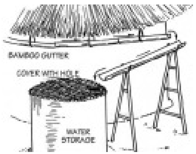
Agro-Ecological Zones

Water Management

- The water cycle and rain information
- Rainwater Harvesting
- Shallow ground water
- Surface water
- Water for domestic



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Water harvesting - DROP
Short description: General ways to collect water for drinking or irrigating

Introduction - The water cycle

The water cycle, or hydrological cycle, describes the way of the water through the environment. Different processec are involved in the water cycle, starting with evaporation (vaporising of water) and transpiration (emission of water vapour from the leaves of plants); continuing with condensation (water chaning back from vapour to a liquit state), cloud formation, and precipitation (rain); and finally going to surface

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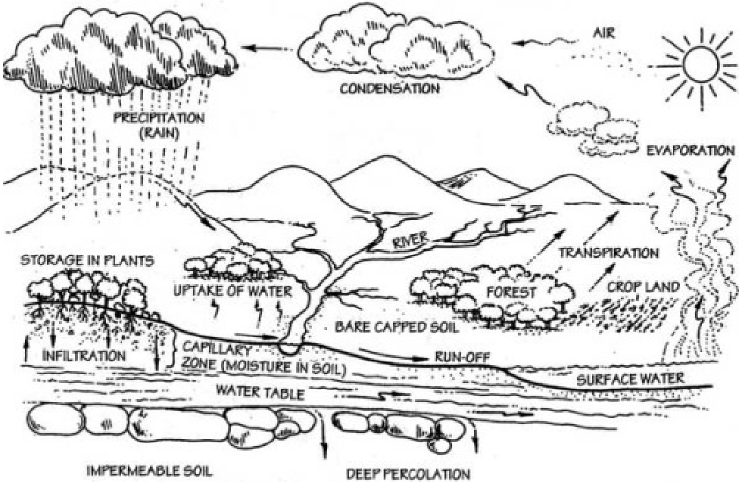
run-off, infiltartion (filtering of water into the soil), percolation (penetration of water into the ground), and water storage.



This illustration of the water cycle shows the way of the water from the ocean, through the atmosphere, brought back to the earth by rain, evaporating again or flowing back to the see, either as surface water or in groundwater flows (Vukasin et al. 1995).

Water can be harvested in different stages of this cycle. Three typical ways of water harvesting are the collection of rainwater, harvesting water from surface waterbodies or obtain groundwater through wells or at sources.

The quality of the harvested water determines if the water can be consumed. For

Sustainable and Organic agriculture

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some kind of water contamination or pollution, there are treatment methods. For other kinds, only prevention and protection of the water sources keeps the water palatable.

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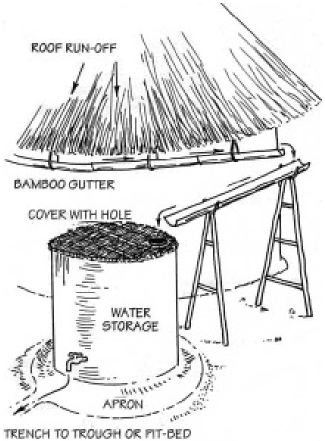
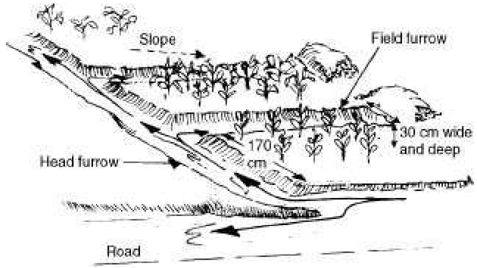
Rainwater

Introduction



Example of a roof rainwater collection installation. Water is collected on the roof and diverted to a covered water storage with a tap to retreive the water for consumption (Vukasin et al. 1995).

In general, rainwater can be harvested from any run-off areas such as roofs, rocks and other surfaces. Depending on the amound of precipitation it is stored in cisterns, tanks, or large dams. The quality of the water and, hence, the possible application depends very much on the run-off area, the catchment system, and the storing. Rainwater can for example be harvested with appropriate installation from roofs. Generally, rainwater is of good quality, but lacks of taste, caused by the absece of minerals.



With the broadbed-and-furrow system, runoff water is diverted into field furrows, allowing to sink into the soil in order to raise the water-table and increase the soil-moisture leve. (IIRR)

Rainwater can also be harvested as surface run-off and used for irrigation. In a broadbed-and-furrow system for example, runoff water is diverted into field furrows. The field furrows are blocked at the lower end. When one furrow is full, the water backs up into the head furrow and flows into the next field furrow. Between the field furrows are broad beds, where crops are grown. With this or similar systems, water is allowed to sink into the soil in order to raise the water-table and increase the soil-

moisture leve. Generally, more water can seep into the soil if it is spread over a large area of soil rather than being concentrated into fast-running streams.

Through the contact with the roof, the cachment installations or by storing it in an imporper tank, rainwater can be contaminated with pathogens and has to be disinfected before drinking. Since every run-off area and storage facility burries the risk of contamination, water should be disinfected before using it as drinking water, for example by using the SODIS method (click to follow link). If no purification methods can be applied, only carefully collected and stored, clean rainwater, for example form a roof catchment (excluding thatched roofs), should be used for consumption. Water from natural pools should not be used as drinking water without purification and disinfection.

Technical application of roof rainwater harvesting

The application of an appropriate rainwater harvesting technology can enable the utilization of rainwater as a valuable and, in many cases, necessary water resource. The method has been practiced for more than 4,000 years and can be applied in areas having significant rainfall but lacking any kind of conventional water supply system, and also in areas where good quality fresh surface water or groundwater is lacking.

A rainwater harvesting system consists of three basic elements: a collection area, a conveyance system, and storage facilities. The collection area in most cases is the roof of a house or a building. The effective roof area and the material used in constructing the roof influence the efficiency of collection and the water quality. Roofs that could potentially leach toxins and pollutants should not be used for water harvesting. Galvanized, corrugated-iron sheets and tiles generally make good roof catchment surfaces. Flat cement or felt-covered roofs can also be used provided

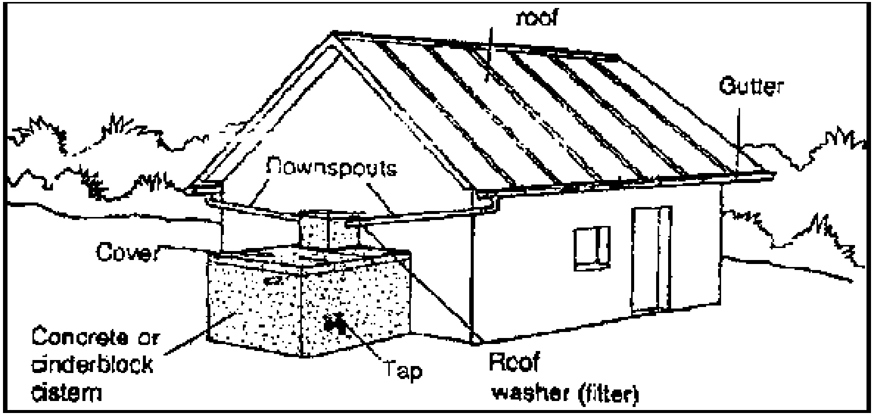
they are clean. Thatched roofs can make good catchments when certain palms are tightly thatched, e.g. coconut and anahaw palms. Most palms and almost all grasses, however, do not produce thatch suitable for high-quality rainwater collection, since they discolour the water and make it less palatable and attractive for domestic purposes. Although painted roofs can be used for rainwater collection, it is important the paint is non-toxic. Painted roofs must be kept in good condition so that the pain does not flock off into the tank. Unpainted and uncoated roof surfaces are best. Mud roofs are generally not suitable. Lead flashing and pesticide treated wood should also not come into contact with any rain water collected.

A conveyance system usually consists of gutters or pipes that deliver rainwater falling on the rooftop to cisterns or other storage vessels. Also drainpipes should be constructed of chemically inert materials such as wood, aluminium, or fibreglass, in order to avoid adverse effects on water quality. If PVC is used for the conveyance system, it should be protected from direct sunlight. The conveyance channel must be big enough to carry the water collected during high intensity storms, and the installation must be a sloped toward the storage tank at a minimum of .5 percent to ensure water flow and prevent blockages. To ensure that all runoff for the roof enters the gutter, splash-guards can be fixed to the roof. They normally consist of a lont strip of sheet metal, bent at an angle and hung over the edge of the roof. To prevents leaves, insects, and other debris from entering the storing tank, a stainless steel or copper-nickel mesh angled 60 degrees from the horizontal can be installed. Another mesh screen of 5mm, in an angle not less than 60 degrees from the horizontal should be installed about 3 cm above the tank inlet to screen the tank inlet. It should be at least 10 times larger than the cross-sectional area of the conveyance channel.

The water ultimately is stored in a storage tank or cistern, which should also be constructed of an inert material. Reinforced concrete, fibreglass, or stainless steel are suitable materials. Storage tanks may be constructed as part of the building, or may be built as a separate unit located some distance away from the building.

The first thing to do is to formulate the size of the reservoir. All rainwater tank designs should include as a minimum requirement: a functional and watertight design; a solid, secure cover to keep out insects, dirt and sunshine; a screened inlet filter, a screened overflow pipe, positioned at the maximum water level of the tank; access for cleaning, like a manhole, an extraction system that does not contaminate the water, e.g. tap/pump: a soakway to prevent spilt water forming puddles near the tank; a maximum height of 2m to prevent high water pressures (unless additional reinforcement is used in the walls and foundations). Additional features might include: a device to indicate the amount of water in the tank; a sediment trap, tipping bucket, or other "foul flush" mechanism; a lock on the tap; a second sub-surface tank to provide water for livestock, etc. To prevent dust, sediment and other debris on the tank floor from entering the draw-off pipe, the tap should be elevated 5cm above the floor. Although this arrangement creates a "dead storage" of 5cm at the bottom of the water tank, it has three benefits: it prevents sludge on the tank floor from reaching the outlet tap, thereby protecting water quality. It ensures water is retained even in an otherwise empty tank, keeping the tank interior moist and protecting the tank from cracking in hot weather.

All catchment surfaces must be made of non-toxic material. Painted surfaces should be avoided if possible, or, if the use of paint is unavoidable, only non-toxic paint should be used (e.g., no lead-, chromium-, or zinc-based paints). Overhanging vegetation should also be avoided.



Schematic of a typical rainwater catchment system of a rooftop catchment system in the Dominican Republic. (Retrieved from http://www.oas.org/dsd/publications/unit/oea59e/ch10.htm)

Harvesting rainwater from trees

This technology is useful for people cannot afford a metal roof and are not near other sources of free water like springs, wells or boreholes, but who have trees in their compounds. Rain falling on the foliage runs down the tree trunk, and is funnelled by a banana leaf or metal sheet attached to the trunk into a bucket, pot or storage tank. Rainwater can be harvested from trees anywhere: it is a question of finding out which trees are appropriate. The best ones have short, smooth trunks, thick crowns and heavy foliage. Jackfruit (Artocarpus heterophyllus) and wild fig (Ficus natalensis) are very suitable. This method is cheap and easy to set up. While the water collected is not as clean as that from a metal roof, it is cleaner than that

collected from thatched roofs. It should be filtered and boiled or SODIS should be applied if it is used for drinking.

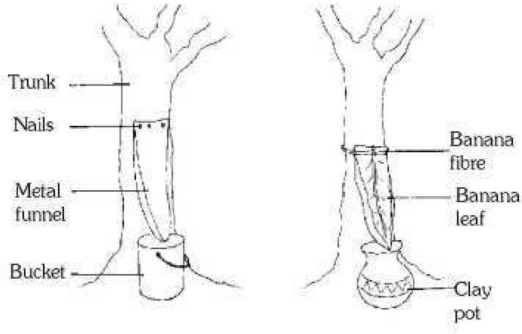


Figure 4a: Rainwater havesting from trees

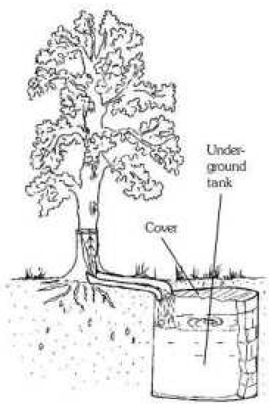


Figure 4b: Rainwater havesting from trees

First flush run off systems

Contaminants from a roof are usually concentrated in the first run off from the roof. After this runoff has passed and washed the roof the water is considerably safer. The amount to be removed varies and a number of studies have had differing results. Despite this uncertainty, first flush systems are a popular method of improving the quality of roof runoff prior to storage, particularly in Asian countries. The two commonest systems use either a floating ball or a tipping gutter to divert and/or store the first flush away from the storage tank.

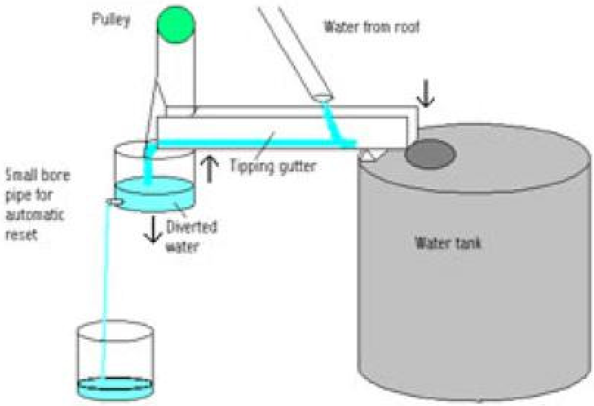
Tipping Gutter First Flush System

The tipping gutter first flush system is very simple to build, operate, and maintain.

Water from the roof lands on a piece of guttering which is tipped down away from the water tank. Therefore the first rains and their debris pour away from the tank and into a storage vessel. The end of the guttering is attached via a pulley to the diverted water tank, and so as the diverted water tank gets fuller (and therefore heavier) it lifts up the end of the tipping gutter. Now the (hopefully) clean water from the roof is directed into the water tank.

The diverted water tank has a small bore pipe fitted near its bottom out of which the accumulated diverted water can escape. Over time the dirty water will leak out and the tipping gutter will reset ready for the next rain shower. Obviously if it is still raining by the time the diverted water tank has emptied, some water will be lost as the diverted water tank will have to be filled up again (this time with clean rainwater) before water is again allowed into the water tank.

A small amount of wastage is more than made up for by the simplicity and elegance of this first flush system. However, if water really is in very short supply then a tap can be fitted to the diverted water tank so that the dirty water can be released manually when the rain has stopped. This saves waste, however if the system is to be left for a few weeks unattended, contaminated water would get into the main clean water storage tank if it rained.

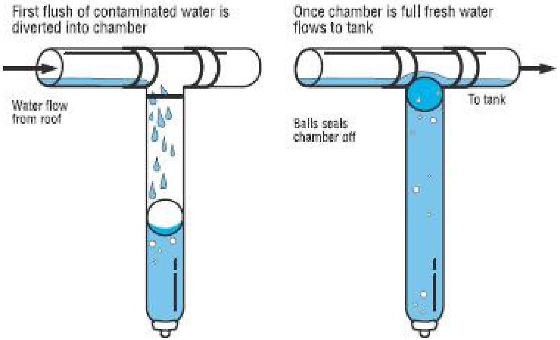


Tipping Gutter First Flush System: The first water from the roof lands on a piece of guttering which is tipped down away from the water tank.

Floating Ball First Flush System

The floating ball first flush system is a little more complicated than the tipping gutter system discussed above although they have some similarities. When the rain starts to fall it accumulates together with any debris in a chamber with a conical top. As the chamber fills a ball floats on the collected water's surface. Eventually the ball becomes stuck in the conical chamber entrance blocking the bottom chamber and therefore redirecting subsequent collected rainwater into the main clean water storage tank.

As with the tipping gutter system, a small bore pipe is used to slowly drain the water from the lower chamber to automatically reset the first flush device. Again a tap can be used if water is at a premium since water dribbles out continuously when it is raining.

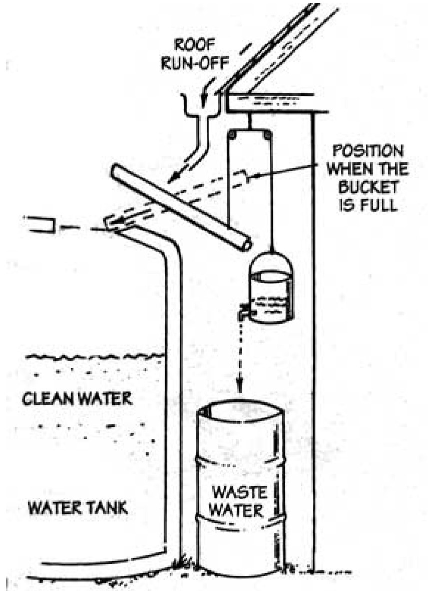


Floating Ball First Flush System: When the rain starts to fall it accumulates together with any debris in a chamber with a conical top. As the chamber fills a ball floats on the collected water's surface and eventually the subsequent collected rainwater is redirected into the main clean water storage tank.

Setting Up a First Flush System

Every roof and every location is different. Basically, the larger the roof and the longer the periods between rain fall, the larger the quantity of water which must be disposed of in the first flush. In the case of the tipping gutter system this is achieved by using

a suitably large diverted water tank and weighting the gutter to ensure that it tips when the required amount of water has been diverted. Again with the floating ball system, the bottom chamber of the first flush tank must be sized appropriately so that rainwater is only allowed into the storage tank after the first flush has been collected.



Example of a tipping gutter first flush system (Vukasin et al. 1995)

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Surface water

Small rivers

Water from small rivers should be harvested as far up, i.e. as near to the source as possible. If a cachment area is constructed, it has to be protected from contamination, e.g. by a fence and an apron.

Rivers, lakes, pools

Normally, there is enough water available in bigger rivers, lakes and pools. The water should be harvested upstream of contaminaiting influxes and about 9m from the shore.

Water from surface water bodies has to be disinfected if used as drinking water, e.g. by using the SODIS method (click to follow link).

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Ground water

What is ground water?

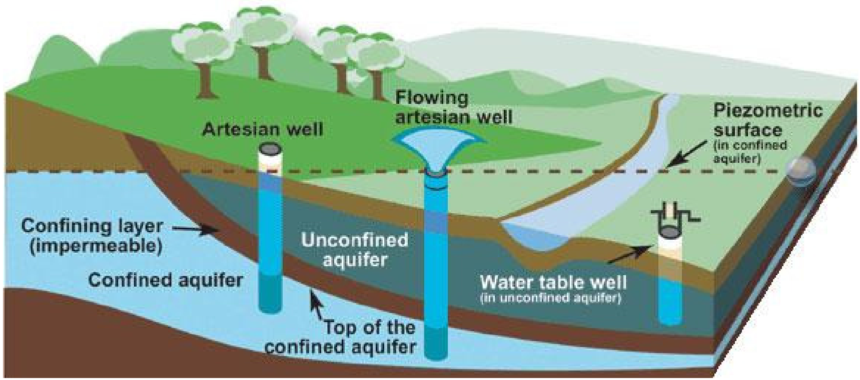
Ground water is the water that is conserved in or flowing through the soil, normally in the spaces between particles of rock and soil, or in crevices and cracks in rock. The level below which all the spaces are filled with water is called the water table. Water normally infiltrates into the soil as far as the soil is permeable. If there is an impermeable layer (a layer without any spaces to hold or transport water), the water can not infiltrate deeper, so it starts to build up or flow downhill, if there is a downward slope. Such water-carrying layers within the soil are called aquifers. Like surface water, groundwater flows toward, and eventually drains into streams, rivers, lakes and the oceans. Groundwater flow in the aquifers underlying surface drainage basins, however, does not always mirror the flow of water on the surface. Therefore, groundwater may move in different directions below the ground than the water flowing on the surface.

Also above the water table, the soil can hold some water, but the pores are not completely filled with water but also with air. Water in this soil layer is called soil moisture.

Multiple aquifers

There can be multiple aquifers at the same site (see illustration). In the illustration, two aquifers are shown. The upper, unconfined aquifer is not protected by an impermable layer above; the upper border is constituted by the water table. In this case, water can directly infiltrate from the surface and can contaminate the aquifer, e.g. if water from a latrine drains into the aquifer. The lower aquifer has a protecting, impermeable layer above it, so no water can directly infiltrate from the surface. These aquifers are often called artesian aquifers. Wells can be dugged or driven into both kinds of aquifers. In an artesian aquifer, the piezometric surface is the level to which the water will rise within a well. If the opening of a well lies below the piezometric

surface of the aquifer it is build into, the water flows continuously, driven by the force of the waterpressure.



Illustrations of ground water aquifers with artesian and water table wells (Environment Canada 2004)

Ground water as a source of water

The ground water can be seen as a natural water reservoir. The water is filtered by the ground and normally quiet clean, but it can still be contaminated, especially in aquifers that have no protecting layer above. Groundwater does not neccessarily be refilled by infiltrating or percolating rain water. Some aquifers have stored water for a long time and do not get refilled. Such aquifers have to be used wisely. To use the ground water for household or farm use, it has to be transported up to the surface, either by a pump or by manpower. Where the water table meets the surface, natural swamps, sources, or other open water bodies appear. Groundwater should be disinfected before used as drinking water.

Wells

One way of accessing the ground water artificially is by wells. Wells provide the household or community with a primary water source, which usually is relatively clean, when the water is handled carefully.

Deep wells and shallow wells

Deep dug or driven wells usually reach depths from 15 up to 30m, boreholes can be more than 40m deep. Construction can be extensive since it is possible that hard rock has to be blasted. Deep wells usually go down to a confined aquifer, which is less likely to be contaminated; water quality and quantity is quiet constant. Such wells are also called artesian wells.

Shallow wells are usually not more than 15m deep and do not penetrate harder rocky layers. They reach a groundwater layer that is only protected by a permeable soil layer. Quality and quantity of water can vary during the year, especially when dry and wet seasons are ocurring. Unprotected aquifers are easily contaminated by latrines, soakways or waste disposals and, hence, the location of a shallow well has to be choosen with care. Disinfection of the water is required in any case. Shallow wells are also called water table wells

Dug, driven or drilled wells

The construction of the well depends on availabilty and condition of the ground water as well as on the available equipment. There are several possibilities to build a well, as shown in the following illustration.

The driven tube well

The driven tube well is constructed by using a specially perforated or slotted tube called "well point", which is driven into the ground. The well point is reuseable and lasts for around 5 years, but is quiet expensive.

The bored tube well
With an auger, a tube well of up to 40m depth can be bored. An auger is a simple tool that can be twisted by hand to drive it into the ground.

The jetted tube well
A pipe is sunk into soft ground, while water is pumped down (or up) the pipe, loosening and removing the soil. The simplest method to do this is shown in the illustration above: the pipe is moved up and down by a lever while a person on the top closes the pipe when riseing and opening it when it falls, using it as a valve to pump water upwards.

The hand-dug well
The hand-dug well is the most common method of well construction. Some skill and knowledge is needed for the construction. It is a cheap way of cunstructing a well with locally available equipment and materials. Furthermore, a dug well can be operated without a pump, using bucket and rope.

Borehole
To construced deeper borehole wells, special, often expensive equipment is needed, for example a special drilling rig which may be trailer- or truck-mounted.

Criteria for a good well

Location
If the well is located in a sloped area, it has to be built above latrines, soakways, waste disposals, etc. If the area is flat and the soil homogenous, there should be a distance of 30m to the next latrine, soakway or waste disposal. In either way, no surface-rain-water should be able to penetrate the walls of the well.

Construction
In any possible case, a deep well should be constructed since it is much less likely to be contaminated. If possible, handpump should be installed and the opening of the well closed. If this is not possible, there should be a balustrade of about 70cm should be installed so no water can run back into the well. Furthermore, there should be a cover and a fixed bucket to take out water - no private buckets should be used.

Surroundings
The surroundigns should be flattened and cleaned of rat-holes etc. The vegetation should also be removed around the well since the roots could damage the coating of the well.

Usage
Washing and bathing at the well should be forbidden since this could lead to the contamination of the well with diseases such as cholera or typhus.

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Protecting water sources

Water sources and ground water have to be protected from contamination with chemicals or microorganisms. To learn more, please read the respective article on water quality and protection.

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Information sources

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Further links and contacts

- Lanka Rainwater Harvesting Forum: http://www.rainwaterharvesting.com/
- The Web of Rain: http://www.gdrc.org/uem/water/rainwater/rain-web.html

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Water storage

Short description: This datasheet describes methods to safely and hygienically store collected water, as well as how to build and repair water tanks, oil drums and jerry cans.

Introduction

Rains produce plenty of clean water running off roads, roofs, and rocks. This rainwater can be stored for the dry seasons when it is needed most. There are three types of storage, namely:

1) Storage in reservoirs, such as eath dams and ponds.
2) Storage in tanks.
3) Storage in situ, such as in soil and sand.

Storage in reservoirs

If farmers want to have water during dry seasons, they should 'harvest' it during the annual four months with rain, just like Scandinavian farmers harvest and store sufficient fodder for their livestock during six months of summer to feed their livestock for the 6 winter months when the animals are tied up in stable.

There are many types of structures suitable for surface storage of harvested rainwater but nearly all of them lose water in one way or another, such as:

1) Evaporation. In hot climates it amounts to about 3 mm/day = 90 cm in a month. The solution for water tanks is to roof them but since earth dams cannot be roofed the evaporation losses cannot be reduced.

2) Increased consumption of water from tanks situated next to a house can be caused by neighbours begging for water and children forgetting to close the water tap. This can be avoided by extending the draw-off pipe into the house and locking the water tap.

3) Animals breaking into fenced earth dams are difficult to prevent. A profitable solution could be to charge the livestock owners a fee for watering their animals.

4) Seepage through the floor of earth dams is reduced by silt brought in by rainy seasons but siltation reduces the storage capacity of earth dams.

These, and other, losses of water during storage should be considered when planning designing a water project for either water for domestic user, livestock or irrigation. For example, since about half of the water stored in earth dams will disappear due to evaporation and seepage, the reservoirs should be built to store

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double the volume of water required.

Storage in Tanks

General guidelines for water storage in tanks

Fresh or purified water can quickly become re-contaminated because:

1) The containers used to store the water are not clean.
2) Unclean things are dipped into the water (this includes hands, clothes, etc.).
3) The water is not covered and so insects, dust or other foreign substances can enter the water.

Chemically disinfected water can have a residual protection which will deal with light recontaminations, but even this protection disappears in time. Thus, to prevent recontamination, only clean storage containers should be used and the water should be protected from any contact with objects other than the container. The container requires periodic emptying, washing, and rinsing with scalding or heavily chlorinated water, to prevent the growth of biofilms.

The storage container should be equipped with a practical mechanism to retrieve the water, e.g. a tap (spigot) especially when bigger containers are used.

Storing water for later use is more difficult than collecting water. Ways to store water for household use include tanks or cisterns. Tanks can be constructed of bricks, masonry, corrugated steel sheets, or reinforced concrete, either above ground or below ground. The capacity of the tanks should be determined based on the run-off

expected and on the estimated daily use.

Before the rain starts, the tank or storage area should be clean. The first direct flush of rainwater should be directed away from the storage, since it contains the dirt from the catchment area. Cover the tank to prevent evaporation from the sun, keep the water surface clean, and prevent mosquitos from entering the water.

The storage tank should be placed near the place of usage, e.g. the kitchen. Furthermore, there should be a possibility to redirect the overflow or spilled water to a nearby garden or orchard.

Storage tanks and reservoirs can become breeding places for malaria mosquitos. The open water area can be used as breeding places for the mosquitos even in the dry season, when malaria transmission is normally decreased. The open water surface should not be accessible to mosquitoes: the tanks should be covered and all other inlets (taps, ventilation pipes) screened with mosquito-proof mesh. It should also be avoided that breeding sites are established downstream of the overflow.

Storage in Situ

The cheapest method of storing rainwater is to recharge shallow ground water aquifers, also called in situ storage, during rainy seasons and draw the water by means of hand-dug wells throughout the year. However, this cheap method may not always succeed because:
1. The water may seep deep into the underground where it becomes salty and unfit for human consumption.
2. The water may be too deep for shallow wells and require investment in expensive boreholes and pumps.

3. The water may not be found in the underground.

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Storage of Agricultural Water in Earth Dams

Cut-off drain

Cut-off drains deliver rainwater run-off from roads onto farmland where it sometimes creates erosion and deep gullies. This potentially destructive practice can be changed to a gain for the farmers by diverting the water into ground tanks, small earth dams or land for seasonal irrigation.

Cut-off drain to a pan

Here a cut-off drain diverts run-off water from a road into a natural and shallow depression on the lower side of a road called a pan. A pan can be made into a pond by deepening the reservoir and place the excavated soil as a dam wall (embankment) with two spillways (overflows) on the lower side of the reservoir. Ponds are small earth dams.

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A ?borrow pit?

© E. Nissen-Petersen, Kenya

Where road contractors have excavated murram for road construction and left 'borrow pits' or 'murram pits', these can be converted into pans or ponds by digging a trench to divert water from a road into the pit.
Usually these pits have water-tight (impermeable) floors through which water cannot leak into the underground.

Charco dams

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Charco ponds and Charco dams are half-ball shaped (hemi-spherical) excavations where the soil is placed as a dam wall around the excavation, except at the inflow channel which has two spillways for safe discharge of surplus water.
Charco ponds and dams are viable in flat land.

Hillside ponds/dams have a semi-circular dam wall made of the soil excavated for the water reservoir. A stony spillway is built onto each end of the dam wall. These dams are designed to be constructed on rolling land and hill sides.

Hillside dam

© E. Nissen-Petersen, Kenya

Valley dam

© E. Nissen-Petersen, Kenya

Valley dams are straight dam walls built across narrow points in valleys. A wide spillway lined with stones is built at each end of the dam wall to discharge surplus water safely. Due to global warming, many valley dams have been damaged by extraordinarily big thunder storms exceeding the design criteria of the highest rainfall in the last 50 years.
For more information on ponds and earth dams click here

Excavation dams should be circular or oval excavations where the excavated soil is used for building the dam walls whose sides should slope at least 45 degrees. The excavation dam in the above photo was a waste of money and labour. The sides are too steep and therefore collapsing. The soil is too porous and can therefore not hold any water.

Excavation dams

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The photo above shows a series of well designed and constructed excavation ponds have been filled with run-off water from roads. The embankments should be stabilised with grass.

Excavation ponds

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Storage of Agricultural Water in Ground Tanks

There are two main types of water tanks, namely:

1) Ground tanks that are built below the ground level. These are mainly used for storage of dirty run-off water from roads and compounds. Ground tanks can also be used as storage for clean domestic water if the tanks are roofed and connected to gutters attached to roofs or rocks.

2) Surface tanks standing on the ground level which are cylindrical and mainly used for storage of run-off water from roofs and rocks.

Ground tanks should always be designed as either hemi-spherical (half ball shape) or cylindrical because those shapes equalize the pressure of water and soil whether the tanks are full or empty.

This hemi-spherical tank (see image above) built of burnt bricks reinforced with barbed wire and chicken mesh is for roof catchment of domestic water.

Cylindrical ground tank

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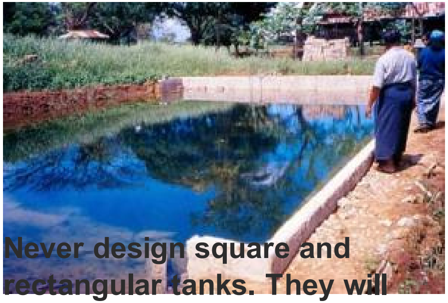
This photo shows a rectangular tank for fish farming in Myanmar. Two sides of the tank caved in when



the tank was emptied of water due to pressure from the soil.

Note: Water tanks should never be designed using square and rectangular shapes because they will collapse due to the uneven pressure of water and soil whether the tanks are full or empty.

Never design square and rectangular tanks. They will collapse!

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A traditional underground cylindrical water tank at a homestead in Botswana from which water is drawn by a bucket tied to a rope.
The catchment area for the tank is the threshing floor for millet and sorghum, which is made water repellant with a coat of cow dung. The floor slopes towards a silt trap where a plastic bottle prevents mice and lizards entering the tank.

Traditional underground cylindrical water tank in Botswana

© E. Nissen-Petersen, Kenya

A simple and cheap ground tank can be made by excavating a cylindrical hole and plastering it with mortar cement onto chicken mesh (Ferro-cement).

A cylindrical ground tank made of ferro-cement

© E. Nissen-Petersen, Kenya

A series of two hemi-spherical ground tanks built of burned bricks collect and store run-off water from a school compound for irrigation of a tree nursery and small irrigation garden.

A roof catchment tank can be seen at the school building. It provides drinking water for the pupils.

Hemi-spherical ground tanks

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The berkad ground tanks for watering livestock in Somaliland are banned by the government because of environmental degradation due to over-grazing caused by insufficient fodder. Moreover, most of the rectangular berkads must be repaired every year due pressure from the soil when the tanks are empty.

Berkad ground tanks in Somaliland

© E. Nissen-Petersen, Kenya

In Kenya, the rectangular berkad was redesigned to be oval-shaped and roofed with barbed wire covered with thorny Bougainvillea climbers, two large silt traps and a staircase made of concrete for drawing water by hand in buckets.

Berkad ground tank in Kenya

© E. Nissen-Petersen, Kenya

The hard sandy surface of the Kalahari Desert in Botswana is used as catchment area for these three large cylindrical water tanks, which provide domestic water for the San people (Bushmen).

Catchment area in the Kalahari Desert in Botswana

In the dry central plateau of Tanzania, a 500 m3 cylindrical water tank, made of reinforced concrete, was built to collect run-off water from a 2 sq.km catchment area.
The water is for domestic use by the communities living nearby.

Building a cylindrical water tank in Tanzania

© E. Nissen-Petersen, Kenya

This ground catchment tank is known as "King David's Well" in the Negev Desert of Israel and it is estimated to be about 2,500 years old.
The conical ground tank is lined with lime stones mortared together with lime mortar.
The catchment area is a large stony hill from where the annual rainfall of 100 mm falling in the month of December is diverted into the tank by long trenches sloping upwards from the tank.

"King David's Well" in the Negev Desert, Israel

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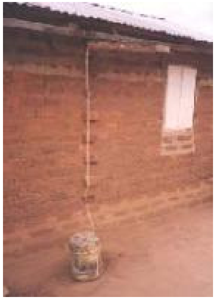
Storage of Domestic Water in Tanks

Water from road catchments should not be used for domestic consumption because the water from murram and dirt roads contains dung and other pollutants, while water from tarmac roads contains tar which is harmful to peoples' health.

Water for domestic use should be collected from either roofs, rocks or drawn from shallow ground water by means of hand-dug wells or hand-drilled boreholes.



Simple roof catchment

© E. Nissen-Petersen, Kenya

Roof catchments for domestic water can be as cheap and simple as the photo on the left shows.

A sheet of metal or of polythene or a length of split Bamboo or Sisal pole is tied to the roof. A rope hangs from the gutter to facilitate rainwater running along the rope into a 20 litres jerry can on the ground.

Plastic jerry cans

Plastic jerrycans play a very important role in rural water supply because nearly all

domestic water is transported from the water sources to the homesteads in jerrycans.

Many women in dry areas have to carry one full jerry can of 20 litres of water, which is equal to 20 kg, on their back every second day. In addition the women must also walk up to 10 km with the empty jerry can from the homestead to the water source which is usually in a riverbed.
They must also wait at the riverbed until it is their turn to fill their jerry cans with the water that seeps slowly into the waterholes they have scooped out of the sand.

They must walk 10 km up hill with the 20 kg jerry can because riverbeds are always in valleys. At home they must ration the 20 litres of water to be sufficient for 2 days consumption because no woman has the stamina to fetch water from 10 km away every day, while also taking care of her children, livestock and homestead.

Woman carrying water

© E. Nissen-Petersen, Kenya

Where water has to be fetched from sources further away than 10 km a donkey has to be purchased. A donkey can carry 4 jerry cans of water for distances up

Transporting water home by donkey

© E. Nissen-Petersen, Kenya

to 30 km during a return trip taking 2 days.

In those dry areas the cost of a donkey is equal to the dowry for a wife. When the rain comes, the cost of a donkey decreases because water can be fetched nearby, while the cost of dowry increases because now manual labour is needed in the fields.

Nowadays, some people prefer bicycles to donkeys for fetching water because bicycles are cheaper and more versatile than donkeys, although a bicycle can only carry a maximum of 3 jerry cans which is 60 kg of water.

Transporting water with a

bicycle

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Jerry cans are expensive for rural communities, therefore jerry cans have to be repaired when they leak or get worn out.
Should a jerry can be worn out, the leakages and holes in it can be sealed by plastic strips melted over a fire.

Repairing a jerry-can

© E. Nissen-Petersen, Kenya

Oil drums

Most rural homesteads can afford an oil drum to harvest rainwater from the roof. Unfortunately, the lower part of oil drums corrodes. The oil drums are than discarded as scrap metal.
Note: Rusty and leaking oil drums can easily be repaired for the cost of half a bag of

cement. The technique is simple.

Repaired oil drums

© E. Nissen-Petersen, Kenya

How to repair oil drums:

Step 1: Mix a 1/8 of a bag of cement with coarse river sand in a ratio of 1 part of cement to 3 parts of river sand.

Step 2: Smear the mixture onto the inside of the oil drum in a 1cm layer and let it dry for a day.

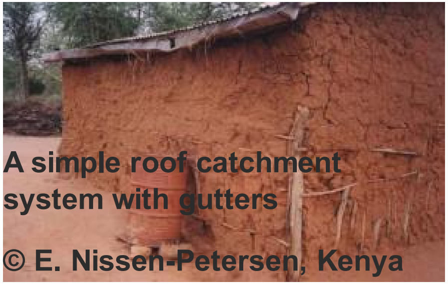
Step 3: Next day apply a second coat of mortar 1:3 being 2 cm thick onto the interior of the drum and smoothen it.

Step 4: Within the same day, mix cement with water until it becomes a slurry called NIL and press it onto the interior plaster with a square steel trowel.

Step 5: Keep the oil drum under shade and sprinkle the plaster with water 3 times a day for a week, then fill it up with water.

Many people plaster their new oil-drums this way because the taste of the water drawn from drums coated with cement mortar has a nice sweet taste.

The image left shows a slightly larger roof catchment system with gutters fixed sloping along the full side of the roof.
A discharged oil-drum with a storage capacity of 210



A simple roof catchment system with gutters

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litres is placed under the lowest point of the gutters where the rainwater will fall from the gutter.

The repaired oil-drums can last for more than 10 years.

An oil drum used for roof catchment at a rural home

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Types of Water Tanks

Water tanks made of PVC for storage of rainwater can be bought from manufacturers but the cost of the tanks and the transport required to bring them to rural areas is high, although some manufacturers can give up to 50% discount.

It is often cheaper to use locally available materials and experienced builders to construct water tanks of concrete in situ (formwork), burnt bricks, soil compressed blocks, quarry blocks and concrete blocks reinforced with a spiral of barbed wire. Water tanks can also be built of ferro-cement made of cement, coarse and clean river sand, chicken mesh, weld mesh and galvanized wires.

For any type and size of water tank these must always be circular, hemi-spherical or spherical (ball shaped) in order to distribute the internal pressure of water equally on the tank walls.
Square or rectangular tanks will always crack.

Storage tanks should always be roofed with airtight covers to prevent mice, rats, lizards and snakes from entering, drowning and contaminating the water. Airtight covers will also reduce evaporation losses in hot climates. Several types of roofs can be fitted onto tanks, although domes build of ferro-cement are the most durable.

The construction cost of the various types of materials and sizes of water tanks varies according to the availability of local materials and skills as well as the cost of transportation. A budget should be prepared to compare the cost of constructing tanks with the cost of purchasing prefabricated water tanks.

Preferably, water should be extracted from storage tanks by gravity through a draw-

off pipe of galvanized iron which is concreted into the foundation of tanks.

Although water can be drawn from tanks situated under the ground level, hereafter called ground tanks, by a bucket tied to a rope, or other types of simple water lifts and hand pumps, it is safer and easier to draw the water from a staircase leading down to a water tap and pipe which is concreted into the bottom of the ground tank.

Easy ways of building water tanks

Farmers and laymen have built several thousands of 5,000 litres water tanks using a technique called *in situ* which consists of compacting concrete reinforced with a spiral of barbed wire in between two cylindrical moulds made of either roofing sheets or old oil drums.

Local artisans, who can build houses, can usually also build water tanks of burnt bricks, soil compressed blocks, quarry blocks or concrete blocks. The volume of such tanks may vary in sizes from 3,000 litres to 30,000 litres.

It is important that the reinforcement of these tanks is made by wrapping a barbed wire, g 12.5, tightly around the outer side of the tank in a spiral spaced 5 cm at the lower half of the tank, where the greatest strength is needed, and 10 cm on the upper half.

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How to Repair Water Tanks

Often it is much easier and cheaper to repair old and leaking water tanks and containers than buying or building new ones.

1)Corrugated galvanized iron sheet tanks

Water tanks made of galvanized iron sheets were popular some decades ago. Unfortunately, the bottom part of the tanks corroded and leaked after 5 to 10 years. They were then considered useless and discharged as scrap metal. These corroded and leaking water tanks can be repaired easily.

A leaking water tank made of galvanized iron sheets

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The technique is as follows:

Step 1 Small holes are punched in the wall for every 15 cm or so using

Chicken mesh tied to the interior of a tank

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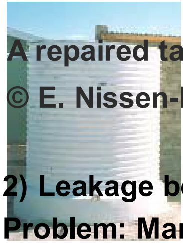
a nail and a hammer.

Step 2 Binding wire is cut in lengths of about 20 cm and bent in a U shape. One person puts the two ends of a U bent wire into two punched holes situated near each other.

Step 3 A second person presses chicken mesh against the wall and uses the two ends of the U wire to tie to chicken mesh tightly against the wall. Thereafter chicken mesh is laid on the floor of tank.

Step 4 Cement can now be mixed with clean river sand in a ratio of 1 part cement to 3 parts sand and some water. This mortar is then thrown onto the chicken mesh in a layer of about 1 cm thick.

Step 5The next day another coat of mortar is added until all binding wires and chicken mesh are covered with mortar. Within the same day, cement slurry (NIL) is pressed onto the moist plaster with a square steel trowel for water proofing. The outside of the tank can be painted with a weatherproof paint made of 1 part cement to 10 parts of lime mixed with water.



A repaired tank

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2) Leakage between wall and foundation

Problem: Many tanks built of masonry leak water through the joint where the wall joins the foundation.
Reason: The reasons are either insufficient reinforcement, poor mixture of mortar or lack of cleanliness when the joint was made.
Remedy: The joint can be made watertight by cleaning the joint, adding more reinforcement and making an apron on both sides of the joint.
Procedure:

Step 1 Drain all water out of the tank and clean the floor and the foundation on the outer side of the tank.

Step 2 Chisel a groove, about 3 cm x 3 cm, all around the joint on both the interior and external sides of the tank.

Step 3 Roughen a 15 cm wide stretch of the foundation on both sides of the joint. Clean the joint and the roughened surface with plenty of water.

Step 3 Wrap 5 rounds of barbed wire tightly around the tank in the external groove.

Step 4 Compact mortar 1:3 into the external and internal grooves with a piece of

timber.

Step 5 Compact a 15 cm wide and 10 cm high apron over the external and internal grooves.

An internal apron can be made with a short length of bamboo or an empty beer bottle.

An external apron is made with a wooden trowel.

3) Leakage through a cracked foundation

Problem: Water leaks through cracks in the foundation.
Reason: Soft soil under the foundation, insufficient reinforcement, poor mixture of concrete or improper curing.
Remedy: The leakage can be sealed by constructing a new foundation onto the old cracked foundation.
Procedure:

Step 1 Drain all water out of the tank and clean the floor.

Step 2 Fill all cracks with bitumen paste.

Step 3 Cut sheets of weld mesh to fit the foundation. All overlaps must be at least 20 cm and tied together with binding wire for every 10 cm.

Step 4Mix concrete with 1 part cement to 3 parts river sand and 3 parts of crushed stones (1:3:3). Compact a 7 cm thick layer of concrete onto the old foundation.

Step 5Lay the weld mesh on the concrete in the tank.

Step 6 Compact a second layer of 7 cm concrete onto the weld mesh in the tank.

Step 7Compact a 1 cm thick layer of mortar 1:3 onto the concrete. Smoothen the

plaster and press a coat of NIL onto the plaster the same day.

Step 8The next day, compact a rounded apron into the joint between the new foundation and the wall.

Step 9Keep the foundation moist and under shade for 3 weeks

Weld mesh cut to fit foundation.

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4) Leakage through walls without cracks

Problem: Water leaks through the wall of a water tank, although the wall has no cracks.
Reason: The wall is leaking due to porosity caused by either a mortar mixture with insufficient cement, insufficient curing or poor workmanship.
Remedy: The wall can be sealed by replacing the porous parts with mortar 1:3 and with NIL. Should the wall still leak after that treatment, the interior of the tank should be coated with a water proofer.
Procedure:

Step 1 Drain all water out of the tank and clean its interior

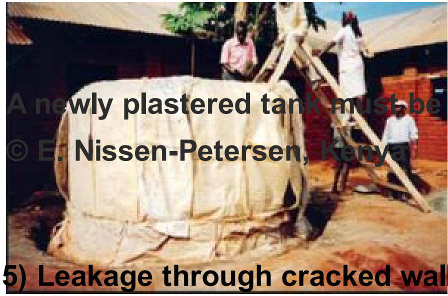
Step 2 Chisel away the porous parts of the interior wall.

Step 3 Clean the chiseled parts with water and throw dry cement onto the watered parts of the wall.

Step 4 Mix mortar of 1:3 and throw a thin layer of it onto the watered parts of the wall.

Step 5 Step 5 Next day, fill up the coated parts with mortar 1:3 and apply NIL with a square steel trowel. Keep the plastered parts moist under shade for 3 weeks, and then fill the tank with water.

Step 6 Should the tank still leak, its internal side has to be painted with a water proofer, such as swimming pool paint, non-toxic bitumen, oil paint or 1 part of cement with 10 parts of lime mixed with water.



A newly plastered tank must be cured for three weeks.

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5) Leakage through cracked walls

Problem: Water leaks through cracks and fissures in the wall of a water tank.
Reason: Vertical cracks are due to insufficient horizontal reinforcement and/or incorrect joining of bricks and blocks. Horizontal cracks are due to incorrect joining between the horizontal courses between bricks and blocks.
Remedy: Build a new tank on the outside of the cracked tank by wrapping reinforcement mesh or wire around the tank and plaster it.
Procedure:

Step 1 Drain all water out of the tank and clean it.

Step 2 Chisel off any loose part on the external side of the tank wall.

Step 3 Tie sheets of weld mesh together with binding wire and wrap them tightly around the tank and plaster the outside of the tank with 3 cm of plaster 1:3.

Alternatively, wrap chicken mesh tightly around the cracked tank after which a spiral of barbed wire, gauge 12.5 is wrapped tightly around the chicken mesh with a

spacing of 5 cm at the lower half of the tank and 10 cm apart on the upper part of the tank. Thereafter plaster the outside of the tank with 3 cm of plaster 1:3.and keep it moist under shade for 3 weeks.

Paint the tank with a weather proof paint made of 1 part cement to 10 parts of lime mixed with water.

Weld mesh wrapped around a tank.

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Chicken mesh and barbed wire wrapped around a cracked tank.

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Easy Ways of Building Water Tanks

Farmers and laymen have built several thousands of 5,000 litres water tanks using a technique called in situ which consists of compacting concrete reinforced with a spiral of barbed wire in between two cylindrical moulds made of either roofing sheets or old oil drums.

Local artisans, who can build houses, can usually also build water tanks of burnt bricks, soil compressed blocks, quarry blocks or concrete blocks. The volume of such tanks may vary in sizes from 3,000 litres to 30,000 litres.

It is important that the reinforcement of these tanks is made by wrapping a barbed wire, g 12.5, tightly around the outer side of the tank in a spiral spaced 5 cm at the lower half of the tank, where the greatest strength is needed, and 10 cm on the upper half.

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Water treatment - DROP

Short description: General notes on water treatment for drinking water after harvesting it from different sources such as rain water, surface water, and ground water.

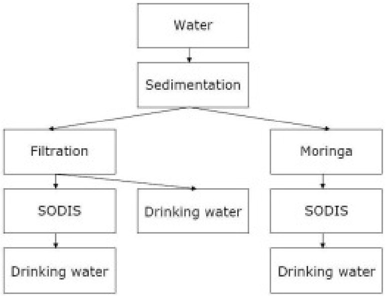
Discribed methods: Sedimentation, filtration, cooking, solar water disinfection, desalination, chemical disinfection, other purification methods (e.g. using *Moringa oleifera*)

Introduction

Generally, it can be said that protecting a water source from contamination is easier than treat contaminated water to get safe drinking water.

Contaminated water can be treated with physical or chemical methods. Physical methods contain sedimentation, filtration, cooking, and solar water disinfection. Chemical methods desinfect with chlorine, iodine, silver, or potassium-permangamate. Most of the time, several of those methods are combined to get safe drinking water. The first step is normally to clean the water optically, i.e. sediment or filter the solid particles. Then, chemical or biological contamination can be removed by disinfection or chemical treatment.

Alternative purification methods include for example plants like a tree called Moringa which supports the coagulation and subsequent sedimentation of solid particles in turbid water. For many chemical or physical desinfection methods, turbid water is treated less effectively.



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Sedimentation

Sedimentation. The first step of water treatment is often sedimentation, especially in the cases of turbid water. Generally, the methods used are very simple. The goal is to let the silt sink down and decant the clear water. Since this takes some time, the sedimentation process takes up to two days. Within this time, even pathogen bacteria can be reduced by 97%.

Sedimentation can be done in simple, covered containers. Also simple flow-through sedimentation tanks can be built.

Although the water is normally fairly clear after the sedimentation process, it is not treated enough for drinking. At least one further step, the filtration, is required.

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Filtration

Filtration

Filtration is the next step after sedimentation. It is an easy and cheap way to treat contaminated water. Depending on the type of filter, up to 100% of bacteria and most of the viruses as well as all bigger organisms (cyts, worm eggs, etc.) are being removed.

There are multiple typs of filters: sand filters, ceramic filters, and cloth filters.

Slow Sand Filtration

Two types of sand filters can be compared: pressure filters and gravity filters. Pressure filters are often used in industrial water treatment. Here, only gravity filters, which are much cheaper in set-up and maintenance, are considered.

The principle of a sand filter is the following: driven by gravity, water flows through a layer of previously washed sand and gets cleaned from solid particles, dissolved compounds as well as to a certain part microorganisms. In slow sand filtration, a biological layer is formed on top of the sand, which is additionally active in deactivation and removal of pathogens from the water. In rapid sand filtration this additional biological filter is missing and, hence, the water is often chemically pretreated before filtration. Rapid sand filters are suitable for large urban centers where land scarcity is an issue, whereas slow sand filters tend to be more suitable for areas where land is more available, since they need a much larger surface area to treat the same amount of water. Slow sand filtration is simpler to operate than rapid filtration, as frequent backwashing is not required and pumps are not always necessary.

The advantage of slow sand filters is that they can be built locally with local materials. When properly maintained, they remove 90-99% of bacteria and also other pathogens. But they require the proper maintenance such as regular cleaning by scratching away the biological layer on top of the sand. During the first 1-2 weeks of use, the water is not cleaned, because the biological layer has to grow first. Also after cleaning, the filter needs some time to recover.

If the filter has to be cleaned very often, the water is too silty and should be allowed to stand in a large tank or prefiltered beforehand. For prefiltration, an upward flow filter is useful. In an upward flow filter, the bed of coarse (3 to 4mm) sand is supported on a plate pierced all over with 2mm holes 50mm apart. The advantages of the upward flow filter is that it is easy to clean the sand bed once a day by shutting of the flow and pulling the drain plug.

Ceramic filters

Ceramic filters have a pore diameter of about 200nm, which means that it can filter bacteria (usually bigger than 300nm) and reduce but not totally filter viruses (which can be as small as 20nm). One simple form of ceramic filters are clay pots. The ceramic filters often have a coating of coloidal silver, which acts as bactericide and enhances in that way the purification effect. Furthermore, the silver hinders bacteria to grow on the ceramic filter surface.

Also ceramic filters remove 90-99% of bacteria as well as other pathogens. But compared with slow sand filters, their throughflow is much smaller, so they are suitable only for household use. Ceramic filders need regular cleaning and proper handling, so they don't break.

Cloth filters

Cloth filters, mostly made of cotton also filter particles with the size of their pores. Since microorganisms are associated with plancton or other bigger particles, they can also be removed by filters with bigger pore sizes than the size organisms themselves. Cloth filters showed to be effective against cholera or the Guinea worm.

Cloth filters should only be used as a last means if no other way of water purification is availabe since its effectiveness is lowest compared with the other described filter methods.

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Coagulation: Water purification with Moringa sp.

Coagulation: Water purification with Moringa sp.

Moringa is a tropical tree with multiple uses, which is resistant to drought. Among the 13 species known, *Moringa oleifera* is particularly easy to reproduce and its growth is very fast. The numerous economic uses of *M. oleifera* together with its easy propagation have raised growing international interest for this tree which originated from India and which is found in most tropical countries (Africa, Asia and America). *M. stenopetala* and other species from Eastern Africa and Madagascar also have potential even though they have been less exploited so far.

All of the parts of *M. oleifera* can be used in a variety of ways. Moringa is full of nutrients and vitamins and is good in human food as well as in animal food. Moringa helps to clean dirty water and is a useful source of medicines. It provides lots of leafy material that can be utilized in alley cropping systems. There are many other uses as for example as fertiliser, living fence, natural pesticide, domestic cleaning agent, and fuel wood. For more information on the different uses of moringa click here.

Water purification

Moringa oleifera has been shown to be most effective as a primary coagulant for water treatment. Thus, seed powder can be used as a quick and simple method for cleaning dirty water. There is a dual advantage to this property:

1. Moringa can be used as a locally-produced substitute for imported flocculent, thus reducing expenditure of foreign currency reserves by third world countries.
2. Moringa flocculent, unlike aluminium sulphate, is completely biodegradable. This aspect may be particularly interesting to developed countries.

The seed powder joins with the solids in the water and sinks to the bottom. This treatment also removes 90-99% of bacteria contained in water. Using Moringa to purify water replaces chemicals such as aluminium sulphate, which are dangerous to

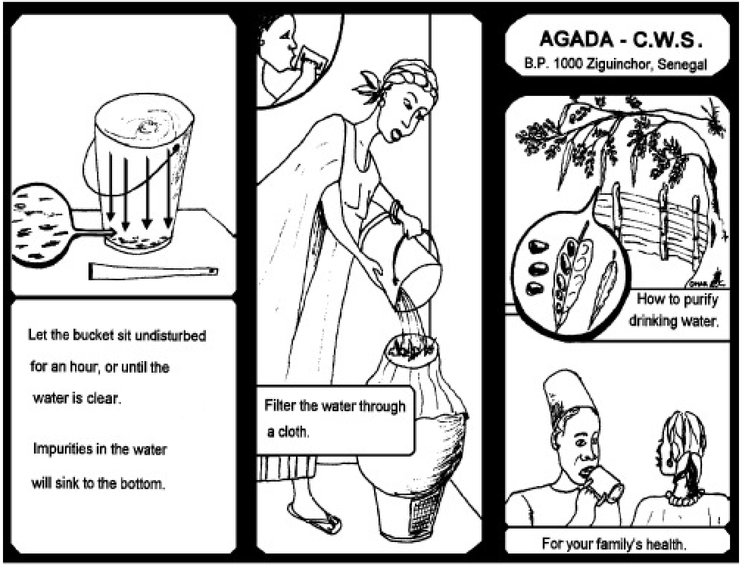
people and the environment, and are expensive.

Water from varying sources will need different amounts of powder because the impurities present might not be the same. Experiments with a jar will help in working out the correct amount needed. Honey and sugar cane juice can also be cleared of impurities using the powder. *Moringa stenopetala* seeds have better water purifying properties than *Moringa oleifera*.

Water purification step-by-step

1. Remove the wings and brown seed coat and discard any seed kernels that have dark spots or any other signs of damage.
2. Ground the kernels to a fine powder.
3. Add 2 grams (2 small spoons) of powder to one cup of clean water, pour into a bottle and shake for 5 minutes.
4. Filter the solution through a clean cloth into the bucket of dirty water that is to be treated.
5. Stir the water quickly for 2 minutes and slowly for 10 to 15 minutes (do not use metal implements).
6. Leave the bucket undisturbed for one hour or until the water becomes clear and the impurities have sunk to the bottom.
7. Filter the water through a clean cloth
8. Boil the water before drinking.

Both the seeds and the seed powder can be stored but the solution made in stage 3 should be freshly made every time water is to be purified.


Let the bucket sit undisturbed for an hour, or until the water is clear.
Impurities in the water will sink to the bottom.
Filter the water through a cloth.
AGADA - C.W.S.
B.P. 1000 Ziguinchor, Senegal
How to purify drinking water.
For your family's health.

Moringa Waterpurification 1

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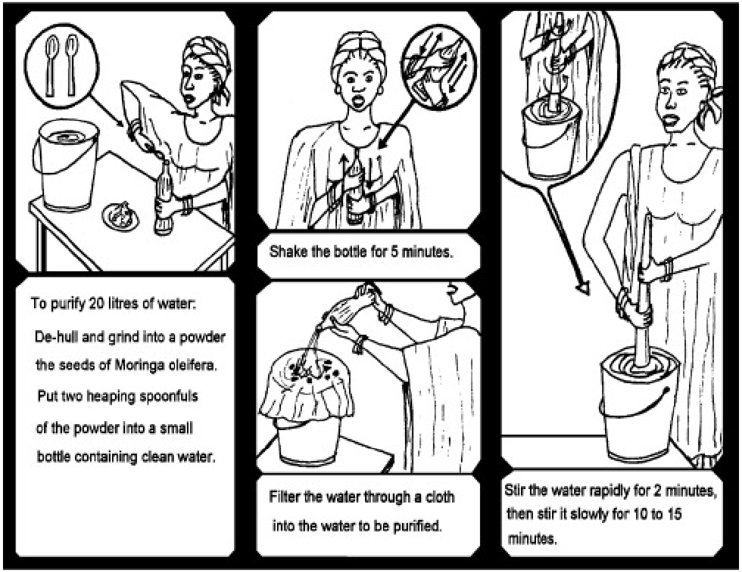

Moringa Waterpurification 2

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Functionality

The crushed seed powder, when mixed with water, yields water-soluble proteins that possess a net positive charge and act as a cationic polyelectrolyte that has proved efficient as a substitute to aluminium sulphate and other flocculent. These proteins attach themselves to, and bind between, suspended particles forming larger, agglomerated solids. These flocculated solids then can be led to settle and filtered. Dosing solutions are generally prepared as 1-3% solutions and are filtered prior to application to the untreated water.

Limitations and possible problems

At low turbidity, as may be experienced during the dry season, the seeds are less effective although their performance is very much dependant on the raw water to be treated. For low turbidity, the contact flocculation-filtration process has to be applied.

Despite the usefulness of *M. oleifera* and other similar organic coagulants for treatment of turbid water, there has been little effort to characterize the active agents in these seed extracts or evaluate the efficacy as coagulants in reducing microbes from waters having different turbidities. The findings so far suggest that such seed extracts may function as a particulate, colloidal and soluble polymeric coagulant (see above) as well as a coagulant aid. The presence of other constituents in these seed extracts is uncertain, and there is concern that they may contain toxicants, because the portions of the plant also are used for medicinal purposes.

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Cooking

Boiling

Boiling is the simplest method to remove all pathogenes from water. Water needs to be cooked shortly at at least 70°C. If the water is heavily contaminated, a cooking duration of 3 minutes is recommended. The water should not be poured in another vessel since it could be recontaminated.

The disadvantage of boiling are the bland taste of the water after cooking and the large amount of energy needed. For one litre of water one kilogram of wood is needed for cooking. In areas with scarse wood availabilty, it is often hard for the women to collect enough fire wood even for cooking. In forest areas, water treatment by boiling increases the pressure on the forest, which can lead to deforestation and subsequent problems like erosion, water scarceness, and loss of biodiversity.

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Solar water disinfection -SODIS

Solar water disinfection - SODIS

Microorganisms which occur in some water resources used as drinking water can cause water borne diseases such as diarrhoea. SODIS is seen by the World Health Organization (WHO) as one of the technically simplest and most practical and economical ways to improve the quality of such drinking water. Water that is contaminated with microorganisms is filled into clean, transparent plastic bottles and exposed to full sunlight for six hours. The solar radiation and temperature destroy the micro-organisms in the water. This method is ideal to produce small quantities of safe drinking water for the household level. The WHO recognises that heating water,

other liquids and other foods using solar radiation is a more accessible, economical and technologically feasible option than heating with fuel.

Requirements for SODIS

Containers

Plastic bottles made from PET are good containers for SODIS. PET soft drink bottles are often easily available. The containers used for SODIS should not exceed a water depth of 10cm, i.e. PET bottles of 1-2 litre volume.

To distinguish a PET- from a PVC-bottle, try to inflame it. PVC is difficult to flame. The material does not burn outside the flame. The smell of the smoke is pungent. PET burns easily when held into a flame. The fire goes out slowly or not at all outside the flame. The smell of the smoke is sweet. You should not use PVC bottles for SODIS.

Water turbidity and quality

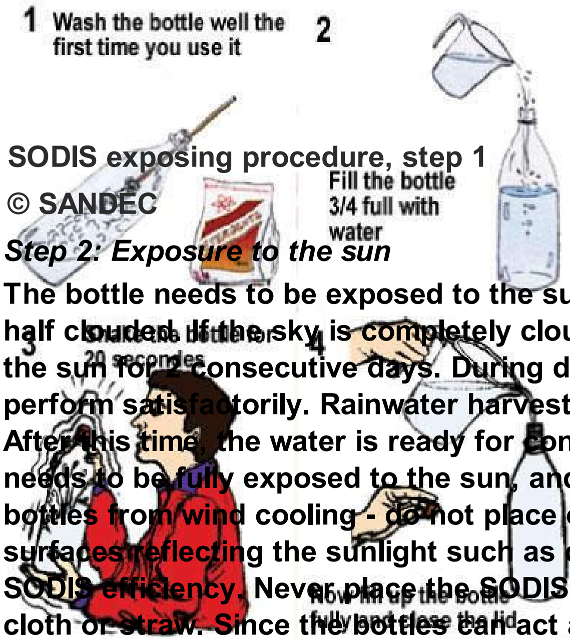
Solar Water Disinfection does not change the chemical water quality. Do not use chemically polluted water. SODIS requires relatively clear water. To test the water turbidity, there is a very simple test: Fill the SODIS bottle with the water and place the bottle on top of a paper with the SODIS-Logo (the letters should have a size of about 1.5cm). Open the lid of the bottle and watch through the bottle to the bottom of the bottle. If you still can read the letters of the SODIS-Logo on the paper, you can use the water for SODIS. If you cannot read the letters, the water is too turbid for SODIS and needs to be filtered or the solids have to be decanted first. Let the full bottle stand until the suspended particles have sunken to the ground. Filter the water through a clean cotton cloth or filter and fill it into a new bottle without the sunken

particles.

Application of SODIS

Step 1: Aerating the water

Wash the bottle well the fist time you use it. Fill the bottle to 3/4 and close it. Shake it a few times. Then fill it completely with water. This procedure is particularly important if you treat standing water (as it is the case for stored rainwater). Oxygen in combination with sunlight helps destroying the micro-organisms in the water. After shaking, the bottle should be filled completely.



SODIS exposing procedure, step 1

Step 2: Exposure to the sun

The bottle needs to be exposed to the sun for 6 hours if the sky is bright or up to half clouded. If the sky is completely cloudy, then the bottle needs to be exposed to the sun for 2 consecutive days. During days of continuous rainfall, SODIS does not perform satisfactorily. Rainwater harvesting is recommended during these days. After this time, the water is ready for consumption. Place the bottles on a surface: It needs to be fully exposed to the sun, and never shaded during exposure. Protect the bottles from wind cooling - do not place on open wood racks. Place the bottles on surfaces reflecting the sunlight such as corrugated iron sheets, which can enhance SODIS efficiency. Never place the SODIS bottles on inflammable materials, such as cloth or straw. Since the bottles can act as a magnifying lens, they can set fire to inflammable materials.

SODIS exposing procedure, step 2

Additional: Increasing the efficiency of Solar Water Disinfection

Place the plastic bottles on a corrugated iron sheet, (this will increase the water temperature by about 5°C.) Use raw water with low turbidity, expose the bottle for two consecutive days on cloudy days, and replace scratched and dull bottles after about one year of regular daily SODIS application.

Factors enhancing SODIS efficiency

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Common mistakes

Mistake Nr. 1: The containers chosen are too big

- **For the best results, plastic bottles of 1-2 litres volumes are used (better surface/volume ratio).**

Mistake Nr. 2: Bottles are placed upright

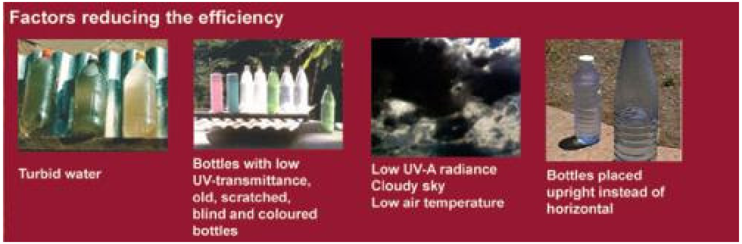
- **Laying the bottles horizontally increases the area for sunlight exposure and reduces water depth. Like this, micro-organisms are more easily destroyed.**

Mistake Nr. 3: After SODIS treatment, the clean water is filled into contaminated containers and the water is recontaminated.

- **Consume the treated water directly from the bottle using a clean glass or a cup.**

Mistake Nr. 4: Green or brown plastic bottles are used for SODIS

- **Green or brown bottles do not sufficiently transmit the sunlight. Therefore, use clear transparent bottles only.**



Factors reducing SODIS efficiency

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Further information on SODIS

How SODIS works

SODIS is used to inactivate the pathogenic microorganisms, predominantly those causing diarrhoea. Most pathogens cannot grow outside the human body apart from a few exceptions such as salmonella, which however requires favourable

environmental conditions (e.g. appropriate supply of nutrients).

Sunlight is treating the contaminated water through two synergetic mechanisms: Radiation in the spectrum of UV-A (wavelength 320-400nm) and increased water temperature. This synergy of UV-A and temperature occurs, if the water temperature rises above 45°C. If the water temperature rises above 50°C, the disinfection process is three times faster. However, through UV-A radiation, SODIS also works in cool climatic areas, such as the Andeas or the Himalaya region, where the water temperature does not exceed 45°C.

Effectiveness of SODIS

The laboratory experiments showed an efficient reduction of the faecal coliforms through SODIS also with initial concentration of 10'000/100ml up to more than one million/100ml. This is much more than normally encountered in common river and ponds (a few thousand/100ml or less). However it has to be considered, that the conditions during the experiments are different from practical situations, where the process might not be applied in a strictly controlled way, materials are not optimal and handling of the treated water often is inadequate.

The application of SODIS inactivates the following microorganisms:

Bacteria:	**Escherichia coli, Vibrio cholerae, Streptococcus faecalis, Pseudomonas aerugenosa, Shigella flexneri, Salmonella typhii, Salmonella enteriditis, Salmonella paratyphi**
Viruses:	**bacteriophage f2, rotavirus, encephalomyocarditis virus**
Yeast and mold:	**Aspergillus niger, Aspergillus flavus, Candida, Geotrichum**

Protozoa: Giardia spp., Cryptosporidium spp.

Effect of aerating the water

With the aeration, oxygen is dissolved in the water. SODIS is more efficient in water containing high levels of oxygen: Sunlight produces highly reactive forms of oxygen (oxygen free radicals and hydrogen peroxides) in the water. These reactive molecules react with cell structures and kill the pathogens.

Recent research however revealed that the bottles should be shaken only at the beginning of the SODIS process. Once the bottles are exposed to the sun, they should not be moved anymore, as continuous shaking of the bottles during the solar exposure will reduce the efficiency of the process.

The taste of solar disinfected water

When water is boiled, the level of the oxygen dissolved in the water decreases. This changes the taste of boiled water, making it taste less fresh and softer.

SODIS on the other side improves the quality of drinking water without changing its taste. The bottles are closed during the exposition to the sun. Therefore, the level of oxygen dissolved in the water remains the same. The taste of the water keeps fresh.

Limitations and possible problems

Limitations

- **Availability of suitable water containers and other needed materials**
- **Lack of sunlight for disinfection**
- **Difficulties in treating highly turbid water and the availability of simple methods for reducing the turbidity of water before solar treatment (turbidity less than 30 NTU needed)**
- **Lack of a residual disinfectant to protect water during handling and storage.**

However, stored in the bottle, the treated water is protected from recontamination. No regrowth has been observed so far, even if the treated water was stored for one week.

- **User objections to the technology due to the length of time to treat the water (several hours or longer)**
- **Lack of effectiveness against chemical water pollutants**
- **Not useful to treat large volumes of water**
- **Weaning food for children less than 18 months should be prepared with boiled water.**
- **Boiled water instead of SODIS water should be used by persons with a considerably increased risk of infectious diarrhoeal diseases including:**
  - **severely ill children and adults**
  - **severely malnourished children and adults**
  - **patients with decreased immunodeficiency (AIDS)**
  - **patients with gastro-intestinal abnormalities or chronic gastrointestinal illnesses**

Possible problems

Repeadedly concerns are expressed abut the possibility of specific compounds leaching from reused and new PET bottles into the water. Therefore, a team of researchers from the EMPA (Swiss Federal Laboratories for Materials Testing and Research) tested the diffusion of adipates and phtalates such as DEHA and DEHP from new and reused PET bottles. The levels of concentration found in the water of reused and new PET-bottles were very low, e.g. in the same magnitude as the concentrations of phtalate and adipate generally found in high quality tap water. Also the concentrations of formaldehyd and acetaldehyd were found to be below the

thresholds for safe drinking water (click here for details). A group of researchers from the University of Heidelberg assessed the diffusion of Antimom from new PET-bottles that had been stored for several months in the supermarket. They found a concentration of 300 to 600ng antimom per liter (click here for details). This concentration is far below the WHO threshold value for drinking water (20 µg/l).

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Chlorination

Chlorination

Chlorination is still a worldwide used method for the desinfection of water. When used with water filtration methods, chlorine is effective against virtually all microorganisms. Chlorine is easy to apply and small amounts of the chemical remain in the water as it travels in the distribution system or is stored in a tank or cistern. This level of effectiveness ensures that microorganisms cannot recontaminate the water after treatment.

Chlorination is useful for the treatment of a central water supply in a village but not for individual household use, since its application has to be done in a professional way. The application of chlorine can produce certain by-products that can lead to health problems.

Chlorine can also be used as a emergency measure for the desinfection of a water storage that has been accidentially contaminated, e.g. after a storm or by a dead animal.

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- WHO. Managing water in the home: accelerated health gains from improved water supply. Available at http://www.who.int/water_sanitation_health/dwq/wsh0207/en/. Accessed on 23.03.2007.

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Further links and contacts

- Drinking water for all; article by Dr. Anumakonda Jagadeesh: http://www.ewb-international.org/pdf/WaterForAllJagadeesh.pdf
- Water Disinfection Using Solar Radiation by IDRC/CRDI: http://www.idrc.ca/en/ev-26972-201-1-DO_TOPIC.html

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Water quality and protection - DROP

Short description: The quality of water is crutial to ensure the health of the people consuming it. There are three main criteria for water quality: firstly its natural co-compounds like calcium or magnesium, secondly pollution by chemicals like pesticides or fuels, and thirdly biological contamination by bacteria or other microorganisms. Biologically contaminated water can be treated and made palatable. Treatment of chemically polluted water is extremely complex and costly, so the best way is to protect the watersources from chemicall pollution.

Water an its co-compounds
Chemically polluted water
Biologically polluted water
Protecting water sources
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Further reading

Water an its co-compounds

Chemically pure water is a molecule that consist of two hydrogen atoms bonded to a single oxygen atom. Water is a tasteless, odourless liquid at ambient temperature and pressure, and appears colourless in small quantities, although it has its own intrinsic very light blue hue. Nevertheless, according to experience, water has often a quiet distinct taste. This taste is caused by numerous co-compounds that are soluted in the water. The most common compounds of groundwater are calcium and magnesium that are soluted from the rock the water flow through. The concentration

of these elements depends on the composition of the respective rock-underground. Calcium and magnesium give the water a special taste and are at the same time essential elements of the human diet. Rainwater lacks of those elements, which has to be considered when consuming only rainwater.

Spring or well water can also contain elements that are toxic when consumed, such as arsene. There are various methods to tread the water. For more information see below the section "Further reading".

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Chemically polluted water

Chemically polluted water
There are various sources of chemical pollution such as for example spilled fuels, pesicides used on crop fields or in house gardens, or heavy metalls leached from rainwater harvesting installations. Generally, chemical pollution of water can not be undone and the water can be rendered unpalatable by chemical pollution. Hence, it is very important to protect water sources from chemical pollution. For more details see protecting water sources in the document water harvesting.

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Biologically polluted water

Biologically polluted water
Besides chemical pollution by fuels, pesticides, etc., water can also be polluted by microorganisms. Microorganisms can cause -- depending on the type and

Agriculture

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Energy

concentration -- light to very heavy illness. Deseases such as Amebiasis, Schistosomiasis, Cholera and many others are waterborne. Generally, biologically contaminated water can be treated by different methods. For more information see water treatment.

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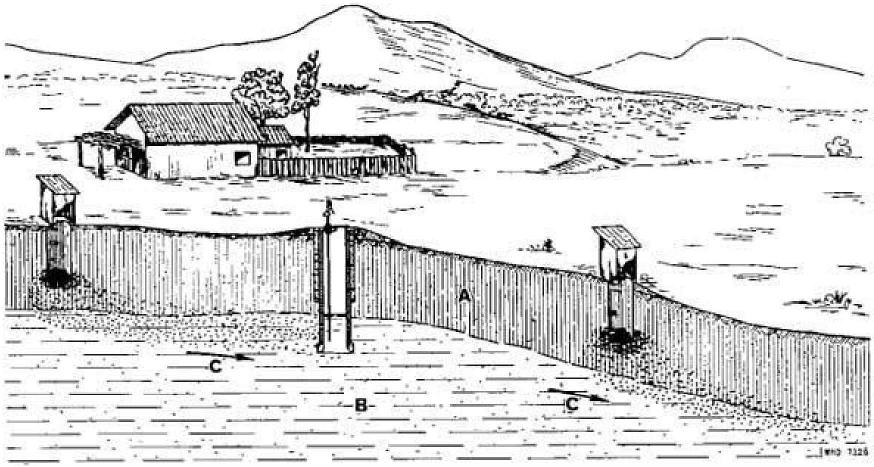
Protecting water sources

Protecting ground water from contamination

Especially when ground water is near to the surface, i.e. in an uncofied aquifer, it needs to be protected from contamination. There are several causes for pollution of the ground water:

- **Drainage of fertilizers and agrochemicals (e.g. herbizides) from fields**
- **Seepage of faeces from a latrin pit**
- **Seepage from waste deponies**
- **Contamination with soluble pollutants from the air**
- **Seepage of hazardeous pollutants from accidents (e.g. of a petrol truck)**

Water infiltrating from the surface, e.g. after a heavy rain, can carry microorganisms from a latrine pit through the soil to the ground water. Thus, when finding a suitable place for a latrine, the ground water flow has to be taken into account. Latrines should always be build downstream to wells or sources. Also other possible sources of contamination should have a minimum distance from wells, sources or surface water. If the watershed of a groundwater flow is known, it should be specially protected, e.g. hazardeous transports should not be allowed to pass through the area.

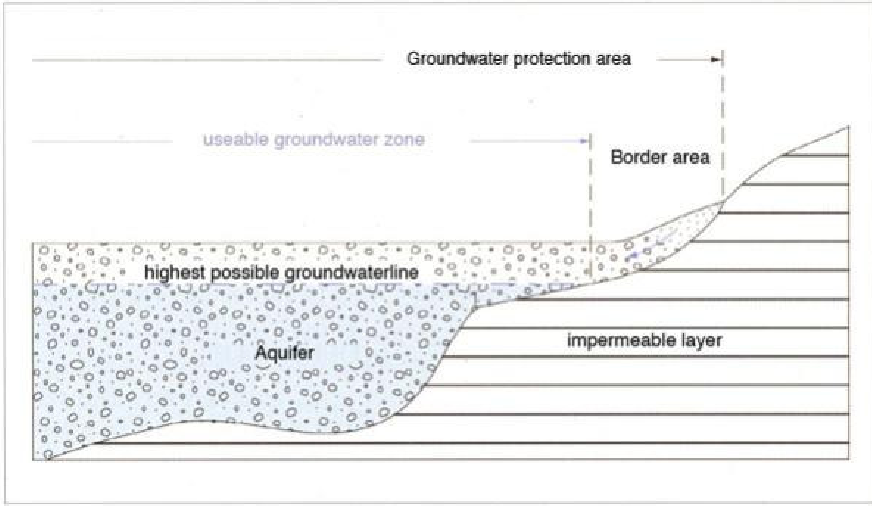


A = Top soil B = Water-bearing formation C = Direction of ground-water flow

Latrines positioned upstream and downstream of a well (Wagner and Lanoix 1958).

Protecting watersheds

A watershed is defined as any surface area from which all rainwater is drained into the same water catchment. This does not only include surface water streams but also groundwater streams. Ground water id usually built by different layers as shown in the figure below.

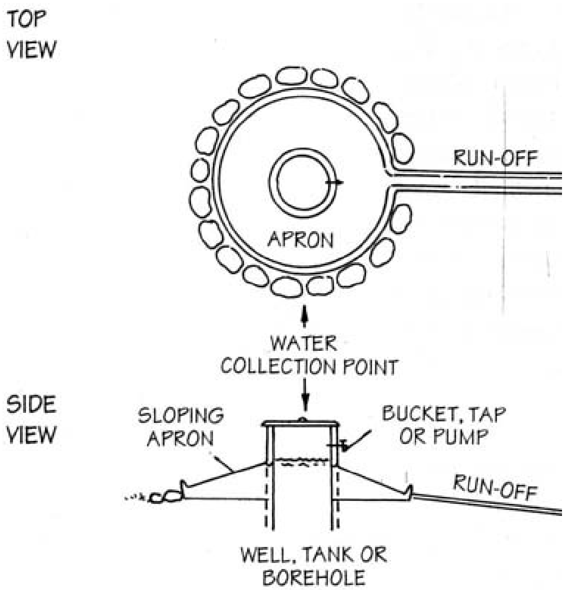


Groundwater conservation area (according to BUWAL 2004)

© BUWAL

Protecting wells

Wells should be constructed according to certain rules: the well should be protected by a concrete apron with high walls from run-off or spilled water. The concrete for the apron should be of good quality and should not have any cracks, allowing waste water from the surface to return to the source.



Example of a well protected by an apron (Vukasin et al. 1995).

Protecting springs

In areas where springs occur, the spring an its surroundings need to be protected from contamination. The area directly around the spring should be fenced to exclude animals and humans. Also the upstream area should be fenced to avoid contamination of the source. The spring chamber should be lined and covered and pipes should be layed to access the water. The access point should be at a safe distance downstream from the spring site.

Preventing loss of water

Water can be lost in different ways: it can run-off, evaporate or being contaminated an not usable any more. How to prevent contamination of the water was discussed above. Evaporation and evapotranspiration (or simply transpiration) gets stronger, the warmer the climate is. Evaporation means the loss of water from the soil surface, transpiration means the loss of water through the leafs of plants. Measures to counter this loss of water include firstly the increase of vegetation, preferably multi storage vegetation, to create shadow and, thus, reducing direct sun; and secondly

by reducing the wind speed with hedges and shelter belts. Leaving the soil undisturbed by practising no or only a minimal tillage also reduces evaporation.

An increased soil cover also increases the infiltration of the water into the soil and, thus, minimizes water run-off. During the raining season, the surface run-off can be spread by different measures to improve the infiltration of the water. One possible method is to build terraces by constructing barriers. Because of the reduced slope and the spreding of the water, it has more time and a bigger surface area to infiltrate and the terraces at the same time protect the soil from eroding and reduce the damage caused by flash floods.

Barriers can also be build in a way that the caught water is diverted to cultivated fields or single trees, providing them with an extra amount of water.

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Information sources

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Further reading

- **Wikipedia: Water pollution. http://en.wikipedia.org/wiki/Water_pollution**
- **WHO: Water sanitation and health. http://www.who.int/water_sanitation_health/en/**

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Surface water

Introduction

Surface water is rainwater running off from land surfaces into rivers, lakes and seas which can be collected, stored and utilized by a technique called *rainwater harvesting.*

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Surveys, designs and permits for water projects
Construction of water projects
Seeking funds for water projects
Water as a

To the surface water structures to collect and store water belong ponds and earth dams such as Charco dams, Hillside Dams and Valley dams.

The type of pond, or earth dam, to be constructed for homesteads depends on the type of landscape available for the construction as follows:

1) The Charco Dam is suitable for flat land, preferable with a road catchment to supply rainwater run-off.

2) The Hillside Dam is the best option for slightly sloping land in places where rainwater flows.

3) The Valley Dam can be built in valleys flooded with low floods from small catchments. Although this type of dam is the most cost efficient, it is also the type most easily damaged or washed away by floods if it is not properly designed and constructed.

Charco and Hillside dams are preferably built in circular and oval designs because:

1) They give maximum storage volume for minimum works.
2) The internal and external pressures are evenly distributed and this prevents cave-in of the soil in the walls of the water reservoir.
3) In sandy soils, they can be lined successfully with clayey soil, because the shapes do not have any corners.

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Charco dams

Farmers and cattle owners in semi arid parts of Tanzania build small earth dams known as Charco, or Milambo in Kiswahili. These dams are built in a way, which tries to reduce evaporation losses by deepening the water reservoirs and minimising their surface area. Trees and shrubs are grown on the windy site of the charco dams to function as windbreaks and reduce evaporation.

Site selection:

The best sites for constructing charco dams are in natural depressions where rainwater either flows or accumulates during rainy seasons. The soil should, preferably, be deep clay, silt or Black Cotton Soil. Coarse textured sandy soils

should be avoided as these are highly permeable and water will drain through them. If seepage is high in charco dams, they can be plastered with clayey soil and compacted using compactors made of tree trunks.

Sites with underlying strata of sand, gravel, limestone or fractured rock at a shallow depth may also result in high seepage losses, unless they are sealed with clayey soil.

Ideally, a charco dam should be located near to a gully or a natural waterway, which carries water during and after rainfalls, as this water can easily be diverted into the dam. Avoid building dams near or downstream from livestock enclosures to avoid organic and/or chemical pollution.

Charco dams

© E. Nissen-Petersen, Kenya

The photo shows the inflow channel to a charco dam seen in the background. Usually, inflow channels have some logs

laid across the floor of the inflow channel functioning as steps and silt traps to prevent the water reservoir from being silted up.


Inflow channel

© E. Nissen-Petersen, Kenya

Charco dams are usually excavated manually by individuals near their homesteads for watering livestock. The water may also be used for some domestic purposes, if it is boiled or treated by the Sun's UV rays in transparent bottles (SODIS). For more information on <u>water treatment click here</u>

Farmers dig their ponds during dry seasons and enlarge them every year, until the owner is satisfied with the capacity of his dam.

The size of Charco dams depend on the following factors:

1) A farmer's financial capacity to hire labourers to assist him excavating.
2)The expected volume of runoff water from the catchment.
3)The area available for constructing the pond.

4)The soil type.

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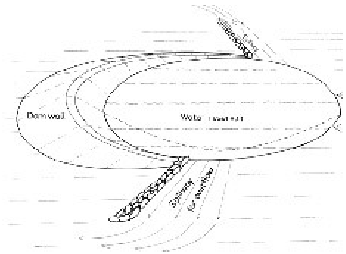
Hillside dams

Hillside dams are small earth dams with curved walls built on hillsides and sloping land are the simplest and second cheapest earth dams to locate, design, construct and maintain.



A bird's eye view of a hillside dam

© E. Nissen-Petersen, Kenya

Site selection:

Suitable sites for hillside dams can be found on almost any sloping land that produces rainwater runoff. The catchment can include roads, compounds, roofs, agricultural land and rock outcrops. To avoid contamination of the water, there should not be any pollution sources, such as drainage from villages, slaughterhouses, latrines, rubbish pits, cattle dips, etc. in the catchment area.

Naturally, the best soil type for constructing a water reservoir should

have a high content of clay. However, soil types other than the clayey type can also be used, although some seepage may occur downstream

.

Curved heap of soil

© E. Nissen-Petersen, Kenya

Hill side dam

© E. Nissen-Petersen, Kenya

Despite seepage being considered as wasted water, it can be turned into an advantage such as; facilitating clean water in a hand-dug well that can be used for domestic water, watering livestock, garden irrigation, making burnt bricks, a wood lot, etc.

The curved heap of soil, shown above, will become the dam wall, while the excavated pit

will be the water reservoir. The size of the dam wall and its reservoir depends on the capacity to remove soil from the reservoir and placing it on the dam wall. The gradient (slope) of the sides of the dam wall should be 2:1, which is 2 m width for every 1m of height.

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Valley dams

An earth dam built in a valley is the cheapest way to create water storage, because the excavation work is less than for Charco dams and hillside dams. However, the gain in cost per volume can be lost overnight by flooding from one heavy thunderstorm or shower, which, unfortunately seem to be bigger and further apart every year. The washout of a dam wall can be very serious and endanger both lives and property. For this reason experienced technical help should always be sought for the design and construction of valley dams which might present a possible threat to

downstream households.

Valley dam

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Valley dam

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Rainwater Harvesting

Short description: General ways to collect water for drinking, for livestock or irrigation

more Images

Evaporation, seepage and leakage

Introduction

Rainwater running off land surfaces can be harvested, stored and utilized using a technique called *rainwater harvesting* instead of being wasted in rivers, lakes and the sea.

Rainwater harvesting consists of 5 components:

1) Rainfall
2) Catchment areas, also called watersheds, onto which the rainwater falls.
3) Gutters, or conveying channels, to bring rainwater from a catchment area to storage reservoir.
4) Storage reservoirs can be tanks, ponds, dams and in situ storage in sand and soil.
5) Retrieval water is extracted from reservoirs either by gravity or by pumps and lifts

A rural homestead should preferably have the following variety of structures for harvesting rainwater to avoid water shortages during dry seasons:

- **1) A roof catchment system for clean domestic water that consists of gutters fixed to the roof which drain the rainwater into a storage tank. The size of a storage tank depends mainly on the financial capacity of the owner and to a lesser degree on the size of the roof and the volume of rainfall. However, the ability to supply sufficient water during years with drought depends on the size of the roof and the tank.**

- **2) A pond or an earth dam for watering livestock and garden irrigation can be excavated by hand or animal drawn implements at a low place in the farmland where rainwater flows, or accumulates, during rainy seasons. Ponds and dams can initially be built small and enlarged during the following dry seasons until they might supply water throughout the years.**

- **3) A hand dug well may supply water if sunk into shallow ground water, e.g. downstream of an earth dam or near evergreen trees growing on riverbanks.**

In situ harvesting of rainwater in farmland increases the yield of crops and will often determine whether there will be anything to harvest at all. Most farmers know and apply some of the techniques of soil conservation that make rainwater percolate into the soil instead of eroding the farmland. Among several techniques the following are being used by many farmers:
1) Contour planting in horizontal ploughing lines.
2) Contour trash lines with grass and farm waste.
3) Contour ridges that develop into terraces.
4) Contour bunds of stones that develop into terraces.
5) Bench terraces that develop slowly from contour ridges.
6) Micro catchments with U and V shaped soil bunds for growing grass and crops and trees.
7) Trapezoidal bunds with a farming area of 1,350 m2 (1/3 acre) for grass and crops.
8) Cut-off drains to discharge surplus rainwater run-off into gullies with check dams and streams.
9) Check dams of stones and vegetation to heal eroded gullies.

10) Check dams of stones and vegetationin valleys.

For more information on soil conservation measures click here

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The Water Cycle

Every living creature and vegetation must have water in order to survive.

Only 3% of all water on Earth is fresh water and 68% of the water is frozen ice on the North and South Poles. All humans and most animals as well as nearly all vegetation can only survive on fresh water free of salt and minerals. Water for irrigation must also be fresh water and applied sparingly by flood, furrow or drip irrigation, otherwise the irrigated soil will turn saline and unproductive for many years to come.

The other 97% of the water on planet Earth is saline seawater in which whales, fish, corals and plankton flourish. Slightly salty water may be used for watering livestock and other animals, although fresh water is healthier.

Nearly half of all deep boreholes are dry or contain saline (brackish) water with minerals harmful to humans, animals and plants. Where fresh water is pumped up from very deep boreholes it is called mining fossil water because the water withdrawn cannot be replaced by rains.

Therefore, there are only two sustainable solutions to the world's increasing demand for water, namely rainwater harvesting and water conservation.

Fresh water sources are replenished in a water cycle through the following activities:

1) Evaporation is an almost invisible vapour rising from water surfaces.
2) Transpiration is evaporation from vegetation and soil surfaces.
3) Precipitation from clouds falls as fogs, mists, rains, hails and snow.
4)Rainwater run-off is rainwater running off all kind of surfaces.
5) Drainage is the ability to drain excess water away from catchments.
6) Infiltration is the movement of water into the soil from the surface.
7) Percolation is the movement of water through the soil to the underground layers.
8) Permeability is the rate at which water penetrates through soils down into the underground water table.
9) In situ storage is storage of water in the voids between particles of soil and sand.
10) Subsurface flow is a flow of water in the voids of soil and sand particles.

Water can be harvested at several stages in the water cycle, such as:

1) Fog screens placed on hills, mountains and near the sea for domestic water.
2) Gutters attached to roofs for domestic water.
3) Garlands of stone gutters on rock outcrops for domestic water.
4) Soil bunds and trenches on farmland for crops and animals.
5) Diversion trenches from roads, rocks and hillsides for seasonal flood irrigation.
6) Hand dug wells in shallow ground water to supply water for all uses.
7) Subsurface dams, weirs and sand dams to increase the yield of hand dug wells situated along seasonal water courses.
8) Boreholes drilled into deep ground water where none of the above options are

replicable, although expensive and only 40% may not supply fresh water.

The quality of water from all these sources can be tested by either a portable testing kit or by a laboratory if the samples can be delivered before deteriorating due to heat over long distances. Contaminated water may be treated by several methods, such as SODIS (Solar disinfection), boiling, water filters, crushed seeds from the Moringa tree, ultra-violet rays (UV) or artificial chemicals.

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Rainfall

Although it is known that clouds can be seeded with chemicals to produce rains, the practice is expensive and unsustainable. It should therefore be realized that rainfall varies from region to region and from one year to another beyond peoples' manipulation and interference.

All fresh water comes from rains, including water in deep boreholes which originates from rains infiltrated into the underground thousands or millions of years ago. Fresh water can only be obtained from four main sources; rainwater harvesting, shallow ground water, deep ground water and desalination of which the two latter options are too expensive to be discussed here.

The North-East monsoon coming from India brings rains to East Africa from October to December every year. The South-East monsoon brings rains from March to June.

Rain falls where and when the two monsoons meet. The area of convergence is called the Inter-Tropical Convergence Zone. This zone follows the apparent movement of the sun, north and south, bringing rain in its wake. But the pattern is influenced by mountain ranges, Lake Victoria and periodic westerly winds from the Atlantic.

The two monsoons bring an annual average of about 600 mm rainfall to the semi-arid eastern and northern parts of Kenya, while the highland zone at Mount Kenya has a mean average of 1,000 mm and the Lake Victoria zone has a mean average of 1,800 mm. The rainfall pattern of East Africa is also presented as a map with different colours for the various average annual rainfalls.

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Catchment areas

Runn-off from catchment areas

Although regions with low and erratic rainfalls appear to be unsuitable for rainwater harvesting, it has been proved many times that rainwater harvesting is the most viable water supply system in arid and semi-desert regions. Rainwater harvesting in dry regions is viable when the following aspects are considered and applied:

1) Catchment areas are enlarged to increase the volume of run-off water.
2) Storage reservoirs are made large to store more water for longer periods.

3) Evaporation is minimised by roofing storage reservoirs.
4) Underground water storage in situ in the soil of farmland and sand of riverbeds.

The following two examples show that rainwater harvesting is viable in regions with little rainfall provided the catchment area is enlarged accordingly:

Example 1
A roof with a catchment area of 100 square metres (m2.) and an annual rainfall of 800 millimetres (mm) can supply 72,000 litres of water (100 m2 roof x 800 mm rain = 80,000 litres minus 10% loss = 72,000 litres).

Example 2
A roof in semi-desert regions with an annual rainfall of 200 mm has to be 4 times larger to supply an equal volume of 72,000 litres of water, because the rainfall is only ¼ of the 800 mm rain shown in Example 1.

To design successful rainwater harvesting systems, it is important to know:

1) How much rainwater falls on a catchment area.
2) How much of the rainwater runs off the catchment area?

If these two figures are not known, the storage capacity of a water reservoir and its spillways cannot be designed properly. The ruins of such improperly designed water projects can be witnessed in most parts of Africa.

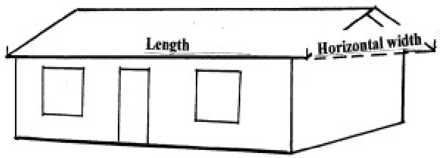
The size of a catchment area is measured in square metres (m2) or in hectares (ha). 1 ha consists of 10,000 m2 which is equal to 2.47 acres. An acre is equal to 4,047 m2.

Farmers measure their acreage of land by walking 70 paces, each pace with a length

of 3 feet, equal to 0.915 metre, around the four sides of a square. 70 walking paces x 0.915 metres are equal to 64.05 metres. When two sides of the square are multiplied with each other the result is 4,102 m2 (64.05 x 64.05), this is close to the actual area of 4,047 m2 for 1 acre.

When the size of a catchment area and the volume of rainwater falling on that catchment area have been found, the volume of rainwater that can be harvested is be calculated by multiplying the length with the horizontal width of the roof.

For example: Length 20 m x horizontal width 5 m = 100 square metres



A sketch showing the length with the horizontal width of a double pitched roof

© E. Nissen-Petersen, Kenya

Farmers may admit: "Okay, it has rained but it was only a drizzle". Nevertheless, a drizzle of 10 mm rain can be sufficient to produce the required volume of water, if the catchment area is sufficiently large. The relationship between rainfall and catchment area can be explained by the following example:

A drizzle of 10 mm rain on10,000 m2 (1 hectare = 100 m x 100 m) area of a roof, rock or tarmac road, it produces 100,000 litres of run-off water minus about 20 % loss = 80,000 litres.

- **10 mm rain x 10,000 sq.m. minus 20% loss = 80,000 litres.**
- **If the same drizzle of 10 mm rains falls on a ten times larger catchment area of 100,000 sq.m. (10 hectares = 100 m x 1,000 m,) it produces ten times more water, namely 800,000 litres x 10 = 8,000,000 litres of water = 8 million litres = 8,000 cu.m.**

A pond for a catchment area

© E. Nissen-Petersen, Kenya

Therefore, a drizzle of 10 mm rains may be sufficient for harvesting a required volume of water, if the catchment area is large enough. Huge volumes of water can thus be harvested from e.g. roads because they have large and hard surface catchment areas.

For example: a drizzle of 10 mm rain on a road 6 metres wide and 1 km (1,000 metres) long road can supply the following volume of water:
A 6 m x 1,000 m road x 10 mm minus 20% loss = 48,000 litres = 48 m3 of water.

Run-off water from a tarmac road.

When designing a reservoir to hold water from a road catchment it is important that spillways can discharge safely the overflowing water during storms.

**For example: A rain storm of 75 mm falling on a 2 km long road produces about:
75 mm rain x 6 m x 2,000 m road minus 20% = 720,000 litres = 720 m3 of water.**

If the storage capacity, such as a pond is 500 m3, then the spillways must be capable of discharging 220 m3 of water (720 minus 500) in a few minutes or the pond will be damaged or perhaps washed away by the flood of incoming water.

Catchment of rainwater from roads is potentially the cheapest water source in

dryland where there are no sandy riverbeds (luggahs or wadis). Tarmacked roads produce more run-off water than dirt roads but the water may contain harmful tar components for people and livestock and should therefore be used for irrigation only.

There are two main types of storage, namely:

1. Storage in reservoirs, such as ponds, earth dams and tanks.
2. Storage in situ, that is in the voids between particles of soil and sand.

For further information on water storage click here

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Evaporation, seepage and leakage

Almost every type of storage reservoir loses some of its stored water to evaporation, seepage or leakage.

Evaporation losses

Open water reservoirs, such as; tanks without roofs, ponds, earth dams and rock catchment dams, lose water due to evaporation. In hot and windy climates the evaporation rate may be over 3 mm per day which is equal to losing a depth of 0.9 metre of water in a month. Water tanks and rock catchments should therefore be

roofed but that is not feasible for ponds and earth dams.

Rainwater stored in the voids between the sand particles of riverbeds is the most economical water storage because up to 350 litres (35%) of water can be extracted from 1 cubic metre of coarse sand while only about 10% of water can be extracted from fine structured sand because its voids are smaller.

In hot regions without sandy riverbeds, rainwater can be stored in situ between the voids between soil particles, e.g. downstream of ponds and earth dams or in terraced land or in seasonal macro and micro irrigation structures as described in "Water Storage".

Seepage losses

In addition to evaporation loses, water stored in ponds and earth dams also lose water to seepage through the floor of these reservoirs. Fortunately, some of the seepage loses from ponds and dams can be utilized by sinking a shallow well into a seepage area. However, the combined losses of seepage and evaporation during long dry seasons usually result in the ponds and earth dams drying up except for very large earth dams.

The seepage loses through the floor of ponds and earth dams can be partly sealed by either:

1. Covering the floor with clayey soil or cow dung followed by cattle driven over the floor for compaction.
2. Waiting for several rainy seasons to deposit layers of silt.

Seepage losses from sand in riverbeds can be avoided if proposed construction sites with boulders and fractured rocks are rejected.

Leakage losses

Loss of water from leaking water tanks, water pipes, water taps should be prevented by using either bitumen paste or cement mortar.

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Gutters

Many rainwater harvesting installations do not perform as well as expected because of unsatisfactory gutters. It is therefore important to give careful attention to the materials used, the way the gutters are fabricated and the way they are installed. Ways of fabricating and installing low-cost gutters are described below.

Semi-circular gutters

The best known gutter is semi-circular and made either of galvanised iron sheet or PVC. Gutters are laid in gutter brackets nailed onto facia-boards or in V-shaped tree branches nailed to the rafters with a gradient sloping towards the water tank. Bamboos and Sisal poles can also be used as gutters when split in two halves.

Simple and cheap gutter laid in tree branches

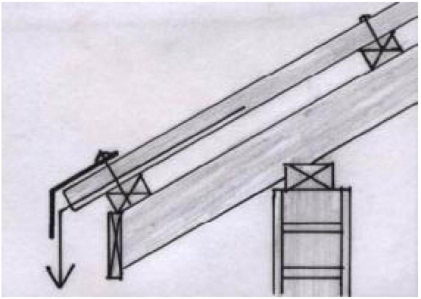
© E. Nissen-Petersen, Kenya

Gutter suspended with a straight slope from a splash-guard nailed onto an uneven roof

© E. Nissen-Petersen, Kenya

Splash-guards

They prevent rainwater from over-shooting gutters. They are made of strips of iron sheets bent at an angle and nailed onto the roof. Gutters are suspended with from the splash-guard using galvanized wires.



A splash-guard, a strip of galvanized iron sheet, nailed onto the roof.

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How to make and install Gutters with Splash-Guard

Marking an iron sheet into three stripes with a wire

© E. Nissen-Petersen, Kenya

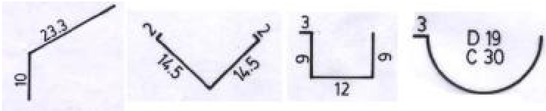
Cut galvanized plain iron sheets of gauge 26 or 28 into three strips, each being 200 cm long and 33.3 cm wide by marking the sheets with a thick wire, about 40 cm long, with each end having a sharp bend and a pointed end to scratch a line. The distance between the two bends must be 33.3 cm in order to make equal width of the cut sheets.

- **The metal strips are bent over a U-shaped piece of iron and hammered into shape with a piece of wood or a mallet.**

Bending the edge of an iron sheet

© E. Nissen-Petersen, Kenya

The shape of the metal strips depends on whether they shall be splash-guards or gutters with one of the shapes shown below: namely the V-shaped gutter, the square gutter and the semi-circular gutter.



From left to right: Splash-guard; V-shaped gutter; square gutter and semi-circular gutter

© Erik Nissen-Petersen, ASAL Consultants Ltd., Kenya

V-shaped gutter suspended from a splash-guard.

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Square gutter installed without splash-guard.

Gutters are fitted into hangers made of 3 mm galvanised wires that are bent over nails hammered into a piece of wood.

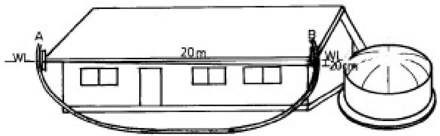
Gutters are fitted into hangers made of 3 mm galvanised wires that are bent over nails hammered into a piece of wood.

Gutters fitted into hangers tied to a splash-guard nailed onto an uneven roof

How to install Gutters

Gutters should be installed with a gradient of 10 cm depth for every 10 m length of a roof. This gradient of 1:100 will facilitate rain water running off the gutter with high velocity and no water will be wasted due to overflow. The high velocity of the water will transport leaves and debris to the inlet sieve without blocking the gutter.

Splash-guard being nailed into a roof



The two water levels in the hosepipe filled with water gives an exact horizontal level

Water level in a hosepipe filled with water

- **A gutter hanger is tied to the splash-guard with its bottom at the level of the water in the hosepipe. A second hanger is tied to the other end of the splash-guard near the tank. This hanger is tied to the splash-guard with a slope 1:100 below the water level in the hosepipe.**

A gradient of 1:100 is distance is found by dividing the length of a roof with a factor of 100.
For example; if a roof is 20 m long, the hanger at the water tank must be 20 cm lower than the other hanger to get the desired gradient of 1:100.

The first gutter laid along a drawn string

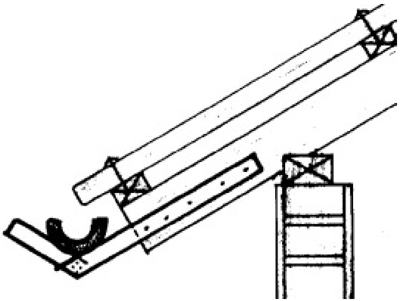
© E. Nissen-Petersen, Kenya

Gutter laid in hangers

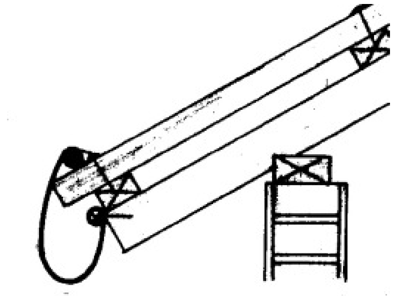
© E. Nissen-Petersen, Kenya

Two hangers are attached to the first gutter with one hanger at the middle and the other hanger at the end of the gutter. Bitumen is smeared on the inner end of first gutter before a second gutter is laid into it and so on until the whole length of gutter is installed.

Other Types of Gutters



PVC pipes or Bamboo cut in half can be laid in timber or branches nailed onto the rafters.



One side of galvanised and corrugated iron sheets can be nailed to the rafters, while the sheets are held in position by galvanized wires tied to the roofing nails.

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Storage reservoirs

The required storage capacity of a water reservoir depends on:

1) The daily required volumes and quality of water measured in litres.

2) The length of the dry seasons during which these volumes and quality of water are required.

Example on water demand for a homestead:

While the number of days in a dry season can be estimated fairly easy, such as 180 days without rain in a semi-arid region, the volume of water required for each of the 180 days can be calculated using the following guidelines on daily requirements of water for a rural homestead:

Water users	Daily requirements