بسم الله الرحمن الرحيم

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RAINWATER HARVESTING GUIDELINE

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بسم الله الرحمن الرحيم

UTILITY REGULATORY AUTHORITY

RAINWATER HARVESTING GUIDELINE

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1. Introduction

1.1. Rainwater harvesting (RWH) is the collection and storage of rain, rather than allowing it to run off. Rainwater is collected from a roof-like surface and redirected to a tank, cistern, deep pit (well, shaft, or borehole), aquifer, or a reservoir with percolation, so that it seeps down and restores the ground water.

1.2. This guideline is issued and implemented by Utility Regulatory Authority (URA) under the powers vested in it by Clause 33 of Act Number 26/2020 (Utility Regulatory Act).

1.3. This guideline will come into effect from the date of publication in the Government Gazette,

2. Design aspects

2.1. Rainwater harvesting systems must be properly designed in order to be effective. An inadequately designed system will result in operational issues, which will increase the operation and maintenance costs, whether it be a storage or recharge structure. The system can possibly stop working as a result.

2.2. Rainfall data is required to design rainwater harvesting system. Preferably data for a period of ten years will be useful. The design will be improved if the data is more dependable and particular to the location.

2.3. The quantity of water available from a rainwater harvesting system depends on the size of the 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. If a catchment surface is too small, it may not provide sufficient water to fill the tank. Furthermore, the rainfall pattern and user-demand are also factors that must be taken into account. Thus, effective rainwater harvesting will depend on optimum match between,

2.3.1. Rainfall data

2.3.2. Roof area

2.3.3. Water storage capacity

2.3.4. Daily consumption rate

2.4. For designing an RWH system and deciding the size of storage tank, it is essential that the following factors are taken into consideration.

2.4.1. Estimate the water demand by considering three factors

2.4.1.1. Number of persons per household

2.4.1.2. Usage of water (quantity)

2.4.1.3. Alternative sources of water for other uses

2.4.2. Consider the duration of dry spell (period without rain)

2.4.3. The quantity of rainwater to be harvested can be decided by considering the following factors

2.4.3.1. Intensity and frequency of rain

2.4.3.2. Surface area of the roof

2.4.3.3. Availability of material and labour

3. Water demand

3.1. Water demand varies depending on the location and water requirement of a household. In the areas where water is very scarce, people may use less water. Common norm of water requirement per person is considered as 20 liters per day. For other domestic uses like toilets, floor washing, cleaning etc. locally available water (ground water) can be used even if it is of inferior quality. The water demand is calculated by the following formula:

$$Demand = water\ use\ \times members\ of\ a\ household\ \times 365\ days$$

Work example

Suppose the water usage is 20 liters per person per day and there are 5 members in a household then, water demand for one year will be:

$$20\ lpcd\ X\ 5\ members\ X\ 365\ days\ = 36{,}500\ liters\ per\ year$$

Average water demand per month will be 3,000 liters.

For a dry period of four months, the required minimum storage capacity is,

3,000 L X 4 months = 12,000 liters

Water supply is calculated by the following formula,

Supply = rainfall (mm/year) X area (sq. m) X

Runoff coefficient

For example, if the rainfall per year is 800 mm, then, a metal sheet roof of 80 m^2 area will supply, 51,200 liters.

4. Runoff and runoff coefficient

4.1. Runoff is the term applied to the water that flows away from a catchment after falling on its surface in the form of rain. Runoff can be generated from both paved and unpaved catchment areas of buildings. Runoff coefficient is the factor which accounts for the fact that all the rainfall falling on a catchment cannot be collected. Some rainfall will be lost from the catchment by evaporation and retention on the surface itself. The rainwater collection efficiency is measured in terms of runoff coefficient. If the collection efficiency of a roof material is 80 %, then, the runoff coefficient is 0.8. The type of roofing material determines the runoff coefficient for designs. The runoff coefficients for roof materials used in Maldives are given in Table 1 below.

Table 1: The runoff coefficients for roof materials

Roof material	**Runoff coefficient**
Sheet metal	0.8 to 0.85
Cement tiles	0.62 to 0·69
Clay tiles (Machine made)	0.30 to 0.39
Clay tiles (Handmade)	0.24 to 0.31

5. Roof Catchment

5.1. In rainwater system component design, the roof material of the building or house is the first choice of the system component. Rainwater can be collected from most forms of roofs. Tiled roofs, roofs sheeted with corrugated mild steel etc., are preferable, since they are the easiest to use and will give the cleanest water. Thatched or palm leafed surfaces are also feasible; although they are difficult to clean and can often taint the runoff. Asbestos sheeting or lead-painted surfaces should be avoided. If the house is small to catch up required rainfall, additional roof/catchment as an open sided shed can be built near or attached with the house.

5.2. The amount of rainfall and household water demand varies from place to place and household to household respectively. Thus, prior to designing the rainwater harvesting system, knowing the roof size of each household is most important for effective rainwater harvesting. The second consideration will be of roof material. Smoother the surface, better the quality and quantity of water. However, the quality and quantity of rainwater from different roofs is a function of roof material, climatic conditions, and the surrounding environment. The runoff from a roof is directly proportional to the quantity of rainfall and the plan area of the roof. A square meter of roof area will produce 1 liter of water for every 1mm of rain, excluding water lost to evaporation, spillage losses, and wind effects.

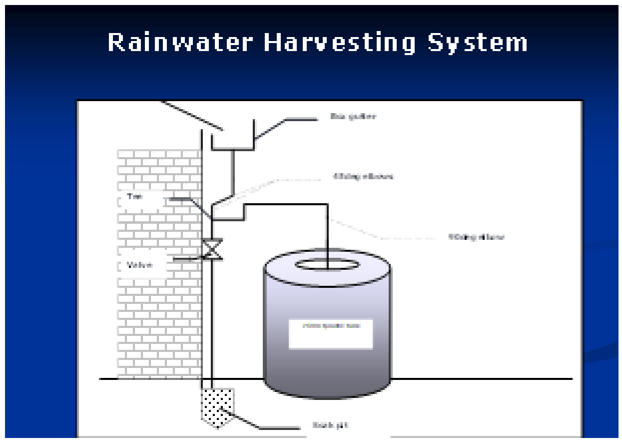

Figure 1: Rainwater Harvesting System

6. Roof materials

6.1. Roofs can be made from a variety of materials. Roofs made from grass and those likely to generate toxic materials are not recommended. The typical roofing materials include the following:

6.1.1. Galvanized corrugated iron or plastic sheets, or tiles.

6.1.2. Thatched roofs made from palm leaves (coconut and palms with tight thatching are best). Other thatching materials and mud discolor and contaminate (through rats) the rainwater.

6.1.3. Unpainted and uncoated surface areas are best. If paint is used it must be non-toxic (no lead-based paints).

6.1.4. Asbestos-cement roofing does not pose health risks - no evidence is found in any research. However, the airborne asbestos fibers from cutting, etc. do pose a serious health risk if inhaled.

6.1.5. Timber or bamboo is also used for gutters and drainpipes; for these materials, regular replacement is better than preservation. Timber parts treated with pesticides to prevent rotting should never come into contact with drinking water.

6.2. The most significant is galvanized steel sheets which is easily available in Maldives. It retains less contamination than rougher surfaces and the runoff coefficient of metal is high. Metal sheets are zero porous so rainwater loss from the metal roofing will be less. Contrary to metal sheet, clay and concrete tiles are both porous.

6.3. Concrete and clay tiles/concrete materials are also easily available in the local market, but more than 10% rain may be lost due to its texture and evaporation. To reduce water loss, porous parts can be reduced by coating with fine cement or painting, but still, probability of bacterial growth in cement or clay tiles is higher than metal roof. If care is taken in maintaining roofs, serious water contamination from roofing is rare. Severe air pollution, lead fittings and toxic paint in roof may contaminate the rainwater as it runs from roof.

7. Suitable materials

7.1. The efficiency of rainwater collection depends on the materials used, the construction, maintenance and the amount of rainfall. A commonly used overall efficiency figure is 0.8. If cement tiles are used as roofing material, the year-round roof runoff coefficient is some 0.75, while clay tiles collect usually less than 50% depending on the production method. Plastic and metal sheets do best with an efficiency of 80-90%.

8. Gutters and down pipes

8.1. Gutters are channels fixed to the edges of the roof to collect and transport rainwater to the storage tank. These must be properly sized, sloped and installed to maximize the efficiency and minimize water loss. Gutters come in a wide variety of shapes and forms, ranging from the factory-made PVC type to home-made gutters using bamboo or folded metal sheet.

8.2. Gutters are usually fixed to the building just below the roof and catch the water as it falls from the roof. For effective operation of RWH, a well-designed and carefully constructed gutter system is crucial. 90% or more of the rainwater collected on the roof will be drained to the storage tank if the gutter and down pipe system is properly fitted and maintained.

8.3. Common materials for gutters and down pipes are metal and plastic; which are available locally. But also cement-based products, bamboo and wood can be used. With high intensity rains, rainwater may shoot over the conventional gutter, resulting in a low production; splash guards can prevent this spillage.

8.4. To keep leaves and other debris from entering the system, the gutters can have a continuous leaf screen made of quarter-inch wire mesh in a metal frame installed along the length of the gutter and a screen or wire basket at the head of the downspout. If not, the gutters must be cleaned regularly.

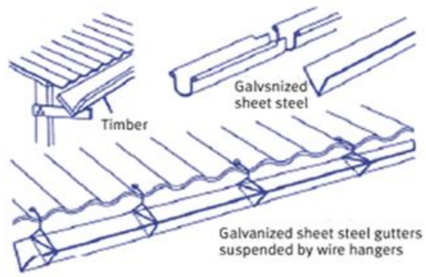

Figure 2: Gutters

8.5. Gutters can be prepared in semi-circular and rectangular shapes. Locally available material such as plain galvanized iron sheets can be easily folded to the required shapes to prepare semi-circular or rectangular gutters. Semi-circular gutters of PVC material can be readily prepared by cutting the PVC pipes into two equal semi-circular channels. Bamboo poles can also be used for making gutters if they are locally available in sufficient quantity. Use of such locally available materials reduce the overall cost of the system.

9. Manufacture of low- cost gutters

9.1. Factory-made gutters are usually expensive and beyond the reach of the common people, if indeed available at all in the local marketplace. They are seldom used for very low-cost systems. The alternative is to make gutters from materials that can be found cheaply in the locality. There are a number of techniques that have been developed to help meet this demand.

9.2. V-shaped gutters from galvanized steel sheets can be made simply by cutting and folding flat galvanized steel sheets. Such sheets are readily available in most market centers (otherwise corrugated iron sheets can be beaten flat) and can be worked with tools that are commonly found in a modestly equipped workshop. One simple technique is to clamp the cut sheet between two lengths of straight timber and then to fold the sheet along the edge of the wood. A strengthening edge can be added by folding the sheet through 90º and then completing the edge with a hammer on a hard flat surface. The better the grade of steel sheet that is used, the more durable the product will be.

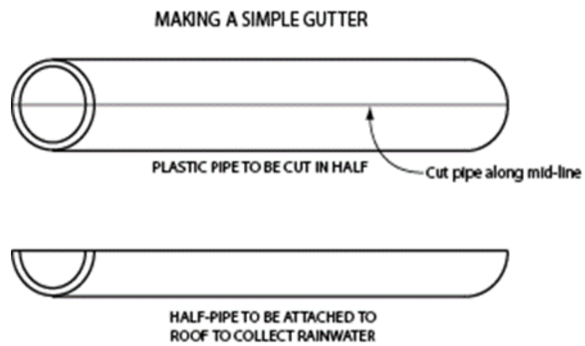

Figure 3: Cutting plastic pipe into half to make gutter

9.3. PVC pipes may be cut into half to make gutters (Figure 3). This requires only a saw and some clamps to fix the half-pipes to roofs. It may be made quickly and cheaply in areas where plastic pipes are available.

9.4. Rainwater is collected in guttering placed around the eaves of the building. Low-cost guttering can be made from 22 gauge galvanized mild steel sheeting, bent to form a 'V' and suspended by galvanized wire stitched through the thatch or sheeting.

9.5. The guttering drains to a down-pipe which discharges into a storage tank. The down-pipe should be made to swivel so that the collection of the first run-off can be run as waste (the first foul flush), thus preventing accumulated bird droppings, leaves, twigs as well as dust and debris and other matter from entering the storage tank.

9.6. Sometimes a collecting box with a mesh strainer (and sometimes with additional filter media) can be used to prevent the ingress of potential pollutants. The guttering and down pipes should be sized so as to be capable of carrying peak volume of run-off; in the tropics this can occur during high intensity storms of short duration.

10. Size of gutter

10.1. The roof size, roof material and its slope are important to design the gutter size. The maximum discharge in gutters at end point can be estimated from rainfall intensity, roof size, roof slope, roof material and gutter slope.

10.2. A guide to the gutter widths and down pipe diameter (adapted from Still and Thomas 2003, Davis and Lambert 2002) is depicted in table below. Lead cannot be used as gutter solder as slightly acidic quality of rain could dissolve lead which is hazardous to human health.

Table 2: Required gutter width and down pipe size

Roof area (m^2)	Gutter width, (mm)	Down pipe, (mm)
17	60	40
25	70	50
34	80	50
46	90	63
66	100	63
128	125	75
208	150	90

11. Down pipe

11.1. Down pipe is the pipe, which carries the rainwater from the gutters to the storage tank. Down pipe is joined with the gutters at one end, and the other end connected to the filter unit of the storage tank. PVC or GI pipes of diameter 50 mm to 75 mm (2 inch to 3 inch) are commonly used for down pipe. Bamboo can also be used wherever available in suitable size.

11.2. In Maldives, both PVC and galvanized gutters are used for rainwater channeling. PVC gutters do not rust and are of light weight, whereas, galvanized steel gutters may start rusting if proper care is not taken. Slightly acidic rain may corrode roof chemical materials that will flow into the tank.

11.3. An inclination in gutter is necessary to maintain free flow condition, cleanliness and retains less debris. Plastic gutters are designed with splash guard. Slope the gutters one-sixteenth inch per one foot of gutter to assure proper downward flow. Place the gutter hangers about every three feet. The outside face of the gutter should be lower than the inside face to assure drainage away from the building wall. Gutters should be placed one-quarter inch below the slope line of the roof so that debris can clear without knocking down the gutter.

Figure 4: Down Pipe

The following table gives an idea about the diameter of pipe required for draining out rainwater based on rainfall intensity and roof area:

Table 3: Sizing of the roof (m²) related to rainfall rate and down pipe size[1]

Diameter Of pipe (mm)	Average rate of rainfall (mm/h)					
	50	75	100	125	150	200
50	13.4	8.9	6.6	5.3	4.4	3.3
65	24.1	16.0	12.0	9.6	8.0	6.0
75	40.8	27.0	20.4	16.3	13.6	10.2
100	85.4	57.0	42.7	34.2	28.5	21.3
125	-	-	80.5	64.3	53.5	40.0
150	-	-	-	-	83.6	62.7

[1] Source: National Building Code of India

12. Leaf Screens/Roof Washers

12.1. To keep leaves and other debris from entering the system, the gutters should have a continuous leaf screen made of 1/4-inch wire mesh in a metal frame, installed along the entire length, and a screen or wire basket at the head of the down pipe. Gutter hangers are generally placed every 3 feet. The outside face of the gutter should be lower than the inside face to encourage drainage away from the building wall. Where possible, the gutters should be placed about 1/4 inch below the slope line so that debris can clear without knocking down the gutter.

12.2. To prevent leaves and debris from entering the system, mesh filters should be provided at the mouth of the drain pipe. Further, a first-flush (foul flush) device section should be provided in the conduit before it connects to the storage container. If the stored water is to be used for drinking purposes, a sand filter should also be provided.

13. First Flush Device

13.1. First flush or the rain diverter is provided to flush off the first rain before it enters the storage tank. The first flush water will be most contaminated by particulate matter, bird droppings, and other material laying on the roof (debris, dirt and dust). During the first rains, it is essential to prevent this unwanted material going into the storage tank. If not, this can cause contamination of water collected in the storage tank, thereby rendering it unfit for drinking and cooking purposes.

13.2. After screening gutters, a first flush device is incorporated in the Rooftop Rainwater Harvesting Systems to dispose of the 'first flush' water so that it does not enter the tank. This device will improve the quality of water, lengthen the life of system components and reduce overall maintenance.

13.3. There are two such simple systems. One is based on a simple manually operated arrangement, whereby, the down pipe is moved away from the tank inlet and replaced again once the first flush water has been disposed.

13.4. In another simple and semi-automatic system, a separate vertical pipe is fixed to the down pipe with a valve provided below the "T" junction. After the first rain is washed out through the first flush pipe, the valve is closed to allow the water to enter the down pipe and reach the storage tank.

13.5. First flush diverters are fitted in most of the houses in Maldives. The diverter is manual type and operated during the start of rainfall. Generally, in islands, people divert the rainwater to the storage tank after the water coming from first flush diverters is noticeably clear. The water from first flush diverters flow through their surface drainage and at some places it is diverted to well for groundwater recharge. Automatic first flush diverter is not seen in Maldives.

Figure 5: First Flush Diverter

14. Filter Unit

14.1. The filter unit is a container or chamber filled with filter media such as coarse sand, charcoal, coconut fiber, pebbles and gravels to remove the debris and dirt from water that enters the tank. The container is provided with a perforated bottom to allow the passage of water. The filter unit is placed over the storage tank.

14.2. Commonly used filters are of two types. One is a Ferro cement filter unit, which is comparatively heavy and the other is made of either aluminum or plastic bucket. The latter is readily available in market and has the advantage of ease in removing, cleaning and replacing. Another simple way of filtering the debris and dust particles that come from the roof along with rainwater is to use a fine cloth as filter media. The cloth, in 2 or 3 layers, can be tied to the top of a bucket or vessel with perforations at the bottom.

15. Design of storage tanks

15.1. Storage tank is used to store the water that is collected from the rooftops. In the rainwater harvesting system, storage tank is usually the most expensive component (almost 90 % of the total cost). For this reason, it is crucial that thorough design is done in order to deliver the best storage capacity at the lowest possible price. The design should be durable, watertight and cost effective. It should take in to consideration the appropriate volume with respect to the catchment area, rainfall conditions and water demand. Local materials, labor skills, cost, personal preferences and other external factors are other important considerations.

15.2. The volume of the storage tank can be determined by knowing the water demand of a household as calculated above. Once the water demand is known, depending upon the requirement and affordability of the household, the storage tank or cistern can be decided. Important factors to incorporate into the design of a storage tank include adequate capacity; overflow protection; inclusion of a manhole for easy access and inspection. Tank size varies depending on the rainfall pattern and the water demand. When there are long dry spells, roof collection area and the tank size will be large, but the wise use of water (good management) and use of alternative water for non-drinking uses will significantly reduce the required roof area and the storage capacity.

15.3. There are almost unlimited number of options for storing water. Common vessels used for very small-scale water storage in developing countries include plastic bowls and buckets, jerry cans, clay or ceramic jars, cement jars, old oil drums, empty food containers, etc. Some of the most popular tanks used in rainwater harvesting are High Density Poly Ethylene (HDPE) rainwater tanks. These tanks are most favored because of the various advantages they have. Firstly, they can be used above the ground or can be kept even below the ground. They are very light in weight and easy to carry around. They are UV resistant and compared to other varieties are less expensive. Fiberglass rainwater tanks are another popular type of rainwater storage tank. The biggest advantage they have is that they are resistant to rust and chemical corrosion. Fiberglass rainwater tanks can also withstand extreme temperatures.

15.4. The different types of materials used to construct rain water storage tank include Ferro cement, bricks and blocks, concrete, metals, plastic, wood and fiber glass. The Ferro cement tanks are usually constructed above ground level because of the advantages, such as, a) ease in finding structural problems/leaks, b) easy to maintain and clean and c) easy to draw water. It is difficult to detect the leaks and take corrective measures in case of underground tanks. Water from underground tanks cannot be drawn by gravity. Some kind of manual or power lifting devices need to be used for drawing the water. Further, in coastal areas, underground tanks are prone to water contamination due to fluctuation in groundwater table and leakage of stored water.

15.5. The storage tank is provided with a cover on the top to avoid the contamination of water from external sources. A lid covers the manhole avoiding exposure of stored water to the outside environment. The storage tank is provided with pipe fixtures at appropriate places to draw the water, to clean the tank and to dispose of the excess water. They are named tap or outlet, drainpipe and over flow pipe respectively. PVC or GI pipes of diameter 20 mm to 25 mm (¾ inch to 1 inch) are generally used for this purpose.

15.6. Open topped vessels such as buckets and drums are not recommended for collection of rain water for drinking purpose as it may get contaminated easily in such open storage vessels. Storage tanks should be opaque to prevent the light to reduce algal growth. Also, thinner walled tanks will tend to heat up in hot climate, so if the tanks are not shaded, thicker walled Ferro cement or concrete is preferred.

Figure 6: Storage Tanks

16. Storage tanks and cisterns

16.1. For storing larger quantities of water, the system will require a tank or a cistern. The storage tanks are normally above-ground storage; cistern are below-ground storage vessels. These can vary in size from one cubic meter (1,000 liters) up to hundreds of cubic meters for large projects. The typical maximum size for a domestic system is 20 or 30 cubic meters. The choice of system will depend on a number of technical and economic considerations listed below.

16.1.1. Space availability
16.1.2. Locally available options
16.1.3. Local traditions for water storage
16.1.4. Cost of purchasing new tank
16.1.5. Cost of materials and labor for construction
16.1.6. Locally available materials and skills
16.1.7. Ground conditions
16.1.8. Use of RWH – whether the system will provide total or partial water supply

16.2. One of the main choices will be whether to use a tank or a cistern. Both, tanks and cisterns have their advantages and disadvantages. The table below summarizes the pros and cons of each:

Table 4: Advantages and Disadvantages of tanks & cisterns

	Tank (above ground)	Cistern (underground)
Pros	• Above ground structure allows easy inspection for leakages • Many existing designs to choose from • Can be easily purchased 'off-the-shelf' • Can be manufactured from a wide variety of materials • Easy to construct from traditional materials • Water can be extracted by gravity in many cases • Can be raised above ground level to increase water pressure	• Generally cheaper due to lower material requirements • Not vulnerable to water loss by negligence • Require little or no space above ground • Unobtrusive • Surrounding ground gives support allowing lower wall thickness, and thus lower costs • Water is cooler
Cons	• Require space • Generally expensive • Can be easily damaged • Prone to weather conditions • Failure can be dangerous	• Water extraction is more problematic, often requiring a pump • Leaks are more difficult to detect • Contamination of the cistern from groundwater is more common • Tree roots can damage the structure • There is danger to children and small animals if the cistern is left open • Flotation of the cistern may occur if groundwater level is high and the cistern is empty. • Heavy vehicles driving over a cistern can cause damage

17. A checklist for design

17.1. Following is the checklist of various components of a typical RWH system.

17.1.1. A typical rainwater collection system for domestic use will consist of following key components

17.1.1.1. Catchment area

17.1.1.2. Conveyance system

17.1.1.3. Storage tank

17.1.2. An appropriate roof for rain water collection shall comply to the following

17.1.2.1. If collected water is to be used for potable water, then the roof material shall be of food grade.

17.1.2.2. A flat roof with gentle slope will drain water towards the storage tank.

17.1.2.3. Provide clean and impervious roof made from non-toxic materials.

17.1.2.4. Lead based paints should be avoided.

17.1.2.5. Sloping roof should have gutter (plastic or other available material) to collect water and channel it down to down pipe.

17.1.2.6. Roof shall be easily accessible to clean when required.

17.1.3. Following shall be considered when designing the conveyance system (Gutters and down pipes)

17.1.3.1. Easy access for inspection and maintenance should be provided.

17.1.3.2. PVC pipes resistant to UV rays is preferable.

17.1.3.3. Sufficient gradient should be provided in the gutters for free flow to down pipes.

17.1.3.4. Provide course filter and first flush devices before the water enters the down pipe.

17.1.3.5. Provide first flush in the down pipe before storage.

17.1.4. An appropriate storage system shall comply to the following

17.1.4.1. Decide the method and location to install the storage tank (ground level or underground and away from places of contamination like toilets, septic tanks etc.)

17.1.4.2. Select the type of storage tank (HDPE or cement concrete or other)

17.1.4.3. Provide an overflow pipe to direct the excess water to a suitable place (maybe another storage tank)

17.1.4.4. Provide a wire mesh to cover the storage tank inlet

17.1.4.5. Provide a well-covered manhole for easy access for the inspection of the tank

17.1.4.6. Provide tank tap or draw off pipe at sufficient height to draw water

17.1.4.7. Storage area should be accessible for maintenance and repairs

17.1.4.8. Storage tank must be impervious to light to prevent growth of algae and bacteria