feasible for pumping the daily average solar radiation at the site should be at least3 kWh/m^2 for every month of the year. It is also recommended that at least a 3-day supply of water or electricity be stored. Solar cells are becoming cheaper and more efficient

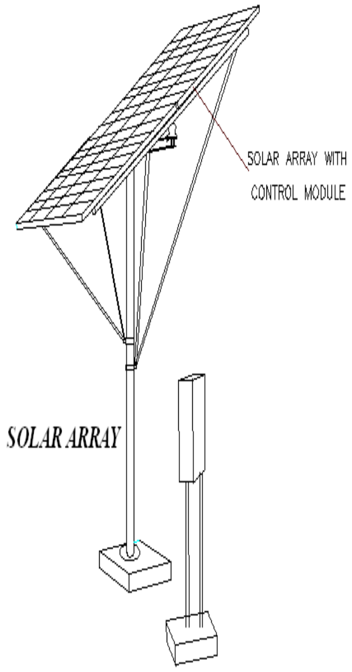

Figure 4-5 Typical Solar Panel with control module

To estimate the solar pump sizes required, the system demand is assumed up to 5m^3 per day. The solar pumps will be discharging to an elevated tank or reservoir on a high ground around the well. For standardizing, the requirements, it is assumed that the pumps will be discharging to an elevated tank in the immediate vicinity of the well.

A GI or PVC riser and transmission pipe of 1 ¼" is assumed for the estimation of head losses.

A maximum total system head of 50-60 meter, including the static head from the well to the elevated tank and pipe system losses, is assumed for all demand ranges. A total pump motor and pump efficiency of 52%, which is typical for pumps in this power range, is assumed for the calculations that follow.

4.6.3.2 Seizing of Solar Pump Systems

Depending on the hydraulic power and total power needed, there is a range of pumping systems, for which a power source is economical. PV is estimated to be the most economical for small power systems.

However, the solar resource at the selected location should be greater than 3 Kwh/m^2 per day for the system to be economically viable.

Generally a PV system should be considered when the hydraulic power (Q times H) is from 200 to 1,500 m-m3/day. Based on this criterion, for systems with a power rating of 0.5kw or less, the best selection is a PV system.

For systems with a power rating above that, while PV is not the most viable system (wind is supposed to be most economical for mid seized systems), but is still economical. Thus, the above selection of PV system rating is the optimal selection for the 5 and 10 m3 per day demand ranges.

The primary considerations for the design of a PV system are:

- The load, (calculated above)
- solar resource(percentage of hours of sunshine) by month in the desired location,
- storage

<u>Solar resource</u>

The following table was used to estimate the average irradiance per day. An average irradiance per day of 210 w/m^2 is used for seizing the PV array requirement.

Table 4-3: Estimated average irradiance per day

Daily mean extra-terrestrial irradiation		Clearness index		Adjusted w/m^2
latitude	kwh/m^2	0.63	w/m^2	
0.00	10.04	6.33	263.55	210.84
5.00	10.00	6.30	262.50	210.00
10.00	9.90	6.24	259.88	207.90
15.00	9.73	6.13	255.41	204.33
20.00	9.49	5.98	249.11	199.29
25.00	9.19	5.79	241.24	192.99
30.00	8.82	5.56	231.53	185.22

<u>Storage</u>

Since the sun's power at a location varies with the time of day and crucially varies with the weather condition. Power on overcast days is around 10% of that on sunny days with clear sky. A battery bank is installed with the system so that the PV array could charge the battery bank during high power conditions. The battery would be used to run the pump on overcast days.

This alternative is not considered here as maintenance of the battery is troublesome and is not feasible in the remote locations where the system could be installed in Ethiopia.

The optimal solution for the storage requirement is to seize the reservoir so that it could carry two days or more supplies and to oversize the pump and array by a percentage. This alternative is adopted for the design.

Seizing of PV array

The energy production for the PV system is estimated as follows:

For a fixed array, the energy day can be estimated as:

Ed = Es * Ec * In * A

Where:

Es, system efficiency = 70%
Ec cell efficiency = 11%

In, average insolation =A, required array area.

Another method is to use the average-day insolation (map value, tilt at latitude) and the power rating of the module.

ED = ES * RP * HS (6.7), where
RP is the rated power, and
HS is the average number of sun hours.

Table 4-4: Characteristics of Solar Pumps for different flow

demand, m3/day	5.00	10.00	15.00	20.00
selected motor rating, kw	0.30	0.50	0.90	1.45
average insolation, hours	5.00	5.00	5.00	5.00
system requirement in watt hours	1500.00	2500.00	4500.00	7250.00
factor for heat and various losses	1.25	1.25	1.25	1.25
array size, watt	375.00	625.00	1125.00	1812.50
module size, watt	125.00	180.00	180.00	180.00
no of modules	3.00	4.00	8.00	12.00
voltage, Voc, V	17.20	43.20	32.80	32.40
voltage, Vmp, V	21.60	34.40	26.20	25.80
current, Isc, A	7.70	5.00	8.00	7.70
current, Imp, A	6.98	4.65	7.63	6.98
check				
total power, watt	375.00	625.00	1125.00	1812.50
module, watt	125.00	180.00	180.00	180.00
area lxw	0.97	1.47	1.47	1.47
no of modules	4.00	4.00	8.00	12.00
average day, kwh/m2/day	5.00	5.00	5.00	5.00
Es, system efficiency, %	70.00	70.00	70.00	70.00
Ec, cell efficiency, %	15.00	15.00	15.00	15.00
Ed = Es*Ec*INd*A, kwh/day	2.03	3.09	6.17	9.26
watthour/day	2032.80	3087.00	6174.00	9261.00
watts	406.56	617.40	1234.80	1852.20

Selection of system

A water pumping systems consisting of a PV array as calculated above, a DC motor driven pump working at the voltages and currents specified above and a controller will be installed. Additionally riser and transmission pipes and tanks seized for the demand range will be installed.

The module or panel will consist of

- Transparent top surface -- glass
- Encapsulant -- thin sheets of ethyl vinyl acetate that hold together the top surface, solar cells, and rear surface
- Rear layer -- thin polymer sheet, typically Tedlar, to seal module
- Frame -- aluminum
- Electrical connection
- The performance of the module will be as per the following standards
    - Standard test conditions -- (STC) 1,000 W/m2, 25°C
    - NOCT -- around 50°C with ambient temperature at 25°C.

4.6.3.3 Main Operation & Management activities

Dust must be removed from the glass plates of the module regularly. In addition, external wires, the supporting structure of the array, covers for the electronic components, and a fence may need occasional repairs. Wood or metal parts that are sensitive to corrosion must be painted every year. Much of the additional electrical and electronic equipment should function automatically for at least 10–15 years, although batteries, AC/DC converters, engines and pumps may need more frequent servicing.

Local organization can be very simple, consisting mainly of appointing a caretaker. However, an adequate number of technicians for repairing such systems must be available at regional or national level.

4.6.3.4 Operation & Management technical requirements

Activity and frequency Materials and spare parts Tools and equipment
Regularly

- Clean the module surface. Water. Cloth, bucket.

Occasionally

- Repair or replace additional Engine brushes, spare battery, AC/DC Spanners, screwdriver, pliers, etc. components; converter, other complete components.
- Repair the fence. Wood, nails, wire. Hammer, machete, pliers.

Rarely

- Repair the mounting structure; Cement, wood.
- Repair the wiring. Electricity cable, insulation tape. Knife, pliers.

4.6.3.5 Potential problems

- vandalism, theft, or cattle damage to the cells, modules or system;
- the storage batteries wear out relatively quickly;
- the initial investment is high;
- the system is not feasible for areas with daily radiation amounts below 3 kWh/m2.

4.6.4 Diesel generator

4.6.4.1 The technology

Diesel generators are frequently used as a stationary power source. Diesel engines differ from petrol engines in that they do not have spark-plugs to ignite the fuel mixture, and work at much higher pressures. Diesel engines need less maintenance that petrol engines, and they are more efficient. Diesel engines can differ in size (from 1–6 cylinders or more) and speed (revolutions per minute), and by the number of engine cycles (2-stroke, or 4-stroke). In general, low-speed four-stroke engines last longer, and high-speed two-stroke engines produce more power per kg of engine weight. Water-cooled engines generally need less maintenance than air-cooled engines.

- diesel engines are well-suited for stationary, high-power output;
- with good maintenance they are dependable energy sources;
- It is important to select a brand that has a good reputation, and for which servicing and spare parts are locally available.

4.6.4.2 Main Operation & Maintenance activities

A diesel engine must be operated by a trained caretaker, and every engine has its own operating instructions.

- Before starting the engine, the levels of fuel, oil and cooling water should be checked, and topped up if any are low.
- During the operation of the engine, check the fuel level and oil pressure, and that the pump and generator are functioning properly.
- Check moving parts may need to be lubricated manually.
- Check engine speed, if it is too low, the engine will have a low efficiency and carbon rapidly builds up in it. This will increase the frequency with which the engine needs to be serviced.
- Record all data on fluid levels and running hours in a logbook.
- Clean the outside of the engine, in dusty conditions, the air filter must be checked and cleaned.
- In moderately dusty conditions, oil-bath air filters are cleaned once a week.
- If the engine is connected to a pump or generator with a v-belt, the belt will need to be replaced regularly.
- Once a year, the engine house must be painted and repaired.
- The engine is serviced for preventive maintenance according to the number of hours it has run.
- Every 50 hours, the clutch (if present) must be greased.
- Every 250 hours, the filters must be cleaned or replaced, the oil changed, and the nuts, bolts and exhaust pipe checked.
- Every 1500 hours, a major service overhaul will be needed, that includes decarburizing the engine, adjusting the valve clearance, etc.

4.6.4.3 Operation & Maintenance technical requirements

Activity and frequency Materials and spare parts Tools and equipment
Daily

- Check fluid levels, and top-up if Fuel, engine oil, cooling liquid. Funnels, containers for liquids.
- necessary;
- start and stop the engine;
- Keep a logbook. Paper, pen.

Weekly

- Check the air filter, and clean or New, dry paper filter, kerosene and Wrench.
- Replace it if necessary; engine oil.
- check for oil and fuel leaks;
- Tighten any loose nuts and bolts. Spanners.

Every 250 hours

- Change engine oil. Engine oil. Spanners.

Regularly

- Clean or replace filters; Oil filter, fuel filter. Spanners, special tools.
- Replace the drive belt. Drive belt. Spanners.

Every 500–2000 hours

- decarbonizes the engine, clean Spanners, brass wire brush, special injector nozzles, adjust valves, etc. tools

Occasionally

- Replace engine parts; Nozzles, injectors, gaskets, bearings, Depends on the part to be replaced, fuel pump, etc.
- Repair the engine mounting and Cement, sand, gravel, nuts and bolts, Trowel, bucket, hammer, chisel, housing nails, galvanized corrugated iron saw, spanners, etc. sheets, wood, etc.

Possible problems

- the generator wears excessively, because O&M is poorly carried out, or neglected;
- the engine is run at less than full loading, which leads to rapid carbon build-up and low engine operating efficiency;
- the drive belts break;
- maintenance is required frequently;
- fuel is difficult to get and its cost is high;
- from time to time, a specialist mechanic will be needed to service and repair the generator.

5. Sanitation and Hygiene for Health Institutions

Latrines for health centers are structures used for managing human excreta at the health centre level. Usually, health centre latrines, depending on the number of the health centre staff and patients visiting the health centre, will have a number of compartments with holes in each compartment to serve the staff and patients of the health centre. The latrines will be constructed by digging long pits and then covered with concrete on top. Compartments are then constructed separating the number of squat holes.

The health centre latrine structure should be of permanent building materials (greater durability) is necessary because of greater usage and of appropriate design to prevent pit collapsing and small children from falling in the hole. For this reason the health centre latrines will be provided with durable lining material such as stone or concrete, concrete floor slab, hollow block walls and corrugated iron sheet roofs.

The sanitation technology options for human excreta disposal covers a range of alternatives from simple and economical technologies such as latrines to more complicated sewerage systems. In the latrine technologies a distinction is made between systems which do not need water (dry systems) and systems which need water for functioning (wet system).

The following technologies are listed in ascending orders from simple technologies such as traditional pit latrines to more complicated sewerage systems.
Dry systems

- Traditional or Improved Traditional pit latrine
- Ventilated improved pit latrine
- Double –vault compost latrine
- Bored hole latrine

Wet systems

- Pour-flush latrine with leaching pit
- Septic tank and aqua privy
- Small bore or settled sewerage system
- Vacuum tanker
- Drainage field
- Conventional sewerage system

From the technology systems described above the most appropriate ones for use for health institutions will be mainly the dry systems as the others require water connection system or adequate water located close by for flushing. Furthermore, the day to day operation doesn’t involve the input of manpower except janitorial service. Therefore in this document only the most recommended dry systems are described.

5.1 Ventilated Improved Pit Latrine

The ventilated Improved Pit (VIP) latrines are designed to reduce two of the problems that are frequently encountered by traditional/improved traditional pit latrines namely smell and production of insects. A VIP latrine differs from a traditional latrine by a vent pipe covered with fly screen. Wind blowing across the top of the vent pipe creates a flow of air which sucks out the foul smelling gases from the pit. As a result fresh air is drawn into the pit through the drop hole and the superstructure is kept free from smells.

The vent pipe also has an important role to play in fly control. Flies are attracted to light and if the latrine is dark inside they will fly up the vent pipe to the light. They cannot escape because of the fly screen, so they are trapped at the top of the pipe until they dehydrate and die. Female flies, searching for an egg-laying site, are attracted by the odours from the vent pipe but are prevented from flying down the pipe by the fly screen at its top.

VIP latrines are a hygienic, low-cost, and indeed sophisticated form of sanitation, have minimal fly and mosquito nuisance, and have only minimal requirements for user care. Figure 5.1shows typical VIP latrine arrangement.

5.1.1 Site Selection

Latrines should be located away from drinking water sources preferably down slope from boreholes or water wells. The following should be considered in sitting latrines:

- At least 50 m away from any water source to avoid risk of pollution.
- A minimum of 6 m away from the health centre block for patients not to travel long distance and yet not to create nuisance or bad odor.
- Avoid locating a VIPL up-hill of a water source to avoid gravity transmission of pollutants via ground water aquifer.
- Located where the soil is firm in order that the structure will not collapse.
- Located on raised ground in order that rain water can drain away easily.
- Located in relation to the appropriate wind direction in order that odor is dispersed away from the latrine surrounding.

5.1.2 Capacity

It is recommended that one squatting pit will be for every twenty patients. According to Healthcare waste generation and its management system: the case of health centers in West Gojjam Zone, Amhara Region, by Muluken Azage, Abera Kumie, published in Ethiopian Journal of Health Development, the mean patient flow per day in all sections and outpatients in each health center was 186. If one caregiver is attending every patient, 186 peoples are expected accompanying the patients. Assuming one squatting hall for 20 people, 10 squatting hall for from which 5 for male and 5 for female are recommended.

Figure 5-1 Typical VIP latrine for Health Center

5.1.3 Construction of VIP Latrine

The size of the pit can be calculated using the following standard procedure. The volume of the pit required for excreta per year per capita is 0.04 to 0.06 cubic meters. Minimum depth of groundwater table level for the latrines is 1.5m.Taking the mean patient flow per day:-

- Volume of pit required for five years operation will be 46.5m3.
- Internal width of the pit is 2.8 meters
- Internal length of the pit to accommodate five separate squatting rooms will be 6.9 meters.
- Depth required to accommodate the above volume will be 2.4 meters.
- Providing 0.6 meter free board,
- Total depth of the pit will be 3 meters.
- Location of VIP latrine must be away from the prevailing wind direction.

It is recommended to line pit using stones. Use dry bonding at the bottom of the pit or use mortar but honey-comb the walls up to one meter from the ground level, then do a solid wall.

The top and bottom width of the masonry structure will be 0.4 & 1.2 meters having vertical internal face.

Reinforced concrete slab is recommended for the floor. The slab will be provided with a hole on the floor close to the wall of the superstructure for insertion of vent pipe. Squatting plates should be cast in an oiled timber mould for ease of construction.

The vent pipe should be 75 - 200 mm, preferably 110mm in diameter. Both the pipe and the screen must be made from corrosion-resistant materials (e.g. fiberglass, PVC). The vent pipe preferably can be plastic with black color or painted black to minimize the deterioration effect by the sun light and absorb heat and increase the temperature inside the vent and expedite the ventilation process.. It should be located in the sunny side of the latrine superstructure allowing the air inside the pipe heat up and create an updraft with a corresponding downdraft through the squatting plate; thus the superstructure will remain odorless. The pipe should be increased to 600 mm if the pipe cannot be located on the sunny side of the superstructure.

The vent pipe should extend for about 0.8m above the roof level and covered with fly-proof netting (thick net that does not allow flies to pass through) material. The pipe can be installed outside the superstructure attached to the wall and passing through the roof structure. The pit can also slightly offset to make room for an external vent pipe.

The VIPL superstructure mainly consists of walls and roofs. The walls could be made from bricks, stone, hollow concrete blocks (HCB) or iron sheets. The roofs could be made from iron sheets or tiles. The entrance to the latrine must be provided with a door.

Figure 5-2 VIP latrine for Health Post

5.1.3.1 Health Centre/Post Hand Washing Facilities

Health centre hand washing facility uses the water from elevated reservoir placed at the left or right elevation of the health centre/post. Hand washing facility promotes the practice of hand washing by patients and staff after they have used a latrine. The practice to hand washing after using the toilet is one of the most effective ways of preventing diarrhea.

A masonry structure with a water supply line from the elevated reservoir is designed. The facility is located at the right or left side of the latrine.

If elevated water tanker is not available, use steel or plastic drum with tap (usually 1000 litre tanks) are used.

The tank should be elevated to provide sufficient pressure for the flow of water and ease of washing hands using the little water available at the bottom of the tank when the tank is not full. This can be achieved by lifting the tank for about 1 meter above ground.

If the health centre tank cannot be connected to water supply line then a borehole or hand dug well should be constructed for safe water supply systems. Afridev pump can be used to fill the bucket whereby labor will be used to fill the tanks and this can be organized by the health centre or a stronger pump such as Climax pump will be used to lift the water to the tank.

5.1.4 Operation and Maintenance of VIP Latrine

5.1.4.1 Operation

A big concern is the keeping of health centre latrines tidy and clean. This is because patients who are already week from other illnesses must not be infected by other diseases from poor sanitation condition of health centre latrines.
Operation of the VIP latrines consists of the following:

- Regular cleaning of the slab with water and a little disinfectant, if available, is required to remove any excreta and urine.
- Wash hands properly once you have cleaned latrines.
- The door must always be closed so that the superstructure remains dark inside.
- The hole should never be covered as this would impede airflow.
- Use of appropriate anal cleansing materials should be available in or near the latrine.
- Ensure you defecate in the hole when using a latrine.
- Wash hands well with soap after each use of a latrine.
- The material used for cleaning / sweeping latrines should never be kept inside the VIPL and should never be used to clean floors in the HC.
- Dispose of children's as well as bedridden or critically ill person's faeces faeces as well as animal waste safely, and wash hands properly soon after disposing the waste.
- Do not throw materials like stones, glass, plastic, rags, etc. into the pit as they reduce the effective volume of the pit.
- Regularly fill the water to hand washing facility, if there is no connected water system
- Seats, raising/support handle for inclusive rooms should be included incorporated and managed properly

5.1.4.2 Maintenance

The following should be practiced regarding maintenance of latrines:

- Check and maintain the slab for cracks.
- Check the superstructure for damage and maintain if any.
- Check that the vent pipe and fly screen are not corroded or damaged.

- Repair of the superstructure (especially light leaks) may be necessary.
- Ensure that surface water continues to drain away from the latrine.
- When the contents of the pit reach the level of 0.5 m below the slab, a new pit has to be dug, Depending on the availability of free space in the Health Institution.
- Transfer the slab and superstructure to the new pit.
- Cover the old pit with at least 0.5m of top soil to hygienically seal it off.

5.1.4.3 Operation and Maintenance Requirement

The VIP latrine is used by patients in the health institution and arrangements should be made for the operation and maintenance of the latrines. The following table shows operation and maintenance requirements for a VIP latrine.

Table 5-1 Operation and Maintenance Requirement of a VIP Latrine

Activity	Frequency	Human Resources	Materials & Spare Parts	Tools & Equipment
Clean drop hole, seat and superstructure	daily	Assigned personnel	Water soap	Brush, bucket
Inspect floor slab, vent pipe and fly screen	monthly	Assigned personnel		
Clean fly screen and vent inside	Every one to six month	Assigned personnel	water	Twig or long bendable brush
Repair slab, seat, vent pipe, fly screen or superstructure	occasionally	General service of HC	Cement, sand, water, nails, local building material	Bucket or bowl, trowel, saw, hammer, knife
Close pit with soil, dig a new pit, transfer slab and superstructure (if applicable)	Every five years	General service of HC	Soil, possibly cement, bricks, nails, and other local building materials	Shovels, picks, bucket, hammer, saw, etc.

5.1.5 Problems and Limitations for Use of VIP Latrine

5.1.5.1 Frequent Problems are:

- Bad quality of the floor slab due to inappropriate materials or improper curing of concrete.
- Inferior quality fly screens get damaged easily by the effects of solar radiation and foul gases.
- Flooding and undermining of improperly sited latrines.
- Children may be afraid to use the latrine because of the dark or because of fear of falling into the pit.
- If the superstructure allows too much light to come in, flies will be attracted by the light coming through the squat hole and may fly out into the superstructure which will jeopardize the whole VIP concept.
- Odour problems may occur during the night and early morning hours in latrines relying more on solar radiation for the air flow in the vent pipe than on wind speed.
- Leakage between pits can occur because the dividing wall is not impermeable or soil is too permeable
- Collapsing because lack of proper casing or pit lining,

5.1.5.2 Major limitations are:

- In hard soils it may be impossible to dig a proper pit
- Pits often fill up too quickly with low infiltration and leaching capacity.
- VIP latrines cannot prevent mosquitoes breeding in the pits.

5.2 Double-Vault Compost Latrine

The double-vault compost latrine consists of two watertight chambers (vaults) to collect faeces. Urine is collected separately in a container as the contents of the vault have to be kept relatively dry. Initially, a layer of absorbent organic material is put in the vault and after each use, the faeces is covered with ash (or sawdust, shredded leaves or vegetable matter) to deodorize the faeces, soak-up excessive moisture and improve C/N (carbon nitrogen) ratio, which ensure that sufficient nitrogen is retained to make a good fertilizer. When the first vault is three quarters full, it is completely filled with dry powdered earth and sealed so that the contents can decompose an aerobically. The second vault is used until it is three quarters full and the first vault is emptied by hand, the contents are used as fertilizer. The vaults have to be large enough to keep faeces for at least a year in order to become pathogen free.

Double-Vault compost latrine can be used where people are motivated to handle and use humus of human excreta as a fertilizer and where no water is used for anal cleansing.

5.2.1 Site Selection for Double-Vault Compost Latrine

The latrine can be built anywhere as there is no pollution coming from the watertight chambers to pollute the surroundings. Where there is rock or a high water table, the vaults can be placed above ground. However for safety, to avoid risk which may result from poor workmanship, it would be better to locate the latrine away from drinking water sources at a distance of not less than 50 m down slope side of the source.

5.2.2 Dimensions for Double-Vault Compost Latrine

The volume of the single pit of the double vault compost latrine must not be less than the volume required for one year to allow the alternate use of the pit to keep faeces for at least a year in order to become pathogen free. The dimensions for the double vault compost latrine can be calculated taking the minimum volume requirement and can be made bigger depending on affordability of the construction cost. Taking the mean patient flow per day:-

- Internal width of the pit is 2.8 meters
- Internal length of the pit to accommodate five separate squatting rooms will be 6.94 meters.
- Volume of pit for one meter depth will be 19.43m^3.
- Volume of latrine space required for excreta disposal for one year is 9.3 m^3.
- The pit can be partitioned in two compartments to be operated alternatively.
- Providing 0.5 meter free board,
- Total depth of the pit will be 3.0 meters.

5.2.3 Construction of Double-Vault Compost Latrine

The superstructure is built over both vaults with squat hole over each vault which can be sealed off. The superstructure mainly consists of walls and roofs. The walls for the latrine

could be made from bricks, hollow concrete blocks or iron sheets. The roofs could be made from iron sheets or tiles. The entrance to the latrine must be provided with a door.
The walls of the pit must be kept straight from top to bottom. Line the walls of the pits and the separation wall with water tight structures such as both sides plastered brick, masonry or concrete structures.
Floor will be from reinforced concrete slabs and finished with cement screed. Seats should be provided on the two holes to only allow the faeces into the holes without urine which has to be collected separately.

5.2.4 Operation and Maintenance of Double-Vault Compost Latrine

5.2.4.1 Operation

Operation of the Double vault compost latrine consists of the following:

- Initially some absorbent organic material is put in the empty vault.
- After each use and whenever available wood ash and organic material are to be added.
- When urine is collected separately it is often diluted with 3-6 parts of water and utilized as fertilizer. If it is not diluted, it may cause a health hazard and should be avoided. Adding ash lime or ash may help, but there is no guarantee that the urine will then be safe.
- Regular cleaning of the slab with water (and a little disinfectant if available) to remove any excreta. Water used for cleaning should not be allowed to go into the latrine as it will make the contents too wet.
- Wash hands properly once you have cleaned latrines.
- Ensure you defecate in the hole and urine is collected separately.
- Wash hands well with soap after each use of a latrine.
- The material used for cleaning / sweeping latrines should never be kept inside the home and should never be used to clean floors in the home.
- Dispose of children's and bedridden or critically ill person's faeces as well as animal waste safely, and wash hands properly soon after disposing the waste.
- Do not throw materials like stones, glass, plastic, rags, etc. into the pit as they reduce the effective volume of the pit and the decomposing process.
- Hand washing facility

5.2.4.2 Maintenance

The following should be practiced regarding maintenance of double vault compost latrines:

- Check and maintain the slab for cracks.
- Check the superstructure for damage and maintain if any.
- Ensure that surface water continues to drain away from the latrine.
- When the contents of the pit reach three quarters full, the contents are leveled with a stick, after which dry powdered earth is added till the vault is full.
- The squat hole is then sealed and the other vault emptied with spade and bucket, after which it can be taken into use.
- The removed contents can be used safely as a fertilizer.
- Household may grow insect repelling plants like citronella around the latrine.

5.2.5 Operation and Maintenance Requirement

Extensive investigation among potential users is needed to find out if the system is culturally acceptable and if they are motivated and capable to operate and maintain the system properly.

Prolonged support by the health office is needed to ensure that users understand the system and execute operation properly.

The following table shows operation and maintenance requirements for a double vault compost latrine.

Table 5-2: Operation and Maintenance Requirement of a VIP Latrine

Activity	Frequency	Human Resources	Materials & Spare Parts	Tools & Equipment
Clean toilet and superstructure, empty urine collection pot	daily	Assigned personnel	Water, lime ash	Brush, bucket
Add ashes or other organic material	After each defecation and whenever available	Assigned personnel	Wood ashes and organic material	Pot to contain the material, small shovel
Inspect floor, superstructure and vault	monthly	Assigned personnel		
Repair floor, superstructure and vault	When necessary	General service of HC	Cement, sand, water, nails, local building material	Bucket or bowl, trowel, saw, hammer, knife
Close full vault after leveling and adding soil, empty other vault, open its squat hole and add 100mm of absorbent organic material before taking into use, store humus or use directly	Depending on size and number of users	General service of HC	Water, absorbent organic material	Shovels and bucket

5.2.6 Problems and Limitations in the Use of Double-Vault Compost Latrine

5.2.6.1 Frequent Problems are:

- Proper operation needs full understanding of the concept, if not results in contents to be too wet making the vault difficult to empty and malodorous.
- Where people are eager to use the contents as fertilizer, they may not allow sufficient time to become pathogen free.
- Flooding and undermining of improperly sited latrines.

5.2.6.2 Major limitations are:

- Only to be used where people are motivated to use human excreta as a fertilizer.
- The system is not appropriate where water is used for anal cleansing (washers).
- The construction cost of a double vault compost latrine is much higher in comparison to traditional pit latrines and VIP latrines.

5.2.7 Recommended Use of Double-Vault Compost Latrine

The use of double vault compost latrine for health institutions may not be practical as the institutions require large volume of hole and the difficulty in handling the latrines.

5.3 Health Centre/Health Post Water points

Adequate drinking water should be supplied for the patients and the caregivers or attendants during their stay in the health institutions. Access to water can be only through water points constructed for this purpose.

A masonry structure with two faucets is designed to serve this purpose. The water supply line will be from the elevated reservoir and the spilling water on the apron is connected to the drainage pipe or the water can be used for watering the green area. The detail should be done based on the specific site condition.

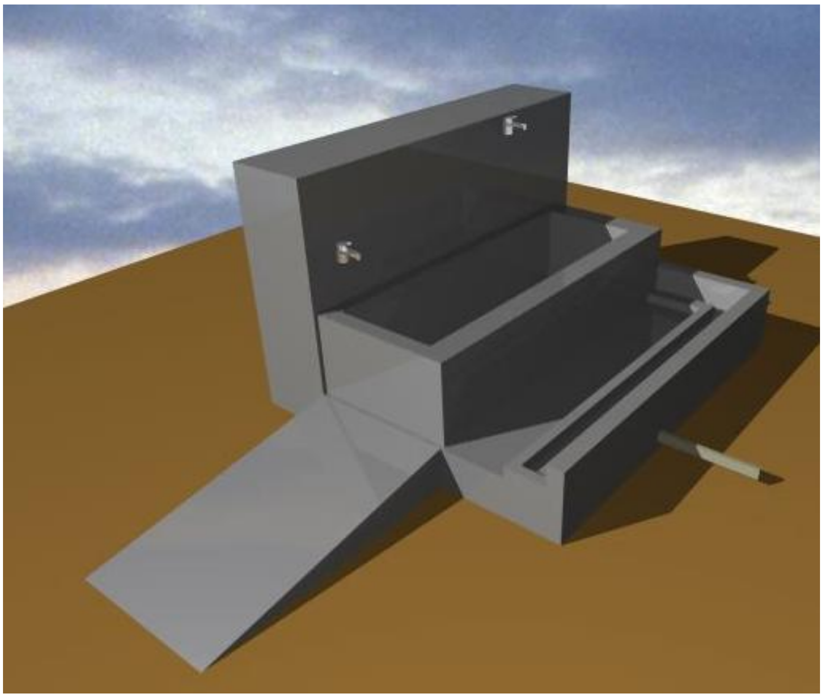

Figure 5-3 Typical Water point

5.1 Cloth Washing Basin

Health center health post cloth washing basins are structures that are used for washing clothes of the inpatients and their caregivers. The existence of washing slabs will encourage washing their clothes which are spoiled by blood from wounds or any other dirt before leaving the health institutions. Washing slabs is designed near the water point and the final location will be confirmed during the construction period. The water supply line is connected to the pipe from elevated reservoir and the dirty water from the washing slab will be drained to the sock away pit or septic tank

Figure 5-4 Typical close washing basin

5.2 Shower room

The provision of shower room in health institutions is to encourage the use of safe water sources when bathing instead of bathing in rivers and lakes. The super structure is designed to be built with similar construction material as the VIPL. The pipe for water supply is connected to the elevated water tanker and the wastewater with the sewer line to septic tank or sock away tank.

Figure 5-5 Typical shower Room

5.3 Health Centre Refuse Disposal

Health institution solid wastes are generated as a result of activities related to the practice of medicine and sales of pharmaceuticals. Some of the health-care solid wastes coming from any particular institution are similar in nature to domestic solid wastes, and may be called "general health-care wastes". The remaining solid wastes are plastic syringes, tissues, bandages; cloths, etc pose serious health hazards because of their physical, chemical or biological nature, and so are known as "hazardous healthcare wastes". In many cases the most dangerous items in healthcare solid wastes are needles from syringes and drips, because the needles shield the viruses from chemical disinfectants and a harsh external environment and the sharp point allows easy access for the viruses into the blood stream of anyone who is pricked by the needle. The key to improving healthcare solid waste management is to provide better methods of storage and to train the staff to adopt safer working practices and segregate as hazardous healthcare wastes from general healthcare wastes.

5.3.1 Quantity of Solid Waste from health centers

According to Healthcare waste generation and its management system: the case of health centers in West Gojjam Zone, Amhara Region, by Muluken Azage, Abera Kumie, published in Ethiopian Journal of Health Development, The daily mean (± SD) healthcare waste-generation rate was 1.79 ± 0.54 kg, which was equivalent to 0.035 ± 0.05 kg/outpatient/day. About 0.93 ± 0.3 kg/day (52.0%) was general and 0.86 ± 0.33 kg/day (48.0%) was hazardous waste. The mean healthcare waste generation rate among health centers did not significantly vary. The above mentioned study also reveals that the mean ± SD (standard deviation) patient flow per day in all sections and outpatients in each health center was 185.8 ± 30.3 and 51.7 ± 11.6 patients, respectively.

A design study for a sanitary landfill for Barhir Dar by Metaferia Consulting Engineers in 2005 revealed that a cubic meter of high-density waste weighs approximately 370 kg.

The annual average solid waste generation from health center is 1718.6Kg from which 893.7 is general waste and 824.9Kg is hazards waste. The total general waste generated in two years time is 1787.4Kg or 4.83m^3.

5.3.2 Segregation, Storage and Transportation.

Prior to final disposal, all wastes must be stored safely and transported to respective disposal sites. It is important that different types of waste are stored separately in order to prevent contamination of 'clean' waste by infectious or pathological wastes, and to allow easy transportation.

5.3.2.1 Segregation

The first step is to determine how waste should be separated or segregated. This will depend on the composition and quantities of waste generated, and how they are to be disposed of. The fact that this may change over time should be considered on-going monitoring should occur.

In general, it is recommended that each treatment, diagnosis and consultation area of the medical centre (including wards, laboratories and immunization points) has a set of three segregated containers: the first for general waste; the second for infectious and pathological waste; and the third for sharps. If pathological wastes such as placentas are to be disposed of separately from infectious waste, for example in a placenta pit, then a fourth type of container should be provided for this and disposal should take place immediately.

5.3.2.2 Storage

All containers should have lids and should be water tight in order to hold liquid. Open cardboard boxes are not recommended since these can easily be tipped over and they disintegrate easily. The size of container will depend on the volume of waste generated in each location but should be easy to handle and transport. It is recommended that containers of uniform color are provided for each type of waste throughout the HC, This facilitates ease of identification and helps to avoid confusion. In addition, containers may be labeled, especially when containing infectious waste or sharps.

It is recommended that needles are stored in specially designed containers. These containers should be disposed of together with their content to eliminate further handling of potentially hazardous needles. Simple sharps containers can be made from empty pharmaceutical or medicine containers. The lid of plastic container is glued or taped shut and a small triangular slot is cut in the lid. Following and injection the user inserts the needle and syringe in the slot, slides it to the narrow point of the slot and pull the syringe away leaving the needle safely in the container. This prevents any handling of used needle.

5.3.2.3 Transportation

Segregated storage containers should be designed so that they can be carried directly to the final disposal point. Containers must therefore be easy to carry, preferably with handles and a tight-fitting but easy-to-remove lid. Where waste is disposed of in an incinerator or pit this should be designed so that it is relatively easy to empty the container without spillage.

5.3.3 General Solid Waste Pits

The appropriate technology to dispose general waste is to excavate a pit within the compound of the health institution. Refuse pit and compost- heap systems could also be practiced at the health centre if appropriate segregation of the general waste is performed.

A pit 2meters long, 2.5meters wide with a depth of 1 meter can accommodate the estimated waste for two years. It is recommended to cover this pit with soil and prepare another one for the preceding two years operation.

The pit can be prepared larger to handle the total amount of garden waste collected. The waste which cannot be composted will be burnet and buried with the ash from incinerators.

5.3.4 Incineration

Incineration is an efficient and effective way to reduce organic and combustible waste to inorganic matter. A medical waste incinerator is designed to disinfect and render hazardous waste safe. Incinerators can be built from a disused oil drum or from brick and concrete with iron or metal doors. Incinerators constructed by brick are highly effective for disposing of sharp, and infectious and pathological wastes. Refuse pit is recommended for dumping the ash from incinerators.

5.3.4.1 Construction Incinerator

The size of the incinerator is usually determined based on the volume of waste to be incinerated. For the standard Health Center and health Post the minimum dimension can be used

Excavate a foundation with 2.5 meters width and 2.5 metrs length with a depth of not more than 0.5 meters. Excavation depends on the type of soil.

- Construct the foundation and the ash pit with reinforced concrete.
- The minimum dimension of the ash pit should be 0.96 meters length and 0.96 meters width having a depth of 0.3meters
- Construct combustion chamber with burnt brick and covered with reinforced concrete..
- Construct brick chimney having a minimum height of 1.5 meters.
- The location of ash pit should be in front of the incinerators ash removal door for easily removal of combusted wastes.
- Location of Incinerator must be away from the prevailing wind direction (always at the back of the facility)

Figure 5-6 Typical Incinerator

5.3.5 Sharp Pits

Where it is not appropriate to construct a proper incinerator, sharps should be disposed of in a specially built and sealed sharps pit. A sharp pit can be a lined or unlined pit in the ground with a sealed cover. The cover is normally constructed from reinforced concrete and has a small hole left in the middle. A tube or pipe rises vertically from the hole. This can be made from steel, asbestos or uPVC and should be approximately 200mm in diameter.

5.3.6 Placenta pits

The construction of the Placenta Pits includes digging two meters deep and around two meters and a half long wide hole. Then the walls are constructed with stone masonry and the whole building is finished with a one and a half meter high "chimney" closed with a cover on top. On one side, there is a fifty centimeters aluminum door where the placenta can be easily thrown. The door prevents the odors from escaping. Everything is painted in yellow to be discreet and nice.

Another very simple way to build the placenta pits is digging a hole and putting inside a big concrete drainage pipe usually minimum one meter in diameter. The door and the chimney can be similar to the conventional placenta pit. This type of pit is recommended for health posts.

5.3.6.1 Construction Placenta pits

Placenta pits are usually constructed below the natural ground level.

- Excavate a circular hole having a diameter of 2.70 meters and a depth of 2 meters
- Provide masonry lining to the internal wall. The masonry structure should have 0.6 meters thickness at the bottom and 0.4 meters at the top with the vertical face to the interior of the pit.
- The internal diameter of the pit should be 1.5 meters.
- Place 30 cm thick gravel at the bottom and a second layer of 20 cm thick course sand acting as a filter media. The liquid from the placenta will seep to the underlying soil through the filter media.
- Construct reinforced concrete cover with access hole to damp the placenta and a vent hole.
- Provide manhole cover and diameter 800 mm vent pipe with vent cap.

5.3.6.2 Operation of Placenta Pits

- Don't close placenta pits with a key and have to be accessible,
- Throw only placentas inside the pit.
- Place a big sticker in the placenta pit saying, "Beware, Placenta Pits, please threw here only placenta and nothing else especially plastic bags"

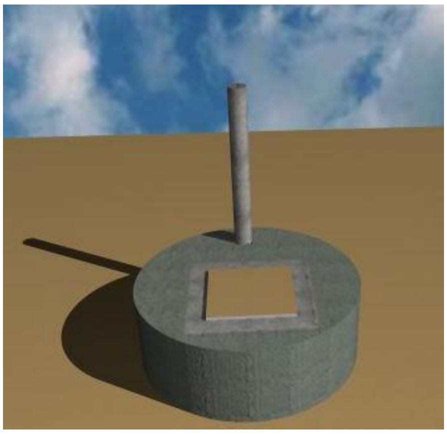

Figure 5-7 Typical Placental Pit

6. Bill of Quantity