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TECHNICAL DEVELOPMENT WITH DEVELOPING COUNTRIES
TWO TECHNISCHE WERKGROEP ONTWIKKELINGSSAMENWERKING

CATCHMENT AND STORAGE OF RAINWATER

C. PIECK

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TOOL is a Dutch foundation linking several (non-profit) groups which *together involve about 400 volunteers based in universities, technical* colleges and consulting engineering firms.

TWO

The Technical Working Group for Development Cooperation (Technische Werkgroep Ontwikkelingssamenwerking TWO), is a non-profit organisation of employees of DHV Consulting Engineers, Amersfoort, The Netherlands.

Numerous people in developing countries find themselves in a very difficult economic and social predicament. Appropriate technology can, in many cases, solve their problems. By placing at their disposal knowledge and technology, appropriate to the local circumstances, the above mentioned organisations wish to help improve the position of the less fortunate in society.

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1 INTRODUCTION

The Technical Working Group for Development Cooperation (Technische Werkgroep Ontwikkelingssamenwerking TWO), a non-profit organisation of employees of DHV Consulting Engineers, Amersfoort, The Netherlands, is often requested to supply developing countries with information on "Catchment and storage of rainwater".

Catchment of rainwater for consumptive use can be a welcome solution for, or an additional supply to existing provision for potable water.

Therefore this note may be helpful in countries which, although being situated in a zone with tropical rain forests, still have to contend with a relatively short drought. To bridge this drought two methods for catchment and storage of rainwater will be discussed. They are:

- catchment on the roof surface of dwellings or public buildings, and storage in a nearby tank,

- catchment on a slope, which has been specially built of compacted soils or linings, and storage in a basin which has been formed as a result of the excavation required to form this slope.

In this note small-scale provisions for potable water are described. They can be made with locally available techniques and materials. Prefab systems for building storage tanks which can be bought nowadays have been left out of this note because of their high purchase and transport costs.

Thanks are due to Jan Casteleijn, John Costa and Hans van Dijk for their critical remarks and their advice during the preparation of this note and to Frans Trieblinig for the translation in the English language.

Cees Pieck.

2 GENERAL

2.1 Design criteria

The principal data required to design a catchment for rain water are:

- the number of people who will use the provision, in other words: the seize of the population,
- the average daily consumption of the population,
- the losses through leakage and evaporation,
- the relevant data of the rainfall.

Other criteria needed for the design are:

- water to be tapped has to be free from pollutions and poisons,
- the surface of the material on which the rainwater will be collected has to be smooth and impermeable, and poisonous materials may not be used for its construction,
- the material to be used for catchment has to have a strong resistance against weathering (for instance damage by ultra-violet radiation),
- the construction of catchment and storage should be sufficiently strong to resist severe weather conditions such as storm and down-pour; nesting of birds and attraction of insects have to be avoided,
- annual cost of the installation has to be low which implies that also the cost of preparation and building will have to be as low as possible,
- maintenance cost will have to be low.

The installation for the provision of potable water to be described in this note will have to meet the criteria mentioned above. Besides the construction has to be simple.

2.2 Location

A good location of the water provision will have to fulfill the following requirements:

- at the shortest possible distance from the users,

- catchment and storage should be placed close together to avoid long conduits,

- the location should not be near or under obstacles in the field, such as high-tension lines or masts,

- the location should not be in the neighbourhood of trees to avoid the installation being dirtied by birds, falling leaves etc. or being damaged by falling branches,

- the storage should be built on the most elevated part of the side if water-transport from the storage to the consumers is to be effectuated by gravity. On a flat site, however, the storage has to be built above ground-level,

- possible damage by cattle should be prevented by means of a fence,

- special precautions (for instance drainage) are required to prevent the soil, which has to support the tank, from being inundated or washed away during high ground-water levels.

Practice has shown that the consumption of potable water from an installation situated in or near a dwelling, is 3 to 5 times higher than from a public tap.

2.3 Design population

Evaluation of the size of the population should be based on the present number of inhabitants plus the increase of the population during the planned period.
Generally the procentual population-increase is taken at 2.5 to 5 percent over a period of 5 to 10 years (which is called the "design horizon"). The percentages on population-increase vary strongly with country, culture and environment etc.
The maximum walking distance to a tappoint is taken at 200-400 metres. In the dry season people are often forced to cover very long distances, whereas in the wet season water is often taken from a polluted open well nearby. Consequently long walking distances should be avoided.

2.4 Average daily consumption

The absolute minimum for man to stay alive and to be able to work varies between 2 and 5 litres per person per day, depending on the

climate. Besides water is also needed for cattle, for personal hygiene, dish-washing and house-cleaning.
If the water has to be carried over long distances consumption will be inversely proportional to the distance.

The average daily consumption Q for a family of n persons can be calculated as follows. If distribution in any form whatsoever does not exist, the volume required daily for one family is:

minimum Q = 10 + n (x 5) litres
sufficient Q = 30 + n (x 7) litres

(Prof. Ir. L. Huisman's formula)

Calculation example

The minimum daily volume for a family with 5 persons is:
Q = 10 + 5 (x 5) = 35 litres/day, or 7 litres/person/day.

The sufficient daily volume is:
Q = 30 + 5 (x 7) = 65 litres/day, or 13 litres/person/day.

However, these values are a rough indication only, because the water consumption can substantially be influenced by climate, culture (e.g. islam), composition of the family, walking distance, level of development etc.

2.5 Precipitation data

Very often the feasibility of a system for catchment and storage of rainwater depends to a large extent on the intensity and the spreading of the rainfall. The precipitation intensity is the amount of water falling in a certain period (most often one year). The precipitation spreading is the distribution of the rainfall over this period.
The surface needed for catchment of the rainwater depends on the intensity of the rainfall, whilst the volume of water needed to bridge the period of drought depends on the spreading of the rainfall.

Often the data on precipitation are known for one or more locations in a country. However, a problem is that considerable differences can occur within a country. Worse still: in points only a few kilometres apart differences of more than 50 percent can occur.

Whether an installation is located -with respect to the dominant wind-direction- on the windward or leeward side of a mountain or hill can matter a lot. Nevertheless the so-called "design" precipitation will have to be estimated in order to be able to calculate the system. Very often it is advisable to do this in consult with experts.

Of course the best data can be obtained from the national meteorologic institute. If this is impossible good information can often be given by local agricultural stations. If nothing is available at all measurements will have to be carried out daily by one's self albeit for verification of the assumptions only.
Assuming reasonable data to be available, the selection of the data to be used is the next question. If data are available over a number of years it is likely that they also have been elaborated statistically. In that case the average anual rainfall is usually known but preferably a system should not be calculated on the basis of this one and only datum. It is better to take a relatively dry year as a starting point. Depending on the deviation over the years -the so-called spreading- and to prevent the emergency case in which storage tank or reservoir have run dry, a significant frequency of 5 or 10 years can be selected. This means the selection of a rainfall-intensity which on the average will not occur once in 5 or in 10 years (which means that it is drier).

The spreading of the rainfall on which the design has to be based can be calculated by establishing the average for each month first of all. Thereafter the rainfall which is not exceeded once in a period of 5 to 10 years can be calculated. The period without rain should not be taken too short because the quality of the system depends on the frequency-duration in which the storage tank is empty.

2.6 Leakage and evaporation losses

Losses through leaks are caused by:

- the use of materials which are not completely watertight such as roof- covers, gutters, down-pipes etc.,
- using leaky couplings or connections,
- applying materials which are not wholly watertight for compaction of the surface, such as linings, compaction materials etc.,
- using materials which are not wholly watertight for building of tanks and reservoirs,
- tap-points which are not completely turned off.

Evaporation losses depend on:

- the size of the (open) watersurface,
- the temperature,
- the wind,

- the storage-time.

In first instance evaporation losses can be reduced by keeping the open watersurface as small as possible with the consequence that the depth of tank or reservoir has to be larger. It is also advisable to provide the tank or the reservoir with a cover. A large span covering, however, may cause constructional and financial problems.

Other methods to cover the evaporation surface are:

- pouring a thin layer of alcohol on the water surface. Because of the cooling effect of the alcohol the water will evaporate less quickly,

- it is better to pour a layer of heated wax on the water. This layer is kept flexible by the heat of the sun, although cold weather will cause cracks. On the other hand evaporation losses will be smaller in cold weather,

- also small plastic balls and polysterene foam can avoid evaporation because they form a floating and flexible layer. The colour of the material used should be white, because this is the most reflective colour.

2.7 Water quality

There are various norms with regard to the water quality. The World Health Organisation (WHO) has laid down the qualitative requirements in "International Standards for Drinking Water".

Amongst others these standards require that:

- water for human consumption may not contain chemicals or micro-organisms in quantities which can be dangerous for the health,

- the water may not be turbid, it must be without colour or smell, and it should have an agreeable taste,

- all possible foci of infection have to be excluded,

- the water must contain a sufficient amount of oxygen and its temperature must be adequate.

In many cases, however, the qualitative requirements of the WHO mentioned above are not feasible.
The most important requirement is that in no case the water may be harmful to the "human health". It follows that bacteriologic reliability is an important requirement, as are the chemical-physical norms, for instance the contents of nitrate and fluoride.

The consumers, however, can immediatly ascertain taste, smell and colour and therefore the influence of these qualities is bigger than of the other ones mentioned earlier. However, it is difficult to make consumers understand that a bad taste is not always the result of chemical or biological defilements.
Especially because of favourable climatic conditions for pathogenic organisms the bacteriologic quality of the water in developing countries is by far the most important factor in the reliability of drinking water and in the occurence of diseases.
Many illnesses, however, are not caused by water of inferior quality only, but especially by an absolute shortage of water, even if this water is of good quality.

In the following table a classification is given of diseases which -in one way or another- are related to water. Of each type examples are given.

category	example
1 Faecal-oral	
(water-borne or water-washed)	
a) low infective dose	cholera
b) high infective dose	bacillary dysentery
Water-borne infections	
a) classical	typhoid, cholera
b) non-classical	infective hepatitis
2 Water-washed	
a) skin- and eye infections	trachoma, scabies
b) other	louse-borne fever
Water-washed infections	
a) skin and eyes	scabies, trachoma
b) diarrhoeal diseases	bacillary dysentery
3 Water-based	
a) penetrating skin	schistosomiasis
b) ingested	guinea worm
Water-based infections	
a) penetrating skin	schistosomiasis
b) ingested	guinea worm
4 Water related insect vectors	
a) bitting near water	sleeping sickness
b) breeding in water	malaria
Infections with water-related insect vectors	
a) bitting near water	sleeping sickness
b) breeding in water	yellow fever
5 Infections preliminary of defective sanitation	hookworm

The relation between the water and the diseases mentioned in the table given above are:

- "water-borne diseases" are infective diseases which are being spread by waterways or by systems for waterprovision,
- "water-washed diseases" relate to infective diseases brought about by a shortage of water for personal hygiene,
- "water-based diseases" are infective diseases carried by organisms living in water,
- "water-related insect vectors" are infective diseases being spread by insects which are dependant on water.

The present knowledge of tropical epidemiology shows that in developing countries with a hot climate the low income population groups have the highest death-rate as a result of direct faecal-oral infections and of infective diseases caused by shortage of water for personal hygiene.

Besides improving the bacteriological quality also the increase of the amount of water and an improvement of its availability should be aimed at.

The table below gives a summery of the most important measures to improve the situation with regard to the various infective diseases.

Transmission mechanism	Preventive strategy
water-borne	- improve water quality - prevent casual use of other unimproved sources
water-washed	- improve water quantity - improve water accessibility - improve quality
water-based	- decrease need for water contact - control snail population - improve quality
water-related insect vector	- improve surface management - destroy breeding sites of insects - decrease need to visit breeding sites

The water quality can be increased still further by disinfection (see section 2.8) or by filtration (see section 3.2).

2.8 Disinfection

By means of disinfection pathogenic organisms can be killed.

There are physical as well as chemical methods for disinfection for small-scale applications, the usual physical methods are:

- boiling (5 - 20 minutes),
- filters (as indicated in section 3.2) or certain domestic filters, such as the Berkefeld filter (fig. 3).

The usual chemical method for small-scale applications is: adding a dose of bleaching-powder and/or chlorine to the water.

Usually bleaching-powder is applied in solutions with 2.5 or maximum 5 percent in weight of active chlorine, in other words 25 or 50 grammes of active chlorine per liter bleaching-powder. However, of bleaching powder containing 25 percent of active chlorine, only 5 to 10 grammes have to be dissolved in 1 litre water.

Chemical means for disinfection can rapidly become obsolete, as a result of which their activity decreases. The phenomenon occurs often in developing countries because transport in general takes much time. It is therefore advisable to create a stock which, if stored in a dark and cool space, can reduce the loss of active chlorine to about 5 percent per month.
The amount of the dose depends on the quality of the water. It follows that dosage has to be carried out within certain limits. Below the lower limit the addition of chlorine has no effect, and above the upper limit the water becomes undrinkable so that the consumer soon returns to the old polluted source.

Therefore it is important that one person of the community is charged with the responsibility for dosing the disinfectants. Preferably this person should attend a training course to become acquainted with this work.

A reasonable good dosing method for continuous disinfection is the so-called "pot-chlorinator". It is made from a coconut (fig. 1) filled with a disinfectant consisting of bleaching-powder and coarse sand in the ratio by weight of 1:1 or 1:2.

- The mixture of bleaching-powder and sand is put in a plastic bag with tiny holes

- For protection it is placed in the shell of a coconut which in turn is suspended about 1 metre below the watersurface, and as far away as possible from the discharge connection of the storage tank

- Slowly and gradually the active chlorine will dissolve in the water, thereby killing the pathogenic germs

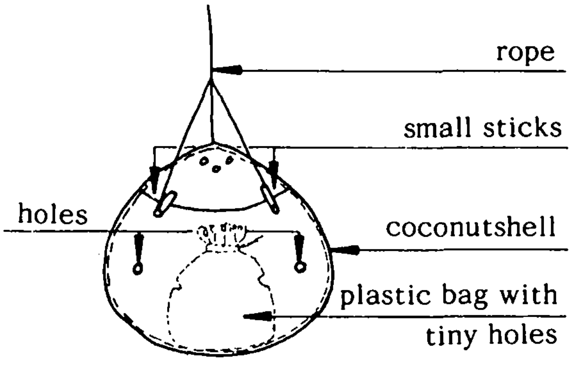


fig. 1

- After 1 to 3 weeks the content of the pot will have to be replaced

A dosing apparatus can also be made from a plastic jerrycan (fig. 2). Filling is by means of a hole made in the bottom of the can. The hole is closed with an airtight lid. The float ensures constant dosing.

In the bucket 100 grammes of chlorine are mixed in 5 litres water. Before pouring this mixture into the dosing apparatus it has to be left alone a few hours after which the inactive sediment has to be removed. Otherwise the water might taste bad because of chlorine residue.

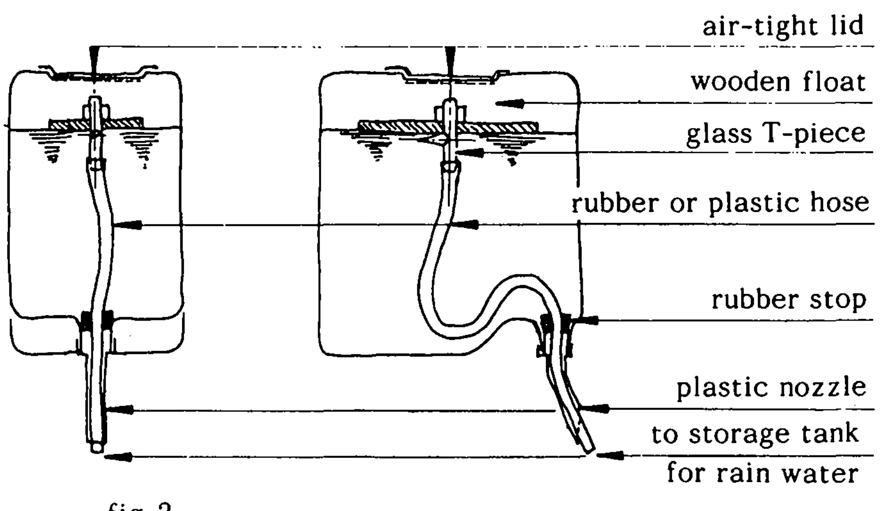


fig.2

DOSING APPARATUS

Another very current type of pot-chlorinator of a pot made of porous earthenware.

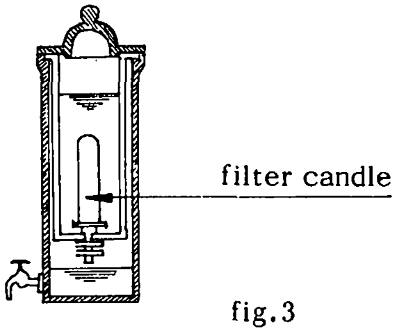


fig.3

BERKEFELD FILTER

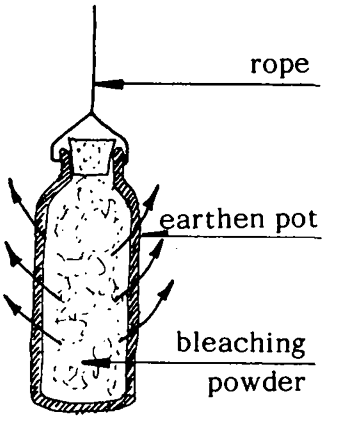


fig.4

POT CHLORINATOR

- The dimensions of this type are: diameter about 20 cm, height about 50 cm, wall thickness varying between 2.5 and 10 mm.

- After the pot has been filled with moist bleaching-powder it is closed with a cork and suspended about 1 meter below the water level in the storage tank.

- Here also the content will have to be replaced after 1 to 3 weeks.

If necessary the taste of chlorine can be removed by means of an active carbon filter.

2.9 Cost of drinking water

To a large extent the consumption of potable water depends on its cost. Consequently one of the first requirements is that the consumer-price may not bear too much on the family-budget.

Supplying drinking water free of charge can arouse the impression that there is always enough water available and this in turn can create a high consumption. The risk of an elevated water-tariff is that people return to unreliable sources in the wet season.
It follows that the water has to be supplied at a reasonable price. This implies that the designers have to look for a compromise between economic facts and the hygienic needs.

The population should participate in the project through the supply of labour, material and money. In this way a considerable saving in cost is possible. Compared with other development projects drinking water provisions are extremely efficient. The return does not show in the form of financial profit, but -after a certain period- in the decrease of the illness-rates. An investigation carried out in Venezuela demonstrated that every dollar invested in a drinking water provision yielded a saving of 8 dollars on cost of sickness as well as a higher work-performance. (C.E.A. Winslow, WHO Monograph Series no. 7).

The best way for the government to financially support the village communities is by means of loans with a low interest or without any interest at all.
Financing in the form of so-called "revolving funds" has been applied sucessfully in Brazil, where a number of villagers obtained interest free capital. Paying by instalments started one year after the installation was put into use. The instalments were then used to provide other communities with capital. After the community had paid off the loan in about 8 years the revenues could be used for maintenance, repairs, improvement and extention. (C.E.A. Winslow-WHO)

2.10 Future users

Already in an early stage the future consumers of the water should be attracted to and engaged in their own drinking water provision. For them it is of utmost importance to be aware that illnesses and deaths can be prevented by the consumption of sufficiently reliable drinking water.

Sometimes, however, resistance and opposition against a drinking water project can come to light during -for instance- education in personal hygiene in the form of:

- religious resistance,
- accepting illnesses as laws of nature,
- resistance because of a low development level,
- dislike of new methods,
- resistance to financial contributions.

Objections like these are only disproved with success if future water users can be made to realize the profits of the new installation.

If possible the installation should be built by the users themselves. They also have to be taught:

- how to maintain the installation
- how repairs can be carried out (handpumps and tap-points)
- how defects can be prevented.

3 ROOF COVERING AND FILTRATION

3.1 Roofcovering

Climatic conditions have a large bearing on the design of an installation for catchment and storage of rainwater and on the choice of the building materials. High temperatures, ultraviolet radiation, down-pours, storms, and also insects, vegetation and soil conditioners can have a considerable influence on the selection of the building materials.

In developing countries as much advantage as possible should be taken of local raw materials and locally made parts and materials.

Roof cover to be used for catchment of rainwater has to be made of smooth and flat material such as:

- roofing tiles,
- slate,
- galvanized iron corrugated slabs,
- aluminium foil,
- bituminous felt and paper strengthened with sisal.

Asbestos should not be used as roof cover because it can cause an unacceptably high concentration of asbestos particles in the drinking water.
Also straw and thatched roofs should not be applied because they often harbour harmful germs, insects etc.

Rainwater should be collected from the roof in a gutter. By means of a down-pipe or a gutter the water can then flow through a filter into a storage tank (fig. 5).

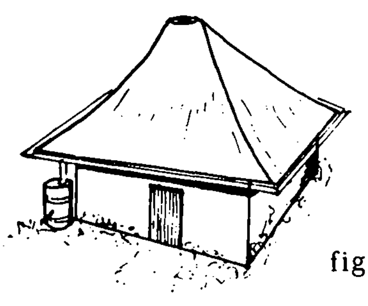
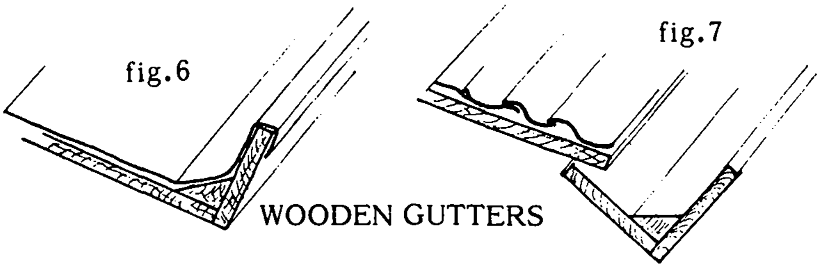


fig.5

COLLECTING RAINWATER FROM THE ROOF

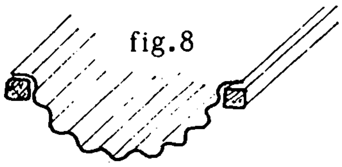
As the roof-surface of separate dwellings is relatively small a larger surface can be created by connecting various roofs by means of pipes or gutters.
Enlargement of the catchment area can also be realized by giving the roofs larger overhangs.
Gutters can be made of wood (fig. 6 and 7 next page) or of bent aluminium or steel sheets (fig. 8 and 10 next page). In the latter case suspension is by means of metal bends (fig. 9 next page).

fig.6 fig.7



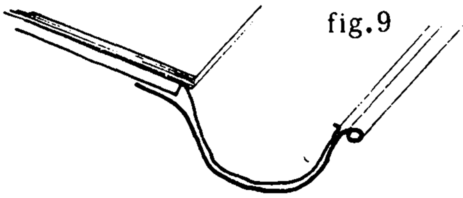
WOODEN GUTTERS

fig.8



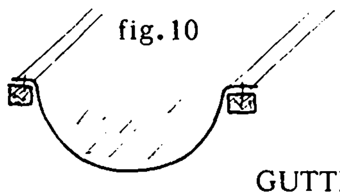
GUTTER MADE OF
METAL CORRUGATED SHEET

fig.9



METAL BEND FOR
SUSPENSION OF GUTTER

fig.10



GUTTER MADE OF
GALVANIZED STEEL SHEET

3.2 Filtration

The water has to be made free from dust, dead leaves and bird's waste by means of a filter between the catchment area and the storage tank. The best position of the filter is on top of the storage tank. The filter can be made from an oil drum.
First of all a number of holes 5 mm diameter are drilled in the bottom. The total opening of all holes together should be about 8 % of the bottomsurface.
Starting from the bottom upwards the following layers are built up:

- gravel (6 - 10 mm) thickness 10 cm
- palmfibres thickness 15 cm
- gravel (3 - 6 mm) thickness 15 cm

(fig.11)

This method, however, is unsuitable for removing all bacteria (see disinfection). Consequently it is advisable to boil the water before drinking, and especially so for people who have no resistance against local bacteria.

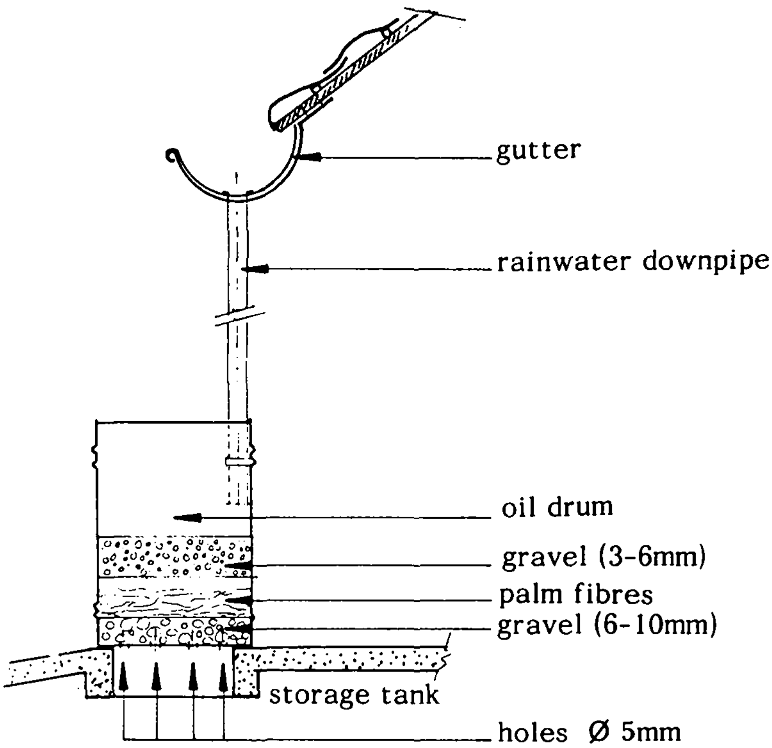
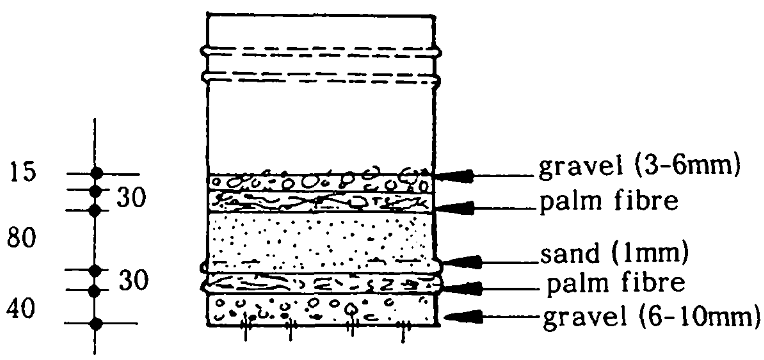


fig.11

dimensions in millimeters



FILTER (variant)

4 VARIOUS KINDS OF STORAGE TANKS AND RESERVOIRS

Storage tanks and reservoirs can be built above ground level as well as in the earth. They have to be provided with an overflow on top and a discharge point about 5 cm above the bottom.

4.1 Storage tanks above ground level

Storage tanks above ground level could be made from an oildrum or various kinds of materials.

4.1.1 Storage tanks made of wood

Wood, for instance a water-butt. Instead of using an ordinary wooden water-butt a storage tank can be built on the same principle, although with larger dimensions, of planks or deals of firwood kept together by metal tension ties. In this way tanks of up to about 40 m^3 can be built.

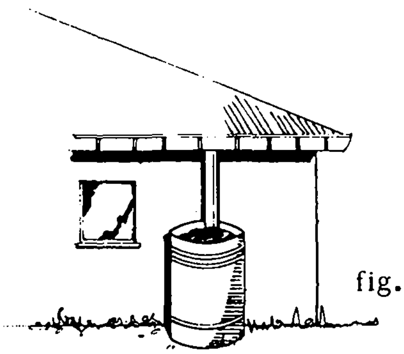
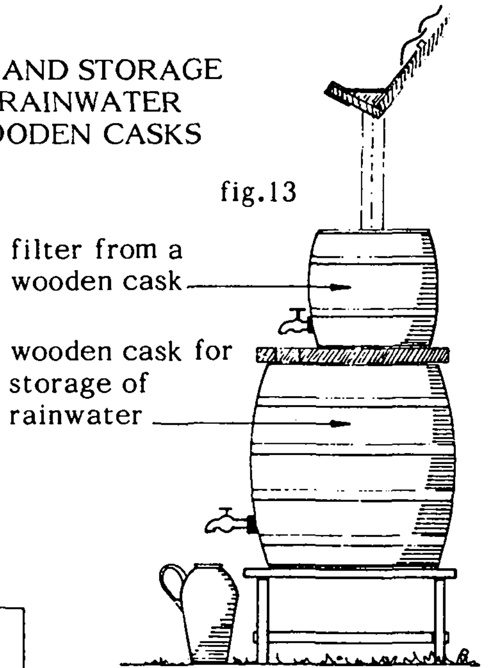


fig.12

RAINWATER STORAGE
IN OILDRUM

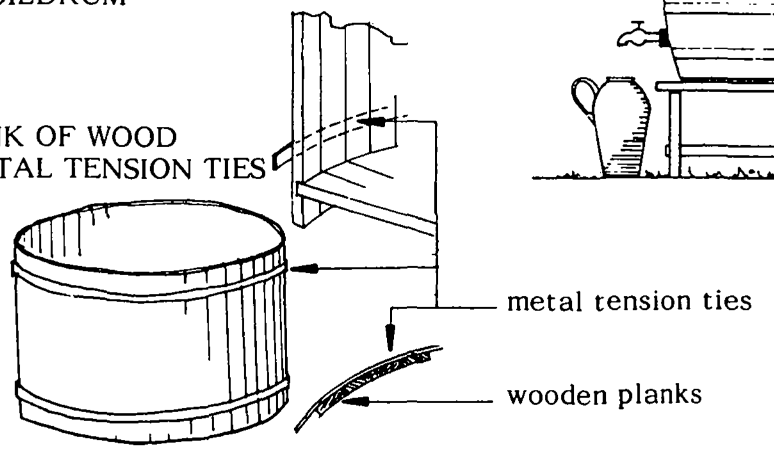
FILTER AND STORAGE
OF RAINWATER
IN WOODEN CASKS

fig.13



TANK OF WOOD
WITH METAL TENSION TIES

fig.14



4.1.2 Storage tanks made of baked clay

In many developing countries people are very skilled in manufactering jars and vessels of baked clay. However, the capacity of these vessels is of necessity rather small.
Simple glazing techniques will help to make the vessels more watertight.

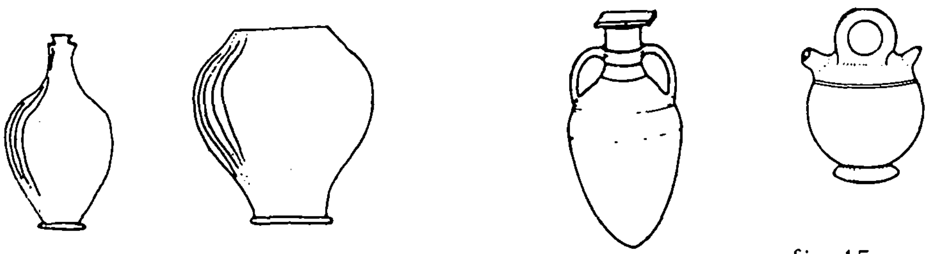


fig.15

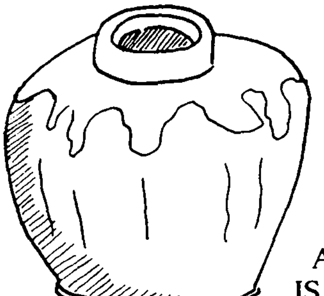
JARS AND VESSELS OF BAKED CLAY
IN VARIOUS FORMS

4.1.3 Storage tanks made of cementplaster

In Kenya UNICEF has developed a tank with thin walls which can be manufactured as follows. A mould is made in the form of a gunny of jute fibre filled with sand or earth. Next the gunny is plastered with mortar of cement and sand in the ratio 1:2, in layers of 0.5 cm to a final thickness of 2-2.5 cm.
After the plaster has hardened the contents of the gunny and the gunny itself can be removed. Finally the tank is covered with a plastic foil during 2 weeks after which it can be put into use.
In this way tanks can be made with a volume of 0.25 m^3 maximum.

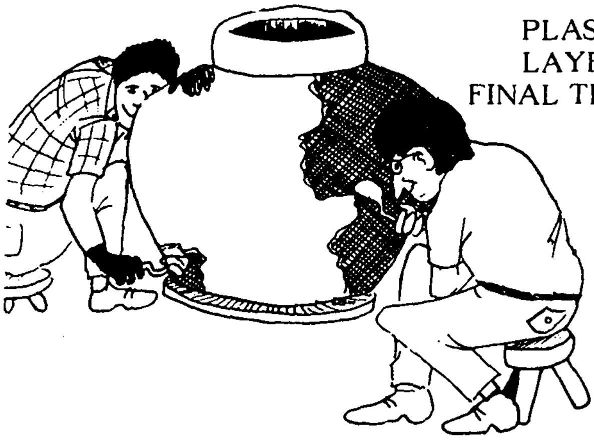
THE GUNNY IS BEING
FILLED WITH SAND

THE GUNNY IS
CLOSED AND PLASTERED



A WOODEN RING
IS PLACED ON TOP

fig.16



PLASTER IS APPLIED IN LAYERS OF 0.5 cm TO A FINAL THICKNESS OF 2 - 2.5 cm

4.1.4 Storage tanks made of framework filled with cement

Frames can be made of branches or bamboo and plastic foils. From these materials big tapered baskets are made which then are plastered inside with a mortar of cement and sand in the ratio 1:2. Plasterwork has to be continued till all holes in the framework are filled and the wall thickness has become 2 to 2.5 cm.
After hardening of the mortar the tank has to be covered with a plastic foil to keep it moist. After two weeks the tank is ready for use. The largest tanks which can be made in this way have a volume of about 3.5 m^3.

See also: "Kehenge water storage tank" UNICEF, Nairobi, Kenya.

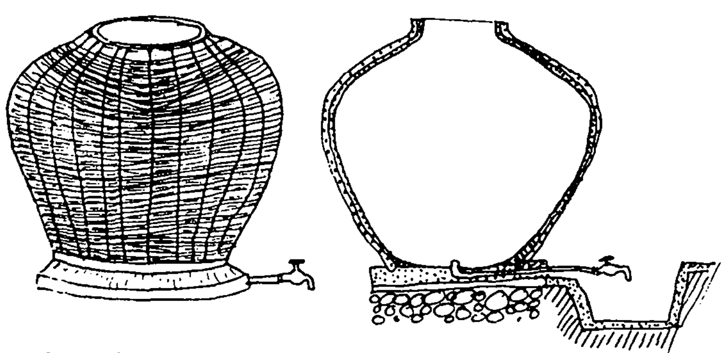


fig.17

BASKET MADE OF INTER-WOVEN BAMBOO OR BRANCHES WITH AN INSIDE COATING OF PLASTER

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FOR COMMUNITY WATER SUPPLY AND
SANITATION (IRC)

4.1.5 Storage tanks made of metal sheets

Watertanks can also be made of galvanized iron sheets, riveted or soldered together. Inside a steel or wooden structure should be fixed to prevent deformation of the tank. Also corrugated steel sheets can be used for the construction of the tanks.
As the manufacture of metal tanks requires some professional skill local people will have to be trained to get familiar with this type of work.
The largest metal tanks built in this way can have a volume of about 10 m^3 .

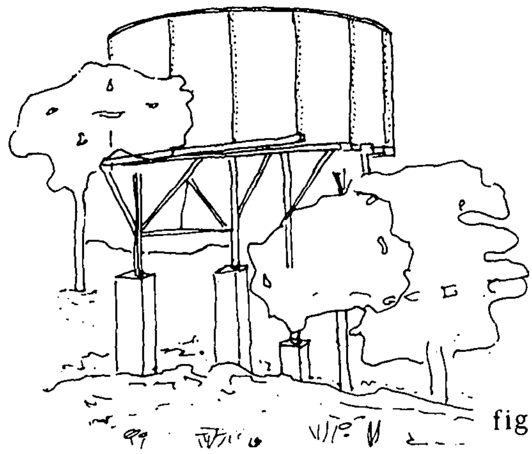

fig.19

ELEVATED WATERTANK
MADE OF METAL SHEETS

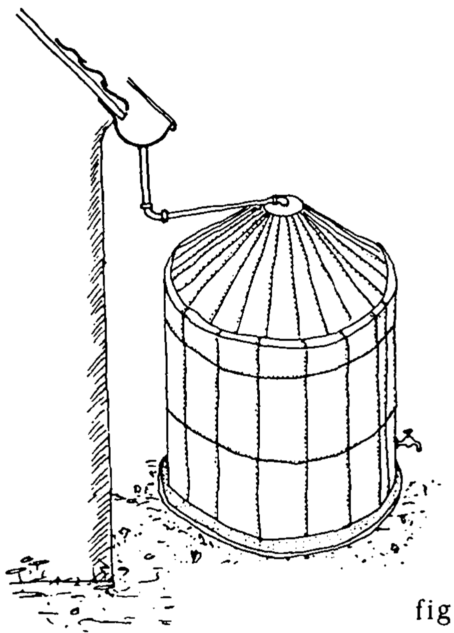

fig.20

WATERTANK OF METAL SHEETS
FOR STORAGE OF RAINWATER

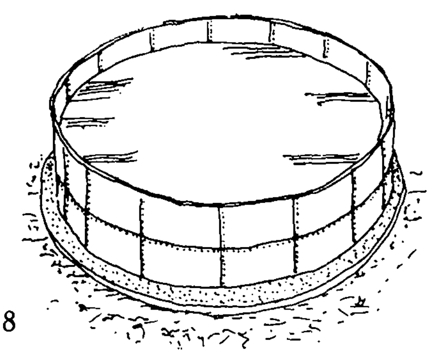

fig.18

WATERTANK MADE OF METAL
SHEETS AND SUPPORTED BY
A REINFORCED CONCRETE SLAB

4.1.6 Storage tanks made of brickwork

Brickwork is very suitable for building larger tanks than the ones described up to now. However, bricks or natural stone have to be of good quality. Cement to be used has to be Portland cement and it must be stored in a dry space. Sand must be clean and without chemical or organic matter. Also the water has to be absolutely clean and without salt. Salt would be disastrous. Mortar has to be prepared in the ratio 1:2 or 1:2.5. Before the bricks are laid they have to be moistened and, once laid, they may not be shifted.

Vertical joints should never be applied in line, one above the other. To ensure a watertight construction the horizontal and vertical joints at the inner side of the tank should be scratched after which the entire wall (inside the tank) should be plastered with a layer of about 1.5 cm thick. Also in this case the whole tank should be covered with a plastic foil for 2 weeks.

Tanks of 150 m^3 maximum can be built in this way, provided the thickness of the walls is adjusted to the volume of the tank.

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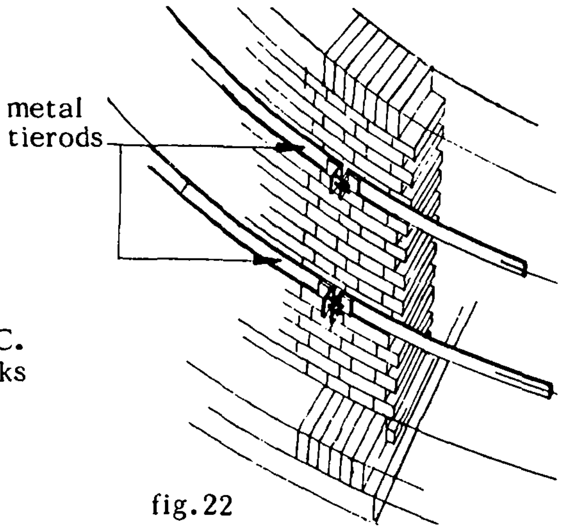


fig.22

PART OF A TANK MADE OF BRICKWORK WITH METAL TIERODS

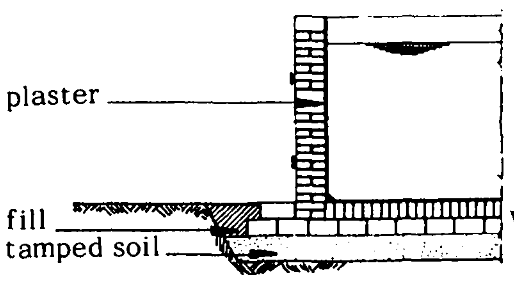


fig.21

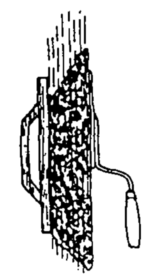
VERTICAL SECTION OF A PART OF THE TANK

4.1.7 Storage tanks made of ferrocement

Ferrocement is suitable for both large and small tanks. It is a cement mortar which is manually applied on a very dense steel reinforcement which prevents cracks to be formed by high temperatures.
The reinforcement itself consists of several layers of wire-netting in combination with rings of steel bars for absorbtion of tangential tensions. Cement has to be Portland cement, stored in a dry space, sand and water for preparing the mortar have to be clean, and may not contain salt or chemical or organic matter. The mortar has to be prepared in the following ratio 1 cement (volume) : 2 sand (volume) : 0.4 water (weight).
After the bottomslab of reinforced concrete has been poured a mould is placed against the vertical ends of reinforcement bars protruding from the bottom slab. The mould can consist of a bamboo frame covered with a wooden mat, or of threeply- or multiply-wood provided with sted rings on the innerside. Wire netting and rings of steel reinforced bars are stretched around the mould after wich the outside is plastered with layers of 1 cm. Then the mould is removed and the inside plastered till the wall has reached its required thickness.

The roof is also made of ferrocement in the same way. After the plastering has been finished the tank is covered for 2 weeks with wet gunny sacks or with plastic foil. In this way tanks with a volume of 500 m^3 maximum can be made.

fig.24



APPLYING LAYERS OF PLASTERS FOR A TANK BUILT WITHOUT A MOULD

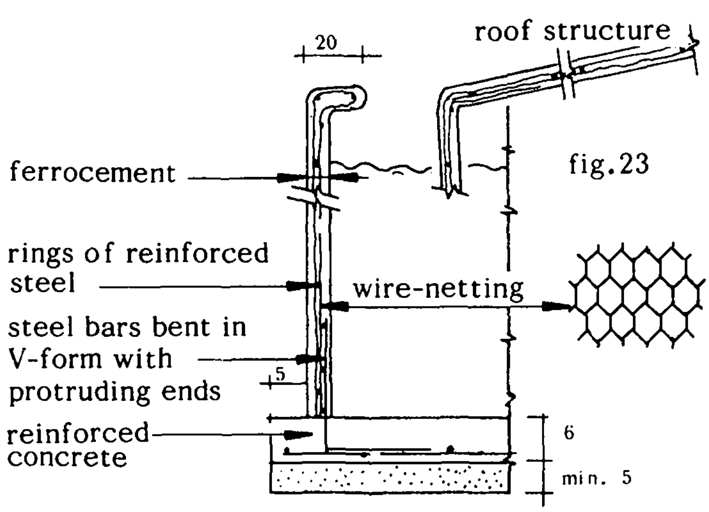
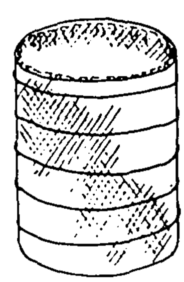


fig.23

VERTICAL SECTION OF A PART OF A TANK MADE OF FERROCEMENT

dimensions in centimetres

fig.25



MOULD MADE OF WOVEN CANE OR FIBRE MAT

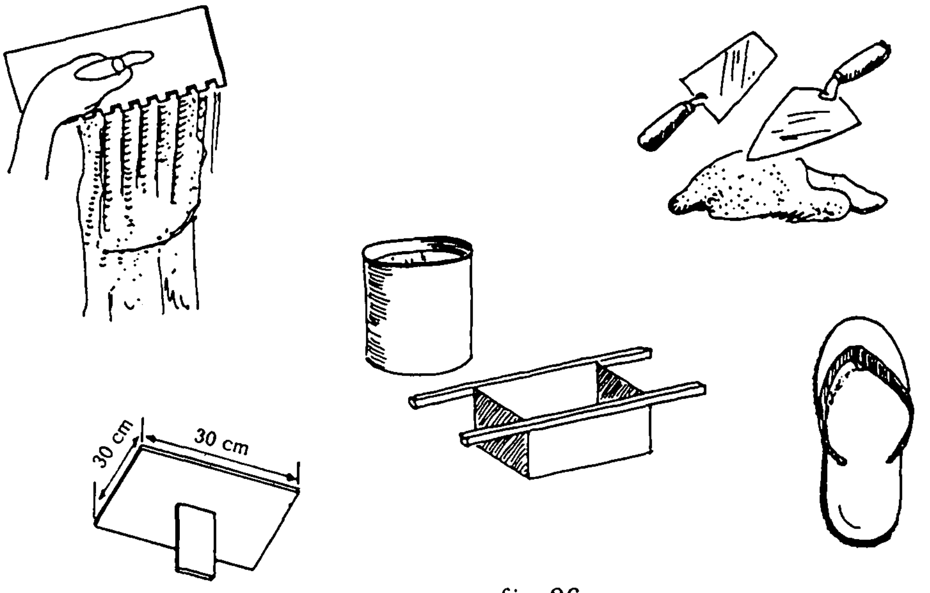


fig.26

TOOLS FOR MAKING A
FERROCEMENT WATERTANK

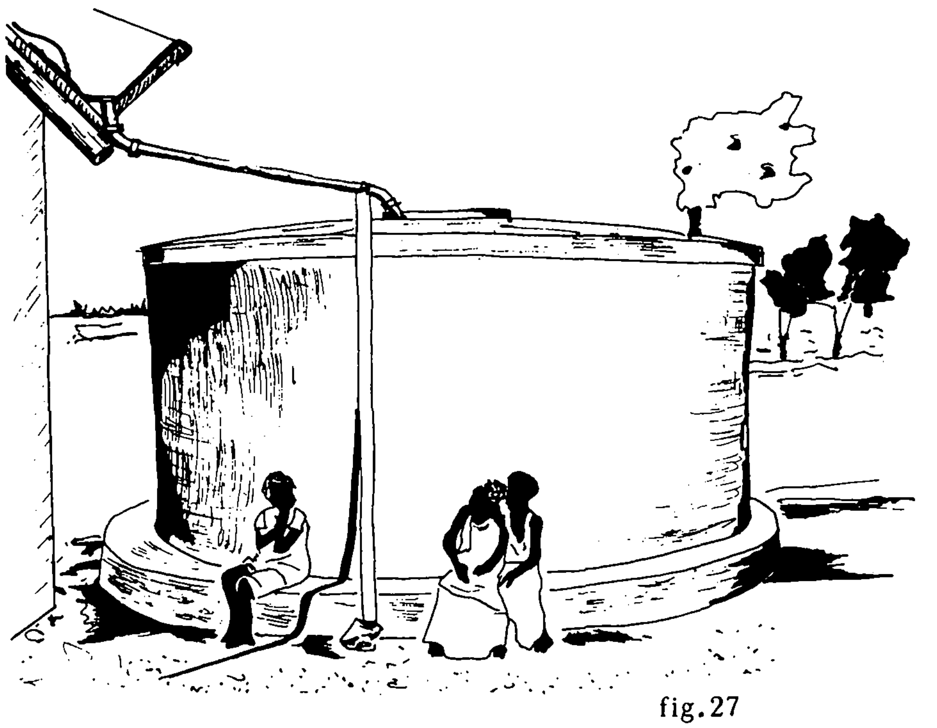


fig.27

FERROCEMENT WATERTANK
NEAR A COMMUNITY HOUSE

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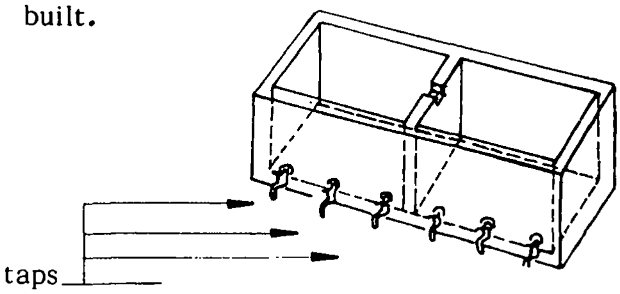
4.1.8 Storage tanks made of reinforced concrete

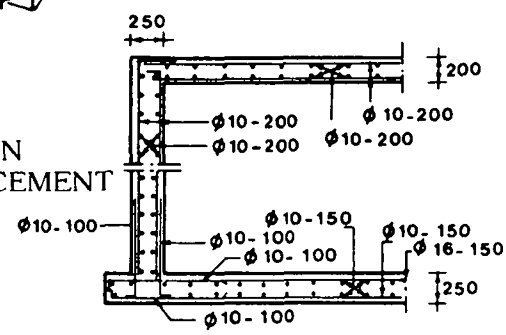
Larger tanks can be built of reinforced concrete. However, this material requires a relatively large quantity of -often expensive- cement. Also the cost of reinforced steel is high. For these reasons the material is less appropriate for small-scale use in developing countries.

After completion of the structural calculations the moulds can be made. Next the reinforcement, consisting of round bars is placed. Its function is to absorb tensile and shrinkage stresses.
The concrete itself is prepared in the ratio of 1 cement, 2 sand and 3 gravel and will have to absorb the compression stress. The moulds are made of wood and can be removed after the concrete has hardened.
In this way tanks with a storage capacity of 500 m^3 and over can be built.



REINFORCED CONCRETE WATERTANKS WITH TAPS

fig.28



CROSS SECTION SHOWING REINFORCEMENT

fig.29

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4.1.9 Storage tanks made of earth bunds

First of all the top layer (20 cm thickness) of the soil has to be removed and replaced by a sand-fill or by soil without sharp objects, roots and the like. The fill has to be compacted. The soil-layer which supports the P.V.C. foil has to be sterilized, for instance with diesel oil. Next the P.V.C. foil is spread over the bottom and the slopes. At the top of the slopes the foil is kept in place by means of tree-trunks (fig. 30).

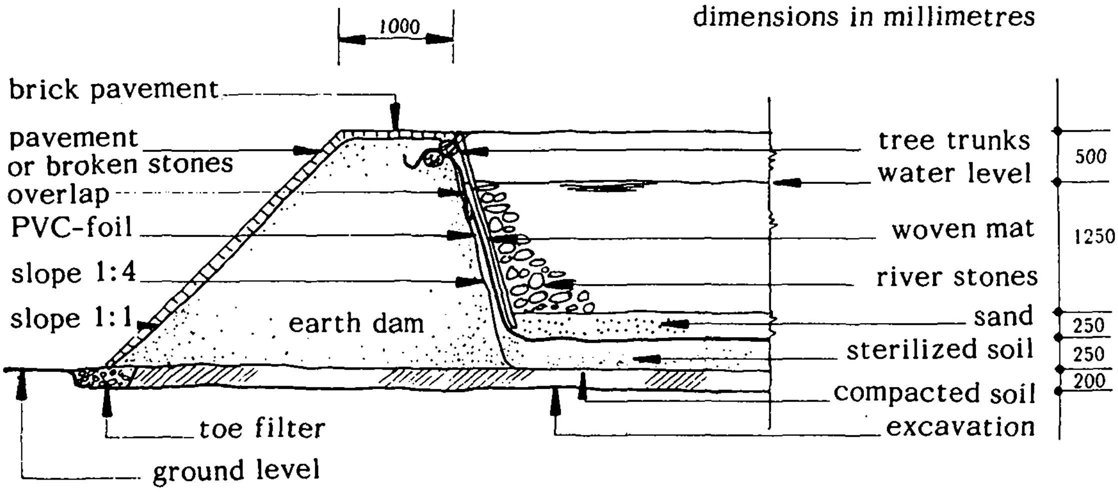

fig.30

RESERVOIR MADE
OF EARTH DAMS

The pieces of P.V.C. foil can be welded together by means of a soldering-bolt or a flat-iron. The foil has to be protected against ultra-violet radiation by means of a layer of sand on the bottom and woven mats against the earth dam. The mats are kept in place by tree-trunks at the top and supported by river stones at the lower end.
Methods for covering the reservoir are described in section 4.2.3

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4.1.10 Storage tanks made of sand-cement sausages

This practical example of appropriate technology was worked out by Doxiadis Ionides Associates Ltd, in Ripply, Surrey, England and has been applied with success by ITDG in Botswana and in Sudan.
Rainwater reservoirs built from this material can be made in an excavation or above ground level by means of earth dams.

After excavation of the pit or having built the surrounding earth dam all sharp objects have to be removed. Next the soil is sterilized by -for instance- diesel oil. Then polythene foil with a thickness of 0.025 mm is spread over bottom and slopes. The various pieces of the foil should overlap at least 1.5 m, which can be reduced to about 10 cm by using a special polythene adhesive. The polythene foil is covered with 15 cm of mud or clay. On top of this layer another layer of polythene foil is spread (fig. 31).

The function of the sausages is to protect the polythene foil on the bottom as well as on the slopes. They are made of tubular polythene foil with a thickness of 0.025 - 0.25 mm and a diameter of about 9 cm. This type of foil is often used for packing purposes and is produced in rolls.

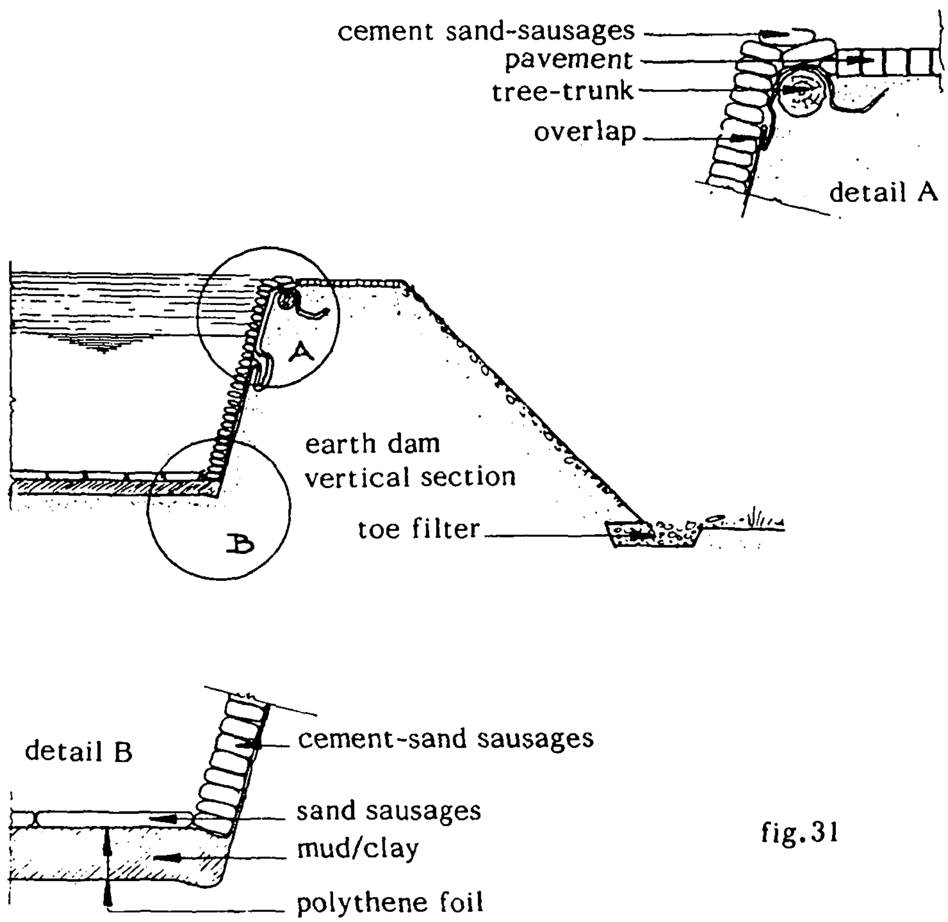


fig.31

The foil is cut into pieces with a length of 80 cm, which are then knotted at one end and filled with a mixture of dry sand and cement in the ratio of 14:1. After having filled a large number of the sausages tiny holes are pierced 10 cm apart in the foil and then plunged in a trongh with water for about 5 minutes. Finally they are stocked against the walls in stretcher bond and rammed with a plank. The polythene foil prevents water needed for hardening to evaporate too quickly. After the mortar has hardened the polythene foil may be broken down by ultraviolet radiation.
The sausages which are to protect the bottom can be filled with sand only.
Covering the reservoir is described in section 4.2.3

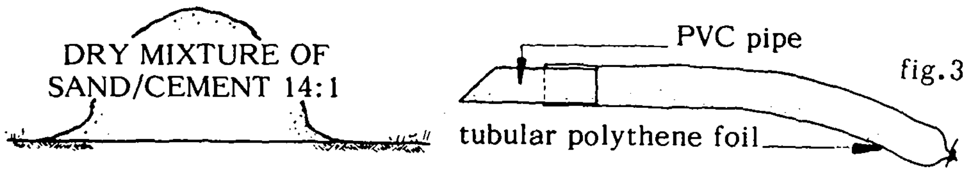
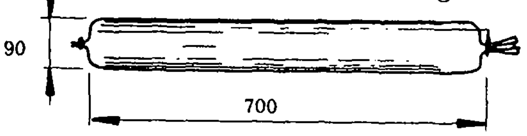


fig.32

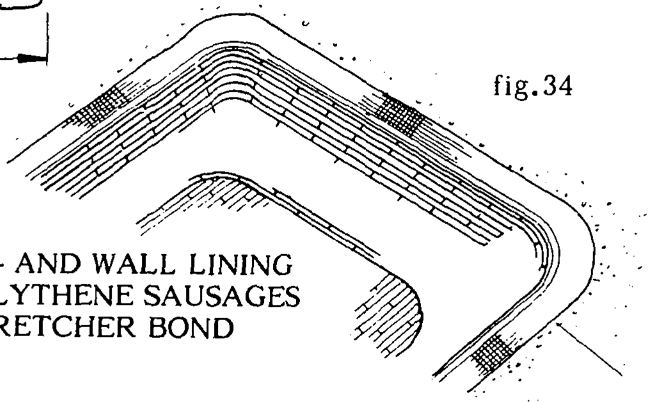
FILLING THE POLYTHENE SAUSAGES

fig.33



POLYTHENE SAUSAGE

fig.34



BOTTOM- AND WALL LINING
WITH POLYTHENE SAUSAGES
IN STRETCHER BOND

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4.2 Storage reservoirs below ground level

Advantages of storage reservoirs below ground level are:

- the stored water stays cool, consequently its quality is preserved,
- losses of water through evaporation are practically nil, provided the reservoir is covered.

Covering the reservoir also prevents the water becoming:

- polluted by dust, human or animal refuse, dead leaves and other rubbish,
- infiltrated by high subterranean water.

Finally covering prevents the growth of algae and the development of mosquitos.

It should be stressed that reservoirs and tanks without covering are in general inappropriate for storage of drinking water because of pollution and growth of algae.

4.2.1 The bottle reservoir

An example of small-scale catchment and storage of rainwater is the so-called "bottle reservoir" designed to supply drinking water for one family only, (about 5 persons)(fig. 35).
The bottle can be made of brickwork, ferrocement or sand-cement sausages.

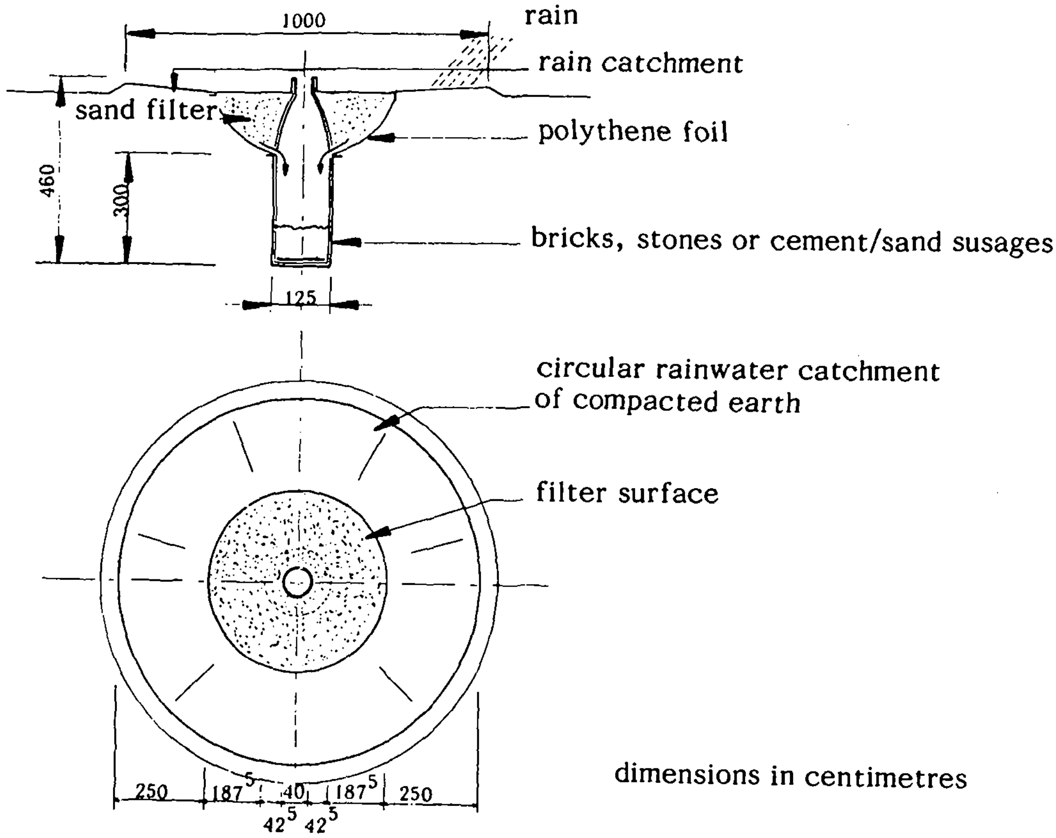


fig.35
BOTTLE RESERVOIR

4.2.2 Reservoir with catchment slope

An example of a somewhat larger catchment and storage of rainwater is an artificial slope, built with soil excavated for the reservoir (fig. 36).

The criteria to be met by this system are given in section 2.1.

Before starting the activities the site should be fenced to prevent damage by cattle.

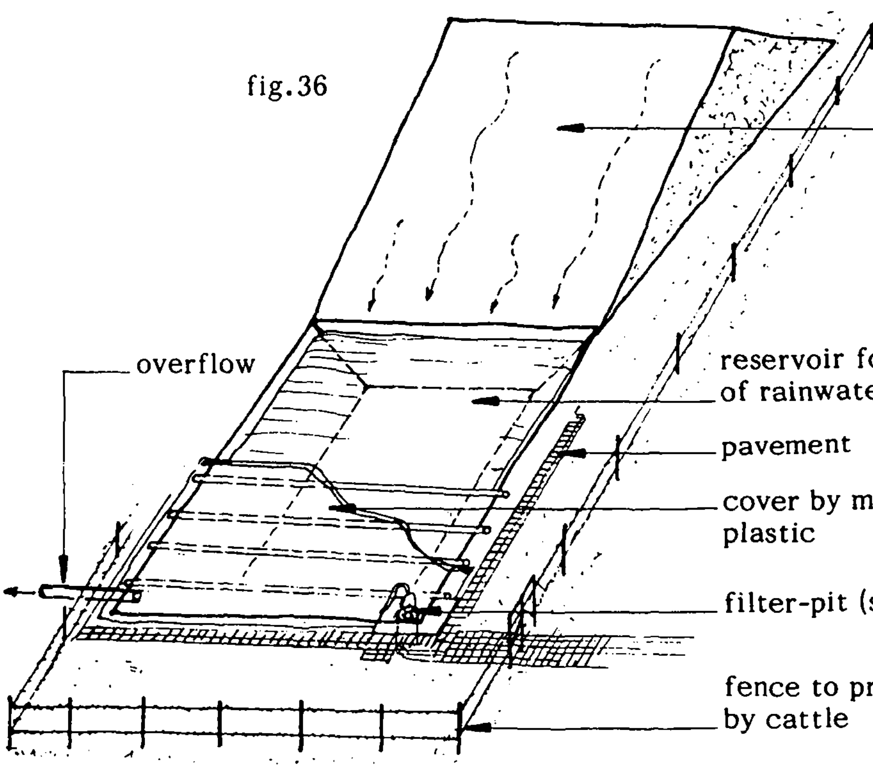
The watertight upper layer of the slope can be made of:

- bricks of which the joints are filled with tar,
- galvanized corrugated steel sheets,
- asphalt,
- cement,
- bitumen.

The watertight layer of the walls can be made of :

- P.V.C. foil
- sand-betonite
- bitumen
- sand-cement sausages

fig.36



Application of P.V.C. or polythene requires sterilization of the lower layer to a thickness of 30 cm to prevent damage by termites and vegetation.
This reservoir can be covered by spanning with treetrunks -core to core 0.5 m- covered with PVC-foil supported by wire-netting.
This PVC-foil must be covered by a thin layer of sand to protect the foil from ultra-violet radiation and blowing up.
Soon the slope will be polluted by dust, bird repose, dead leaves or

other rubbish. So it is advisable to make a filter-pit in a corner of the reservoir to pump clean water (fig. 37).

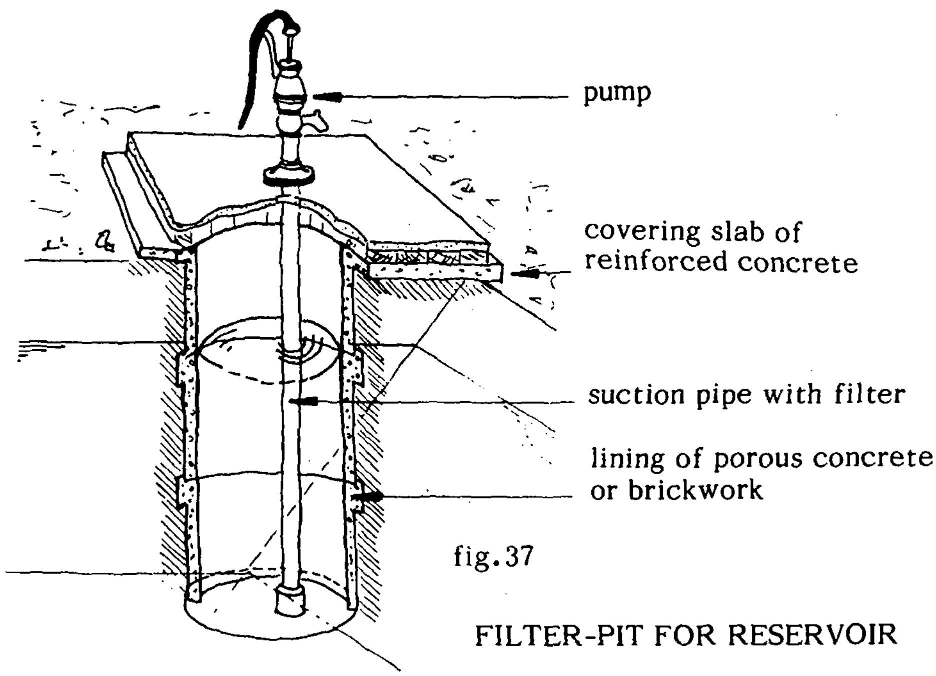


fig.37

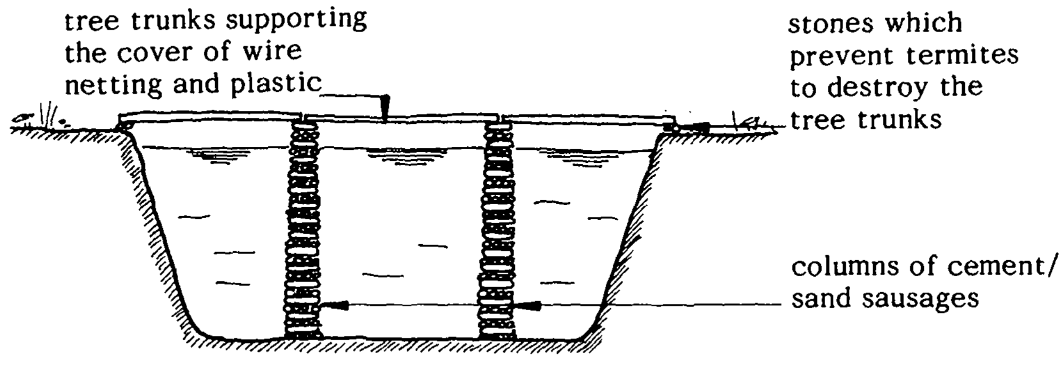
FILTER-PIT FOR RESERVOIR

4.2.3 Covering of storage tanks

To cover a reservoir with a wide span columns measuring 70 cm x 70 cm can be built of concrete sausages (described in section 3.3.2 and shown in fig. 31 - 34). A disadvantage is that the space needed by the columns considerably reduces the effective volume of the reservoir (fig. 38).

SECTION SHOWING COLUMNS OF CONCRETE SAUSAGES TO SUPPORT THE COVER

fig.38



A second way to cover the tank is by means of mats made of sorghum canes. The construction is as follows:

- separate sorghum canes are fixed to each other by wires to form the mats
- the mats are pulled over and fixed to wire-netting
- the wire-netting and the mats are supported by strong elastic wires stretched tight over the reservoir and fastened to sturdy pickets (fig. 39).

This way of covering is inexpensive. Materials are locally available. The wire needed may be fairly expensive but the required quantity is rather small.

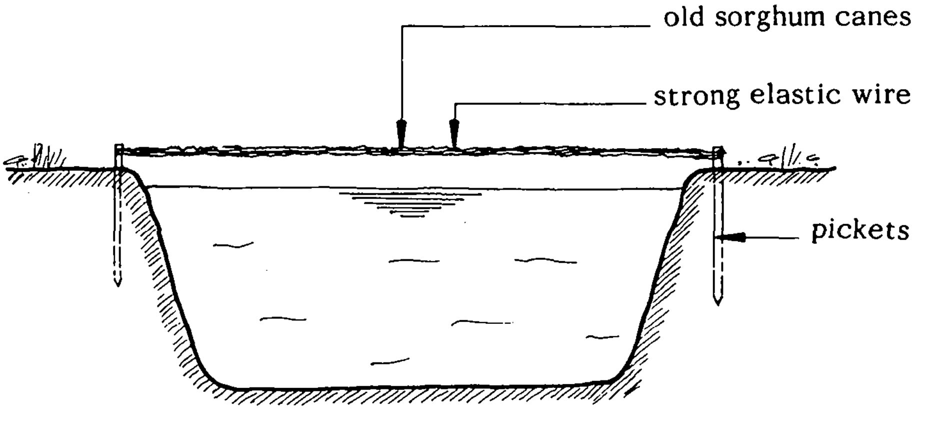


fig.39

CROSS SECTION OF A RESERVOIR
SHOWING STRONG ELASTIC WIRE
FOR SUPPORT OF THE COVER

5 CALCULATION EXAMPLES

5.1 Type 1 Rainwater collected from roof catchments stored in tank(s)

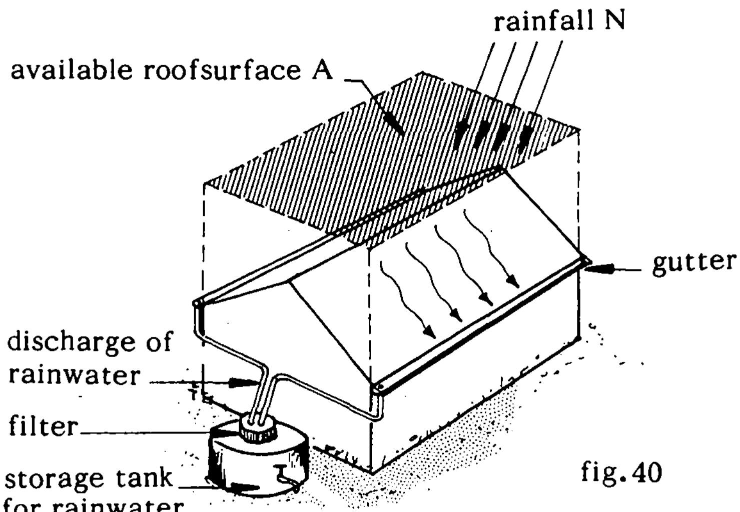


fig.40

RAINWATER FROM ROOF CATCHMENT STORED IN TANK

5.1.1 Example A - type 1

data:
- population size: 80 persons
- increase in population: 2,5 percent
- "design horizon": 8 years
- required volume per head (including cattle): 25 l/day
- annual rainfall: 850 mm (once in 5 years, from measurements over several years)

problem: a) to calculate the required roofsurface
b) to calculate the required capacity of the storage tank

solution:
- present (1985) population: 80 persons
- with 2.5% increase in population and a design horizon of 8 years the size of the population will be in 1990:

$$80\,(1.025)^{8} = 97 \text{ persons}$$

their average consumption will be 97x25=2425 litres/day
added: 20 percent for evaporation = 485 litres/day

total daily consumption =2910 litres/day

a) calculation of the required roof surface:

annual rainfall (lowest value in a period of 5-10 years, see section 2.5) is 850 mm
consumption 2910 litres/day
annual consumption 365 x 2910 = 1,062,150 litres
required surface 1,062,150 / 850 = 1250 m^2

b) calculation of the required storage capacity:

assuming the dry season to last about 4 months, or 125 days, the required capacity is 125 x 2910 = 364 m^2

It is advisable to build in some additional capacity for abnormal circumstances such as:

- an abnormal dry year,
- a higher consumption than anticipated,
- higher evaporation and leakage losses than expected.

for these reasons two storage tanks of 200 m^3 each should be built. They also help to spread the risk of -for instance- a break-down of the discharge valve of the tank.

5.1.2 Example B - type 1

With the data of example A the capacity of the storage tank(s) can be calculated more accurate if the monthly rainfall (lowest rates in a period of 5 to 10 years) is known.

- To obtain a general picture of the rainfall in a certain country and/or region the average monthly rainfall can be shown in a diagram (fig. 41).

- If, however, the average monthly water-output has to be presented in a graph the average monthly rainfall N will have to be multiplied by the roof-surface A which is available for rainwater catchment (fig. 42).

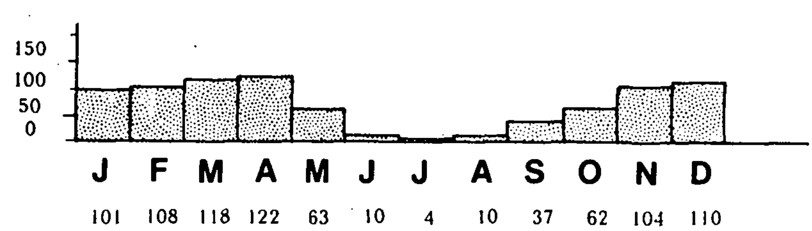


fig.41

AVERAGE MONTHLY RAINFALL IN MM
IN A PERIOD OF 5 TO 10 YEARS

output NxA in m^3

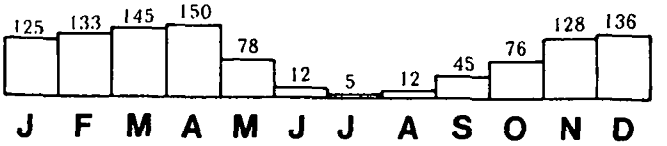


fig.42

AVERAGE MONTHLY WATER OUTPUT

Example:

The average rainfall in January being 101 mm the water-output is found *by multiplying this rainfall N with the available roofsurface A*

N x A = output, or:

101 x 1250 = 126.250 litres = 126 m^3

Because the rule of thumb is:

1 mm rainfall per m^2 roofsurface yields 1 litre water

5.1.3 Determination of the required storage capacity

The average monthly water-outputs and the average monthly water consumptions can be cumulated graphically in a diagram. From the two lines thus obtained the required storage capacity can be found by measurement. This is done in fig. 43 which shows:

line a) a straight broken line representing the cumulated average monthly water consumption of which the total annual volume (365 x 2910 litres) is given at the right hand side of the diagram

line b) a stepped broken line which gives the cumulated average monthly water outputs without storage capacity

The diagram shows that from August onwards the water outputs are smaller than the water consumptions (shaded areas in the diagram). This is caused by the scarce rainfall in the dry season. The shortage in consumption water can be met by introducing a certain storage capacity.

The required storage volume (at the beginning of the dry season) can be found graphically in the following way:

the stepped broken line of the cumulated average monthly water outputs is shifted vertically upwards till all shaded areas are gone. This will be

the case as soon as there is only one point of contact between lines a) and b).
The required storage capacity can then be measured at the beginning of the dry season, as indicated in figure 43.

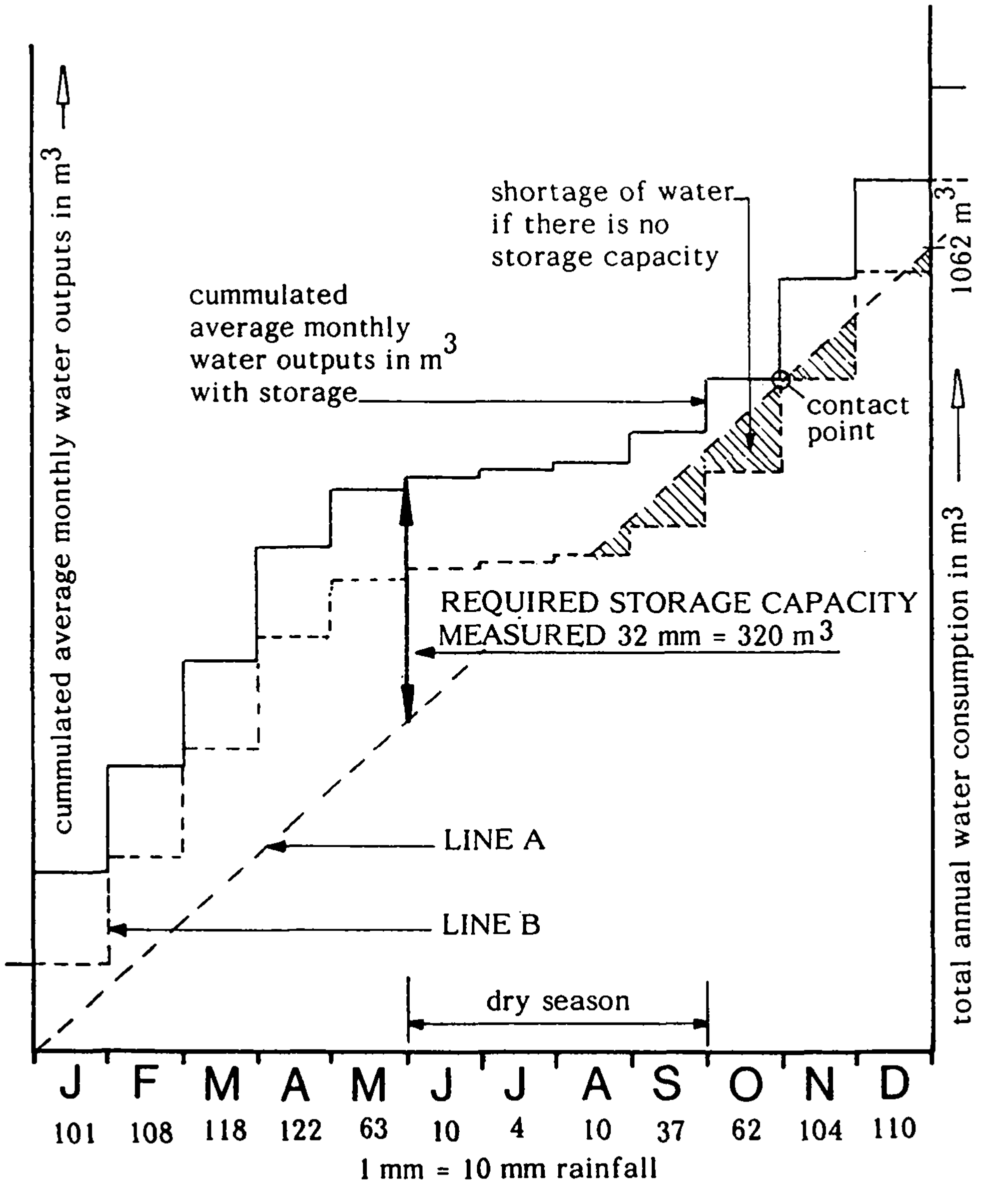
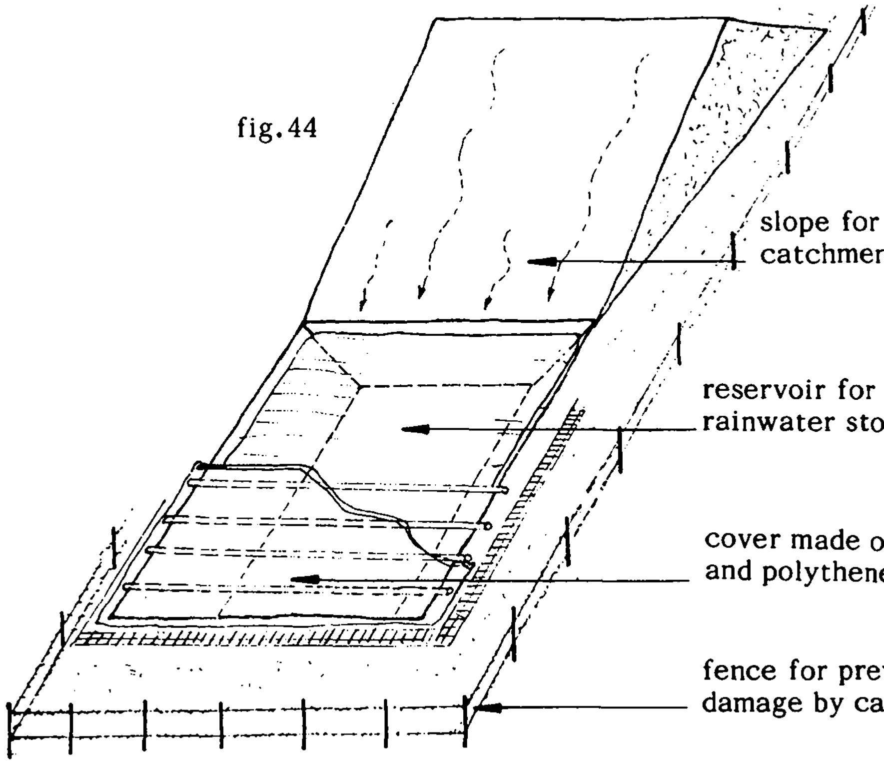


fig.43

GRAPHICAL DETERMINATION OF REQUIRED STORAGE VOLUME BY SETTING THE CUMULATED AVERAGE MONTHLY WATER OUTPUTS AGAINST THE CUMULATED AVERAGE MONTHLY WATER CONSUMPTIONS

5.2 Type 2 Rainwater caught from man-made slope stored in nearby reservoir

fig.44



5.2.1 Example A - type 2

data:
- size of population: 100 persons
- population growth: 2 percent
- "design horizon": 10 years
- required volume per head (including cattle) 20 litres/day
- annual rainfall: 980 mm (once in five years, from measurements over several years)

problem:
- a) the required surface of the slope
- b) the required storage capacity

solution:
- present (1985) population size = 100 persons
- for a population growth of 2 percent and a design horizon of 10 years the size of the population will be in 1995:

  $100 \times (1.02)^{10} = 122$ persons

- its average daily consumption, including an additional 20 percent for evaporation and leakage is
  122 x 20 x 1.20 = 2928 litres/day

a) calculation of the required surface of the slope

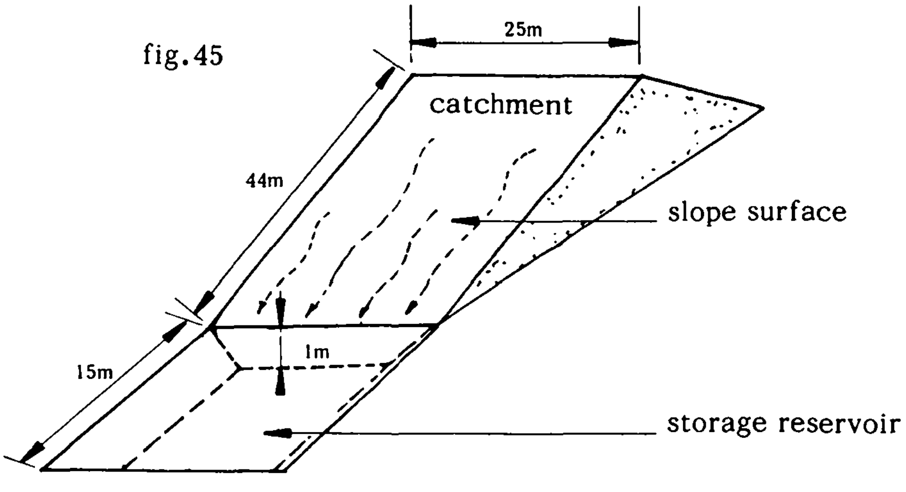
annual rainfall (lowest values in a period of 5-10 years) = 980 mm
consumption 2928 l/day
annual consumption 365 x 2928 = 1,068,720 litres
which requires a slope surface of 1,068,720 / 980= 1090 m^2

For a width of 25 metres the length is 1090 / 25 = 44 metres

b) calculation of the required storage capacity

This is 2928 x 125 (4 months) = 366 m^3
Width reservoir = width slope = 25 m
For a depth of 1 m. the length is 366 / 25 = 15 metres.

fig.45



6 CONCLUSION

Catchment of rainwater from roofs or from man-made slopes and storing it in tanks or reservoirs is a good solution, and especially so in case sources with suitable drinking water cannot be found in the neighbourhood.
Moreover the construction of the installation can be kept simple.

Examples of alternative solutions are i.e.:

Digging of pits, which can be a good solution if:

- the pits can be digged at walking distance from the village,

- there are no rivers in the vicinity, because digging of pits may result in a shift of the course of the river,

- the level of the ground water is adequate and at the same time the pit is protected against overflow,

- the water is of good quality.

Building of dams in small rivers, creeks etc. which is possible if:

- the water is of good quality and without bacteria and poisonous matter,

- sufficient amounts of materials such as clay, large stones, plastic etc. are available to build the dam,

- transport of the water can be effectuated by gravity (free fall) because a diesel-driving pumping installation has many disadvantages (lack of expertise, expensive fuel, spare parts), a hydraulic ram might be a solution,

- maintenance of the dam is possible: sliding of soils etc. has to be prevented.

Remark: Open water -and especially still water- can easily become contaminated. It should at least be purified somewhat before it is used.

The final choice of the most preferable solution out of various possibilities depends on a number of factors, such as:

- available or easily obtaintable materials
- the cost of these materials, and parts
- the availability of man-power and skilled people
- wages
- cost of maintenance
- quality of water

In short it is largely a financial matter. Again everything turns around money. Of every alternative a list of quantities, showing all materials, quantities, unit pieces and costs, has to be drawn up.
From this list the total cost of all materials is established by addition. Next the total number of man-days and the cost of labour per day have to be established in order to arrive at the total cost of labour.
The real cost of the project is the sum of the total cost of the list of quantities and the total labour cost. These calculations have to be carried out for each alternative, in order to arrive at a financially justified selection.

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12 Rainwater harvesting
Vraagbaak, volume XIII, no. 3, september 1985

Catchment of rainwater for consumptive use can be a welcome solution for, or an additional supply to existing provisions for potable water.

"CATCHMENT AND STORAGE OF RAINWATER" may be helpful in countries which, although being situated in a zone with tropical rain forests still have to contend with a relatively short drought. To bridge this drought several methods for catchment and storage of rainwater are discussed and small-scale provisions for potable water, which can be made with locally available techiques and materials, are described.

Catchment of rainwater from roofs or from man-made slopes and storing it in tanks or reservoirs is a good alternative, and especially so in case sources with suitable drinking water cannot be found in the neighbourhood.

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