Guidelines and Manual for
Rain Water Harvesting in Maldives

Published by,

Ministry of Housing Transport and Environment

Government of the Republic of Maldives

Technical Support,

World Health Organization, Male, Maldives

July, 2009

Index

Chapter – 01
Introduction:

Water is a basic human right. The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use. An adequate amount of safe water is necessary to prevent death from dehydration, to reduce the risk of water-related disease and to provide for drinking, cooking, personal and domestic hygiene requirements.

Inadequately treated water leads to unsafe water supplies and potentially impacts on the health and well being of the community. Provision of safe drinking water is fundamental to the protection of public health. Diarrhea and worms are both caused due to unsafe drinking water.

The Maldives is a small island nation with limited water resources and challenging vagaries of weather. There are practically no surface water sources and the limited ground water is in the form of shallow lenses. The over exploitation of ground waters have induced sea water intrusion and the indiscriminate discharge of community waste have rendered ground waters unfit for drinking use at many places. The growing population, the changing climate and the rapid urbanization have exacerbated the water supply problems. The situation has forced the authorities to think of alternatives which include rain water harvesting and desalination of sea water.

Rain water harvesting has emerged as promising options available as it is technically feasible, easy to operate and affordable even to poor communities. The country is blessed with plenty of rainfall spread over long time in two spells. Moreover the communities are convinced about this option and the supportive environment is also available. It is also eco friendly and can ensure water supply during disasters and emergencies. Thus rain water harvesting is known to Maldivians as an old practice and has many advantages but it needs revival and improvement in its efficiency to cope with the increasing water demand and reliance.

It is observed that in most of the rural population of remote islands (except capital Male and a few urbanized islands) rain water harvesting is practiced widely. However there are shortfalls in terms of optimizing the yield and protecting the water quality. There are some misconceptions about the use of rain water as a source of drinking water and also applying chlorination to make collected rain water safe for drinking purpose. The operation and maintenance of the system though simple needs to be streamlined defining tasks, role, and responsibilities. It is observed that no sufficient catchment is utilized for rain water collection. Due to poor collection and storage, water shortage is experienced during dry period which turns acute if the dry period is prolonged. Due to offensive smell and taste of chlorination, it is not practiced paying high cost in terms of water borne illnesses. Due to poor maintenance of the system, the communities are deprived of its full benefits and the authorities are under pressure to manage the water supply.

There is a scope for improvement in optimizing the system making it efficient and effective. The government is providing support by subsidizing the system and providing 2500 L capacity storage tank (mostly HDPE tanks). Although there are no national standards or norms for rain water harvesting and its use, of late the national government has realized the need for establishing guidelines for domestic rain water harvesting and its operation. The country office of WHO was requested to extend support by way of providing technical expertise to develop draft guidelines for adoption.

WHO responded positively and provided technical experts to study the issue at depth and frame out the guidelines in consultation with the government (MHTE) and the stakeholders. Prof. Vonod Shakya of Nepal from SAARC Disaster Management Center, New Delhi, was initially invited (2008) to prepare draft guidelines which he submitted in well earnest. The draft was reviewed by the government through a technical working group and inviting comments from other departmental experts. The working group felt that in the draft prepared by Prof. Binod Shakya certain importance issues needed inclusion and the whole draft needed revision and redrafting incorporating the observations of the working group and comments received from the experts.

The work of revising and redrafting the guidelines was assigned to WHO consultant Dr. Jagdish Barot who was hired by WHO for other tasks. Dr. Barot accepted this additional responsibility and completed the work in a short time of about a month. He conducted fresh visits, stake holder workshops and consultations with experts to make the draft a useful practice guide.

The scope of these guidelines included only household rain water harvesting for domestic use and hence other uses of rain water including the ground water recharge are not discussed here. Although there is a need for ground water recharges and use of stored rain water for agricultural uses, it is high time for the government to consider the encouraging policies as well as guidelines for the same.

Chapter-02
Country setting:

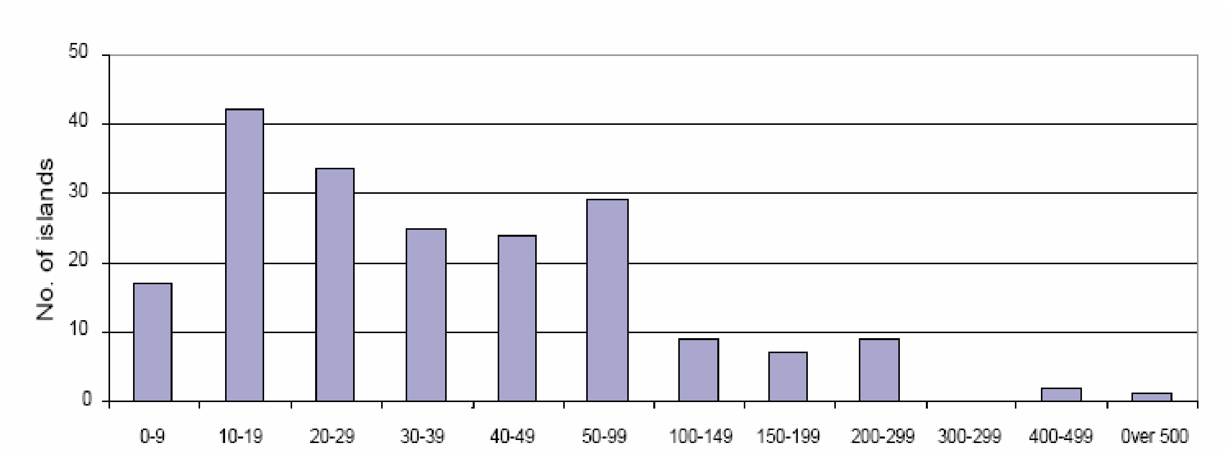
1. Geography and Land

The Maldives consists of a chain of coral atolls, 80-120km wide, stretching 860km from latitude 706’35”N to 0042’24”S, and lying between longitude 72033’19”E to 73046’13”E. These coral atolls are located on the 1600km long Laccadives-Chagos submarine ridge extending into the central Indian Ocean from the south-west coast of the Indian sub-continent. The Maldives shares boundaries of its Exclusive Economic Zone (EEZ) with Sri Lanka and India on the northeast and the Chagos Islands on the south.

There are 26 geographic atolls in the Maldives and they vary enormously in shape and size. The largest atoll is Huvadhu Atoll with an area of approximately 2800km^2 (MPND 2000) and the smallest atoll Thoddoo Atoll has an area in the order of 5.4km^2

A total of 1192 islands are found in the chain of 26 geographic atolls, and the islands differ depending on location, form and topography (Woodroffe 1989). The islands vary in size from 0.5 km^2 to around 5.0 km^2 and in shape from small sandbanks with sparse vegetation to elongated strip islands. The largest island is Gan in Laamu Atoll with an area 5.16 km^2.The total land area of the Maldives is about 300 km^2.

The population of over 300,000 is thinly dispersed in 202 islands out of total 1190 islands. Some 87 islands are developed as resorts and a few are used for industrial and agricultural purposes. Only 16 islands have a population of greater than 2000 and 68% of the inhabited islands have population fewer than 1000. The islands are grouped in to 26 geographical atolls which are divided in to 20 administrative atolls.



The land area of around 96 percent of the islands is less than 1 sq km and 80 percent of land is less than 1 meter above mean sea level. The highest point in Maldives is only three meters above sea level.

2. Climate:

The Maldives has a warm and humid tropical climate. The weather is dominated by two monsoon periods: the south-west (rainy) monsoon from May to November; and the north-east (dry) monsoon from January to March when winds blow predominantly from either of these two directions. The relative humidity ranges from 73% to 85%.

Daily temperatures of the country vary little throughout the year with a mean annual temperature of 28oC. The mean daily minimum temperature recorded for Malé during 2003 was 25.4oC and the daily mean maximum temperature for the same year was 31.1oC. The highest temperature ever recorded in the Maldives was 36.8oC, recorded on 19 May 1991 at Kadhdhoo Meteorological Office. Likewise, the minimum temperature ever recorded in the Maldives was 17.2oC, recorded at the National Meteorological Centre on 11th April 1978.

Rainfall patterns are measured throughout the country by eight rainfall stations and it is evident that there are variations in rainfall from north to south through the atoll chain, with the north being drier and the south wetter. Average monthly and annual rainfall for Malé is 162.4mm and 1,948.4mm respectively. There has been considerable interannual variation in rainfall from 1,407mm to 2,707mm over the last 30 years. Figure below shows average annual rainfall for Malé and Gan over the last 30 years. The wettest months are May, August, September and December, and the driest January to April. The highest rainfall ever recorded in the Maldives with in 24 hour period was recorded on 9th July 2002 at Kaadedhdhoo Meteorological Office and amounts to 219.8mm of rainfall.

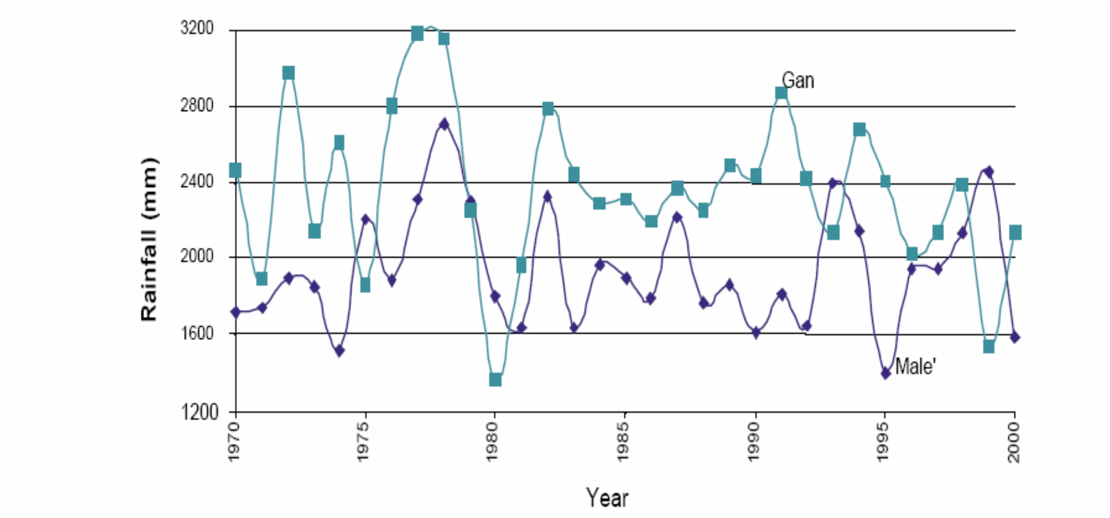


Figure- Average annual rainfall for Malé and Gan over the last 30 years

3. Water resources in Maldives:

The Maldives has very little in terms of freshwater resources. There are no rivers or streams in any of the islands and only a few wetlands or freshwater lakes exist. The country's freshwater resources exist as groundwater, generally unconfined in nature and extending below sea level in the form of a thin fresh water lens.

Groundwater aquifers formed by the accumulation of the recharged rainwater on top of the saltwater are found in all islands. These aquifers normally lie at a depth of 1-1.5 meters below the surface. The thickness of an aquifer is normally dictated by several factors including net rainfall recharge, size of the island and permeability of the water through the soil column. Since these parameters vary from island to island, the quality of the aquifer also varies from island to island. Moreover, the proximity of the aquifers to the surface also makes them highly susceptible to pollution and contamination from human activities as well as possible salt water intrusion due to soil erosion. Thus, the availability of the groundwater as a freshwater resource is also limited.

Rainwater harvesting is the primary source of drinking water in 90% of the outer islands with groundwater used for washing, agriculture and other domestic uses. Groundwater accumulates in rainwater recharged aquifers which lie at a depth of 1-1.5 meters below the surface. Prior to the tsunami, only 39 of the inhabited islands had groundwater that was suitable for drinking. Following the tsunami groundwater on most of the islands showed a high degree of saline and faecal contamination.

Groundwater is not considered safe for drinking purposes. The degradation of the groundwater is exacerbated by a combination of factors such as improper sewage disposal, poor technology, excessive groundwater abstraction and lack of awareness. The inhabited outer islands (with a few exceptions) prior to the Asian tsunami of December 2004, managed their own water supply and sanitation needs at the household level. According to surveys carried out in the islands (GWP consultants 2006) 98% of all households rely on rainwater harvesting for potable supplies, 100% rely on household wells (groundwater) for non-potable water supplies.

A significant difference in the type of water used for cooking is seen when Male' is compared with the Atolls. Even though rainwater remains as the most prominent source of water across the country at 54 percent of all households, only 3 percent of the households in Male' uses rainwater for cooking, whereas the same is at 76 percent in the atolls. Similarly desalinated water being the second most prevalent source of water for cooking remains at 27 percent nationwide, only 479 households (1%) in the atolls uses desalinated water for cooking, whereas the same is at 86 percent in Male'.

4. Access to safe water:

Access to the safe drinking water is a major limitation faced by the people of Maldives. Until early nineties people used to depend on shallow ground water aquifers for their water demand including drinking (1). Groundwater accumulates in rainwater recharged aquifers which lie at a depth of 1-1.5 meters below the surface where they are highly vulnerable to: (i) contamination from inadequate sanitation facilities and other human activities; (ii) solid waste run-off; (iii) over exploitation; and (iv) saline intrusion through soil erosion and flooding (storms, tsunami etc). Scarcity of freshwater gets aggravated due to sea water intrusion and pollution of ground water from release of domestic wastes, industrial effluents and poor agricultural practices. Today 100% population in Male is supplied with desalinated water and all the island communities depend on rain water for their drinking water needs.

5. Water quality:

As Maldives has no surface water sources, almost all the islands have ground water. The depth of aquifers and their yield is normally dictated by several factors that includes net rainfall recharge, size of the island, vegetative cover, and permeability of water through the soil strata. The high water table in most of the islands suggests that they are susceptible to contamination from anthropogenic activities. Water quality testing has indicated faecal contamination rendering the water unfit for potable uses. The septic tank seepage has made ground water highly offensive in colour and smells that can not be used even for bathing and other domestic uses. The over exploitation of ground water has also accelerated the sea water intrusion and increased the salinity making water further contaminated. The Tsunami of 2004 has further exacerbated the water quality problems forcing the authorities to opt for other dependable and safe water quality sources.

6. Desalinated water

The history of desalination in Maldives began with the installation of first desalination plant of 200 m^3 /day Male in 1985. Desalination has since become popular in Maldives, particularly in the resort islands and more plants are being installed. Nevertheless desalination is still considered very expensive for most of the small islands communities. In response to the water shortage created by the Tsunami of 2004, UNICEF, IFRC and several other international donors provided more than 35 desalination plants to the island communities.

7. Bottled water

To cater for the increasing demand for fresh water, private companies are producing mineral water in the country. From 1995, Maldives Aerated Water Company distributes at a large scale for the local market as well as for the tourist resorts. In 2002, International Beverages Company has started producing to cater for some of the tourist resorts. Maldives Water and Sewerage Company have also made plans to produce water in the near future.

Another important indictor which illustrates the rising demand for water is the quantity of water imported into the country. The number of bottles imported to the country is on an increasing trend from 1996 - 2002. Within this period the annual increase is 31 percent. However, from 2002 to 2003 a downward shift has been observed reflecting that the domestic supply of bottled water is catering for a larger share of the local as well as the tourist market.

8. Rainfall characteristics

Maldives rainfall is mainly determined by the two seasons: the northeast monsoon and the southwest monsoon. The southwest monsoon prevailing from May to November is the rainy season and the northeast monsoon from January to March is the dry season.

Average monthly rainfall from 1994 to 2003 shows that February is the driest month for the southern stations while in Hulhule and Hanimaadhoo, March is the driest. The southern stations show the highest mean rainfall for this dry period while Hanimaadhoo has the least rainfall.

The average monthly rainfall shows a maximum during May for most stations. For the north most station, Hanimaadhoo, the peak rainfall is occurring during July. There is increased rainfall in October and the south station in Kadhdhoo shows its peak rainfall of 307.17 mm during October. Long term records of rainfall at Hulhule and Gan show that rainfall in Maldives increases from north to south.

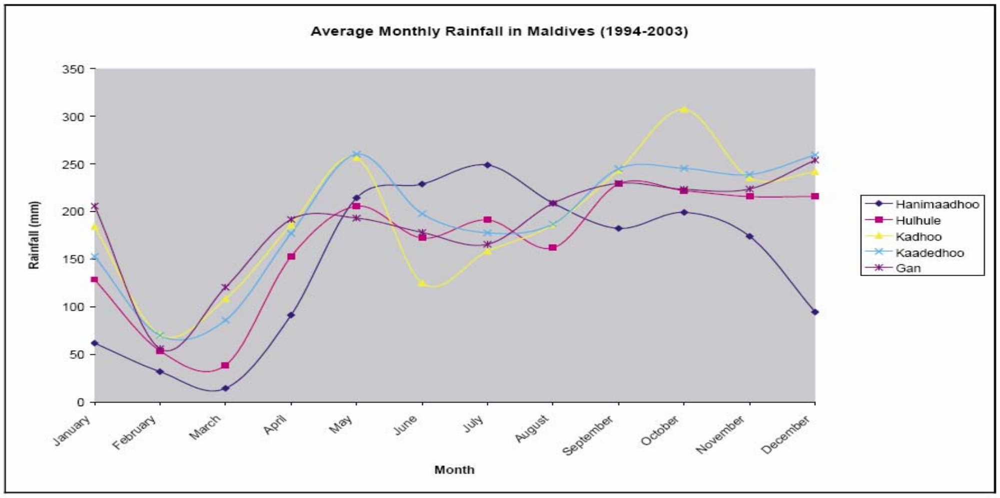


Figure 4.1: Average monthly rainfall (1994-2003)

Figure: Average monthly rainfall in Maldives

Chapetr-03
Rain Water Harvesting in Maldives

1. Need for rain water harvesting

Due to the scarcity of available groundwater and surface water, rainwater is an important source of freshwater for Maldivian. There are practically no sources of surface water and the ground water available is very limited. What ever little ground water is available is vulnerable to contamination from sea water instruction and indiscriminate discharge of waste water and other community wastes.

The country is facing serious threats of climate change which directly affects the water resources and vagaries of weather. Many islands face the water scarcity during dry period and there are no alternative sources of water available. Out of the two alternative options available today, ground water is limited and facing serious threat of contamination where as desalination is difficult to practice for small communities due to its prohibitive cost.

Prior to the tsunami, only 39 of the inhabited islands had groundwater that was suitable for drinking. Following the tsunami groundwater on most of the islands showed a high degree of saline and faecal contamination (2).

Access to safe water is targeted by the ministry of health to reduce mortality and morbidity associated with unsafe water.

2. History of rain water harvesting in Maldives:

Rainwater collection can be traced back to 3,000 years in Maldives. In the country, it has been a longstanding traditional means of collecting high-quality water for domestic, drinking, agricultural and other uses. Maldives is blessed with a relatively regular and substantial rainfall. However, the country is not able to utilize this important resource to its full advantage due to limitations in availability of land, the lack of space, and insufficient storage facilities.

Rainwater harvesting was slow in developing because many people were not yet convinced of the link between contaminated ground water and disease, and they were used to drinking groundwater, which at the time was relatively safe in terms of salinity and other chemical parameters. In addition, many simply could not afford to build their own rainwater tanks.

From the historical perspective rainwater harvesting began early in the 20th century in Maldives as a result of groundwater contamination due to prevailing sanitary practices. The first concrete decision to provide safe drinking water to the people of Maldives was made in 1904. Between 1906 and 1908, the government constructed two rain water harvesting tanks. However, following the diarrhoea epidemics of the 1970s and 1980s, significant steps were taken to encourage people to harvest rainwater. According to a study carried out in 1974 (Binnie and Partners, 1975), only 15 percent of the 2600 households in Male' had private rainwater tanks at that time. Following the outbreaks of cholera (1978) and shigellosis (1982) throughout the country, Government began to promote and invest in rainwater harvesting and a nation-wide campaign was launched. In 1985, Government launched the first major water supply and sewerage project in the Maldives. The project allocated more than $2.5 million US, roughly 33 percent of the total project cost, for the construction of steel tanks with a total storage capacity of 9,900 cubic meters and the construction of 1,154 private rainwater tanks in 1,116 households providing a total storage capacity of 4,157.5 cubic meters. The private tanks were provided on cost recovery basis, payable over a period of 5 years.

To provide freshwater for the rural population, Government, with financial assistance from UNICEF, constructed 1,925 Ferro-cement tanks with a total capacity of over 6,000 cubic meters for community use on 200 islands, serving a population of 234,008. In addition, 222 households have been provided with construction materials for the construction of private rainwater storage tanks. Since 1994, the program has focused on providing high-density polyethylene (HDPE) tanks instead of the Ferro-cement tanks. More than 2,914 HDPE tanks with a total capacity of 14,520 cubic meters have been distributed free of cost for community use, and 1,588 HDPE tanks, with a total capacity of 3,176 cubic meters, have been distributed to households on a cost recovery basis. The HDPE tanks, because of their durability, ease of handling and mobility, are proving to be more acceptable and popular among the rural population. The program has had limited success in achieving the water sector goals and objectives, particularly in reducing mortality and morbidity from water-borne diseases. A recent study by the Maldives Water and Sanitation Authority in four atolls has shown that over 30 percent of rainwater tanks and 40 percent of groundwater wells were found having faecal contamination. Comparison of this data with health statistics confirms a direct correlation between unsafe rainwater harvesting practices and diarrhoea diseases.

As against the high cost of desalination (USD 5 to 6 per 1000 liters), rainwater is free resources and only affordable cost of installation and disinfection involved, the GOM is keen to promote and popularize RWH as much as possible. Awareness programs are initiated with technical support from World Health Organization (WHO) and other UN agencies. The GOM has approached WHO with a request to develop rainwater harvesting guidelines for community and as well as for individual household of islands to optimize the rain water storage and safeguard the quality of collected water.

The Government at first began to provide HDPE water tanks to households on a cost recovery basis under a revolving fund scheme. However, after the tsunami all affected islands were provided with a 2500 liter water tank to each household for free. Following this in 2006 the government implemented a programme to provide the rest of the islands with water tanks which will be given free to each household. After the tsunami due to groundwater contamination and destruction of water supplies and sewerage facilities the most affected islands were provided with desalination plants.

3. Supportive factors for rain water harvesting in Maldives:

- ✓ Sufficient rainfall is available
- ✓ The projects are technical feasible
- ✓ Technical skill and resources are available locally
- ✓ RWH system are cost effective and affordable
- ✓ Community is enthusiastic and cooperative
- ✓ Government is fully supportive
- ✓ Positive health impacts are noticed
- ✓ The projects have proved environmental friendly
- ✓ Alternative sources of water are available (ground water and desalinated)

✓ Capacity to manage the RWH system and operation is available in all Atolls

In Maldives, the wet season- southwest monsoon runs from mid-May to November. In this season Maldives experiences torrential rain. Central, Southern and Northern parts of the Maldives receive annual average rainfall of 1924.7mm, 2277.8mm, and 1786.4mm, respectively. The highest rainfall ever recorded in the Maldives with in 24 hour period was recorded on 9th July 2002 at Kaadedhdhoo Meteorological Office and amounts to 219.8mm of rainfall. The fact that the Maldives is located at the equator, Maldives receives plentiful of sunshine throughout the year. On average Southern atolls (Gan) of the Maldives receives 2704.07 hours of sunshine each year which will be helpful in solar water disinfection. Furthermore, on average central (Hulhule) parts of the country receives 2784.51 hours of sunshine per year (Source: Maldives Meteorology Department)

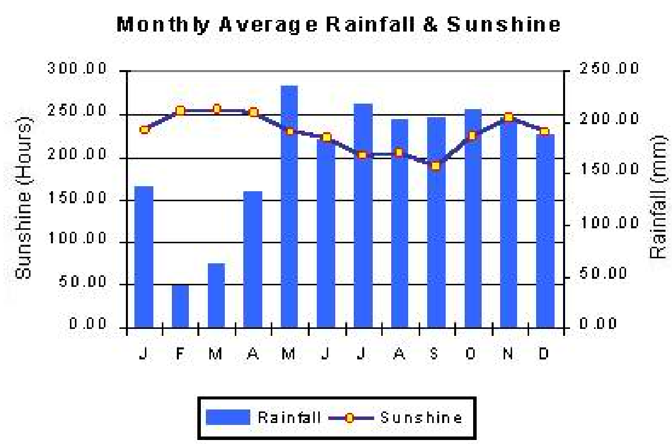


Figure No 1.2: Average annual rainfall and sunshine hour data

(Source: Meteorology Dept. Male)

4. Lessons learnt:

✓ Rain water harvesting systems have a long history in Maldives

- ✓ Rain water harvesting is the most preferred source of water for domestic use in islands
- ✓ Rain water harvesting is an appropriate and acceptable system for domestic water supply especially in rural areas
- ✓ RWH can provide a cheap, clean and reliable source of domestic water in a cost-effective way and that the roof-catchment system has significantly improved the living condition of the rural population.
- ✓ Rain water harvesting can reduce pressure on other fresh water sources
- ✓ Project should not depend only on assistance from government or donors but community should be encouraged to develop the system themselves over a longer period of time
- ✓ Rainfall information should be considered a valuable input for design aspects
- ✓ All attempts should be made to make the system sustainable
- ✓ Community support should be ensured in all rain water harvesting projects
- ✓ The physiographic condition of Maldives is making dependability on rainwater harvesting
- ✓ There is need for improvement in existing practice to augment quantity and safeguard quality of water
- ✓ Rain water harvesting works well during wet period but during dry period its reliability comes to question
- ✓ Limited roof area is presently utilized for rain collection and storage tanks are selected on ad hoc basis as readily available (2500 Liters)
- ✓ RWH can be beneficial to ecological systems and assist environmental conservation through encouraging the re-establishment of tree seedlings on sloping land and encouraging reforestation.
- ✓ It provides self-sufficiency in water supply of superior quality which is soft and low in minerals
- ✓ There is a scope for recharge to ground water which can improve water quality of through dilution
- ✓ It is very much less expensive as compared to desalinated water

- ✓ The necessity to integrate design of rainwater water harvesting with conventional building practice i.e. to interfere minimally is of great importance in reducing cost.
- ✓ There is urgent need for providing training to mesons and awareness to building contractors
- ✓ Role of media is critical in popularizing the system
- ✓ Popularizing the system in schools can prove a change agent and create long term benefits of the system
- ✓ There exists a necessity to establish a monitoring and evaluation cell in the ministry of water supply to regularly update the system and improve the efficiency

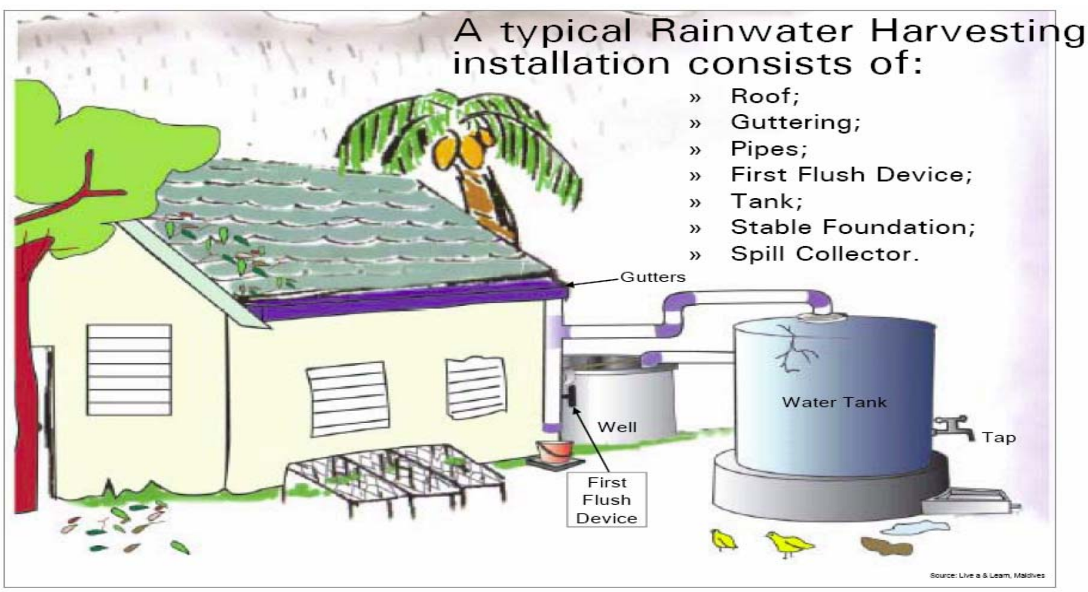
Chapter-04
Basics of RWH

Rain Water Harvesting is a technology used for collecting water from surface on which it falls and storage of this water for use when needed. It is an oldest method of collecting water for domestic uses. There are two main techniques of rainwater harvesting, namely:

1. Storage for future use
2. Recharge into the ground

Water can be collected either from rooftops or from the ground or a combination of both. Rainwater harvesting systems can vary widely in scope and complexity. It can be the simple collection of rainwater from the rooftop of a house or collection from a large complex (school or office) for domestic uses or recharge into the ground.

1. Components of a Rainwater Harvesting System



All rainwater-harvesting systems comprise three basic components irrespective of the size of the system.

1. Catchment Area/Roof: The surface upon which the rain falls; the roof has to be appropriately sloped preferably towards the direction of storage and recharge.

2. Gutters and Downspouts: The transport channels from catchment surface to storage; Gutters and/or Down pipes have to be designed depending on site, rainfall characteristics and roof characteristics.

3. Cisterns or storage tanks: Sumps, tanks etc. where collected rain-water is safely stored or recharging the Ground water through open wells, bore wells or percolation pits etc.

Briefly the system involves collecting water that falls on roof of a house made of impervious material during rain storms, and conveying it by an aluminum, PVC, wood, plastic or any other local material including bamboo drain or collector to a nearby covered storage unit or cistern. Rainwater yield varies with the size and texture of the catchment area. A smoother, cleaner and more impervious roofing material contributes to better water quality and greater quantity.

Rainwater systems are decentralised and independent of topography and geology. They deliver water directly to the household, relieving the burden of water carrying, particularly from women and children. Implementation is similar to managing the installation of on-site sanitation and once systems are in place they are owned by the householders who can manage their own water supply.

Rainwater harvesting systems can serve households or communities of various sizes. Household systems generally catch rain from the rooftops of homes and store it in tanks adjacent to the homes. Water is drawn from the tanks by means of taps at the base of the tanks. In some cases rainwater may be reticulated within a house using a pump/pressure system. Alternatively the tank may be partly buried and a hand pump used to withdraw water. In cases community systems the roofs of large community buildings, such as churches and schools, are used as catchment surfaces and the water is stored in large tanks adjacent to these buildings. Alternatively, if no suitable catchment surface is available, a separate catchment surface is built adjacent to, or directly over, the water storage tank. Residents of the community walk to these tanks, draw water from a tap at the base of the tank, and transport it back to their homes for drinking or cooking.

Materials commonly used in the construction of the roofs are corrugated aluminum and galvanized iron, concrete, asphalt or fiberglass shingles, tiles with a neoprene-based coating, which is used primarily in rural areas. Roofs are generally sloped to avoid pounding and roof coatings are required to be non-toxic.

The effective roof area and the material used in constructing the roof influence the collection efficiency and water quality. Because natural roofing materials attract rodents and insects, and often yield contaminated and coloured water, most people find them objectionable for use as a collecting surface. In such cases, specially-constructed ground surfaces (concrete, paving stones, or some kind of liner) or paved runways can also be used to collect and convey rainwater to storage tanks or reservoirs. These surfaces should be fenced to prevent the entry of people and animals.

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. Ground catchments would normally use pipes and/or open channels to convey rainwater to the storage tanks/reservoirs.

The rainwater ultimately is stored in a storage tank, which should also be constructed of inert material. Reinforced concrete, Ferro cement, fiberglass, polyethylene, or stainless steel has been found to be suitable. Storage tanks may be constructed as part of a building or may be a separate unit some distance away.

2. Influencing Factors

Among the several factors that influence the rainwater harvesting potential of a site, eco-climatic conditions and the catchment characteristics are considered to be the most important.

Rainfall Quantity:

Rainfall is the most unpredictable variable in the calculation and hence, to determine the potential rainwater supply for a given catchment, reliable rainfall data are required, preferably for a period of at least 10 years. Also, it would be far better to use rainfall data from the nearest station with comparable conditions.

Rainfall Pattern:

The number of annual rainy days also influences the need and design for rainwater harvesting. The fewer the annual rainy days or the longer the dry period, the more will be the need for rainwater collection in a region. However, if the dry period was too long, big storage tanks would be needed to store rainwater. Hence in such regions, it is more feasible to use rainwater to recharge ground water aquifers rather than for storage.

Catchment Area Characteristics:

Runoff depends upon the area and type of the catchment over which it falls, as well as surface features. All calculations relating to the performance of rainwater catchment systems involve the use of runoff coefficient to account for losses due to spillage, leakage, infiltration, catchment surface wetting and evaporation, which will all contribute to reducing the amount of runoff. (Runoff coefficient for any catchment is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface).

The collection efficiency accounts for the fact that all the rainwater falling over an area cannot be effectively harvested, because of evaporation, spillage etc. Factors like runoff coefficient and the first-flush diverter are taken into account when estimating the collection efficiency.

The rain water is harvested in following manner.

- Collect rain water from the roof top
- Drain it down from the pipes
- Store it in a tank
- Treat it if required
- Draw it for use

3. Requirements for Roof water Harvesting

For roof water harvesting to be viable there are a number of environmental requirements:-

- Rainfall should be over 50mm/month for at least half of the year (unless other sources are extremely scarce)
- Local roofs should be made from impermeable materials such as iron sheets or tiles
- There should be an area of at least $1m^2$ near each house upon which a tank can be constructed
- There should be some other water source, either ground water or (for secondary uses) surface water that can be used when the stored rainwater runs out

4. Benefits of Rainwater Harvesting

Rainwater harvesting provides the long-term answers to the problem of water scarcity. Rainwater harvesting offers an ideal solution in areas where there is sufficient rain but inadequate ground water supply and surface water resources are either lacking or are insufficient. Rainwater harvesting system is particularly useful in remote areas as it has the ability to operate independently. The whole process is environment friendly. There are a number of ways in which water harvesting can benefit a community – water harvesting enables efficient collection and storage of rainwater, makes it accessible and substitutes for poor quality water. Water harvesting helps smoothen out variation in water availability by collecting the rain and storing it more efficiently in closed stores or in sandy riverbeds. In doing so, water harvesting assures a continuous and reliable access to water.

A water harvesting system collects and stores water within accessible distance of its place of use. While traditional sources are located away from the community, collecting and storing water close to households, villages greatly enhances the accessibility and convenience of water supplies.

The rainwater collected can be stored for direct use or can be recharged into the ground water to improve the quality of ground water and rise in the water levels in wells and bore wells that are drying up as well as reduce the soil erosion as the surface runoff is reduced. Rainwater harvesting is an ideal solution to water problems in areas having inadequate water resources and helpful in mitigation of the effects of drought and attainment of drought proofing.

Water harvesting provides an alternative source for good quality water (rainwater is the cheapest form of raw water) seasonally or even the year round. This is relevant for areas where ground water or surface water is contaminated by harmful chemicals or pathogenic bacteria or pesticides and/or in areas with saline surface water. The rainwater harvesting systems can be both individual and community/utility operated and managed.

Rainwater collected using various methods has less negative environmental impacts compared to other technologies for water resources development. The physical and chemical properties of rainwater are usually superior to sources of ground water that may have been subjected to contamination. Rainwater is relatively clean and the quality is usually acceptable for many purposes with little or even no treatment.

Rainwater harvesting technologies are flexible and can be built to meet almost any requirements. Construction, operation, and maintenance are not labour intensive. Predictions regarding global warming could have a major effect in significantly increasing water demand in many cities. At the same time increased evaporation from reservoirs and reduced river flows in some areas may decrease the available surface water supplies. A greater uncertainty regarding yields from major reservoirs and well fields is likely to make investments in the diversification of water sources, better water management and water conservation even more prudent in future.

The role of rainwater harvesting systems as sources of supplementary, back-up, or emergency water supply will become more important especially in view of increased climate variability and the possibility of greater frequencies of droughts and floods in many areas. This will particularly be the case in areas where increasing pressure is put on existing water resources.

In urban areas, scarcity and accelerating demand of water is a major problem and it can be reduced by rainwater harvesting, using various existing structures like rooftops, parking lots, playgrounds, parks, ponds, flood plains, etc. to increase the ground water table, which saves the electric energy to lift the ground water because one metre rise in water level saves 0.40 kilowatt hour of electricity. Subsequently it can also reduce storm drainage load and flooding in city streets.

5. Limitations of the system:

Rainwater harvesting systems are completely dependent upon the frequency and amount of rainfall. There will be shortages during dry spells or prolonged droughts, which can be exacerbated by low storage capacities. If greater storage capacities are provided, the additional construction and operation costs may be expensive for some households. Leakages from cisterns can cause the damages to the foundation of building and may increase construction cost that may have adverse effect on home ownership. Also the water may become contaminated if the storage tanks are not adequately covered, and uncovered or poorly covered storage tanks can be unsafe for small children. Contamination can also occur from dirty catchment areas. Water treatment is infrequent in many countries due to lack of adequate resources and lack of treatment may lead to health risks. Similarly neglect in routine maintenance can also impair the quality of water and affect health. In the case of community systems, people have to walk significant distances for water if a distribution system is not in place. All systems require maintenance to minimize wastage through broken gutters, drainpipes, leaking storage tanks or outlet taps.

6. Main drivers and key factors determining the feasibility of rainwater harvesting

Feasibility is defined as something that is practicable or achievable. A series of interlinked factors determine the feasibility of rainwater harvesting in rural areas. Rainwater harvesting becomes viable when the following factors become acceptable together and also separately:

a) **Water availability**: The volume of rainfall and rainwater collected should meet a significant part of the water needs of the household. The technology features of the system and water management practices have a direct effect on water availability.
b) **Acceptability:** Use of rainwater harvesting for drinking and other purposes has to be culturally accepted by the users. The positive impacts, i.e. the benefits, that the rainwater harvesting system brings to the community influences the level of acceptability towards the RWH system. The users are able to give expression to how valuable rainwater harvesting is to them. An analysis of the benefits that rainwater harvesting offers to the users will help to determine whether the amount of water collected makes a difference.
c) **Cost of the system:** The cost of installing a rainwater harvesting system should not be substantially higher than other water supply options suitable for the community of study. The availability of credit and financial resources also determines the ability to install rainwater harvesting systems.
d) **Water quality:** quality of rainwater should be safe for human consumption. Operation and maintenance needs to be done properly to ensure good quality water.
e) **Policy:** Regulations and guidelines for implementers and users need to be put in place to ensure the effectiveness of rainwater harvesting programmes and risk minimisation.

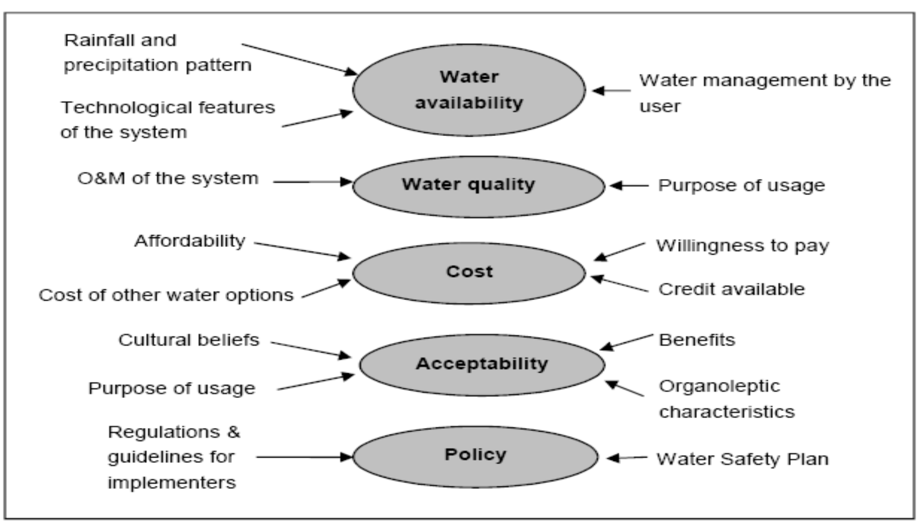


Fig: Main drivers and key factors determining the feasibility of RWH

(Source: Feasibility of rain water harvesting in Nepal-WHO)

7. A checklist:

- Rainfall and catchment must be sufficient to meet with the demand
- Deign should be appropriate in respect of affordability and maintenance
- Technical skills and construction materials should be available locally
- The system should have better quality of water and should have positive impact on health
- All reasonable alternatives water supply arrangements be considered before going for RWH
- Using other options of water in combination with RWH should also be considered
- Willingness to maintain the system (cleaning and repairing) should persist

Chapter - 05
Design aspects:

Effectiveness of rain water harvesting depends on appropriate design of the system. Be it storage or a a recharge structure, an improperly designed system will lead to operational problems, thereby raising the operation and maintenance costs. It may even lead to non functioning of the system.

For designing rain water harvesting system rain fall data is required. Preferably data for a period of ten years will be useful. The more reliable and specific the data is for the location, the design will be better. The rainfall data information can be available from the ministry of environment (weather), water resources or agriculture. Airport authorities in the area can also have such data.

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 rain water harvesting will depend on optimum match between,

1. Rainfall data
2. Roof area
3. Water storage capacity
4. Daily consumption rate

For designing a RWH system and deciding the size of storage tank it is essential that following factors are taken in to consideration.

1. Estimate the water demand by considering three factors
    a. Number of persons in family

b. Uses of water (quantity)
c. Alternative sources of water for other uses

2. Consider the duration of dry spell (non rainy period)
3. Decide the quantity of rain to be harvested considering following factors
    a. Intensity and frequency of rain
    b. Size of the roof surface
    c. Availability of material and labour

1. Water demand:

Water demand varies depending on the area and water requirement of a family. In the areas where water is very scarce people may use less water. Common norm of water requirement per person is considered as 20 litres 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 little inferior quality. The water demand is calculated by the following formula

Demand = water use X family members X 365 days

Suppose the water use is 20 litres per person per day and there are 5 members in s family then water demand for one year will be,

20 lpcd X 5 members X 365 days =36,500 litres per year

Average water demand per month will be 3000 litres.

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

3000 L X 4 months = 12,000 litres

Water supply is calculated by 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,

800 X 80 X 0.8 = 51,200 litres per year

2. Runoff and run off coefficient:

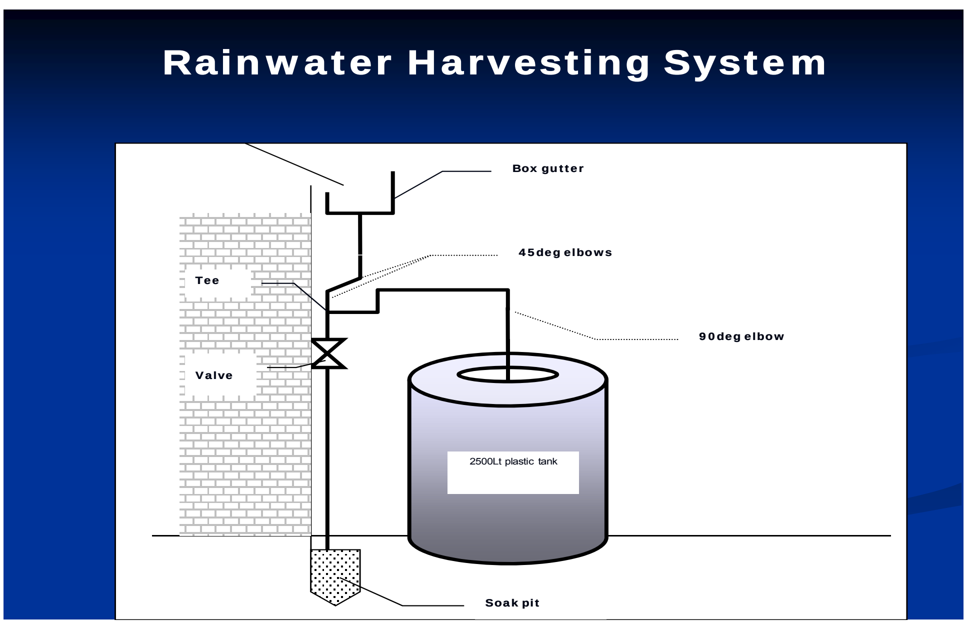
Runoff is the term applied to the water that flows away from a catchment after falling on its surface in the form of rain. Runoff can be generated from both paved and unpaved catchment areas of buildings. Runoff coefficient is the factor, which accounts for the fact that all the rainfall falling on a catchment cannot be collected. Some rainfall will be lost from the catchment by evaporation and retention on the surface itself. The rain water 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 and the runoff coefficients for roof materials used in Maldives are given below.

Roof material	Runoff coefficient
Sheet metal	0.8 to 0.85
Cement tiles	0.62 to 069
Clay tiles (Machine made)	0.30 to 0.39
Clay tiles (Hand made)	0.24 to 0.31

3. Roof Catchment:

In rain water 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 roof. 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 run-off. Asbestos sheeting or lead-painted surfaces should be avoided. If the house is small to catch up required rainfall additional roof/catchment as open sided shed can be built near house or attached with house.

The rain amount and household water demand varies from place to place and family to family respectively. Thus prior to designing rainwater harvesting system, knowing roof size is most important for each household 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 rain water from different roof is a function of roof material, climatic conditions, and the surrounding environment. The run-off from a roof is directly proportional to the quantity of rainfall and the plan area of the roof. For every 1mm of rain a square meter of roof area will yield 1 litre of water, less evaporation, spillage losses and wind effects.



4. Roof materials

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 material include the following,

- Galvanized corrugated iron or plastic sheets, or tiles.
- 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.
- Unpainted and uncoated surface areas are best. If paint is used it must be non-toxic (no lead-based paints).
- 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.
- 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.

Of them 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 rain losses from the metal roofing will be less. In contrary to metal sheet, clay and concrete tiles are both porous. 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 losses, porous part can be reduced by coating fine cement or painting but still probability of bacteria 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. Sever air pollution, lead fitting and toxic paint in roof may contaminate the rainwater as it runs from roof.

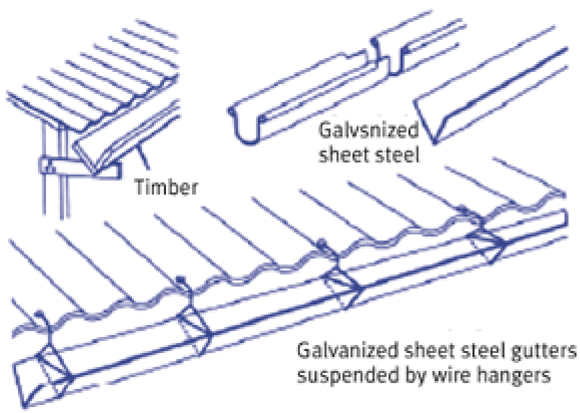
Suitable materials include:

The efficiency of rainwater collection depends on the materials used, the construction, maintenance and the total 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 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%.

5. Gutters and down pipes:

Gutters are channels fixed to the edges of roof all around to collect and transport rainwater from the roof to the storage tank. These must be properly sized, sloped and installed to maximize 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. 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. 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. 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. Or, just clean out gutters regularly.

Gutters can be prepared in semi-circular and rectangular shapes. Locally available material such as plain galvanized iron sheet can be easily folded to required shapes to prepare semi-circular and 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 over all cost of the system.



Source: Water Aid,

6. Manufacture of low- cost gutters

Factory-made gutters are usually expensive and beyond the reach of the poor 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; one such technique is described below

V-shaped gutters from galvanised steel sheet can be made simply by cutting and folding flat galvanised steel sheet (Figure ----). Such sheet is readily available in most market centres (otherwise corrugated iron sheet 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 90^{o} 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 will be the product.

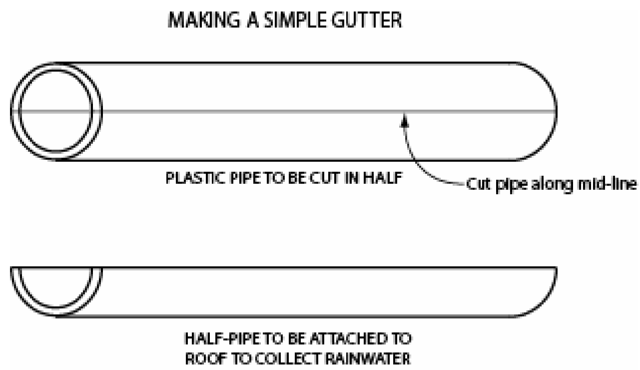


Figure: Cutting plastic pipe into half to make gutter

Plastic pipes may be cut into half to make gutters (Figure --- above). 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.

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

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 to waste (the first foul flush), thus preventing accumulated bird droppings, leaves, twigs and other vegetable matter, as well as dust and debris, from entering the storage tank.

Sometimes a collecting box with a mesh strainer (and sometimes with additional filter media) is 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.

7. Size of gutter:

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. The calculation makes more complication and may not easily understandable by layman. 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:. 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

8. Down pipe:

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 is 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.

GUTTERS AND DOWN PIPES IN MALDIVES

In Maldives both PVC and galvanized gutters are used for rain channeling. PVC gutters do not rust and are of light weight, whereas, galvanized steel gutter may start rusting if proper care is not taken. Little acidic rain may corrode roof chemical materials that will flow into tank. A little Inclined in gutter is necessary to maintain free flow condition and cleanliness. Little inclined gutter retains less debris. Plastic gutters fitted 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.

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

9. Sizing of rainwater pipe for roof drainage

Diameter Of pipe (mm)	Average rate of rainfall in 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

Source: National Building Code of India

10. Leaf Screens/Roof Washers:

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 their 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.

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.

11. First Flush Device:

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 particulated matter, bird droppings, and other material laying on the roof (debris, dirt and dust). When the first rains arrive, it is essential to prevent this unwanted material to go into the storage tank. This can cause contamination of water collected in the storage tank thereby rendering it unfit for drinking and cooking purposes.

After screening gutters a first flush device is incorporated in the Rooftop Rainwater Harvesting Systems to dispose off 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.

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

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 first flush pipe, the valve is closed to allow the water to enter the down pipe and reach the storage tank.

First flush diverters are fitted in most of the houses In Maldives. The diverter is manual type and operated during start of rainfall. Generally in islands people diverts the rain water in storage tank after they notice clear water starts coming from first flush diverters. 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.

12. Filter Unit:

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. 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 came 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.

13. Design of storage tanks:

Storage tank is used to store the water that is collected form the Rooftops. In the rain water harvesting system storage tank is usually the most expensive part (almost 90 %

of the total cost). It is therefore essential that careful design is made to provide optimal storage capacity while keeping the cost as low as possible. 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, skills, cost, personal preferences and other external factors are other important considerations. Care should be taken to protect collected water from contamination.

The volume of the storage tank can be determined by knowing the water demand of a family as calculated above. Once the water demand is known, depending upon the requirement and affordability of family 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.

There are an 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, the HDPE tanks 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.

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 under ground tanks. Water from under ground 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, under ground tanks are prone to water contamination due to fluctuation in groundwater table and leakage of stored water.
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.

Open topped vessels such as buckets and drums are not recommended for collection of rain water for drinking purpose as contamination may easily enter 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. **Water storage tanks used in Maldives**

14. Storage tanks and cisterns

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 vessel. These can vary in size from one cubic meter or so (1000 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.

- Space availability
- Options available locally
- Local traditions for water storage
- Cost of purchasing new tank
- Cost of materials and labour for construction
- Materials and skills available locally
- Ground conditions
- Use of RWH – whether the system will provide total or partial water supply

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

	Tank (above ground)	Cistern (under ground)
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	• Generally cheaper due to lower material requirements • Not vulnerable to water loss by tap left open • Require little or no space above ground • Unobtrusive • Surrounding ground gives

	• Easy to construct from traditional materials • Water extraction can be by gravity in many cases • Can be raised above ground level to increase water pressure	support allowing lower wall thickness, and thus lower costs • Water is cooler
Cons	• Require space • Generally more expensive • More easily damaged • Prone to attack from weather • 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 uncovered • 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

15. Ferro cement tanks

Tanks of larger capacity can be made of Ferro cement, which are cheaper to construct than tanks made of masonry, block work, reinforced concrete etc, and do not require the rendering with waterproof cement mortar that masonry and block work often need.

Above ground level, tanks are constructed with a plain or reinforced concrete base, cylindrical walls of Ferro cement and a roof of Ferro cement, or sometimes mild steel sheeting.

The construction of Ferro cement walls is carried out by first assembling a cylindrical mesh of chicken wire and/or fence wire reinforcement, with or without the aid of formwork. On to this, a cement-rich mortar of 3:1 sand: cement is applied by trowel and built up in layers of about 15 mm to a finished thickness of between 30 to 100 mm, depending on wall height and tank diameter.

Thicker walls may have two layers of mesh. The mesh helps to control local cracking and the higher walls may call for the provision of small diameter vertical steel reinforcing bars for bending resistance.

Sometimes barbed fence wire is wound spirally up the wall to assist with resistance to ring tension and stress distribution.

Effective curing of the mortar between the trowelling of each layer is very important and affects the durability of the material and its resistance to cracking. Mortar should be still green when the next layer is placed.

This means that the time gap between layers should be between 12 and 24 hours. The finished material should then be cured continuously for up to 10 days under damp Hessian, or other sheeting.

A Ferro cement tank is easy to repair and, if the mortar has been properly applied and cured, should provide long service as a water-retaining structure at a fraction of the cost of a reinforced concrete structure.

16. Waste water collection pit:

A small pit is dug in the ground, beneath the tap of the storage tank and constructed in brick masonry to make a chamber, so that a vessel could be conveniently placed beneath the tap for collecting water from the storage tank. A small hole is left at the bottom of the chamber, to allow the excess water to drain-out without stagnation. Size of collection pit shall be 60 cm x 60 cm x 60 cm.

17. A checklist for design:

1. **System components**

   A typical rain water collection system for domestic use will consist of following key components

   a. Catchment area
   b. Conveyance system
   c. Storage tank

2. **Design the appropriate roof for rain water collection**

   a. Only the roof water should be collected for drinking and cooking purposes
   b. A flat roof with gentle slope will drain water towards the storage tank
   c. Provide clean and impervious roof made from non toxic materials
   d. Lead based paints should be avoided
   e. Sloping roof should have gutter (plastic or other available material) to collect water and channel it down to down pipe
   f. Roof should be neat and easy to clean when required

3. **Conveyance system (Gutters and down pipes)**

   a. Easy access for inspection and maintenance should be provided
   b. PVC pipes resistant to UV rays can be a best choice
   c. Sufficient gradient should be provided in the gutters for free flow to down pipes
   d. Provide course filter and first flush devices before the water enters the down pipe

4. **Storage system**

   a. Decide the location properly where to install storage tank (ground level or underground) and away from places of contamination like toilets, septic tanks etc
   b. Select the type of storage tank (HDPE or cement concrete or other)
   c. Provide an overflow pipe to direct the excess water to suitable place (may be another storage tank!)

d. Wire mesh to cover storage tank inlet
e. Provide a well covered manhole for easy access and inspection of the tank
f. Provide tank tap or draw off pipe at sufficient height to draw water
g. Storage area should be accessible for maintenance and repairs
h. Storage tank must be impervious to light to prevent growth of algae and bacteria.

Chapetr-06
Quality of rain water:

Rainwater is relatively free from impurities except those picked up by rain from the atmosphere but the quality of rain water may deteriorate during harvesting, storage and household use. The quality of rain water is thus dependent upon local atmospheric pollution, roof top condition (cleanliness of roof top), harvesting method and water storage system. Generally the quality of rain water collected through rooftops is found to be good and much better than the traditional ground water available in Maldives. Being free of dissolved salts and soft in chemical nature is good for health and does not cause any scale formation and mineral deposits.

Rainwater catchment systems are open to environmental pollution because of the nature of the catchment area (e.g. rooftop is always open to sky). There are several ways the contaminants can enter the rainwater system and deteriorate the water quality. While the rain comes down from the sky, air pollutants like gases and particulate matters can enter the rainwater. Metals and colors of the component system can leach in to rain water while collection and conveyance. Windblown dust and dirt and falling leaves form the catchment area can enter the rain water if they are not properly removed before onset of rains. Bacteriological contamination can enter the rainwater through birds dropping, dead animals (birds, cats, lizards, rat, insects etc), faulty collection and storage system and poor usage habits. As cats are known to use roofs as resting place in Maldives, it is very likely that they will defecate on the roof. Poor hygiene in storing water and abstracting water from storage tank at point of use can also contaminate the water.

Entry by small animals and birds to rainwater tanks can lead to direct faecal contamination, even if the animals escape from the tank. In some cases, animals become trapped in tanks and drown, leading to very high levels of contamination. In the case of larger animals, such as rodents and cats, this will almost certainly have a distinctive impact on the taste and odour of the water.

Rainwater tanks can provide excellent habitats for mosquito breeding. In addition to causing nuisance, certain types of mosquito can be vectors of arboviruses.

Of particular concern are species of mosquito that can be vectors for dengue virus, which occurs in tropical country like Maldives. Rainwater tanks have been identified as potential breeding sites for vectors of dengue virus and the World Health Organization (WHO) recommends all tanks have screens or other devices to prevent adult mosquitoes from emerging (WHO 1997).

Rainwater from well maintained roof catchments is generally safe to drink without treatment. Except in heavily urbanized and industrialized areas or regions adjacent to active volcanoes, atmospheric rainwater is very pure and any contamination of the water usually occurs after contact with the catchment system. Rainwater from ground catchment systems is not recommended for drinking unless first boiled or treated.

A degree of chemical and microbiological contamination of roof rainwater runoff is inevitable, but this will not generally cause a problem if the roof, gutters and storage tank are properly maintained and regularly cleaned and inspected.

The chemical and physical quality of stored rainwater is normally high. Care should be taken to avoid any possible sources of lead or other heavy metals, e.g. from lead flashings or lead-based roof paints.

Rainwater tanks can provide breeding sites for mosquitoes, which in some areas act as vectors for diseases such as dengue fever, yellow fever and malaria. It is therefore essential that any openings to the tank are fully screened.

To protect water quality, good system design, operation and maintenance are essential. Water quality will generally improve during storage, provided light and living organisms are excluded from the tank, and fresh inflows do not stir up any sediment.

The use of filters and first-flush diverters can further improve the rainwater quality. Further treatment through boiling, exposure to sunlight or ultraviolet radiation and chlorination can be undertaken if there are concerns over the water quality.

To prevent leaves and debris from entering the system, mesh filters should be provided at the mouth of the drainpipe. Further, a first-flush device should be provided in the conduit before it connects to the storage container.

Methods to protect rainwater quality include appropriate system design, sound operation and maintenance and use of first flush devices and treatment. Treatment is mainly appropriate as a remedial action if contamination is expected. First flush devices can be effective in reducing levels of contamination if properly maintained. Good system design, operation and maintenance are generally the simplest and most effective means of protecting water quality.

1. Precautions:

To protect the quality of rain water collected and to be used for drinking and cooking purposes, following precautions should be taken.

1. Catchment surface or the roof top should be impervious roof made from smooth, clean non-toxic material.
2. Roof surface should always be kept clean and free of debris. . Roof over which waterfalls should be cleaned before rain fall. Over hanging branches above the catchment surface should be removed
3. Rain water collection tanks should be designed to protect the water from contamination by leaves, dust, insects, vermin and other pollutants. The grill at the terrace outlet for rainwater arrests most of the debris carried by the water from the rooftop like leaves, plastic bags and paper pieces.
4. The suitable type of first flushing device to be installed and initial 10 to 15 minutes of runoff should be diverted.
5. The water collected from roof top only, should be stored in storage tank for direct use.

6. Tanks should preferably be sited away from the trees and with good fitting lid and kept in clean condition. Trim trees and brushes near the area to prevent animals from entering the storage tanks
7. In coming water to the storage tank should be filtered or screened and allowed to settle to take out foreign matter. A coarse filter and/or foul flush device should be fitted to intercept water before it enters the tank for removing leaves and other debris.
8. Taps or draw-off pipes on tanks should be at least five centimeters above the tank floor (more if debris accumulation rates are high). A tank floor sloping towards the sump can greatly aid tank cleaning.
9. No sunlight should enter the inside of tank otherwise algae will grow producing slime and smell. Keep water storage tanks shaded and use non-transparent tanks to prevent sunlight from fostering bacteria growth.
10. The area surrounding to the tank should be kept in good sanitary condition and entry of animals near the tank should be prevented (by fencing)
11. Keep children away from the storage tank area
12. Pools of water gathering around the storage tank should be drained away
13. Storage tanks should not allow any entry of insect inside the tank to prevent mosquito breeding and spread of Malaria and Dengue. Wire or nylon mesh should cover all inlets to prevent any insects and other creatures from entering the tank.
14. If the water is to be used for drinking, always use some type treatment system to deal with the potential bacteria.

2. Table showing possible routes of water contamination:

No	Contaminant	Source	Prevention/Removal
1	Particulate matter (Dust and dirt)	Atmospheric pollution, blowing wind	Control of air pollution, first flush, regular cleaning

2	Dissolved gases and salts	Air pollution, sea spray and leaching of tank material	
3	Colour, odour and taste	Leaves, debris, bird dropping, paints, tank sediments	Flushing of tank before use is advised to avoid it
4	Heavy metals	Paint coating on roof, metal piping	
5	Bacteria and pathogen	Birds droppings, dead animals, falty handling of water, open tanks	
6	Mosquito larvae	Mosquitoes laying eggs in gutters and tanks	Cleaning of gutters and tank, cover the tank opening with lid, avoid water spillage in surrounding areas.

3. Rain water and health:

Good drinking water quality is essential for the health and well-being of all people. Criteria for safe drinking water quality warrants,

1. Water is clean and does not have bad smell or taste
2. Water has no chemicals or substances that would cause harm to the health
3. There are no bacteria or any other micro organisms that may cause water borne illnesses like diarrhea or typhoid etc

To protect human health, water sources must be protected against contamination and the conveyance system should be maintained in a good condition.

Rain water collection systems are commonly believed to provide safe drinking water without treatment because the collection areas (roofs) are isolated from many of the usual sources of contamination (e. g. sanitation system).

Occurrence of pathogens is generally lower in rainwater than in unprotected surface waters and the presence of non bacterial pathogens could be minimized. Higher microbial concentrations are generally found in the first flush of rain water and the level of contamination reduces as the rain continues. Apart from contamination, rainwater tanks which do not have adequate mosquito protection present a health risk of because the water provides a suitable habitat for mosquito breeding. Certain types of mosquitoes can be vector of arboviruses including dengue viruses. It is possible to treat water if mosquitoes are present but the best way is to prevent mosquitoes entering the tank.

Rain waters are very low in dissolved minerals but slightly acidic as it dissolves carbon dioxide rendering it relatively aggressive. Rain water can dissolve heavy metals and other impurities from materials of catchment and storage tank. Normally, chemical concentrations in rain water are within acceptable limits, however possibility of zinc and lead leaching from metallic roofs and storage tanks can not be ruled out.

Rain water lacks minerals like calcium, magnesium, iron and fluoride, which are considered essential for health. However most of them are derived from food.

4. Mosquito breeding

Mosquito breeding in roof water harvesting systems has been associated with reported outbreaks of malaria and dengue in several locations. However, storage systems have usually been described as poorly designed and maintained, particularly in the case of unscreened and open-topped tanks. Gutters are also quoted as an important breeding site, particularly if they are incorrectly installed or installed with a low gradient so they do not drain properly, allowing water to pool in the gutter and/or debris to build-up. The 'out of sight out of mind' nature of many parts of a rainwater catchment system is seen as a particular problem. Many parts of the systems are above eye-level and do not receive the attention they need – gutters are not cleaned and screens and covers are not checked regularly. Even a well screened tank will often allow insects to enter, mainly as "tight fitting lids" tend not to be as tight fitting as they appear. It is not uncommon to find adult mosquitoes in rainwater tanks. Mosquito eggs are also found as they can be laid by the adult directly in the tank or in the gutters and then washed into the tank with the next rains. A fair proportion of these eggs will hatch out to become larvae, which present an aesthetic problem. However, the main issue from a public health viewpoint is whether adult mosquitoes emerge from tanks and represent an increase in the total population. Mosquito larvae go through four stages before they pupate and emerge as adults. Larvae eat bacteria and protozoan but these organisms are rare in well designed rainwater tanks that don't allow the entry of light. Laboratory studies have found that in the absence of nutrients, larvae don't develop beyond the third stage and therefore adult mosquitoes don't develop under those conditions. RWH systems are also reported to be only a fraction of the available breeding sites for mosquitoes and so should be considered as a part of a larger effort to mitigate their breeding. Mitigation and control measures are described in detail in annexure

5. Protection of rainwater quality:

Quality of rainwater assumes greater importance when it is to be used for drinking purposes including cooking and washing hands. If this water has to be used directly for drinking purpose, then quality of water must be ascertained before use. The water used for drinking should comply with the provisions of guidelines for drinking water quality (as given in annexure- 03 at page 82)

The best initial step to protecting water quality is to ensure good system design. Water quality will generally improve during storage provided sunlight and living organisms are excluded from the tank and fresh inflows do not stir up any sediment. The steps suggested in Table on previous page be followed while designing the system.

Proper operation and maintenance of rainwater harvesting systems helps to protect water quality in several ways. Regular inspection and cleaning of catchment, gutters, filters and tanks reduce the likelihood of contamination. Water from other sources should not be mixed with that in the tank.

c. Treatment: Treatment of stored rainwater only makes sense if it is done properly and if hygienic collection and use of the water will ensure it does not suffer from re-contamination.

6. Water quality standards:

No government approved standards for rain water quality exists. However the government advises to use the guidelines for water quality of drinking water published by world health organization (WHO) in third edition of 2004. These guidelines are also used for deciding the drinking water quality from other sources also. The gist of such water quality guidelines is given at annexure No-03 at page 82 for use by the users. It could also be found at http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/

The water quality for drinking purposes is tested by the water laboratory of National food and drug administration at Male. The contact details of that laboratory are provided here below.

Director General, Maldives Food and Drug Authority, Sosun Magu, Male
Tel: +960 331 2264 Fax- +960 3304570
Website www.mfda.gov.mv

However for further details or guidance following agencies could also be contacted

1) EPA- MHTE, Fen Building, Ameenee Magu, Male
2) CCHDC, Ministry of Health & Family, Ameenee Magu, Male

Atoll administration could also provide guidance or help

Chapetr-07
Water Treatment:

The cleanliness of the roof in a rainwater harvesting system most directly affects the quality of collected water. The cleaner the roof and other parts of the system (gutters, pipes and storage tank), less treatment is required. We have seen above in protecting the water quality that removal of hanging tree branches, preventing access of rodents, lizards and other small animals, selection of proper materials (roofs, pipes storage tanks) and paints can help to protect the quality and avoid treatment. For keeping the water quality potable, a plain galvanized roof or a metal roof with epoxy or latex paints and not asphalt paints are recommended.

There are several types of treatment possible, the most common being chlorination, boiling, filtration and exposure to ultraviolet or natural sunlight.

1) Chlorination:

Chlorination is most appropriately used to treat rainwater if contamination is suspected due to the rainwater being coloured or smelling bad. It should only be done if the rainwater is the sole source of supply and the tank should first be thoroughly inspected to try to ascertain the cause of any contamination.
Chlorination is done with stabilised bleaching powder (calcium hypochlorite - CaOCl2) which is a mixture of chlorine and lime. Chlorination can kill all types of bacteria and make water safe for drinking purposes. About 1 gm (approximately 1/4 tea spoon) of bleaching powder is sufficient to treat 200 litres of water.

2) Chlorine tablets:

Chlorine tablets are easily available in the market. One tablet of 0.5 g is enough to disinfect 20 litres (a bucketful) of water.

3) Boiling:

Boiling is a very effective method of purification and very simple to carry out. Boiling water for 10 to 20 minutes is enough to remove all biological contaminants.

4) Direct sunlight:

This can also be used to kill many of the harmful bacteria in water by exposing it in clear glass or plastic bottles for several hours. Although feasible in some circumstances, the water must be clear, the weather fine and the water cooled overnight before consumption.

This treatment is also known as SODIS (Solar disinfection) which is explained in detail in annexure –

5) UV Radiation:

Ultra violet (UV) light can be used to kill bacteria, viruses and cysts by exposure to UV light. Turbidity or the suspended particles in water should be removed before treatment otherwise pathogens can hide in the particles and the treatment will not be effective. UV lights do not leave any residue or bye product so problem of smell or taste like chlorine can be eliminated. They use minimum power for operation. The operation manual will be provided by the manufacturer.

Table: Summary of water quality care and treatments

Treatment Method	Place or location	Result/ removal of impurity
Pruning of hanging tree branches	Over the rooftop	Prevents leaves and birds droppings
Leaf screens or strainers	Gutters and down pipes	Prevent leaves and other debris from entering the tank
First flush diverter	Before the storage tank, on the down pipe	Reduces particulate and suspended matter
Filtering	Inlet of tank	Retains small impurities
Settling	Within tank before tap	Settles out particulate or

		suspended matters
Disinfection	Before water use	Kills microorganisms
Activated charcoal	After chlorination or before water use	Removes excess chlorine and odour or colour
Cleaning of tanks to remove bottom sediments	Storage tank	Elimination of turbidity and odour etc.
Care in handling water while use	At household level	Prevents human borne contamination of water

Chapetr-08
Operation and maintenance:

Rainwater harvesting systems require minimal attention with respect to their operation. Maintenance is generally limited to the annual cleaning of the tank and regular inspection of the gutters and down pipes. Maintenance typically consists of the removal of the removal of dirt, leaves and other accumulated material. Such cleaning should take place annually before the start of the rainy season. However cracks in storage tank can create major problems and should be repaired immediately. Additional care is required to protect the structures from damage and contamination by people and animals. The O & M serves two purposes: to provide good quality of water by protecting it from contamination and keeping the system in good working condition.

Contamination of water as a result of contact with certain materials can be avoided by using appropriate materials during construction, or selecting tanks made from acceptable materials. The major concern is to prevent the entry of contaminants into the tank while it is being replenished during a rainstorm. Bacterial contamination can be minimized by keeping the rooftop surfaces and drains clean. 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 rainwater harvesting systems:

A procedure for eliminating the "foul flush" after a long dry spell deserves particular attention. The first part of each rainfall should be diverted from the storage tank since this is most likely to contain undesirable materials which have accumulated on the roof and other surfaces between rainfalls. Generally, water captured during the first 10 minutes of rainfall during an event of average intensity is unfit for drinking purposes. The quantity of water lost by diverting this runoff is usually about 14L /m^2 of catchment area.

The storage tank should be checked and cleaned periodically. All tanks need cleaning; their designs should allow for this. Cleaning procedures consist of thorough scrubbing of the inner walls and floors. Use of chlorine solution is recommended for cleaning, followed by thorough rinsing.

Care should be taken to keep rainfall collection surfaces covered, to reduce the likelihood of rodents, lizards, mosquitoes, and other pests using the cistern as a breeding ground. Residents may prefer to take care to prevent such problems rather than have to take corrective actions, such as treating or removing water, at a later time.

Disinfection of the cisterns or storage tanks is necessary if the water is found to be contaminated (impart smell or growth of algae etc).

Gutters and down pipes need to be periodically inspected and cleaned carefully. Periodic maintenance must also be carried out on any pumps used to lift water to selected areas in the house or building. More often than not, maintenance is done only when equipment breaks down.

Community systems require the creation of a community organization to maintain them effectively. Similarly, households must establish a maintenance routine that will be carried out by family members.

Maintaining water quality at a level where health risks are minimized. In many systems, this involves chlorination of the supplies at frequent intervals.

Problems usually encountered in maintaining the system at an efficient level include the lack of availability of chemicals required for appropriate treatment and the lack of adequate funding.

Community systems require community involvement and organisation for effective maintenance, while household systems require a correspondingly smaller scale involvement by residents. 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. Additional requirements for ground catchments include fencing the paved catchment to keep out trespassing animals that can affect water quality, cleaning the paved catchment of leaves and other debris, and repairing large cracks in the paved catchment that result from soil movements, earthquakes, and/or exposure to the elements

Problems commonly encountered in maintaining the system at an efficient operating level are the lack of availability of chemicals required for appropriate treatment and the lack of adequate funding.

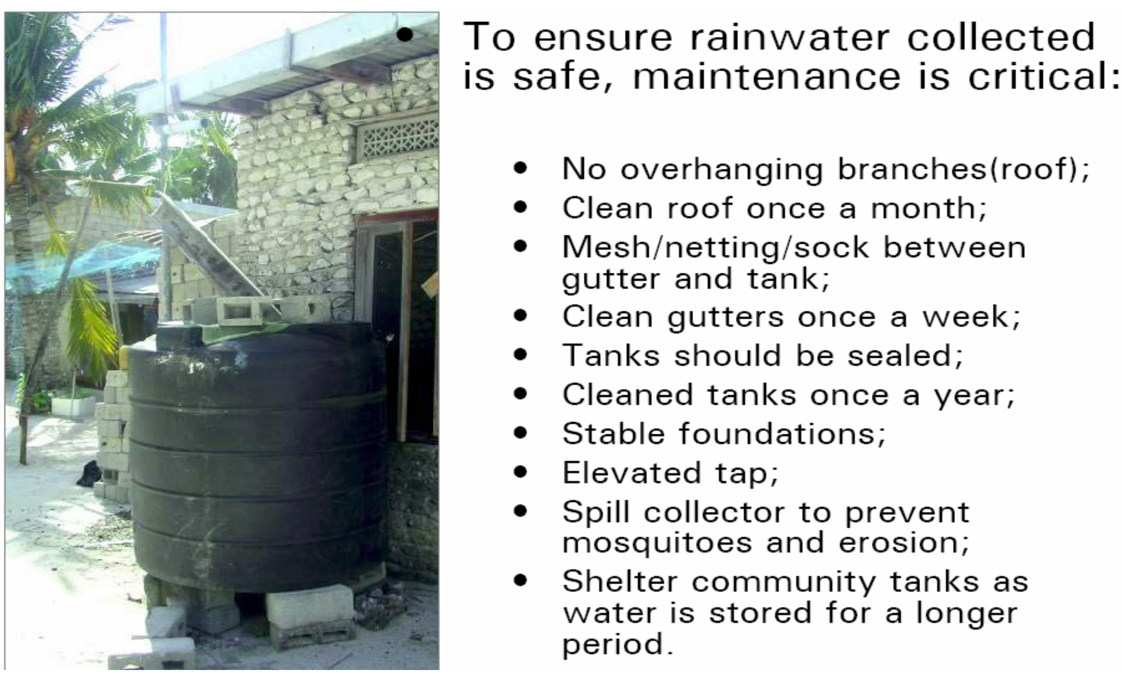


Photo- UNICEF

Table: Summary of regular maintenance schedule:

Part	Maintenance	Frequency
Roof	Wash off roof with water when dust /dirt accumulates diverting wash off away from tank inlet	Monthly and especially after a long period of dry weather or heavy wind
	Sweep off leaf litter	Regularly and especially after heavy winds and just before the rains set in.
	Trim and cut trees around roof	When required
	Repair damages to roof (broken tiles or cracked water proofing etc)	At the earliest and before the rainy season
	Paint using lead free paints	If the rust is found present
Gutters and down pipes	Clean and wash out bird droppings, leaves etc with water	Check monthly and especially after a long period of dry weather or heavy wind. Check daily during rainy period
	Ensure proper slope in gutters and down pipes for steady flow	During installation and after heavy rains
	Repair leaks in gutters, down pipes and elbows	When required
Filters	Clean filters	Before and after rainy season
First flush device	Check and clean	Before and after the rainy season and after every roof top cleaning
Tank	Clean	Before and after rainy season
	Repair leaks	As required but at the earliest
	Cut nearby tree roots	If underground tank

	Ensure lid is sturdy and secure	At all times
	Ensure there are no gaps where insects can enter	At all times
	Secure fasten insect screen over the end of overflow pipe	At all times

O & M Checklist:

1. Keep the roof catchment clean
2. Cut tree branches that overhang the roofs
3. Use an installed first flush (or foul flush) device,
4. Conduct regular inspection and cleaning of gutters
5. Clean gutters, down pipes and first flush devices
6. Monitor tank levels
7. Check and clean the storage tank periodically
8. Cover and ventilate the tank
9. Repair leaks
10. Provide water treatment as necessary
11. Avoid stagnation of water on the roof, in the gutters and near storage tank
12. Change filters regularly
13. Perform disinfection of water (if required)
14. Get tested water quality periodically
15. Adopt efficient water use practices

Chapetr-09
Rain water harvesting at schools:

Rain water harvesting can be a valuable source of drinking water supply for the schools which are in remote areas or where water supply is limited. Schools face many difficulties where water supply is not reliable especially during dry periods. Students can pay better attention to studies if water is ensured for drinking and sanitation purposes. They can save upon time spent to fetch water or go out to drink water or use toilet. Parents are attracted to send children to schools where safe and accessible water supply facilities are available. Girl students need more water for their menstrual cleanings which increases the drop out at puberty from schools where no water is available.

Adequate provision of water at schools can also improve hygiene of students and reduce the risk of water borne diseases which is more due to poor immunity at child age. Besides water harvesting can prove a demonstration model for the parents to adopt at home and provide children inspiration to use and maintain such system at home. Involvement of children in operation and maintenance of system provides them extra curricular activity and develops a long lasting habit of using and maintaining such plants and develop self confidence to use it. The additional benefits include water availability for kitchen (canteen), toilets, washroom, school garden and plantation. It will also help schools to reduce their water bills.

1. Why use rainwater harvesting in schools?

- Long lasting clean and safe source of drinking water will be ensured
- Ideal solution for schools in remote rural communities lacking water for drinking and sanitation
- Water shortage experienced during dry periods could be overcome
- Year round water will be available for hygiene improvement
- Water will be available for flushing toilets
- Water will be available for girls who need it for their menstrual cleaning

- No water at school means children spend school hours getting water instead of learning
- The system is not costly like the conventional one and it will reduce water bills of the school (Solutions based on local groundwater or other water sources are often too costly, and foster dependency on external resources, equipment, knowledge and skills)
- The project will work as a demonstration model to make it popular for household use
- Schools will become more attractive and attendance will increase
- Reduces incidence of water borne diseases as children are more vulnerable if water is not adequate or safe

2. Guidelines for schools:

- Roof should be cleaned by elders only, never by children
- Keep the roof clean, remove tree leaves from the roof and gutter daily
- Keep a filter to trap leaves and other large particles before storing water in the storage tank
- Store water in a whitewashed tank
- Always keep the water storage tank covered
- Separate the first flush of rain. Clean the separator daily
- Disinfect water before using it for drinking and cooking if required

3. School activities:

- Involve students in monitoring rainfall, total rain in a year, water collected in the rainwater tank and teach them how to ensure good maintenance of the system
- Putting an information board with maintenance details, and keeping a small rain gauge in the schools, etc will be helpful
- Cut the shady trees above the catchments roof or ensure removal of falling leaves regularly to prevent blockage in the gutters and pipes. Decaying leaves may also colour the water and cause bad odour

- Put a rain separator and wash out the first rains to prevent the dirt to come into the filter and the tank
- Paint the storage tank white on the outside, to keep the water inside cool and prevent the growth of bacteria. Every year the tank must be white washed neatly. Now fiber glass tanks are used in many places. These tanks also must be cleaned regularly, at least once a month
- The tank also should be sealed from the top using covers and keep it always fully covered. This will prevent the growth of algae or bacteria in the tank
- The tank should also be completely water tight. If there is any leak in the tank or even dampness, the problem should be addressed immediately with the help of a trained mason
- Water quality checking needs to be done regularly if it is used for consumption. Simple testing kits will be helpful for such testing
- The method suggested for treating for bacteria is chlorination. Liquid chlorine or chlorine tablets are available for treatment of water. Depending on the volume of the rainwater in the tank, chlorine needs to be added to disinfect the water
- Repair the system in time and ensure smooth operations.

HIGHLIGHTS OF SCHOOL RAINWATER HARVESTING GUIDELINES, MALDIVES

- School should have adequate capacity of rainwater storage to meet student needs (1.5 litres/day/student
- Facilities should be designed child friendly
- Material of Tank should be PVC
- Tank should be placed above ground (20-30 cm)
- Roof and tanks must be well maintained and free from contamination.
- Rainwater harvesting system must be clean and first rain should be flushed before collection.
- After first flush, check the quality by using H_2S strips.
- Protect tank from insect entry and protect roof from overhanging branches of trees.
- Clean Tank twice a year and use chlorine to disinfect the tank.

Source: Ministry of Education, Maldives, 2007

Chapter- 10
Stakeholder consultations:

Stake holders' consultations were held at various places/ regions to invite comments on draft guidelines and suggestions.

1. Consultation at Male

The first stakeholder meeting was organized on January 29, 2009 at Male, the capital of the country with the support of MWSA of MHTE.

Major issues related to present practice of rainwater harvesting system in Maldives were focused. Concern was expressed about the water quality of microbiological and chemical contamination of water within rainwater harvesting system. Also inquiries were answered about feasibility of rainwater harvesting system in urbanized island like Male. Rain water quality improvement and brown cloud/ trans-boundary air pollution and its impact on rainwater were also discussed in the meeting. As no more information is available on effect of brown cloud on rainwater research involving water quality monitoring was felt necessary.

2. Points emerged out of discussions:

1. Impacts of asbestos sheets if used as roof materials on water quality
2. Scope for harvesting rain water in urban areas like Male
3. Use of cement tanks for rain water storage
4. Tax concessions on using household water disinfection appliances like UV tube etc
5. Introduction of auto first flush diverter devices
6. Chlorination of water and other disinfection options

3. Observations of field visits:

Field visits to following islands in southern province of the country (Addu atoll) and northen province (Lhaviani Atoll) were organized with the support of Atoll Hospitals and the local administration.

1. Feydhoo
2. Mardhoo-Feydhoo
3. Mardhoo
4. Hithadhoo
5. Gan
6. Naifaru
7. Kurendhoo
8. Mafilafushi
9. Hinnavaru

Meetings were held with the atoll/ island councilors, atoll administration, health staff, NGO representatives and community leaders. Private and public systems were inspected and interactions were held with household people about the performance and maintenance of systems. Salient observations during the site visits are enumerated below.

- Almost every house has RWH system
- Rain water tanks are provided by government and INGOs during Tsunami
- Safe distance between septic tank and water tank is not maintained
- Method of harvesting is not adequate and maintenance not satisfactory
- Problems of mosquitoes and lizards in water tank exist
- Public awareness is necessary
- Government has provided storage tanks but then no follow up or monitoring
- Dengue is a problem due to mosquito breeding
- Community needs guidance and support to improve the system/ maximize benefits
- Cleanliness maintained. No spillages or wastage of water
- People prefer desalinated water over rain water
- People do not like chlorine smell and test
- No sufficient storage facility is available.
- People are using public tank supply when private storage gets exhausted
- When dry period is prolonged then water supply is a problem

- Ground water is highly contaminated and is smelling badly
- People want sewerage system to replace septic tanks and prevent ground water contamination
- People believe that they cannot depend only on rain water. Desalination should also be considered
- No provision of funds for maintenance of public water supply system
- Shortage of space is experienced to put additional storage tanks

4. Points emerged out of island visits and discussions with councilors, local leaders and health officers:

- General cleanliness and hygiene habits are good
- People understand the importance of rain water and practice it
- Government provides one storage tank free (2500L) per family
- No follow up or monitoring by government. No care or guidance is provided
- The gutters, pipes and other civil works is the responsibility of household owner
- Community water tanks are provided by government (mostly at prayer houses)
- No maintenance of public system. Govt. does not provide any funds for that
- People are using public tank supply when private storage gets exhausted
- No wastes of water or spillages around the tanks are noticed
- Quantity of water stored is not sufficient. More storage is needed
- Dry period creates shortage of water and difficult to manage
- Many people do not drink rain water because of no taste (misbelieve that rain water is not good for drinking)
- People do not like chlorination also because of smell and taste of water
- People prefer desalinated water and buy mineral water bottles
- Problem of mosquitoes and lizards in storage tanks
- Dengue is prevalent
- Septic tanks have polluted ground waters heavily
- Sewerage system is a felt need

- Rain water contamination causes diseases especially among children (eye and ear diseases)
- Public awareness and education are highly required
- Rumors about asbestos sheets

- Schools children and teachers need to be focused for awareness

Questions asked during visits and workshop:

- Can asbestos be used for roof if the water is to be used for drinking purpose?
- What should be the appropriate design of the system?
- How to protect the drinking water quality
- Is rain water good for drinking? It has no taste and minerals.
- What should be the safe distance between rain water storage and toilet/ septic tank?
- What should be the role of community and the government in management?
- Is chlorinated water harmful to drink?
- How to remove chlorine smell and taste?
- What are the other methods of disinfection?
- Should we drink mineral water only for good health?
- How to apply chlorine in the tank water? Can we use bleach liquid?
- Who will provide us chlorine? Where to get chlorine from? What should be the strength of chlorine?
- How long we can use stored rain water?
- How much chlorine we should add in to storage tank?
- Where we get chlorine tablets?
- What is H2S test? Where we get test vials?
- Can we build underground tanks for water storage?

Group work recommendations:

1. **Collection and conveyance**
   a. Tin roofs get rusted. So plastic roofs are good
   b. Many houses have no first flush diverter. All should provide first flush diverter to prevent debris, leaves and other particles going to storage tank

c. Screens should be used at the end of gutters to remove any coarse impurities form the roof
d. Overflow water is wasted now. It should be used for ground water recharge
e. Poor people can start with small catchment area and gradually expand as funds are available

2. **Storage and treatment**
    a. Tanks should be cleaned and checked regularly
    b. Tanks should be under shadow or underground as far as possible for protection and keeping the water cool
    c. Filter/ cloth should be provided at the inlet of the tank to prevent impurities
    d. Tanks mouth should be kept closed/ covered to prevent mosquitoes and lizards
    e. Water should not be wasted during drawal and surrounding should be kept clean
3. **Maintenance and management of community system**
    a. Maintenance schedule (time table) should be established with list of activities and frequencies
    b. Government should appoint focal point to oversee systems and provide monitoring, quality check and technical guidance. (Atoll administration should be asked to fix the responsibility from existing staff as part of decentralization)
    c. Outsiders (from other islands) should not be allowed to take away water from public tanks or should be charged for water
    d. Push and draw type taps should be provide at public tanks to avoid waste of water
    e. Hospital staff could be requested to advise on mosquitoes breeding at community tanks as part of their routine check up
4. **General recommendations**
    a. Rain water harvesting can be made mandatory for all government buildings including schools, hospitals and other offices. These systems should provide model for public to follow.

b. It should also be mandatory for private buildings with more than 100 sq m floor area. Necessary provision can be made in national building code

c. Children going to school carry water with them (mostly mineral water bottle). It should be made mandatory for the school to maintain their water system in good condition and children should be encouraged to drink rain water at schools

d. School education and public education/awareness need to be intensified

e. Ground water recharge through rain water harvesting and rain water use for agricultural uses should be encouraged

f. Government should accord priority to this program and provide incentives to the community for popularizing the system

g. Rain water harvesting cell/unit need to be created within the ministry of water to coordinate and monitor the program and provide technical guidance to community.

h. Instead of providing 2500L storage tank (HDPE) per family, it should be provided according to the size of the family. It is recommended to provide 500 L storage capacity tank per person.

i. There is no adequate space for keeping additional water tanks at household. So underground tanks need to be considered.

Hithadhoo Island chief Mr. Shamin Ali addressing the workshop at Gan (Addu) on 10 June 2009

Participants to the rain water harvesting workshop at Lh Naifaru island 24 June 2009

Chapetr-11
Rain water harvesting Guidelines:

1. System Components

A rainwater harvesting system consists of the following components:

- catchment area (roof),
- conveyance system (gutters and down pipes),
- storage (tank or cistern)

2. Catchment area (roof):

Rainwater harvesting can be done with any roofing material if it is for non-drinking use only. For potable use of rainwater, the best roof materials are metal, clay, and cement products. Asbestos roof materials should not be part of a system to provide drinking water. Asphalt shingles can contribute grit to the system and need a pre-filter for the water before it enters the cistern. Lead materials in any form should not be used in the system.

3. Conveyance system

- Gutters are used to convey water from the roof to pipes to the storage tank or cistern.
- If a straight run of gutter exceeds 60 feet, use an expansion joint.
- Keep the front of the gutter one half inch lower than the back.
- Provide a gutter slope of 1/16 inch per foot minimum.
- Provide gutter hangars at 3.
- Gutter should be a minimum of 26 gauge galvanized steel or 0.025 inch aluminum.
- Down pipes should provide 1 square inch of opening for every 100 square feet of roof area.
- The maximum run of gutter for one down pipe is 50 feet.

- The conveyance piping from the gutter system to the cistern or filter should be preferably of PVC of appropriate diameter.
- Do not exceed 45 degree angle bends in horizontal pipe runs and provide 1/4 inch slope per foot minimum.

4. Storage system

- The storage tank (cistern) must be sized properly to ensure that the rainwater potential is optimized. See the previous section regarding capacity for sizing information.
- Cisterns can be located above or below ground.
- The best materials for cisterns include concrete, steel, ferro-cement, and fiberglass.
- When ordering a cistern, specify whether the cistern will be placed above or below ground and if the cistern will be used to store potable water. (Fiberglass cisterns are constructed differently to meet the various criteria.)
- If using a manufactured tank designed to hold drinking water, the tank should conform to the published specifications of the American Water Works Association.
- Cistern characteristics

    - ✓ A cistern should be durable and watertight.
    - ✓ A smooth clean interior surface is needed.
    - ✓ Joints must be sealed with non-toxic waterproof material.
    - ✓ Manholes or risers should have a minimum opening of 24 inches and should extend at least 8 inches above grade with buried cisterns.
    - ✓ Fittings and couplings that extend through the cistern wall should be cast-in-place.
    - ✓ Dissipate the pressure from the incoming water to minimize the stirring of any settled solids in the bottom of the cistern. This can be accomplished in a concrete cistern by placing concrete blocks

(cavities facing upward) surrounding the base of the inlet pipe. The blocks can be 8"x 8"x16" blocks with the pipe exiting one inch above the bottom of the cistern. Baffles to accomplish the same result can be made as part of fiberglass cisterns. This is not a concern for cisterns that always have a large reserve.

- ✓ The use of two or more cisterns permits servicing one of the units without losing the operation of the system.
- ✓ Have a fill pipe on the cistern for adding purchased water as a backup.
- ✓ Have a cover to prevent mosquito breeding and algae growth from contact with sunlight.

5. Filtering system

- ➢ The rainwater may become contaminated by dirt, debris, and other materials from the roof surface. The best strategy is to filter and screen out the contaminants before they enter the cistern.
- ➢ A leaf screen over the gutter and at the top of the downspout is helpful.
- ➢ A primary strategy is to reject the first wash of water over the roof. The first rainfall will clean away any contaminants and is achieved by using a "roof washer."
- ➢ The main function of the roof washer is to isolate and reject the first water that has fallen on the roof after rain has begun and then direct the rest of the water to the cistern. Ten gallons of rainfall per thousand square feet of roof area is considered an acceptable amount for washing. Roof washers are commercially available and afford reliability, durability, and minimal maintenance to this function.

- ➢ Roof washing is not needed for water used for irrigation purposes. However, prefiltering to keep out debris will reduce sediment buildup. A sand filter can also be used.

6. Distribution

- Removing the water from the cistern can be achieved through gravity, if the cistern is sufficiently high enough, or by pumping.
- Most cases will require pumping the water into a pressure vessel similar to the method used to withdraw and pressurize water from a well (except a smaller pump can be used to pump from a cistern).
- A screened 1.25 inch foot valve inside the tank connected to an 1.25 inch outlet from the cistern approximately one foot above the bottom (to avoid any settled particles) will help maintain the prime on the pump. A float switch should be used to turn off the pump if the water level is too low.
- Another alternative is the use of a floating filter inside the cistern connected to a flexible water line. This approach withdraws the water from approximately one foot below the surface which is considered to be the most clear water in any body of water.
- The water that will be used for potable purposes can pass through an inline purification system or point of use water purification system. Other uses for the water do not need additional purification. (Water purification options are not discussed in the Sourcebook.)

7. Protecting water quality:

- Prevent polluters from degrading drinkable rainwater.
- Disinfect your tank with chlorine/bleach at least once a year. Store your rainwater in reserve tank and disinfect main tank. Since rain is main potable water source in Islands in Maldives, disinfect storage tank after onset of monsoon.
- Check pH level of rainwater in tank using pH strip. If water is acidic (pH ≈ 5.5) a slight buffering half table spoon of baking soda to 2000 litres of water in the tank will neutralize water.
- If community or individual is not against the ingesting chlorine one can select chlorine disinfection methods.

- If community or individual is against the ingesting any kind of chlorine one can select other disinfection methods such as Boiling, UV treatment, 1 micron filtration for drinking.
- Boil water for 5 minutes or buy UV water disinfection information from nearest market. 1 micron filter slowly allow water to pass thus, good only for small amount of water.
- If you have doubt in your water, collect your water sample for faecal coliform test.
- As an alternative method of water disinfection, one can adopt SODIS method (Annex).

8. Rain water harvesting in emergencies

- Disasters can disrupt rainwater harvesting system so knowledge of where to store emergency rainwater and how to make it safe to drink be provided
- At least drinking, brushing and some water for cooking should be stored for two-three days during disaster. At least 5 liters of water per person per day should be stored at safe place. The best method one can adopt is fill empty bottle with rain water and store in a cool and dark place. Well sealed containers can last for at least a year. Mark containers with the current date. Containers that have held fluids or materials that were not drinkable or edible should not be used.
- If stored emergency water is found contaminated in the disaster, then learn how to purify water. Water that has been exposed to the air for a few days should be boiled vigorously for 5 minutes to kill bacteria. Chlorination can also be used
- Laundry bleach or liquid chlorine bleach need to be stored in house

9. General checklist

To optimize the yield, ensure safe water quality and reduce maintenance of the system following checklist should be adopted

- Ensure the roof surface is suitable for collecting quality rain water
- Install roof gutters and down pipes of appropriate size and standards
- Provide gutter mesh system to prevent leaves and debris from blocking gutters
- Keep the gutters Incline to 3-5 degree
- Keep bushes and trees away from roof and tank.
- Use good filter/roof washer to disallow dirt and particles.
- Fit insect proof screens to all pipe openings
- Fit appropriate sized First flush water diverter
- Provide water storage tank of sufficient capacity
- Obtain potential of rainwater storage from Annex 1A and Annex 1B
- Ensure proper maintenance of system
- Block off or remove any possible access to your roof and tank by animals.
- Use good rain roof washer/filter before rain interring storage tank.
- Use coarse filter box with nylon mess as screen or sand filter.

Abbreviations used in this report:

No	Abbreviation	Full form
1	G o M	Government of Maldives
2	HDPE	High Density Poly Ethylene
3	IFRC	International Federation of Red Cross
4	L	Liters
5	lpcd	Liters per capita (person) per day
6	MHTE	Ministry of Housing, Transport and Environment
7	MOH	Ministry of Health
8	m	meter
9	m^2	Square meter
10	mg/L	Milligram per liter
11	mm	Millimeter
12	mm/ h	millimeters per hour
13	MWSA	Maldives Water & Sanitation Authority
14	RWH	Rain Water Harvesting
15	UNICEF	United Nations Children Fund
16	UNDP	United Nations Development Program
17	WHO	World Health Organization

References:

1. State of the environment, Maldives 2004, Ministry of Environment, Male, Maldives
2. Maldives Environmental Assessment by Asian Development Bank, September 2007
3. UNICEF-Maldives -Water, environment and sanitation program (Module-4) webpage- http://www.impact.net.mv/training/TM4.pdf
4. UNEP-Sourcebook of Alternative Technologies for Freshwater Augumentation in Small Island Developing States-web page- http://www.unep.or.jp/ietc/publications/techpublications/techpub-8d/harvesting.asp
5. Water Resources Management in Maldives with an emphasis on desalination, Ms Shaheedha Adam Ibrahim et al, Maldives Water and Sanitation Authority,
6. Environmental Health Country Profile, World Health Organization, December-2008
7. Rain water harvesting, Quality, Health and Hygiene Aspects by Han Heijnen and Namrata Pathak, http://raindrop.philwatershed.org/members/superuser/vln3/newsitem.2007/
8. Manual on Rooftop Rainwater harvesting system in schools , The Government of Karnataka, India, http://www.rainwaterclub.org/docs/MANUAL
9. Water Supply and Sanitation Master plan for the Republic of Maldives, Ministry of Environment, Energy and Water, Maldives Water Supply and Sanitation Authority, and World Health Organization, Male, Maldives, January 2008.
10. Water and Sanitation Master plan for the republic of Maldives (Draft) by MHTE, MSWA and WHO- January 2008

Drinking water quality guidelines:

Drinking water quality guidelines are required to ascertain the safe quality of water for drinking, cooking and other domestic uses. The national government decides the drinking water quality standards and suggests methods of tests. The World Health Organization has published drinking water guidelines for the countries to take guidance to frame national standards. The Government of Maldives is in process of formulating the national standards for drinking water quality that includes, public water supply and bottled water. Rain water to be used will have the same water quality standards as for public water supply.

Meanwhile the Ministry of Water and Environment (MHTE) has approved the below mentioned drinking water quality guidelines for deciding the drinking water quality in Maldives. Obviously these national guidelines are based on WHO Guidelines published in 2004 (Third Edition).

No	Parameter	Unit	Maximum allowable limit
A	**Physical parameters**		
1	Colour		colourless
2	Taste & Odour		Not offensive
3	Turbidity	NTU	Less than 1
4	Electrical conductance	µS/cm	Less than 1500
5	pH		5.0 to 9.5
B	**Chemical parameters**		
1	Free chlorine	Mg/L	0.08 to 0.2
2	Chloride as Cl		Less than 250
3	Nitrates as NO_3		Less than 50
4	Ammonia as N		Less than 1.5

5	Lead as Pb		Less than 0.01
6	Iron as Fe		Less than 0.3
7	Zinc as Zn		Less than 3
8	Copper as Cu		Less than 1.5
9	Aluminum		Less than o.2
10	Hydrogen Sulfide		Less than 0.05
C	**Bacteriological parameters**		
1	E. Coli	Count /100 ml	• Absent in 99% of samples • Maximum 1 in 1% samples
2	Total coliforms		• Absent in 95% of samples • Maximum 1 in 4% of samples • Maximum 10 in 1% of samples
Note	For full details and more explanation refer to water quality guidelines published by World Health Organization (WHO), Third Edition of 2004.		

Chlorination

Chlorination is one of the most reliable methods of disinfecting drinking water. It is most widely used method for drinking water disinfection as it is effective and economical. The process of Chlorination is known as the addition of chlorine gas or some other oxidizing chlorine compound (sodium or calcium hypochlorite, chlorinated lime, chlorine dioxide) to the water to be treated.

It is advisable to remove or reduce prior to chlorination, the turbidity and particulate substances by means of sedimentation and/or filtration which would impede disinfection.

Chlorine gas and chlorine dioxide are widely used in water treatment on account of their high efficiency and ease of application. Several chlorine compounds which have various active chlorine contents (see table below) are more easily applicable. In some form or another they are available virtually anywhere.

Strength of Various Chlorine Preparations

Name	% Active Chlorine	Amount for Preparation of 1 L of 1% Solution
Sodium Hypochlorite	14 (10-15)	71 g
Household Bleach	5 (3-5)	200 g
Chlorinated Lime	30 (25-37)	40 g
HTH	70 (60-70)	15 g

Household bleach is generally available in dissolved form. Its commercial strength in terms of active chlorine is between 3 to 5%. It is stored in dark glass or plastic bottles. The solution loses some of its strength during storage. Sunlight and high temperatures accelerate the deterioration of the solution. The containers therefore should be stored in cool darkened areas. The stability of the solution decreases with increasing contents of available chlorine.

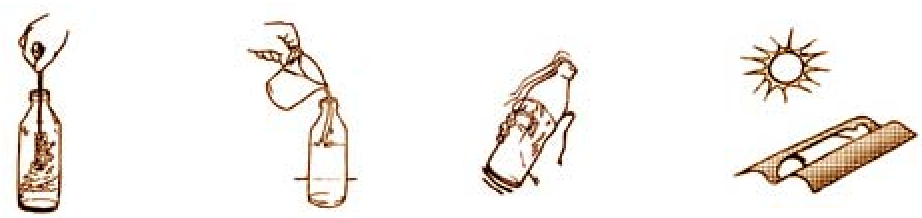
Chlorinated Lime or Bleaching Powder is readily available as powder and is inexpensive. It is stored in corrosion resistant cans. When fresh, it contains 35% active chlorine. Exposed to air, it quickly loses its effectiveness. It is usually applied in solution form which is prepared by adding the powder to a small amount of water to form a soft cream. Stirring prevents lumping when more water is added. When the desired volume of the solution has been prepared, it is allowed to settle before decanting. Solutions should have concentrations between 5 and 1% of free chlorine, the latter being the most stable solution. Some 10% of the chlorine remains in the settled sludge.

High Test Hypochlorite (HTH) is a stabilized version of calcium hypochlorite (Ca(OCI)2) containing between 60% and 70% available chlorine. Under normal storage conditions, commercial preparations will maintain their initial strength with little loss. Even though HTH is expensive, it may be economical, thanks to its properties. It is available in tablet or granular form (commercial names: Stabo-Chlor, Caporit or Para-Caporit).

Solar Disinfection of water (SODIS):

Solar disinfection is a process where in microbes are destroyed through temperature and ultra violet radiation provided by the sun. Water is filled either in a clean transparent or painted (Black) bottle oxygenated by shaking, followed by topping up. It is placed in the horizontal portion on tope exposed to direct sunlight for 4-6 hours. Such an exposure increases the temperature of water and also gives an extended dose of solar radiation killing the microbes.

It has been proven that synergies induced by radiation and thermal treatment have a significant effect on the die-off rate of microorganisms. The processes involved are indicated in the illustration.



Clean the bottle well	Fill the 3/4th of the bottle with water and cap it	Shake the bottle well	Keep the bottle on black iron sheet for minimum 6 hours in sunlight before consumption

Functioning of Sodis depends on the following factors:

1) Weather and climate: Sodis requires sun's radiation and temperature to purify drinking water. The container needs to be exposed to direct sunlight for about six hours. If the temperature rises above 50 degrees Celsius, the disinfection process is three times faster. If weather conditions are not optimal the efficiency of the disinfection process can be increased by using half-blackened plastic bottles, which achieve approximately 5 degrees C higher water temperatures than fully

transparent, non painted bottles. Placing the plastic bottles on a black corrugated zinc sheet would also help in achieving disinfection

2) Water Turbidity: Suspended particles in the water reduce the penetration of solar radiation into the water and protect microorganisms from being irradiated. Sodis requires relatively clearer water with a turbidity of less than 10 NTU (Naphelometric Turbidity Unit - naphelometer is a modern commercial instrument used to measure turbidity)
3) Material: Various types of transparent plastic materials are good transmitters of light in the UV and visible range of the solar spectrum. Plastic bottles made of PET (Poly Ethylene Terephtalate) are preferred because they contain less UV- stabilizers than PVC (Poly Vinyl Chloride) bottles.
4) Shape of containers: More the area of bottle exposed to sunlight, more would be efficiency in achieving disaffection.

Oxygen: Sodis is more efficient in water containing high levels of oxygen. Shaking a water container which is about 3/4th full for about 20 seconds before they are filled completely could increase oxygen levels. On reacting with this water, sunlight produces highly reactive forms of oxygen (oxygen free radicals and hydrogen peroxides). These reactive forms of oxygen kill microorganisms

Annexure-06

Mosquito control in RWH Systems

A. Points to remember:

1. RWH is the abbreviation of Rain Water Harvesting
2. RWH system consists of three main components- Catchment (roof), conveyance (gutters and down pipes) and storage tanks (rain water collection)
3. RWH can be a potential source of mosquito breeding if no preventive and controlling action are taken
4. Mosquitoes need water to grow and lay eggs
5. Stagnation of water in the system promotes mosquitoes breeding
6. Avoiding stagnation of water and providing barriers in the RWH system are the best preventing measures to control mosquitoes
7. Dengue fever is endemic in Maldives
8. While Dengue(Aedes Aegypti) and Malaria (Anopheles) mosquitoes breeding takes place in clean water ,the filarial mosquitoes (Culex) breed in dirty water (waste water)

B. Factors causing stagnation of water in RWH system

1. Defective design of harvesting structures and lack of sufficient gradient to flow water freely
2. Falling tree leaves from hanging branches on the roof and other objects
3. Dust and debris accumulated on the roof (catchment)
4. Blockages in gutters and conveyance system

5. Cracks and leakages in down pipes and storage tanks
6. Gaps in joints at the connecting pipes
7. Keeping the storage tank opening uncovered
8. Poor operation and maintenance

C. Care in maintenance

1. The catchment area (roof/terrace) should be kept clear and clean of falling tree leaves and debris
2. Free flow of water in the gutters should be ensured. Leaves and other obstructions should be removed
3. Easy access for inspection and maintenance of gutters should be provided
4. The inlet of down pipes should be covered with screen or mesh to prevent entry of leaves and debris
5. Bends in down pipes should be avoided as far as possible and first flush operated as required
6. The storage tank should be kept covered at the inspection opening
7. Cracks and leaks in piping and tanks should be repaired promptly
8. Filters should be disinfected with household bleach

D. Cleanliness of surrounding area

1. Spillages and stagnation in the surround area of the storage tank should be avoided
2. Tank overflow should be channels to drains or for ground water recharge
3. Use larvicides where required in open pounding (Kerosene or permitted chemicals)

4. Remove unwanted grass and vegetation
5. Adopt hygienic life style
6. Organize community awareness and health education programs
7. Use mosquito repellants where possible (smoke of burning wood or leaves and oils)
8. Take personal protective measures to prevent mosquito bites

Water quality testing by H_2S Strip Test:

If the roof, the gutter, the first flush and the filter is clean, the collected rainwater will be clear. But if the water is dirty in color or if it smells bad, suggests that system is not being kept clean. Sometimes even if the water is clear and does not smell still it could contain micro-biological contamination. To test – use H_2S strip test bottle. This simple test checks for coliform or bacterial contamination and provides an indicator of water quality. It is very simple, easy and user friendly test for monitoring the drinking water quality.

The presence of coliform bacteria in drinking water is associated with hydrogen sulfide (H_2S) – producing organisms and faecal pollution of water can be established by demonstration of H_2S production. Some examples of such microorganisms are Enterobacteriaceasp (eg. Citrobacter) Chlostridium, Citrobacter, Proteus etc.

Procedure

- Wash your hands with clean water before performing the test
- Take one crew capped H_2S strip bottle
- Open the plug and cap of the bottle
- Fill the water to be tested up to “fill line”
- Replace the cap tightly and mix the water gently
- Keep the bottle at room temperature for 24 – 48 hours and observe the results

Observations:

- If the colour of the sample in the bottle turns black then it is positive test and the sample is unfit for drinking purpose
- If the colour of the sample in the bottle does not change then it is negative test and the water is fit for drinking purposes
- If the sample shows negative test then the water is micro-biologically contaminated and requires treatment before being used for drinking.

Points to remember:

1. The culture media is inoculated on filter paper strips.
2. No special storage is required. It is advisable to keep the bottles/vials in a cool dry place
3. The culture media has indefinite storage life
4. Instruction for use will be printed on each bottle/vial
5. Each vial or bottle will be normally of 30 ml with marking at 20 ml
6. Dispose of the used H_2S vials in safe manner
7. Keep the vials away from children

Black coloured bottles are contaminated and unfit for drinking use while brown bottles are uncontaminated and fit for drinking use.

Table: Use of water as main source of supply for drinking & cooking in various regions of Maldives: (2006)

Region	Population (in thousands)	% population using ground water	% population using rain water
Total Maldives	299.0	15	54
Male	103.7	0	03
Atolls	195.3	21	76
North Thiladhunmathi	13.5	30	69
South Thiladhunmathi	16.2	24	76
North Miladhunmadulu	11.9	12	86
South Miladhunmadulu	10.0	39	60
North Maalhosmadulu	14.8	34	65
South Maalhosmadulu	9.6	41	57
Faadhippolhu	9.2	31	68
Male Atoll	15.4	14	75
North Ari Atoll	5.8	11	87
South Ari Atoll	8.4	10	87
Felidhe Atoll	1.6	07	90
Mulakatholhu	4.7	15	72
North Nilandhe Atoll	3.8	20	78
South Nilandhe Atoll	5.0	34	64
Kolhumadulu	8.5	10	80
Handhdhunmathi	12.0	04	90
North Huvadhu Atoll	8.3	06	93
South Huvadhu Atoll	11.0	05	93
Gnaviyani	7.6	09	89

Addu Atoll	18	32	67

Source: Draft National Water Supply & Sanitation Master Plan 2008

Annexure-09

Public appeal (draft notice):

At the onset of monsoon, public needs to be alerted to get prepared for the harvesting. The families will require cleaning their system and repairing faults if any. This will help them to store maximum water and protect the quality of stored water. Government (water supply department) may consider giving public notice in the press for the benefit of people and avoiding water shortage in the dry period. The draft of such appeal is given below for ready reference.

Get prepared to harvest rain water:

It is time again to welcome the rains and get ready for storing precious rain water for our drinking and other domestic needs. Maldives is blessed with sufficient rains to meet with our requirements provided we store and use it wisely. We get rain water free from nature that is of pure quality. Also it is available at our home and we can store as much as we want. Wise people say that "we must make best use of every drop of rain water before it reaches the sea." There are many benefits of storing rain water in addition to making us self reliant.

Salient benefits of storing rain water at household level can be enumerated as below,

1. Provide good quality water
2. Save water charges to be paid for public supplies
3. Reduces exploitation and contamination of ground water
4. Water is available during disasters and emergencies

The ministry of water (EPA) wish to alert you and urge to cooperate in storing rain water and help mitigate the water shortage of the country. You can follow the checklist provided here below to get ready for harvesting the rains.

1. Provide rain water harvesting system with adequate design and proper materials
2. Maintain the system in a good condition to get sufficient quantity and good quality of water
3. Clean the system before onset of monsoon to prevent contamination of water
4. Repair the system (leakages and damages)
5. Procure necessary chemicals

The government of Maldives has provided incentives by way of providing free storage tanks in the aftermath of Tsunami of 2006. The government has also developed rain water harvesting guidelines and a manual for system operation and maintenance. In addition free technical guidance and help will be available from the following addresses

Contact addresses:

You can also refer to following websites for any additional information or help.

Web addresses -----------

Frequently asked questions (FAQs)

1. What is rainwater harvesting?

Rain water is the ultimate source of fresh water. Fortunately it comes FREE from the sky. As per Webster's dictionary harvest is defined as 1) to gather in or 2) to accumulate a store of. Consequently to harvest rainwater means to gather it in.

The activity of collecting rainwater directly or recharging it into the ground to improve ground water storage in the aquifer is called as Rain Water Harvesting. It simply means catching and holding rain where it falls and using it. You can store it in tanks or you can use it to recharge groundwater. It can be a complementary source used to meet the domestic demand.

2. Why should I harvest rainwater?

It's a shame to let runoff go to waste when it can be used indoors and/or for irrigation. Rain Water can be harvested to conserve and augment the storage of ground water, to reduce water table depletion to improve the quality of ground water, and to arrest sea water intrusion in coastal areas.

Rainwater harvesting is environmentally friendly and most of all the rainwater is free. So saving rainwater yourself is becoming more popular eco friendly and saving huge costs on water.

Rain water harvesting is a social responsibility every home owner should take part in.

3. What is Rooftop Rainwater Harvesting (RRWH)?

Rooftop Rainwater Harvesting (RRWH) is a traditional practice that has existed in rural communities for hundreds of years

Rooftop Rainwater Harvesting (RRWH) involves

Catching rainwater where it falls using rooftops of home, schools and other buildings channeling it into above or underground leak-proof tanks made of locally available, low-cost materials

RRWH is a viable, low-cost way to provide drinking water and sanitation to remote rural communities.

4. How Rain Water can be harvested?

Rain water can be harvested by two ways.

a) Rain water that falls on the terrace of the buildings and

b) In the open spaces around the buildings

Our ancestors harvested rain just as naturally as they tilled the ground to grow crops. We lost touch with these local solutions. But now, as the taps dry up, more and more people are reviving this age-old system and practicing it very successfully.

5. Who can Harvest Rain Water?

Every individual family can harvest rain water at their home from their rooftop for domestic uses. Similarly business people can harvest it for supporting their business or industrial operations. The government offices, , institutions, hospitals, schools or other community organizations can harvest water from rooftop to meet their needs.

6. What are the precautions to be taken for roof top harvesting?

The terrace of the building should be maintained clean. A grill/mesh has to be fixed at the entrance of the rainwater pipe in the terrace to arrest large particles such as papers, leaves, etc. A filter chamber has to be provided to filter small/minute dust particles before diverting the rainwater into the storage tank or open well/bore well.

7. What kind of catchment surfaces is most efficient?

The effective catchment area and the material used in constructing the catchment surface influence the collection efficiency and water quality. Materials commonly used for roof catchment are corrugated aluminium and galvanized iron, concrete, fiberglass shingles, tiles, slates, etc. Mud is used primarily in rural areas. Bamboo roofs are least suitable because of possible health hazards. The materials of catchment surfaces must be non-toxic and should not contain substances which impair water quality. For example, asbestos roofs should be avoided; also, painting or coating of catchment surfaces should be avoided if possible. If the use of paint or coating is unavoidable, only non-toxic paint or coating should be used; lead, chromium, and zinc-based paints/coatings should be avoided. Similarly, roofs with metallic paint or other coatings are not recommended as they may impart tastes or colour to the collected water. Catchment surfaces and collection devices should be cleaned regularly to remove dust, leaves and bird droppings so as to minimize bacterial contamination and maintain the quality of collected water. Roofs should also be free from overhanging trees since birds and animals in the trees may defecate on the roof.

8. How is water quality of rainwater systems?

Rain water is generally free of harmful minerals and in most cases chemicals, but can be adversely affected by air pollutants and/or contaminated by animals in the catchment area. Consequently, rainwater for drinking should be carefully stored and treated if required prior to consumption. Several technologies exist for home treatment including: boiling, chlorination, solar disinfection etc...

9. Is rain water safe to drink?

Generally rain water is safe to drink. It does not need any treatment if it is clear, without smell and not contaminated. Rainwater is naturally soft (unlike well water), contains almost no dissolved minerals. In the storage tank, bacterial buildup can occur in that case it needs treatment before drinking it.

10. How can I know my rain water is safe to drink?

You can do some physical taste by yourself. They are tests done by your own senses (eye, tongue, skin etc)

If the water is not clean in appearance then some impurities have entered the water (debris, leaves, dust etc). If some colour is there then it has entered from paints of the components.

If some smell comes from water then it can be from dead animal (small (rodents, birds, bats etc) or may be due to algae growth in the tank

If the water irritates your skin then it is acidic (pH is less then 7) and if your skin feels soapy then the water is alkaline (pH is more then 7)

If the taste of water is different (salty or bitter) it might have come from some chemicals

If someone falls sick in your family due to illnesses like diarrhea, cholera or stomach disorder then may be due to presence of some microorganisms in your water.

You can get a water testing kits for your home to do periodical testing yourself or send the water for testing to the government laboratory (addresses given elsewhere in this manual). Most important test is hydrogen sulfide test for bacterial quality of water

11. What are the quality standards for drinking water?

Quality of water for drinking purpose is decided by the guidelines prescribed by the government of Maldives (Ministry of water). The details are provided in the annexure No----. These guidelines are based on WHO guidelines for drinking water quality (see web ------)

12. What is the maintenance required?

No difficult maintenance is required. The filter needs to be checked regularly for blockages, e.g., leaves, as rainwater may by-pass the tank if the filter is blocked. Apart from that, the whole system needs checking once a year (like your other home appliances) to see if anything requires replacing, but usually, the components should last about 10 years. Once every year, the storage tank needs to be emptied (usually before onset of monsoon when little water is inside) and the inside walls washed thoroughly.

Remember rainwater harvesting means that you have to get involved. This is about making water all our business. This is about building our relationship with water. Harvesting rain means learning the value of each raindrop.

13. Can I harvest rain in my own house?

Yes you can. Structures to harvest rain require little space. A dried bore well, a row of soak pits or a tank--concealed below the ground- are all that you need. The open spaces -- rooftops and ground - can be used as your catchment (surface to catch rain).

14. How to protect the quality of rainwater?

The safe quality of water depends on ensuring correct design and installation followed by careful maintenance. Always remember that the rainwater system involves “low maintenance” but not “no maintenance”.

Following care is required to protect water quality.

Clean the tank and entrance pipe before the rainy season.

Place a filter or screen over the tank to keep out insects, leaves and dirt.

Place a sealed cover over the tank to keep the water clean and prevent mosquitoes from breeding.

Make sure that water is taken out through taps only and not by buckets or other containers dipped into the tank,

Allow the first rainfall of the season to run through the tank without being used.

15. How much will it cost?

Rainwater harvesting systems are inherently simple in form and can often be assembled with readily available materials by owner-builders with a basic understanding of plumbing and construction skills. The cost varies, depending on the area of your roof and other structures that you will use to harvest rain. But rainwater harvesting does not require major construction work, so the expenses suit most of our pockets
A rainwater harvesting system designed as an integrated component of a new

construction project is generally more cost effective than retrofitting a system onto an existing building. Other variables which affect system economics include choice of tank and filtration. In general, maximizing storage capacity and minimizing water use through conservation and reuse are important rules to keep in mind to make it cost effective.

Rainwater harvesting methods are site specific and hence it is difficult to give a generalized cost. But first of all, the major components of a rainwater harvesting system - rain and catchment area - are available free of cost. A good proportion of the expenses would be for the pipe connections. By judiciously fixing up the slopes of roofs and location of rainwater outlets, this could be brought down considerably. However the cost varies widely depending on the availability of existing structures like wells and tanks which can be modified and used for water harvesting.

16. Who will build it and how long will it take?

You need someone who understands rainwater harvesting. It is simple but it still needs someone who has experience in the principles of rainwater harvesting. You can seek advice from local government office or NGO in your area. Then a skilled mason or a plumber can do the job for you within 10 days.

17. When can I harvest the rainwater?

The peak season for collecting rain water is during the monsoon with the wet months falling between May through November. Rainwater can be collected whenever it rains and provide you with a complementary source of water throughout the year.

18 How long can I store rainwater?

You can store the rainwater for long time if it is not contaminated. The quality of water does not get affected by long storage. In fact it will improve by stabilization of impurities and dieing away of bacteria in absence of food etc. Only care is to be taken to protect it from direct sunlight and extraneous pollution.

19 What is the minimum required size of the catchments area (roof or surface ground)?

Any size of a roof can be used to collect water. A 25m2 (5 m X 5 m) roof can potentially harvest 32,200 liters of water. The larger the collection areas the more amount of water that can be collected.

20 Who will give the technical support to build the system? Whom to contact?

Give details of Maldives…….

21 How to prevent mosquito breeding in the water storage tank?

Mosquitoes and other insect breeding could be prevented by avoiding pools of rain water in system or surrounding to the water tanks. The mouth or opening of the tank should be covered with insect proof mesh and the outlet of the tank (tap to draw water) should not be leaky. The opening of the storage tank should be covered with a lid and leaks or cracks if any in the tank be repaired quickly. The stagnation of water in the channels and piping that conveys the water from the roof to storage tank should also be avoided. There is no known treatment for killing mosquitoes so prevention is ideal. Regular inspection of tank and cleaning is essential to prevent mosquito breeding.

GLOSSARY OF TERMS:

Activated carbon:

A water treatment medium found in block, granulated or powered form which is produced by heating carbonaceous substances, bituminous coal or cellulose based substances such as wood or coconut shell. Activated carbon is commonly used for de-chlorination and for reducing trace and soluble materials such as organic chemicals.

Algae

It is a diverse group of aquatic plants that contains chlorophyll and other photosynthetic pigments. Many are microscopic (often being single cells) but some can be large, including the large seaweeds. They grow as single cells or aggregations of cells (colonies)

Aquifer

It is a porous geological formation which can store an appreciable amount of ground water and from which water can be extracted in useful quantities.

Bacteria

They are single-celled microorganisms which can exist either as independent (free-living) organisms or as parasites (dependent upon another organism for life). Cells range from about 1-10 microns in length and from 0.2 to 1 micron in width

A good definition of bacteria is that, they are organisms, microscopic in nature; they are unicellular and reproduce asexually. They've different shapes such as rods, spheres, spirals and so on. They are an ancient form of life and most of them have spores that are resistant to dryness. Some bacteria are helpful to man, others harmful

Bottled Water

Water that is packaged and sold in individual bottles

Brackish water

It is slightly salty water. Brackish water at the Earth's surface often occurs in estuaries and lagoons where freshwater and seawater mix. Water containing dissolved solids in the range of 1000 to 15000 ppm

Catchment

A catchment is any device or structure that captures water. A protected area in which water is harvested for use is called catchment.

Cistern

Cistern is an above or below ground tank used to store water, generally made of galvanized metal, fiberglass, Ferro cement or concrete.

Chlorination:

The use of chlorine for disinfection of water

Contaminant

Any harmful or undesirable substance found in water. Contaminants include microorganisms, dissolved naturally occurring minerals, human-generated chemicals, and radiological materials.

Contamination

Contamination is the presence of pollutants or other unwanted materials in water. Introduction into water, air, and soil of microorganisms, chemicals, toxic substances, wastes, or wastewater in a concentration that makes the medium unfit for its next intended use for the treatment of water disinfection or oxidation

Collection area

Area from which rainwater is collected for use in a rainwater harvesting system (e.g. roof area)

Coliform

Bacteria found in the intestines, faeces, nutrient-rich waters, soil and decaying plant matter are known as coliform.

Debris

Rubbish materials like leaves, coarse particles, plant materials etc

Desalination

Desalination means the removal of salts and minerals in either ocean or brackish water and to make it safe for human consumption and use.
Removal of salt (sodium chloride) and other minerals from the sea water to make it suitable for human consumption and/or industrial use. The most common desalination methods employ reverse-osmosis in which salt water is forced through a membrane that allows water molecules to pass but blocks the molecules of salt and other minerals.

Disinfection

It is a treatment of water to remove or inactivate viruses, bacteria, and other pathogenic organisms. In other words it is elimination of disease causing micro organism also known as pathogens.

Down pipe

A pipe to carry rainwater from a roof to a drain or to ground level

Erosion:

The loss of topsoil that occurs as a result of run-off

Filtration:

Physical removal of water contaminants by means of separation from the output flow
The process of separating particles of 2 microns or larger in diameter from water is carried out by means of a porous substance such as a permeable fabric or layers of inert material housed in a media filter or removable cartridge filter.

First flush:

It is the initial runoff from a catchment following the start of a rainfall event which contains higher loads of microbiological contaminants and suspended solids.

First Flush Device

It is a device or method for removal and debris from collection surface by diverting initial rainfall from entry into the cistern.

Ground water

Water that infiltrates into the ground and no longer flows across the surface. Water found below the Earth's surface in geological reservoirs known as aquifers. Groundwater flows out of the ground naturally in springs and seeps, and can also be pumped out by wells.

Grey water:

The wastewater from residential appliances or fixtures except toilets and kitchen sinks.

Gutter:

A shallow trough beneath the edge of a roof, or a channel at the side of a street, for carrying off rainwater

Ground Water:

The water retained in the pores of soil or fissures of rock below the water table is called ground water.

Hardness:

It is the characteristic of ground water due to the presence of dissolved calcium and magnesium, which is responsible for most scale formation in pipes and water heaters. The term hardness was originally applied to waters that were hard to wash in, referring to the soap wasting properties of hard water.

Hydrologic cycle:

The continual exchange of water from the atmosphere to the land and oceans and back again.

Heavy metals

Metallic elements with high atomic weights e.g. mercury, barium and lead are called heavy metals. They can damage living things at low concentrations and tend to accumulate in the food chain

Harvested Rain water

Rainwater that is collected / stored in the cistern/ tank

Hygiene

Sanitary and cleanliness practices, like hand washing, that promote good health and help prevent illness.

Leaf screen:

A mesh installed over gutters and entry points to down pipes to prevent leaves and other debris from clogging the flow of rainwater.

Microorganisms

An organism so small that can not be seen by the naked eye. Plant or animal life so small that it can only be seen through a microscope such as bacteria, yeasts, algae, and protozoa. Some microorganisms are beneficial while others pose risks to human health.

Nitrate (NO3)

It is a common anion in water. Common sources of nitrates are fertilizers, septic tanks, and untreated or incompletely treated sewage. Nitrate is highly soluble under most conditions and is therefore difficult to remove from water. At high levels, nitrate in drinking water can cause methemoglobinemia, which is commonly known as "blue baby syndrome."

Particulates

They are small, solid particles that are suspended in water.

Pathogen

They are micro-organisms that can cause disease in other organisms or in humans, animals and plants. They may cause bacteria, viruses or parasites and are found in sewage, in run off from animals and in water for swimming e. Bacteria, viruses, and parasites are common pathogens.

An agent that causes disease, especially a living microorganism such as a bacterium or fungus Most pathogens are infectious microbes, such as bacteria or viruses, which are capable of causing disease. Other parasites, such as fungi and protozoan, are also considered pathogens. Because not all microbes are harmful, pathogens refer specifically to those that can cause disease or other harm.

pH

It is a logarithmic scale of values of 0 to 14 that measure of hydrogen ion concentration in water which determines whether the water is neutral (pH 7), acidic (pH 0-7) or basic (pH 7-14).

Pollution

Water pollution occurs when waste products or other substances, e.g. effluent, litter, refuse, sewage or contaminated runoff, change the physical, chemical, biological or thermal properties of the water, adversely affecting water quality, living species and beneficial uses

Pollutant

A foreign substance that adversely affects water quality

Potable water:

Water which is suitable and safe for human consumption is called potable water.

Rainfall

The amount of rain, usually expressed in millimetres or inches depth of water on an area, that reaches the surface of the earth. The term sometimes also includes other forms of atmospheric precipitation such as snow, hail and dew, but technically only the term *precipitation* should be used in this broader scope.

Rain water:

Water that has fallen as rain and contains little dissolved mineral matter is called rain water. They are drops of fresh water that fall as precipitation from clouds Runoff water from precipitation, draining from roofs or parking lots and other paved, impermeable surfaces and stored for use

Rainwater harvesting

The principle of collecting and using precipitation from a catchment surface Rainwater harvesting involves the collection, storage and distribution of rainwater from the roof, for use inside and outside the home or business.

It is the gathering, or accumulating and storing, of rainwater. Traditionally, rainwater harvesting has been practiced in areas where water exists in plenty, and has provided drinking water, domestic water, water for livestock, water for small irrigation and a way to increase ground water levels.

Recharge

Water added to an aquifer, typically by rainfall or snowmelt that seeps into the ground, but sometimes by humans through wells or infiltration ponds.

Run off

Water from precipitation that flows across or just under the land surface to enter streams, rivers and other surface waters is called run off.

Rain water

Water collected from runoff of roofs or other structures after a rain event.

Rainwater harvesting system

Water system for utilizing rainwater, consisting of a cistern, pipe, fittings, pumps and/or other plumbing appurtenances, required for and/or used to harvest and distribute rainwater

Recharge:

The process of surface water (from rain or reservoirs) joining the ground water aquifer.

Roof washer:

A device used to divert the first flush rainwater from entering a cistern.

Run-off

Runoff is the term applied to the water that flows away from a surface after falling on the surface in the form of rain.

Salinity

The concentration of chemical salts dissolved in the water. It is usually expressed in milligrams per litre (mg/L) or parts per million (ppm).

Sanitation

The process of maintaining clean, hygienic conditions by the proper disposal of garbage and human waste is sanitation. Good sanitation practices help prevent disease.

Sedimentation

The gravity-driven process by which suspended particles settle to the bottom of a body of water

Surface water

All water, fresh and salt, that is direct contact with the atmosphere. Oceans, rivers and lakes are all sources of surface water.

Turbidity

The visual appearance of cloudy water filled with suspended particles. Turbidity, as an optical property, may be measured and used to rate water quality and clarity.

Water Quality:

It is a graded value of the components which comprise the nature of water. Established criteria determine the upper and/or lower limits of those values which are suitable for particular uses (organic, inorganic, chemical, physical).

Water Pollution:

The addition of harmful or objectionable material causing an alteration of water quality

Water Table:

The level of water within it granular pores of soil or fissures of rock, below which the pores of the host are saturated.

Wetlands:

Areas of marsh, fen, peat lands or water, natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water less than six metres deep at low tide

Water cycle:

It is the Sun-driven process of evaporation, condensation, and precipitation that moves water from the oceans and Earth to the atmosphere and back again. It is also called the hydrological cycle.