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***CONSULTANCY ON SMALL SCALE WATER TREATMENT SYSTEMS***

***IN UNICEF's - INTEGRATED AREA-BASED PROGRAMME***

***IN UKWALUDHI, NAMIBIA***

***FINAL REPORT***

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*Consultancy on Small Scale Water Treatment Systems*

*In UNICEF's - Integrated Area-Based Programme*

*In Uukwaludhi, Namibia*

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## *Abbreviations and Acronyms*

CCN	Council of Churches of Namibia
CHW	Community Health Worker
DWA	Department of Water Affairs
HA	Health Assistants
HO	Health Officers
IABP	Integrated Area-Based Programme
IRC	IRC International Water and Sanitation Centre
NGO	Non-Governmental Organization
NTU	Nephelometric Turbidity Units
O&M	Operation and Maintenance
R	Rand (currency)
RWH	Rainwater Harvesting
TDS	Total Dissolved Solids
UC	Uniformity Coefficient
UV	Ultra-Violet
WES	Water and Environmental Sanitation
WHO	World Health Organization
WRC	Water Research Commission

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The consultant would like to express his thanks to all UNICEF staff involved in the Integrated Area-Based Programme in Namibia for devoting their time and energies into making the carrying out of this consultancy possible in the time available. Their commitment resulted in an effective exercise in the short time period available. Particular thanks are due to the IABP Project Officer, the WES consultant in Tsandi, the UNICEF Tsandi office staff and the IABP Assistant Project Officer. Many people in Uukwaludhi district gave their time to discuss water supply issues with the consultant and this is gratefully acknowledged.

The consultant would also like to thank UNICEF Windhoek for the opportunity to carry out this consultancy, and for the support provided.

Mr Jo Smet, Sanitary Engineer IRC

## *0. Executive summary*

UNICEF requested for its Integrated Area Based Programme (IABP) a consultancy on small-scale water treatment. The mission was done in May 1993 by IRC International Water and Sanitation Centre, The Hague. The project had started with some experiments with sand/charcoal/gravel water filters which did not lead to a satisfactory and acceptable solution. Furthermore, low-cost desalination solutions for areas with groundwater with high salinity were needed.

The consultant reviewed the past experiments. Viewing the poor physico-chemical and bacteriological water quality of the oshana water, but also other surface water sources a comprehensive review is made of the available water sources in rural Uukwaludhi.

Considering several criteria including water quality, water quantity, accessibility and reliability, rainwater harvesting and omifima with filter/collector well are assessed as the most potential water sources. The report gives suggestions to improve the water supply in quantitative and qualitative terms of surface catchment of rainwater and omifima systems using filter and collector well.

Several experiments with small scale water filters were carried out. Because of the poor surface water quality (high turbidity, high concentration of colloidal suspended solids), pretreatment is always needed. Good results are achieved with an appropriate coarse gravel upflow filter (using a barrel):....% reduction of turbidity/suspended solids. Batch coagulation gave also good results. All pretreatment systems require final treatment to render the water safe in bacteriological aspect. Slow sand filtration and UV-radiation are further discussed as final treatment options. All suggested technological options are reviewed in terms of cost, availability of materials and spares, technical capacity to produce treatment options, need for extra support, operational care required, operation and maintenance costs, involvement of women in operation , and appreciation of the benefits.

Desalination techniques are reviewed; the conclusion is that small-scale techniques have low yields and have relatively high investment costs. More potential has the development of rainwater harvesting systems in combination with piped water supplies.

In consultation with the project staff a Plan of Action is made focusing on five issues: participatory community survey; rainwater harvesting; omifima with filter/collector well; household water treatment systems; and training and promotion.

## *1. Introduction*

UNICEF started its Integrated Area Based Programme (IABP) in 1992 (UNICEF, 1991). It aims to reduce disparities among communities in Namibia by achieving the national goals for Child Survival, Protection and Development. It therefore will intensify the national sectoral programmes and develop new approaches in selected disadvantaged communities. The promotion and application of participatory development processes is the key strategy. UNICEF and the Council of Churches in Namibia (CCN) started a pilot project in Uukwaludhi district in 1990. One of the nine activities of the Community-based Rural Development Project of the IABP is "Water and Sanitation".

According to information collected by UNICEF, water is probably the highest priority issue for rural communities. Most families have to walk for near to 2 hours to fetch a small quantity of water. Among the activities planned are the introduction of water resource development technologies such as lining and protection of wells, improvement and protection of excavated dams, water harvesting systems and water filters (UNICEF, 1991). Demonstration units were planned for each district.

The water activities concentrated around the collection of rainwater, using several technologies. Because of the poor quality of the surface water from oshanas and other surface water sources, the urgent need was expressed to develop effective and reliable systems to make this surface water drinkable. The project had started with some experiments with sand/charcoal/gravel water filters. These experiments did not lead to a satisfactory and acceptable solution. Therefore UNICEF requested assistance "to rapidly advance the development of suitable systems for slow sand filtering with a focus on use at the household level". Furthermore, considering the high salinity of the groundwater, investigation of possibilities for desalination systems was requested. The detailed terms of reference are attached (appendix 2).

The consultancy was done in the period 10 to 26 May 1993. The itinerary is appended (3).



## 2. The area characteristics

A large part of Owambo is characterized by oshanas. These shallow depressions are fed with water from the rains, from surface runoff (poor quality, salts) and irregularly by an efundja (major flood). Oshanas are interconnecting each other and recharge groundwater, hand-dug wells and open dams, renew grazing, bring fish and provide water for humans and animals (Marsh and Seely, 1992). The map of the oshana (figure 1) drainage zones shows that the origin of the oshanas is in Angola and the end is in the Etosha Pan.

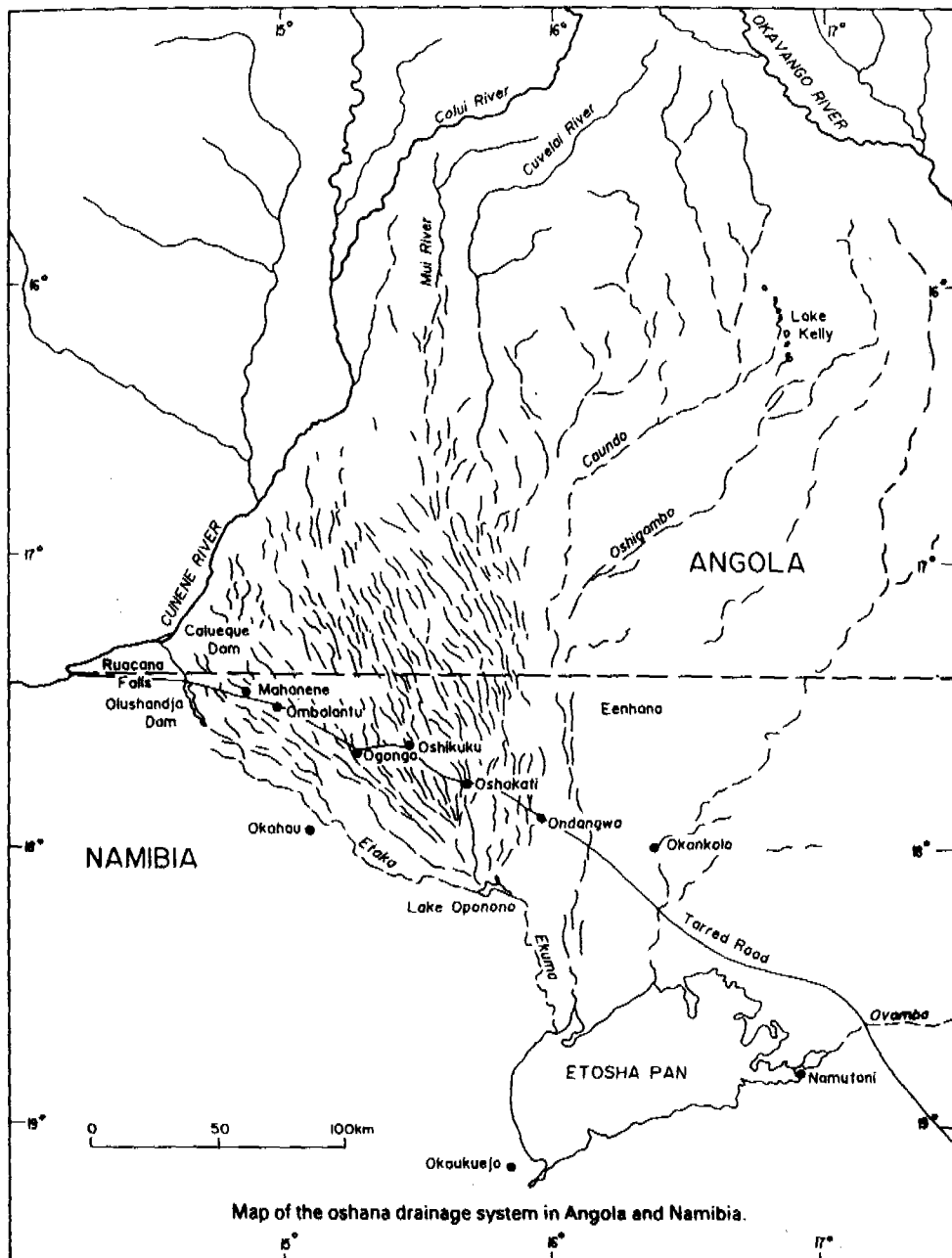


Figure 1: Drainage Zones of the oshana system (source: Marsh and Seely, 1992)

## 2.1 Rainfall

Owambo is a very dry area with semi-arid characteristics. The rainfall is highly variable by year and place. About 99% of the rain falls in the period between October and April (summer) and varies from about 550 mm in the east of Owambo to about 300 mm in the west (Marsh and Seely, 1992). The rainfall for Owambo is illustrated in figure 2.

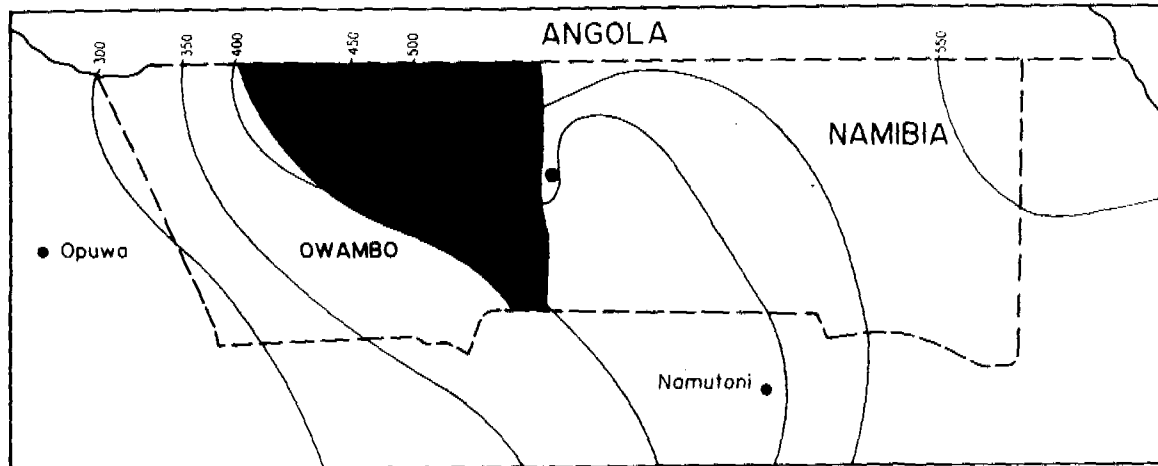


Figure 2: Rainfall in Owambo (the oshana area is shaded) (source: Marsh and Seely, 1992)

## 2.2 Evaporation

The potential annual evaporation in the oshana area is very high, reaching levels of about 2,500 mm.

## 2.3 Surface water

The surface waters as e.g. found in oshanas, borrow pits, omifima, dams etc. are heavily contaminated with faecal human and animal material. Furthermore, the chemical composition shows calcium, potassium, sodium and magnesium probably due to re-suspension during surface runoff of salts (including sulphates (gypsum)) present in the top soil layer. The re-suspension of some of these salts gives the surface water a highly turbid, "milky" colour which in itself may have no adverse effects to health. Obviously, surface runoff will be very likely heavily contaminated. Although this white colour makes the water not very attractive to drink, people are used to it and seem to accept it as a fact of life. The turbidity of the surface water is caused mostly by colloidal matter which makes it difficult to improve both the bacteriological and physico-chemical quality of the water using conventional one-step systems, e.g. sand filtration.

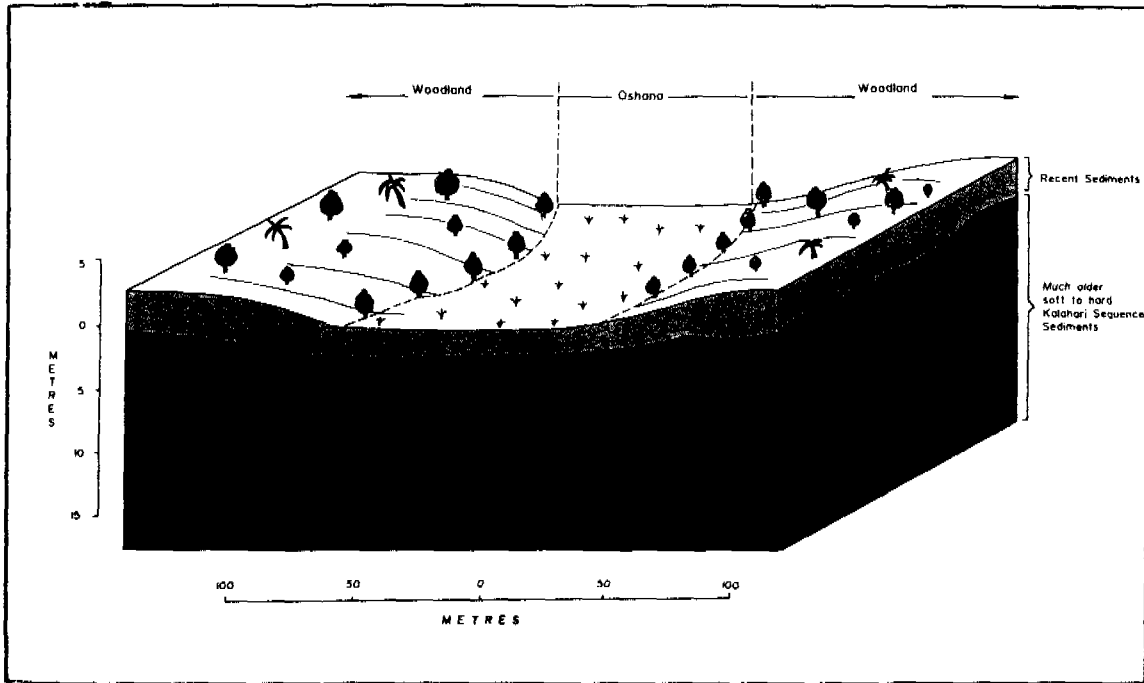


Figure 3: Oshana (source: Marsh and Seely, 1992)

## 2.4 Groundwater

A very large part of Owambo land experiences saline groundwater at varying depth. The history of this phenomenon dates from several million years ago when the saline lake Etosha was formed through the drainage of several rivers into it. Through evaporation the salinity content of the lake increased and lower formations became progressively salinized. At a point in time drainage from the lake via rivers stopped, whilst evaporation continued resulting in large deposits of salt.

The sensitive availability of the fresh groundwater in Owambo is determined by the presence of a huge aquifer of salt water at varying depth, the very limited recharge due to low rainfall and the yearly fluctuating and therefore unreliable oshana flow and efundja (i.e. major floods mainly coming from the Angola catchment area). Fresh water lenses float on the salt water with varying thickness depending on recharge from oshanas, see figure 4.

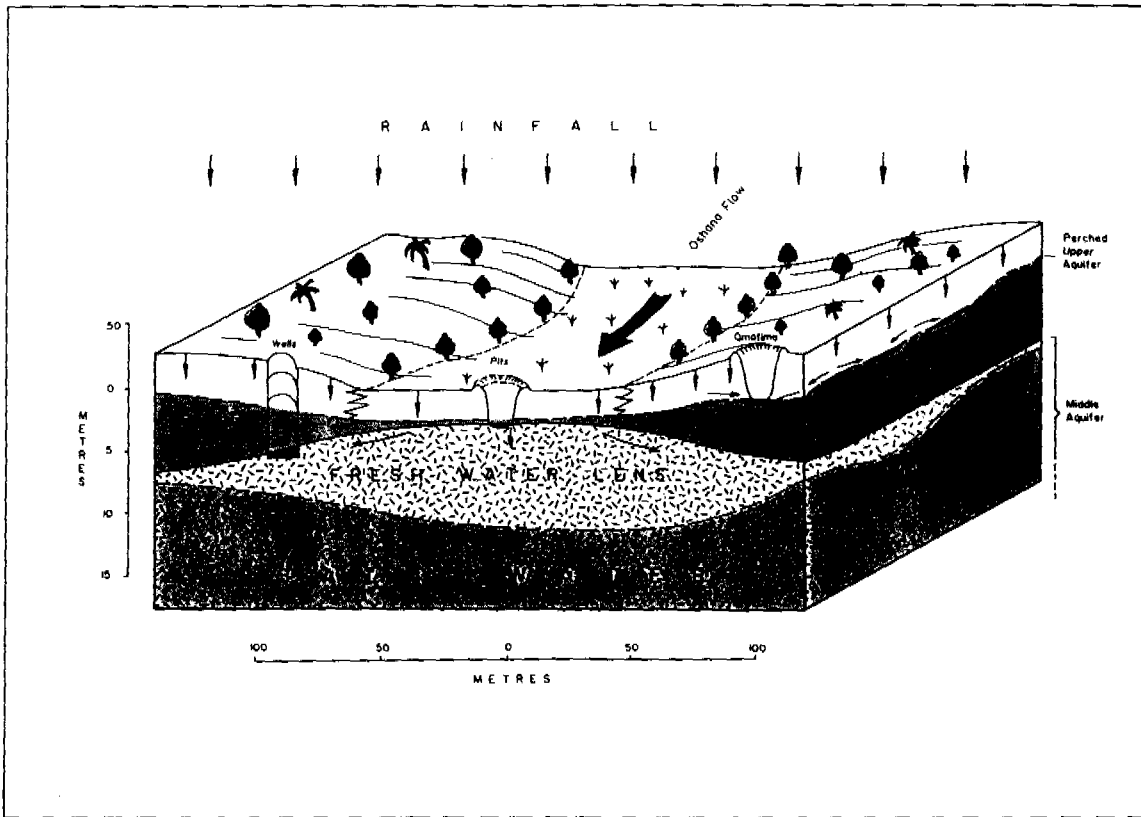


Figure 4: Groundwater resources with fresh water lenses (source: Marsh and Seely, 1992)

## 2.5 Settlement pattern

Most people (80%) in Owambo live in dispersed rural settlements on individual farms of 2 to 5 hectares in the central oshana area. Density may be up to 100 people per km<sup>2</sup>. These centres of population are separated by communal grazing and woodland or scrub. Outside of the oshana area, settlement is much less dense and almost entirely dictated by the availability of water (Marsh and Seely, 1992).

### 3. Existing rural water supply systems

#### 3.1 Water sources

Water is among the highest problems expressed by the people. Their concern of water is both the quantity and the quality. Closely related to this are the reliability and the accessibility of the water. Each water source may have its own advantages and disadvantages in terms of the four above mentioned features.

The prevailing water sources in the area are mainly the following:

- \* rainwater directly collected from the roofs and ground surface
- \* groundwater (figure 4)
  - traditional shallow wells or omifima (sing. omufima) along the edges of the oshanas
  - hand-dug shallow wells along the edges of the oshanas
  - hand-dug pits in the oshana
  - boreholes outside the oshanas
- \* surface water
  - oshana, i.e. shallow depression fed with rainwater, surface runoff (poor quality, salts) and irregularly by an efundja (major flood)
  - dams built by the government
  - circular dams built by the government for schools and clinics (about 200 were built in the 1960s)
  - omufima; many are built so that they can collect also surface runoff water
  - borrow pits along the main roads
  - canal; earth-lined and concrete lined
- \* piped water supply

More piped water supplies are being constructed in the rural areas of Owambo.

A more detailed description of the different sources is required to assess their potential for water supply for drinking and household purposes and for cattle or stock watering. The description will concentrate on four important elements in water supply: quantity, quality, reliability and accessibility. In section 5.4 an elaboration will be given on other aspects concerning the choice of technologies for these water supplies, such as costs, replicability and sustainability.

##### 3.1.1 Rainwater

As stated in chapter 2, Owambo is a very dry area with semi-arid characteristics. Rain fall varies from about 550 mm in the east of Owambo to about 300 mm in the west (Marsh and Seely, 1992). The period from October to April is the typical rain period. With no rains during a period of five to six months.

### Water balance

The potential annual evaporation in the oshana area is very high, reaching levels of about 2,500 mm. The rainwater that is directly available for groundwater recharge and for the growth of vegetation and crops is about 17% of the total rainfall. This corresponds with about 50 to 95 mm per annum. See figure 5. The typical soil composition of very fine Kalahari sand mixed with calcium and potassium salts (including gypsum like compounds and clay) makes the infiltration into the ground of rainwater and runoff water very limited.

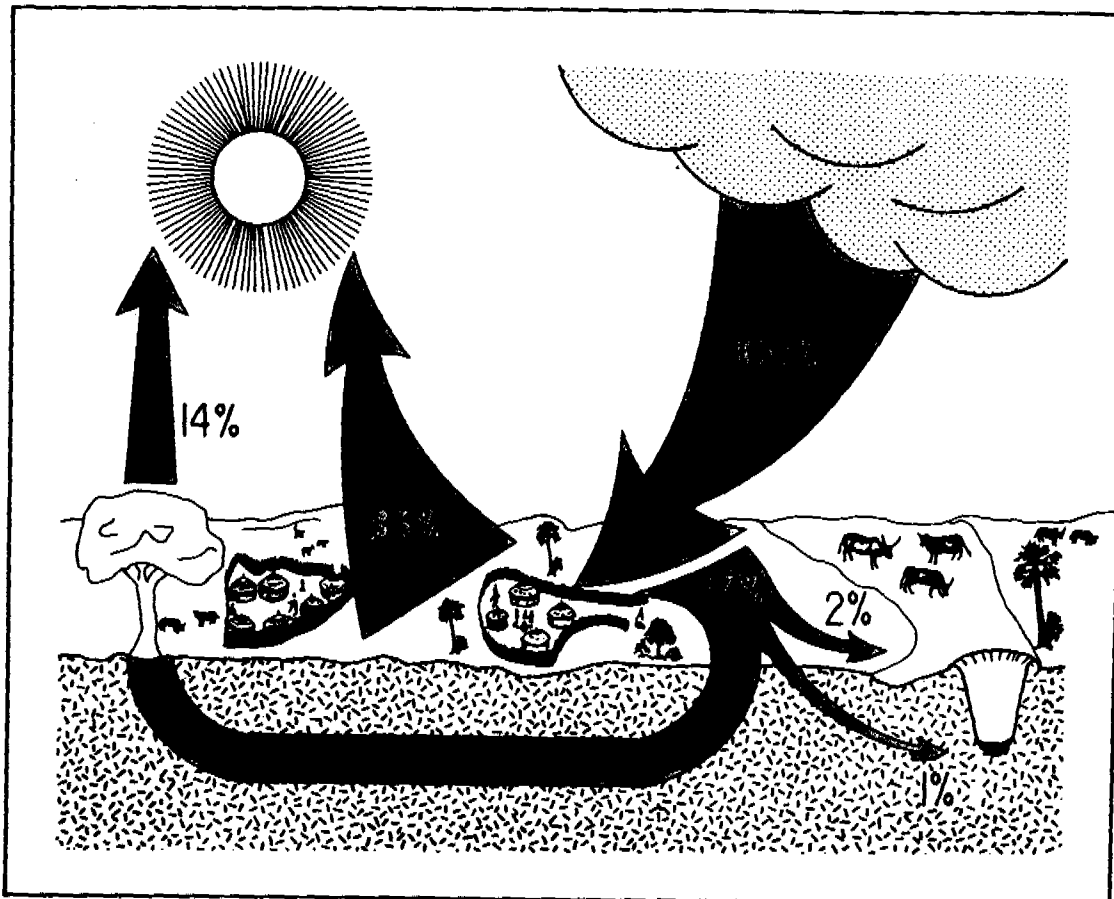


Figure 5: Schematic water balance of oshana area (source: Department of Water Affairs)

### Runoff water quality

The rainwater runoff dissolves the salts present in the top layer of the soil. This runoff water is collected in the oshanas, omifima and dams etc.. As most water evaporates, the salinity in the remaining water increases and eventually the salts remain on and in the soil. Salinity of groundwater is partly attributed to this phenomenon. Similarly, the calcium/potassium content of the runoff water and in the depressions, reservoirs and dams increases (CHECK). The salts deposits and the organic load remaining in the depressions etc. very much contribute to the low permeability of these locations.

The surface runoff water also picks up pollution and impurities from human and animal faecal material and household waste. Considering the low coverage of latrines and the abundance of stock, particularly near water pockets, the contamination of the waters must be very high.

### **Advantage rainwater**

In view of the high evaporation, the increasing salinity and the contamination of the rainwater as soon as it reaches the ground, rainwater collection from roofs and protected surface areas is very advantageous in terms of quantity and quality.

Although the accessibility of rainwater systems (close to the home) is obviously very high, its reliability is low as the collected water volume is limited. This is due to the low rainfall, the limited roof and ground catchment surface area, and the high initial investment per cubic meter for rainwater harvesting systems. Effective rainwater collection is determined by the runoff coefficient varying per type of collection. Restriction of rainwater for drinking purposes will make the reliability higher.

### **Observation rainwater systems**

Presently, household-based rainwater collection systems are rarely seen. At schools and health centres/dispensaries rainwater collection systems are more common (see photograph: appendix 5). However, it was observed that systems were often not properly maintained: taps were found broken, covers removed and waste thrown in the tanks.

### **Surface catchment**

Surface catchment systems were seen, and were said to be traditional systems in the Uukwaludhi area, called oshipale. In the harvesting season these oshipales are used for harvest collection and trashing. Because the top layer is very hard, the runoff coefficient is probably fair. However, the pollution risks could be greatly reduced by applying a more impermeable underground. The system observed had no reservoir and harvested water had to be scooped into buckets and containers.

The experiment started by the UNICEF project with surface catchment from polythene-covered area (5x5 m<sup>2</sup>) was viewed unsuccessful as a lot of dust and sand was collected. Improvements are suggested in chapter 4.

#### **3.1.2 Groundwater**

##### **a. Traditional shallow wells or omifima**

These are found along the edges of the oshanas. As observed, omifima are usually found in a number close to each other. Fresh water aquifers are very localized. If one fresh water location is found, other people will come and dig other wells close to the first to be ensured of fresh water as well. However, this results in increased and very localized abstraction of fresh water from the often relatively thin layer of perched fresh water aquifer above the salt water (fresh water layer less than two metres (Mhone, personal communication)) (see figure 4 and photograph: appendix 5). An omifima is usually owned by one family but used by several families. All families assist in digging when the omifima dries up.

During the rainy season the omifima collects surface runoff water, as they are located at the lower side of the slope towards the oshanas. Most omifima visited during the fieldwork were filled up with water and the surroundings flooded.

The depth of the omifima is usually limited to 3 to 5 metres depending on the groundwater table. In the dry season the water depth of an omifima is usually less than one metre. Digging deeper results in caving in of the walls because of instability as the soil is highly plastic if saturated with water.

One omifima was found to have a filter and collector well with a non-functioning handpump installed by the DWA (see figure 6 and photograph: appendix 5). No information could be obtained when this was done, and what type of filter construction was installed. According to Götze (1993, personal communication), it is unlikely that any filter is constructed apart from the filter gravel pack around the concrete rings, as gravel was very scarce years ago. The water from the collector well was used by all families living in the neighbourhood of the well. When after some months the well run dry, water is still found in the separate omifima, and digging through communal efforts further extends the availability of water of this omifima. Digging extends in the discontinuous perched water aquifer and also into the underlying salt water aquifer.

When the omifima are running out of fresh water, the water collection may be restricted to one bucket per family per day for human consumption only (Mhone, personal communication). Stock watering is found in the further south-western parts of Owambo where fresh water from deeper boreholes is abundant.

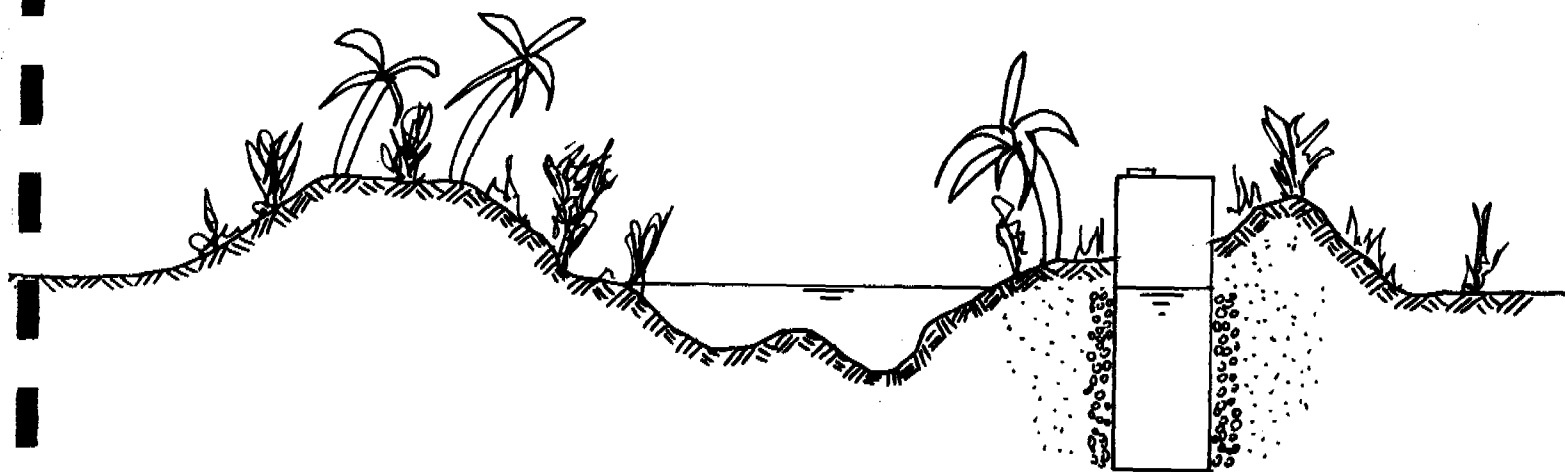


Figure 6: Omifima with filter and collector well as observed. (The actual filter construction is not verified in-situ.)

b. Shallow hand-dug wells (lined and unlined)

These were found further away from the oshanas, and therefore the depth was greater compared to the omifima. Typical depths are 5 to 25 metres (Marsh and Seely, 1992). These wells are dug through hard Kalahari sediments (limestone-like rocks) into the discontinuous perched water aquifer and also in the fresh water lens on top of the salt water aquifer (see figure 4). Water bodies of these dug wells are usually shallow: approximately 50 cm (Hussey, 1993). Often these wells hit the salt water aquifer.



Due to situation, people drink water with rather high salinities, i.e. TDS levels of up to 2,000 mg/l and more.

As for the omifima, the wells are usually owned by one family but drawing water is allowed for all families from the neighbourhood which participate in up keeping of the well (see photograph: appendix 5).

c. Hand-dug pits in the oshanas

After the oshanas have dried up, people dig pits to search for water. These pits get to the perched shallow aquifer and to the fresh water lenses. As the oshanas fill up again during the rains, these pits are not accessible anymore and so not used. The water in the pits is of poor quality as a result of infiltrated salts and impurities.

d. Boreholes drilled by DWA

These are meant both for human consumption and stock watering. They are particularly located in areas where no other groundwater sources and dams are feasible. Boreholes are drilled into the relatively shallow (at depth of 20-30 m) fresh water lenses or aquifers. Often no fresh water is found in sufficient quantities to develop a well. Another problem is the intrusion of the very fine Kalahari sand and consequent blocking of the filter and tear of the pump.

### 3.1.3 Surface water

a. Oshana

These shallow depressions are fed with water from the rains, from surface runoff and irregularly by an efundja (major flood). The surface runoff brings also dissolved salts, clays and organic materials which all settles when the water is in rest. In this way a impervious layer is created, reducing the infiltration of water into the ground. The quality of the oshana water is very poor in terms of bacteriology, conductivity and total suspended solids. The colloidal portion of the suspended solids content is high making the water hard to treat in conventional ways.

As the oshana is very flat and the water body is very shallow, the evaporation is high and water in oshanas is usually evaporated before end of June. The reliability is therefore rather small (see photograph: appendix 5).

The accessibility is high for the many families living near oshanas.

b. Earth dams built by the government

Most receive the water from surface runoff while some are connected with the canal from Olushandja. The water quality is poor in physical and bacteriological terms. As the depth of these dams is more than the oshanas, they provide water to man and stock after the oshanas have dried up.

Dams have been constructed by the DWA at many places to increase the availability and accessibility to more reliable water sources.

c. circular dams

These were built by the government for schools and clinics in the 1960s. About 200 were constructed (Marsh and Seely, 1992).

According to information received (Götze, personal communication) many of these dams are no longer in use, although they could be a reliable water source in quantitative terms for man and stock alike.

d. omifima

As described above, many omifima are dug along the oshanas by local people and community efforts. Most omifima collect also surface runoff water.

e. canal

There are earth-lined and concrete lined canals.

The concrete canals are particularly for bulk water supply to towns where the canal water is treated first. These days pipelines are preferred by DWA because of lower loss through infiltration and evaporation, and for reasons of lower pollution levels. However, due to high costs compared to earth-lined canals the construction of the pipelines is limited.

Earth-lined canals are mainly used to provide water to the people and stock in the rural areas during dry periods. The earth-lined canal from Ruacana to Tsandi branches off in two near Tsandi. At the time of visit (May) no water was flowing in canal. Families visited stated that when common water source have dried up, they go to the canal to fetch water for household purposes. The quality of the canal water is poor as the water picks up chemical, physical and bacteriological impurities alike during its passage from Ruacana (see photograph: appendix 5).

f. borrow-pits

Pits created for road construction collect rainwater and surface runoff water. They have the same water quality characteristics as the omifima. For the people and their stock living near they provide an accessible source. Their reliability is limited as they also dry up quickly.

### 3.1.4 Piped water supply

A piped water supply line exists between Olushandja and Ogongo, passing Tsandi. The water comes from the Calueque dam and is meant for the town population along the line. In the period 1990-1992 around 65 water points were constructed in the rural areas between Olushandja and Ogongo, to provide water to people and stock. Each water point consists of a communal standpost and a cattle water trough. The consumption is metered but meter readings are not made as there is not yet a clear policy on costs for water from standposts. The original idea was to make one person responsible for the standpost and have him managing the water point (see photograph: appendix 5).

As these water points are mostly far away from the people's homesteads, they use them only when all nearer sources have run dry.

The water is treated and of good quality.

The above description of characteristics of available water from different sources have been tabulated below.

Table 1: Available water sources in rural areas of Uukwaludhi area and their characteristics

Water source	Specification	Water quantity	Water quality	reliability	accessibility
Rainwater	roof catchment	+	+++	++	+++
	ground catchment	++	++	++	+++
Groundwater	omifima	+	++	+	++
	shallow hand-dug well	++	++	++	++
	oshana pits	+	++	+	++
	boreholes	+++	+++	+++	+
Surface water	oshana	++	+	+	++
	government dams	++	+	++	+
	circular dams	++	+	++	+
	omifima	+++	+	++	++
	canal	+++	+	++	+
	borrow pits	++	+	++	++
Piped supply	standposts	+++	+++	+++	+

legend: +++= good, ++=fair, +=bad or poor

By applying the four criteria (quantity, quality, reliability and accessibility) the most potential water sources in rural Uukwaludhi are rainwater and next the omifima. The potential for boreholes is limited because of salt groundwater occurrence and an extensive piped supply network is financially not feasible.

Samples were taken from several different water sources while visiting them for reconnaissance. Table 2 gives the results of the analysis done by DWA (Windhoek) for a limited number of parameters. Full data of the analysis are attached in appendix 6. DWA sampled in 1991 three oshanas west of Oshakati; the results of the analysis of these samples are added in appendix 6.

Table 2: Water quality of several visited water sources as well as raw water and filtrates used in experiments (see also appendix 6: water analysis data).

source	location	pH	conductivity ms/m	Total Dissolved solids mg/l	chloride mg Cl/l	sodium mg Na/l	potassium mg K/l	calcium mg CaCo <sub>3</sub> /l	magnesium mg Mg/l	turbidity NTU	Total Suspended Solids mg/l
omifima	Onangalo	8.1	24.3	160	13	5	8	87	8	11.00	
flooded omifima	Onangalo	7.8	16.0	106	21	22	7	32	16	330	
collector well of omifima	same as above	8.0	21.9	145	13	16	7	55	12	35	
shallow dug well	Okasheidhi	8.2	273.0	1802	52	62	11	462	128	16.0	
protected dug well	Okasheidhi	8.5	220.0	1452	185	245	9	87	474	3.7	
oshana	Tsandi source 1	7.6	191.9	1267	500	360	18	37	29		10282
dam	Tsandi source 2	7.9	31.3	207	23	41	9	47	16	520	2701
omifima	Tsandi source 3	7.7	53.2	351	136	92	59	37	25	450	2697
filtrate 1	sand filter	8.4	184.3	1216	270	305	49	105	66	0.5	
filtrate 2	gravel filter	7.6	51.1	337	31	52	9	97	45	15	50

remarks: all tests were done by the water laboratory of DWA in Windhoek (with confirmation by the field conductivity meter of UNICEF and turbidity analysis done using the HACH DREL 2000 of FINNIDA)

### Water sources selection per season

In general, most people in the rural areas depend on several water sources through the year. The utilization preference of the water sources is mainly determined by the distance from the homesteads and to a much lesser extent by the quality of the water. As they have to walk often long distances when nearer sources have dried up, they appreciate the nearby sources. The short walking distances coincide with a busy harvesting period during the months after the rains.

### 3.2 People's perception of water quality

People in Uukwaludhi hardly make a distinction in selecting the water sources for their drinking water or water for other household purposes. Women interviewed in several families expressed their concern over the quality of the water but accept it as they do not know how to improve its chemical/physical quality. Particularly drinking water for infants and under-fives is boiled before use to improve bacteriological quality. Long storage of water that would have beneficial effects on quality of the drinking water is generally not practised. Drinking water is separately stored from water for other purposes; the commonly used clay pots (10-15 litres) are covered with a lid.

From information received, people tend to stick to traditional but probably contaminated source if water from new source, although safer, has a different, unusual taste. More information and education on potential health and other benefits from using safer drinking water may contribute to changes of behaviour.

### **3.3 Water treatment systems applied by DWA**

There are several water treatment plants for bulk water supply to urban areas in Owambo area, all operated by DWA. The treatment systems applied are (i) the conventional three step system and (ii) batch system.

#### **Ogongo**

The conventional system visited in Ogongo consists of a continuous coagulation/flocculation/sedimentation process, sand filtration (pressure filter) and chlorination. Coagulant dosing depends on turbidity which is regularly determined. For turbidity of 80 NTU the dosing was 65 mg alum per litre. The plant's capacity is presently expanded from 750 to 1500 m<sup>3</sup>/hour.

#### **Ombalantu**

The batch system visited in Ombalantu applies coagulation/flocculation and sedimentation as a batch process by treating 100 m<sup>3</sup> at the time with a sedimentation time of about 2 hours. The plant treats about 500 m<sup>3</sup> per day. Chlorination is done at the same moment as the coagulant (alum) dosing. Alum dosing is between 30 and 72 mg/l depending on turbidity of the water and determined on experience.

#### *4. Potential water supply options for rural Uukwaludhi*

##### **4.1 Considerations for source and technology selection**

The following criteria and considerations should be applied to come to a well-balanced selection of potential water supply and water treatment options for drinking and household purposes in rural areas in Uukwaludhi:

\* consumer and community-related aspects

- organizational capacity
- political, administrative or traditional authority
- communal spirit to cooperate
- experience with communal projects
- social and cultural factors influencing choice of water source
- economic and financial bearing capacity (capacity to pay)
- willingness to pay for improved water quality and/or service level
- availability of construction materials and mechanical parts
- availability of technical skills to construct or manufacture supply and treatment methods
- present water supply situation
- preferred water supply and service level

\* institutional considerations

- institutional responsibilities and/or roles of government departments and NGOs
- availability of technical, training and organizational support structure from government departments, NGOs or from private sector

\* technical considerations

- water availability, quantity and quality
- water source accessibility
- present and potential pollution sources
- cost of the system

To many of these considerations answers are known by project staff from studies done, experiences gained and discussions held with the families.

Issues influencing the choice of water source (social, cultural) are not yet fully known. The same applies to the ability and willingness to pay, and to the institutional considerations.

It is recommended that additional data are collected through discussions with families (community survey) to obtain a full picture of the potential for water supply and treatment options.

The use of participatory techniques in obtaining these data is advised to ensure realistic views from the people and particularly the women. Many participatory techniques for the issues raised have been developed (Srinivasan, 1990).

## 4.2 Most potential water sources

As concluded from the table 1, rainwater and omifima are the most potential water sources in terms of quantity, quality, accessibility and reliability. Oshana waters observed and tested were generally of very poor quality and should not be promoted as drinking water sources. As will be seen all small scale water treatment options failed to function and to perform sufficiently for this type of water.

The two most potential water sources will be further discussed in terms of technologies to be considered for further development and field testing.

### 4.2.1 Rainwater

Rainwater harvesting is the most effective method to collect the water. Rainwater is hardly contaminated or polluted. As soon as the water reaches the ground it will get contaminated with all types of pollutants. As seen before, the specific pollutants and especially the uptake of calcium and potassium salts, make the water hard to treat. Furthermore, a large portion of the surface runoff will just evaporate and is completely lost for the water supply.

#### **Some considerations**

Rainwater harvesting (RWH) has the serious drawback that the initial investments to construct the catchment area and the storage reservoirs are usually high. Cost indications for various systems have been given by Lee and Visscher (1992). The IABP has also compiled cost data for RWH (Badloe, 1993). As the systems are household-based, the major costs are to be borne by the people. Technical advice and training of artisans should be considered by the project, as well as limited subsidy and transport of construction materials. The involvement of the private sector has a high potential. Available carpenters, plumbers, masons can all have their role in the construction of rainwater harvesting systems.

#### **Potential RWH systems**

Harvesting systems to be considered as most potential are:

- rooftop rainwater harvesting from non-thatched roofs
- rooftop rainwater harvesting from public buildings (schools, dispensaries, police stations etc.) also for controlled communal use
- surface catchment using cemented or plastic-covered surface.
- storage in small 200 litres (or more) non-reinforced cement-plastered tanks
- storage in underground tanks (ferro-cement, plastic foil-lined)

Most houses in the rural areas have their roofs thatched. Local beer-houses usually have c.i.s roofing. Therefore, for rural homesteads the surface catchment has most potential.

#### **Surface catchment potentials**

The experiment, started by the project with surface catchment from polythene-covered area (5x5 m<sup>2</sup>), was viewed unsuccessful as a lot of dust and sand was collected. Improvements can be made on the drainage system between the sheet and the reservoir including a sand/silt trap (see figure 7). The recommendation made in the Review Report of Doyle (1993) to revive this surface catchment is supported. However, Doyle's design (appendix 7) has several drawbacks: the cost of plastic bag and pump, the unavailability of

large volumes of required coarse sand, and the vulnerability for damage of the buried water bag by animals and man.

As explained in section 3.1.1 most millet-growing families have a so-called oshipale, a flat ground surface also used for water harvesting. Collection efficiency could be increased by making the surface slightly sloping, putting polythene sheets (overlapping, non-sealed), and constructing sand trap (or a small gravel/sand filter) and ground storage reservoir of 5m<sup>3</sup>. Sheets have also the advantage that no impurities, solids and salts from the ground will be picked up during collection. Sheets can be spread when rains are expected to come, to enlarge their lifetime. This field needs further investigations in field and through experiment.

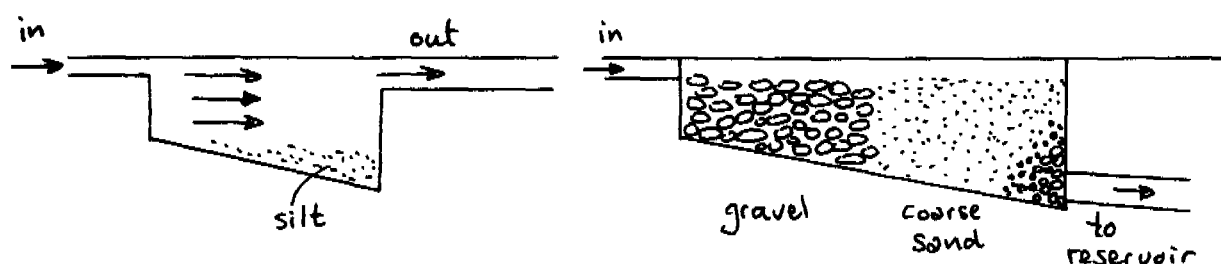


Figure 7: Sand/silt-trap and gravel/sand filter for surface rainwater catchment

Runoff coefficients for different catchment options are summarized in Lee and Visscher, 1992.

### Fencing

Fencing of surface catchment and storage, but also of rooftop collected water storage is recommended to prevent misuse and vandalism. It further protects the source of some pollution (Lee and Bastemeijer, 1991) Fencing places emphasis to the importance and sensitivity of the asset. Fencing of property is a very common phenomenon in the area.

### 4.2.2 Omifima

Many omifima are located in such way that they can receive surface runoff water from higher areas. The wells get flooded during the rains. The excavated sand forms small hills around the omifima. Rainwater caught in the omifima will be retained by the sand heights. These also create a good growing environment for plants particularly for palms. Trees provide shade which may reduce the evaporation, while on the other hand evapotranspiration is higher. To minimize the evaporation, the omifima should be dug as deep as possible and the surface area reduced. The depth of the omufima may be limited by the nature of the soil (high plasticity) and the risk to reach the salt water table.

However, the problem remains the poor quality of the surface and rainwater collected in the omifima. As a matter of fact, this water is mostly of much better quality than the water in the oshanas.



### Collector well

The omufima with the collector well (see figure 6) (as also observed in Onangalo) is a good example of a rural water supply system highly potential in this area resulting in optimal water quantity, quality, accessibility and reliability. This option is very suitable for optimal involvement of the future user families as it requires their involvement from the very planning, their commitment and finally their management in water distribution and upkeep.

### Filter composition

The composition of the filter needs special attention in view of the specific water characteristics (high proportion of colloidal material, probably caused by over-saturation of calcium and potassium carbonates salts). The design should require minimal operational attention and care. Filter cleaning should be done preferably not more than once every three to five year. A filter composition based on experiments done with household filters is given in figure 8.

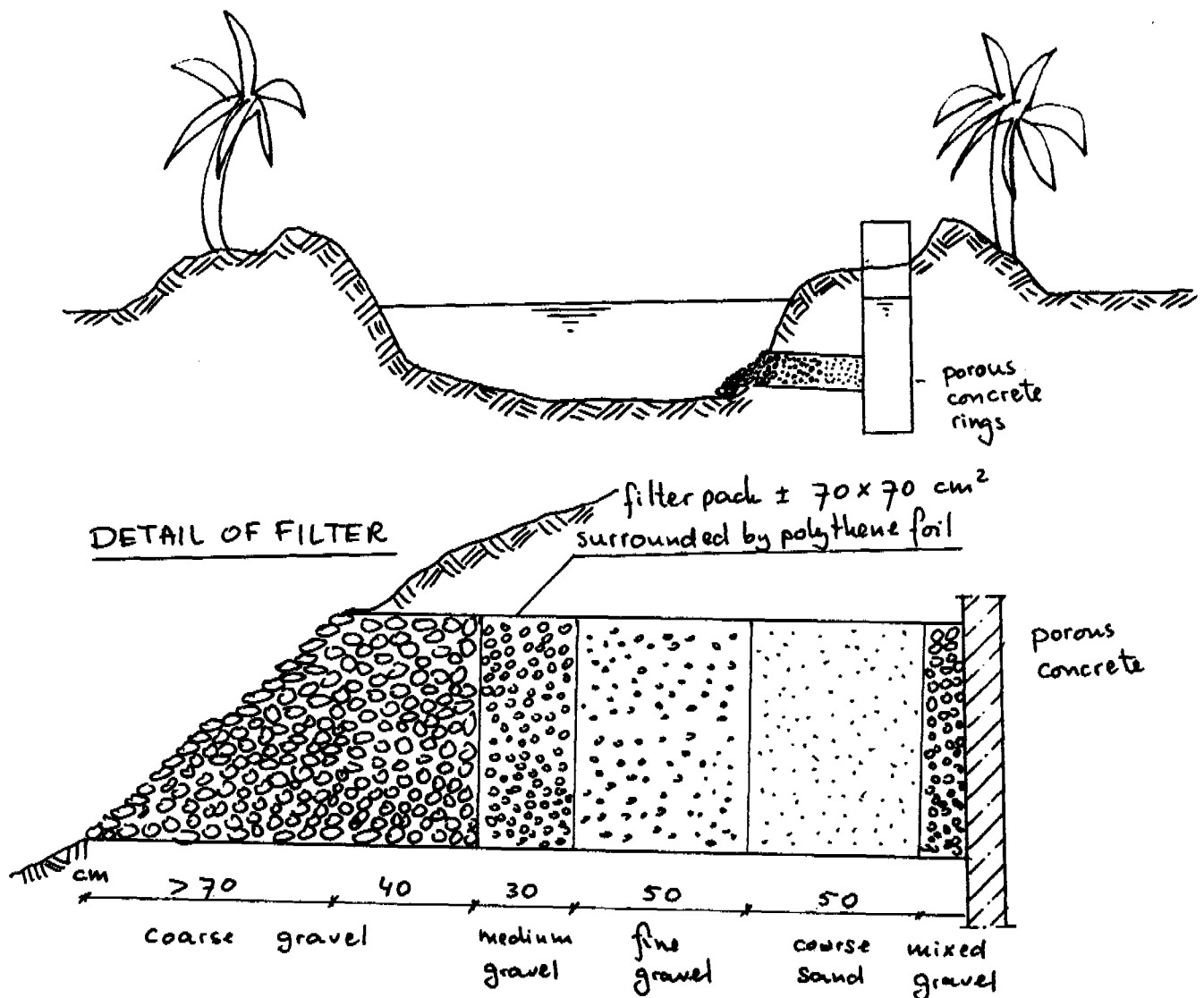


Figure 8: Possible filter construction for omufima with collector well

### **Water lifting**

Water lifting methods can be simple low-lift pumps (Blair pump, Tara pump), bucket pump but also a windlass and bucket system. Cost and required attention in O&M, availability of spares and technical support should be considered in the technology selection. The final decision is to be taken by the user families after full consideration of the implications of the options.

### **Follow-up**

Some further field investigations are needed to determine whether the present systems have a filter in constructed or only a filter gravel packs installed around the rings of the well. Obviously, these investigations can only be done when the omufima is dry.

The users of the omufima with the collector well can be asked how they appreciate this source and its water quality, and how they organize themselves in deepening the wells, cleaning possible filter etc.

### **Fencing**

The omufima used for drinking water supply should be fenced to prevent animals to pollute it. If the omufima is the only source for man and stock, it should preferably split in two sections: one fenced for human water consumption and one for stock watering. The fencing of the source should also illustrate the importance of safe water for health. This drinking water source protection should be one of the topics in the information and education of the people.

#### **4.2.3 Ground storage with built-in filter**

Similarly as above described for the omifima, such excavations with reduced surface area and enlarged depth can be constructed in other areas outside the oshana environment. Dams and borrow pits could be considered for this option. The aspect of evaporation reduction justifies this choice. The composition of filter could be as for omifima.

### **4.3 Ultimate water source**

When all options of water supply within an easily accessible range have been dried up, people have to go to the final reliable sources being the canals and the piped water supplies. As this water is "imported" the availability depends on technical conditions. Distances to these sources are usually far from the homesteads. The possible options for water supply depending on availability are schematized in figure 9. To reach sustainability of the piped water supplies, the management of these systems has to be developed and established, both at institutional level (DWA) and communal level. The roles and responsibilities of each actor has to be determined. Community management, operation and maintenance and cost recovery are among the important issues to be discussed. This water has to be seen as an economic good, and so has a price for the consumer.

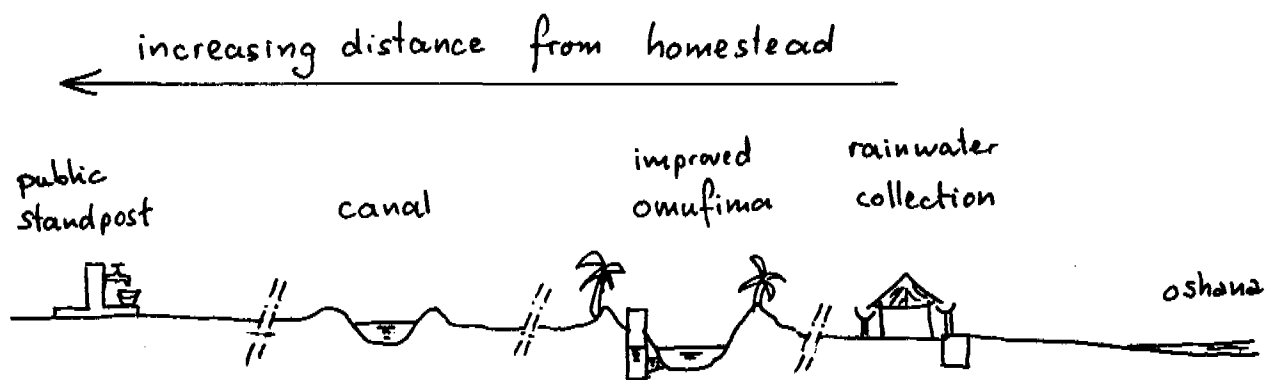


Figure 9: Schematic overview of different water supply options depending on their reliability

If people have to get water from further away, the quantity of water collected will be significantly reduced (Feachem et al., 1978). Water quantity reduction for household and personal use has direct effects on health, particularly diseases in the faecal-oral transmission and water-washed groups (Cairncross and Feachem, 1983).

### Water transport

The project should look into possible sustainable means to overcome or reduce the heavy burden of carrying the water. The introduced option of the aqua-roller seems to be feasible although acceptance by the people remains unclear. Other means of water transport that could be considered for further study and field introduction are donkey carts and plastic tanks to be put on the sides of the donkey's back (see figure 10 and photograph). These methods are commonly used in other semi-arid areas in Owambo and were observed between Ondangwa and Oshiveko. Selling of water may then become an income-generating activity.

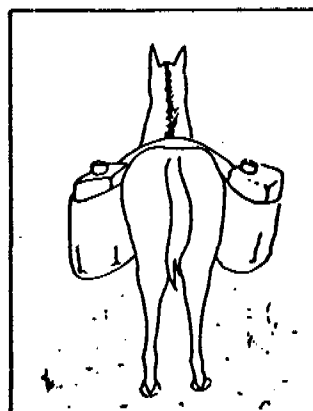


Figure 10: Plastic or leather water containers for donkeys

### Awareness raising

Awareness raising on the relation water quantity and diseases, i.e. the discussion on good quality of water for drinking and sufficient water for personal hygiene can be conducted by community health workers. Their training should be geared towards this goal.

According to verbal information from DWA, the piped water supply to Uukwaludhi would suffice the drinking water requirements for all people in the area. Presently, most people consider this source less convenient because of long distance and prefer wells nearer to their homes.

## 5. Household-based water treatment options

### 5.1 Review of present filtration system

Four household filters were found to be installed, i.e. two at the Garden Centre (income-generating project of IABP), one near the house of Meme Anna (UNICEF Tsandi staff), and one at the compound of the King. These filters are using an oil drum. Two other filters made of a ferro-cement tank, constructed near omifima, were out-of-order, apparently for a long time. This was also noted in the reports of the WES consultant.

The sand filter at the King's place functioned satisfactorily, according to his saying. The influent is tap water already treated. Water is used for drinking and cooking. The running of the three other filters had stopped some time ago as they produced water with a bad smell. The water used was then coming from the canal. The major reported problems were the bad smell of the water and that after some time the filter stopped producing water.

The composition of the sand filters is illustrated in figure 11. One older filter at the Garden Centre had a charcoal layer of 6 cm of the type promoted in the DWA/UNICEF pamphlet (figure 12 and appendix 8).

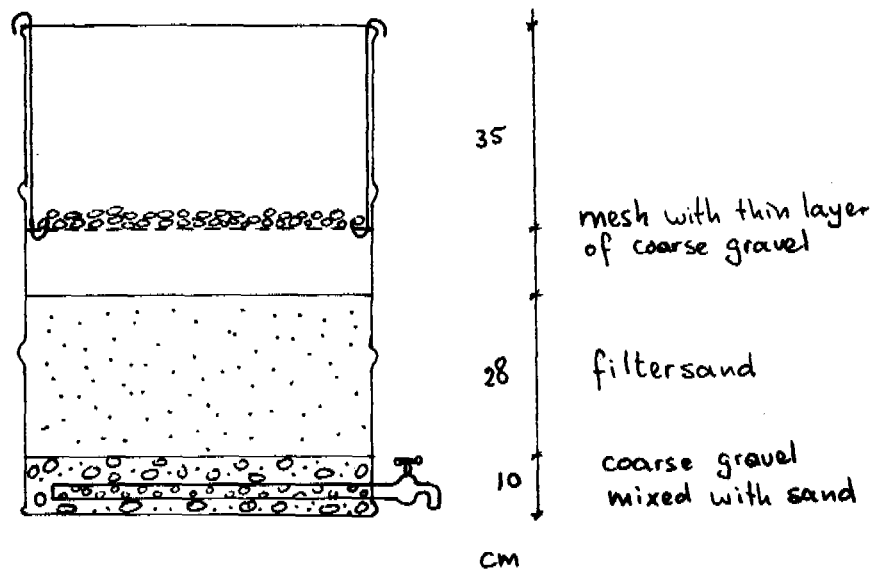


Figure 11: Composition of old sand filter

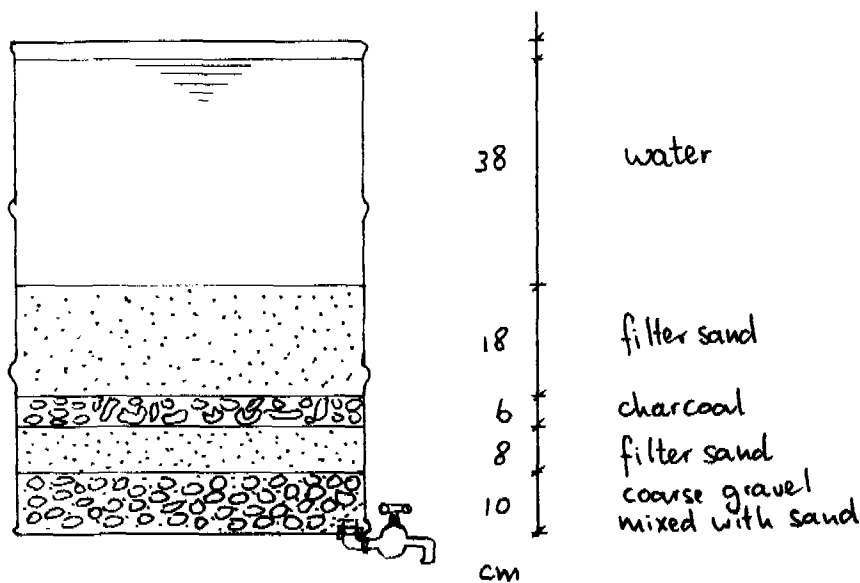


Figure 12: Composition of the sand filter with charcoal layer

## 5.2 Experiments with small scale water filters

### 5.2.1 Old filter at Garden Centre

One filter at the Garden Centre (without charcoal) had been restarted one week before the consultancy, i.e. the filter was filled up with water but without flow or tapping water. Neither had the sand been removed and washed. The supernatant of the filter was drained, and it was observed that the sand surface was seriously damaged by too abruptly pouring in of raw water. A sample of the upper sand layer was taken for testing the organic content. It was found that about 30 volumetric percent consisted of fine silt and calcium compounds which very slowly settled. A sample taken from the mid-sand depth of the other filter gave only about 10 volumetric percent fine material. This indicates that particularly the upper sand layer retains the impurities and colloidal materials (including over-saturated calcium and potassium salts) present in the raw water.

#### **Modifications prior to re-start**

Before re-starting the filter some modifications were made. A sieve was installed and the filter was re-started by pouring in raw water using a spray-headed watering container; this to avoid damaging of sand bed. Furthermore, the outlet was raised to above the sand level to prevent the sand bed of getting dry if tap was left open. Daily about 120 litres of water was filtered through. The raw water came from the oshana and had a Total Suspended Solids content of 10,282 mg/l. The effluent of the filter did not show an improvement in water quality compared to the influent. The filtration rate applied was too high. After four days the filter was stopped and the water drained. The dried sand bed showed a hard cemented surface, probably due to sedimentation of calcium and potassium salts present in the water.

### 5.2.2 New sand filter

Reference is also made to the general overview of experience with household water filtration systems, made as part of this consultancy for UNICEF Namibia using the documentation holdings of IRC.

### New design

To overcome the problems faced with the old filters, a new design was made and tested. The composition of the filter is given in figure 13. The major features are (i) three gravel layers to prevent sand intrusion at water collection height; (ii) sand bed of 45 cm; (iii) water outlet above sand level; and (iv) screen to uniformly distribute the raw water. The raw water level was kept just under the rim of the drum. The sand was collected from the canal, with an effective diameter ( $d_{eff}$ ) of 0.2 mm and a uniformity coefficient (UC) of 2.5. The sand curve is given in appendix 9.

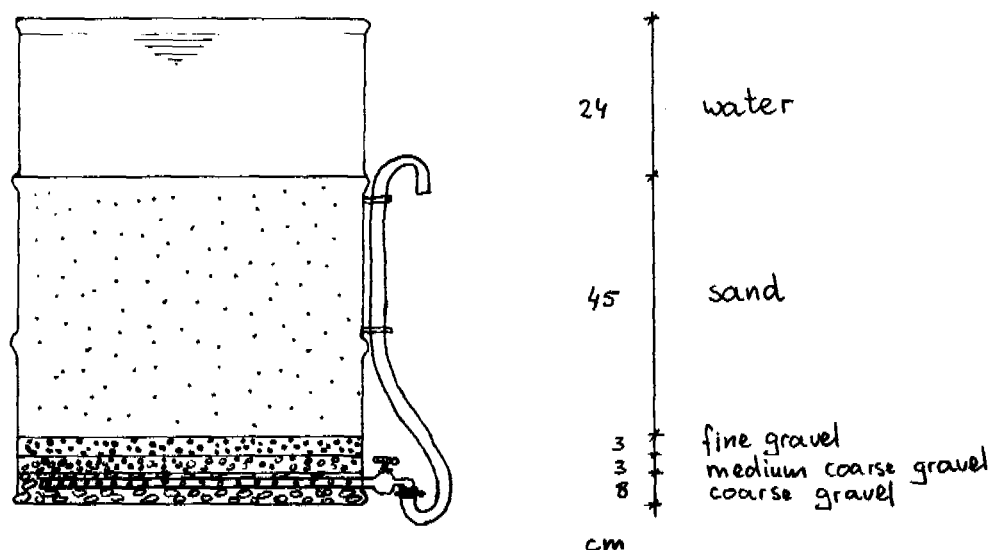


Figure 13: Composition of new sand filter

#### Sand filter run 1

The filter was started with water from the oshana with a total suspended solids content of 10,282 mg/l. After four days the filter got nearly completely clogged, and no more water came out. No breakthrough of impurities had happened. In total about 50 litres of water with very low turbidity was tapped. It was found that most suspended solids were retained in the upper part of the filter, although also deeper penetration took place (as also for old filter). It is very obvious that no substantial bacteriological improvement of water can be expected as the required biological film (Schmutzdecke) will not develop on top of the sandbed due to high suspended solids content and short filter run.

#### Sand filter run 2

After draining and scraping off about one centimetre of the sand bed, the filter was restarted with water from a dam with a turbidity of 520 NTU and suspended solids content of 2,701 mg/l. It was obvious that water with such characteristics would not give good results. The water was tapped almost continuously during day time. In three days about 40 litres of water was tapped. The production of the filter had then diminished to nearly zero.

#### Conclusion

After these experiments it can be concluded that the sand filter is inappropriate for raw waters such as from oshanas, dams, omifima, canal etc. The suspended solids content is much too high to ensure filter runs of reasonable length (say at least 4 weeks) and satisfactory bacteriological improvement. The water needs to be pre-treated first.

If water quality is acceptable, i.e. turbidity below 20-30 NTU, the sand filter is expected to function satisfactorily. Water of such low turbidity is for instance coming from the suggested collector wells in the omifima.

The modification required is the fixed outlet (tap) above the sand level as indicated in figure 14. The proper operation requires continuous flow of water; therefore the water should flow in a container and the tap strangled that no more than 150 litres is tapped per day. This represents a filtration rate of 0.022 m/h. (Usual rate for slow sand filtration is 0.15-0.20 m/h). This lower rate is advisable because of the small size of the filter and the possible effects from the large ratio of circumference and surface area.

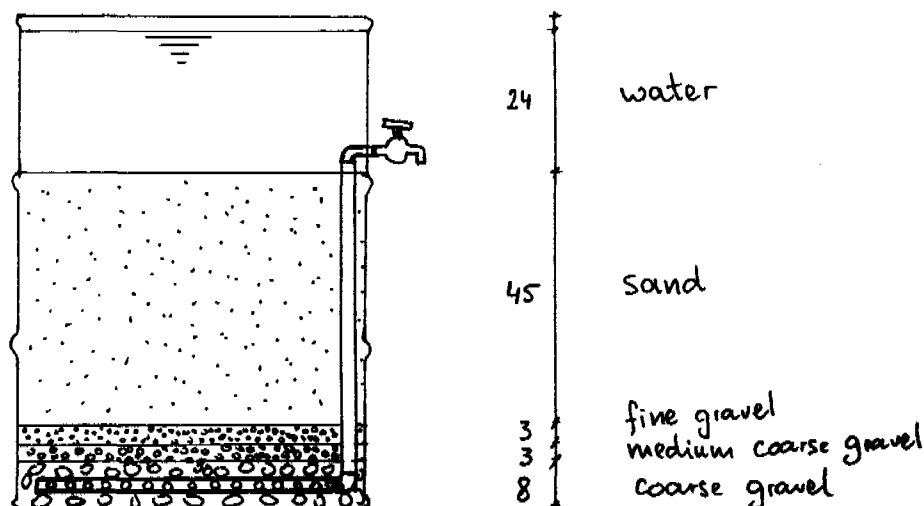


Figure 14: Proposed sand filter

### 5.2.3 Pre-treatment options

The pretreatment options considered are:

- \* upflow gravel filtration
- \* batch coagulation

Prolonged storage (48 hours and more) will not have the usual effect of reduced turbidities as a result of sedimentation as a very large part of the suspended solids is of colloidal nature, and will therefore not settle. However, a short sedimentation period (2-6 hours) is recommended to allow settling of solids that became re-suspended as a result of whirling in the water during the collection from the surface water source.

#### Upflow gravel filtration

Building on experience with upflow gravel filters in Colombia (Galvis, 1992) which yielded high potential to remove high loads of suspended solids from surface water, the experiment with an upflow gravel filter was started. The filter composition was made up of three gravel layers, the fine gravel being the most important, and a thick layer of coarse sand. The design is given in figure 15. Gravel came from Ruacana, local sand was sieved using a mosquito mask screen (see photograph: appendix 5).

The gravel and sand characteristics are:

- coarse gravel  $d_{10} = 15 \text{ mm}$  and  $d_{90} = 25 \text{ mm}$  (estimated)
  - medium coarse gravel  $d_{10} = 11 \text{ mm}$  and  $d_{90} = 17 \text{ mm}$
  - fine gravel  $d_{10} = 3 \text{ mm}$
  - coarse sand  $d_{\text{eff}} = d_{10} = 1.3$  and  $UC = 1.3$
- (see also appendix 9, for sieve analysis made by DWA).

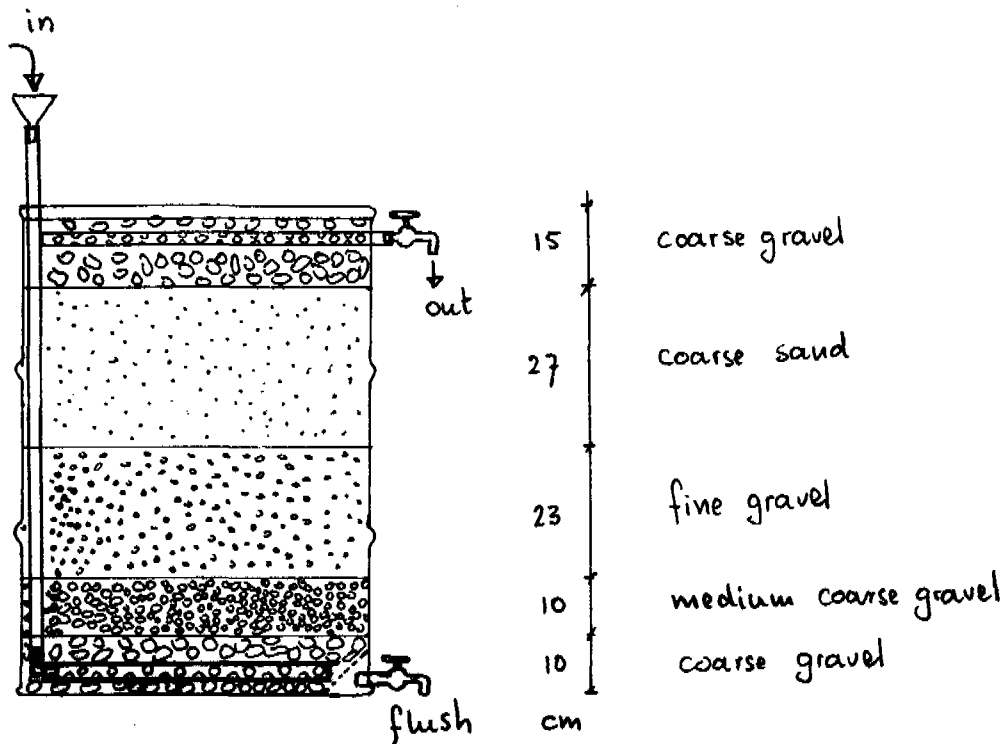


Figure 15: Composition of upflow gravel filter

### Performance

Some thirty litres of water was flushed upward to remove impurities from the filter. Then the filter run was started using raw water from a dam. After less than 24 hours, the first water was tapped, as 10 litres of water was brought in. The quality appeared to be much improved. Apparently, most colloidal suspended solids were removed from the water by the filter. Filtering of water continued at a rate of 30 litres per day (three times 10 litres at 4 hours intervals). After two days water from a nearby omufima was used. The sample taken after 48 hours of operation gave a low turbidity 15 NTU. The turbidity removal efficiency is therefore in the order of 97%. (see photograph: appendix 5).

The excellent performance of the filter is the result of the large fine gravel and coarse sand pack which give sufficient surface area for the suspended solids to settle on. Sedimentation is viewed as the primary purification mechanism. As bacteria, viruses etc. may be attached to the suspended solids, a small proportion of the total microbiological density may be retained. However, the bacteriological quality of the effluent will not be satisfactorily sufficiently improved because of the characteristics of the filter (gravel and coarse sand).

The gravel filter has shown high potential to drastically reduce the suspended solids of the troublesome dam and omifima water.



### **Further testing**

Further testing on this gravel filter is needed to arrive at the most optimal operation and performance. It is expected that up to 60-90 litres of water of reasonable clear water can be tapped from the filter. As the water volume in the filter barrel is about 120 litres, the retention time in the filter is for the indicated volumes 2 to 1.5 days. It is proposed to equally distribute the drawing volumes in portions of 10 litres over the 12 hours day-time. This will ensure sufficient retention time of the water in each part of the filter.

### **Smaller containers and baskets**

If the above described gravel filter performs well at a production rate of 60-90 l/day, smaller containers may give satisfactory results as well at a 30 l/day rate. The project could start some experiments on this. For both the sand filter and the gravel filter the option of using the traditional baskets may be considered, if costs of the manufactured filters are beyond the financial capacity of the people and if traditional baskets are culturally more acceptable.

### **Cleaning**

After several weeks the filter may get saturated with retained suspended solids. Then the filter is to be cleaned by draining the water in the filter barrel (about 120 litres) through the drain valve at the bottom. The need to add extra water from the top may be considered. Through experimenting the need for this additional down-draining and the volume of water required can be determined by the sludge load of the drained water. This drained water should be nearly as clean as the wash water used.

### **Dual filter**

Further treatment to produce bacteriologically safe water may be considered. The option of having a ferro-cement tank vertically split in two equal parts, one for the upflow gravel filter and the other for the sand filter may be field tested. A schematic drawing of such a dual filter is given in figure 16. The costs of the filter will be a disadvantage. The dual filter needs more users' attention which is hard to sustain. For instance, the effluent of the gravel filter flows automatically into the sand filter and so deterioration of gravel filter effluent (high turbidity) may not be noticed but seriously affect the operation and performance of the sand filter. Therefore, separate pretreatment (gravel) filter and sand filter arrangements are recommended.

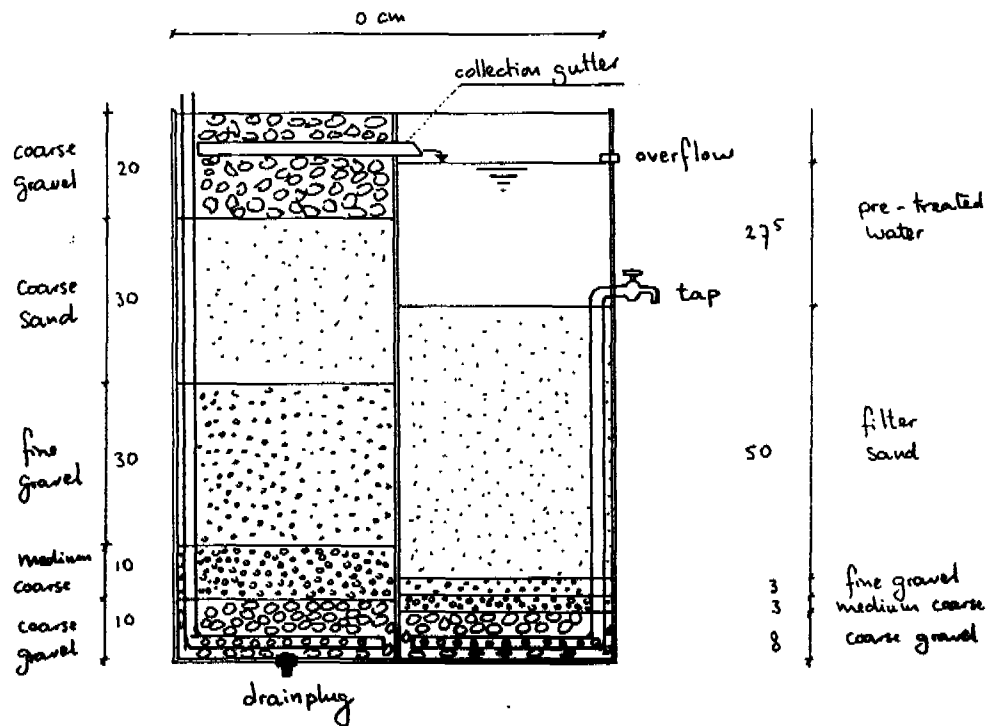


Figure 16: Dual filter: combined upflow gravel filter and sand filter

### Batch coagulation

In common water treatment practice, raw water with such a high colloidal suspended solids load is treated with chemicals. The conventional technology is then coagulation and flocculation followed by sedimentation. This method is also used by DWA in their batch treatment system in Ombalantu. There, water from the canal (turbidity below 100 NTU) is treated with aluminium sulphate and lime (for optimal flocculation) with good results.

Therefore, a batch coagulation experiment was started using different water and only aluminium sulphate (alum) as chemical. Lime was not added as this would make the process too complicated.

A 200 litres drum was filled up with raw water and alum (dissolved in water) was added. The water was thoroughly stirred for five minutes. Then the water was left to flocculate and for sedimentation of the formed flocs.

Three batch coagulation experiments were carried out:

1. with oshana water (total suspended solids = 10,282 mg/l) to which 20 grams of alum was added (equivalent to 100 mg alum per litre). The water quality had hardly improved after 6 hours and observable but insufficient improvement after 24 hours of settling time.
2. with water from dam (total suspended solids = 2701 mg/l and turbidity = 520 NTU) to which 15 grams of alum was added (equivalent to 75 mg alum per litre). The water had visibly improved after 6 hours and reasonably after 24 hours of settling time.
3. with water from omufima (total suspended solids = 2697 mg/l and turbidity = 450 NTU) to which 20 grams of alum was added (equivalent to 100 mg alum per litre). The water was substantially cleared after 6 hours and very clear after 24 hours of settling time.

The water must be tapped through a tap installed at 20 cm from the bottom, connected to a water pipe with holes drilled only at the lower side to avoid tapping sedimented solids (see figure 17). The effective volume of clear water will then be about 150 litres.

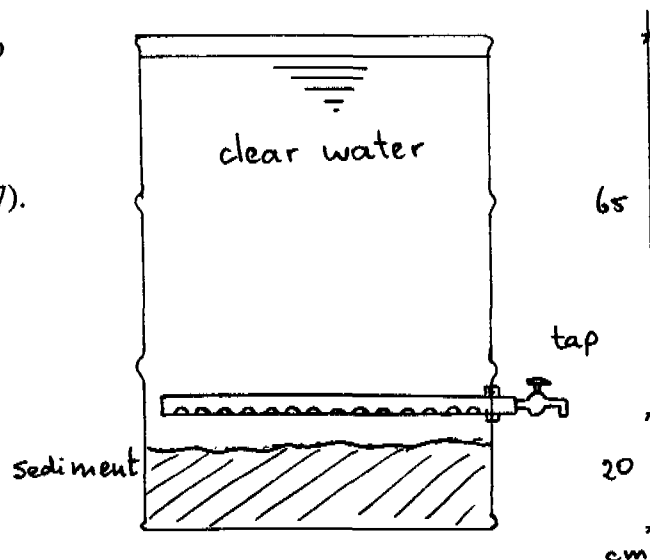


Figure 17: Batch coagulation barrel

### **Bottle-test**

The amount of alum to be added can be determined with the 'bottle-test'. Five bottles of one litre are filled with raw water to which different volumes of a stock solution of alum is added; for instance 30, 50, 70, 90 and 110 mg/l. After five minutes mixing, and allowing to settle for two hours the optimal alum dosing can be determined from the alum concentration used for the bottle showing the best clarity of the water.

### **Alum availability and cost**

The availability and costs of alum are the crucial criteria for introducing this pretreatment option. According to information from DWA, alum is not available at the market in small quantities. However, it was expected that if there is a market the private sector would step in. The required package weights would be sachets of 10 grams. Another option is larger packages and the use of a weight-indicating plastic scoop. The price for alum is in the order of Rand 300 for 50 kg. With a packing, transport and profit factor of 10, the price of 10 grams alum comes to R 0.6. For treating 150 litre of dam or omufima water one would have to pay R 1.2. The re-packing of alum could be considered as an income-generating activity for women.

#### **5.2.4 Possible effects of water plants on turbidity**

It was observed several times that water in dams and borrow pits that contained many water plants, had a much lower turbidity than neighbouring dams/borrow pits without. It is not fully clear whether the mechanisms responsible for that are the increased sedimentation area (leaves and stems) created by the plants or bio-chemical processes play a role. This could be an area for further research in which a university may be interested.

In the meantime the project may consider to encourage people to cultivate plants in their nearby water source. However, it was also observed that water from such locations have a very rich water fauna. The bacteriological quality will not have changed much and hence slow sand filtration is highly recommended.

### 5.3 Final treatment options for safe water

Several discussed water supply and treatment options greatly improve the water quality but will not render the water fully safe, i.e. free of pathogens, to drink. Therefore, some additional treatment steps could be considered:

- \* sand filtration
- \* UV radiation
- \* chlorination
- \* boiling

#### 5.3.1 Sand filtration

The technology has been extensively described in earlier sections. Slow sand filtration is capable to reduce bacterial densities with 95 to 99.99% (Visscher et al., 1987; Huisman and Wood, 1974). Also protozoa will be retained by the filter.

The capacity of the slow sand filtration to produce bacteriologically safe water is primarily based on the presence of a biological film (Schmutzdecke) made up of all kind of micro-organisms on top of the sand layer.

Proper operation is important (e.g. continuous flow) as well as careful cleaning at the end of filter runs, which are determined by far insufficient production of clean water. Operational instructions are clearly presented in Slow Sand Filtration, manual for caretakers (Visscher and Veenstra, 1985).

#### 5.3.2 Ultra-violet radiation

Ultra-violet radiation has the power to kill bacteria. If water with low turbidity in clear glass or plastic bottles is exposed to direct sunlight for six hours than nearly all bacteria and many other micro-organisms present in the water will be killed (Acra et al., 1984). Protozoa cysts may be killed if temperatures reaches above 50°C. Overcast reduces the UV radiation and therefore the exposure time is to be increased to 10 hours. A copy of instructions for solar disinfection by Acra (1984) is appended (appendix 10).

This method is simple but needs some routine handlings. Pre-treated water or water from collector well meant for drinking, is to be poured in covered clear glass or plastic bottles and be placed in the sun. The water may cool down during the night, ready for drinking the following day.

As clear glass bottles are abundantly available in Namibia and sufficient sun appears not to be the problem, this method is recommended.

#### 5.3.3 Chlorination

Chlorination is an effective way of killing most pathogens, except the protozoa cysts. It is commonly applied in conventional water treatment practices. However, application at household level faces several drawbacks. The availability and cost of the chlorination agent may be a problem. Another common problem is that people have problems in

applying the right doses of chlorine. Too much chlorine may result in a bad taste and rejection of the water for drinking. Too little chlorine may not be sufficiently effective to kill all pathogens.

Chlorination agents that could be used for household include Milton, Javil, Jik and other bleaching agents.

The commercially available Chlor-Floc powder (from Noristan, S.A.) has a double action: coagulation of suspended solids and disinfection. The cost of treating 20 litres is R 0.5 (one packet). For the oshana water two packets are needed for clarifying the water (Mhone, personal communication). The costs and availability of the Chlor-Floc (and the taste/smell of the water) do not favour the introduction of Chlor-Floc in the rural areas.

Because of the for-mentioned problems chlorination of water at household level is not recommended.

#### *5.3.4 Boiling of water*

Boiling water is an effective mean to kill all pathogens provided the water is boiled for several minutes.

The reasons that boiling is mostly not applied although many health workers continue to recommend this method are: (i) boiling takes a long time; (ii) it consumes a lot of scarce and expensive firewood or other fuel; (iii) it flattens the taste of water; and (iv) it takes a long time to have the water cooled down.

Therefore, boiling is not recommended. Yet, boiling of the drinking water for small children may be a good option.

### **5.4 Replicability and sustainability of treatment options**

The replicability and sustainability of the technologies suggested is reviewed in terms of cost, availability of materials and spares, technical capacity to produce treatment options, need for extra support (from outside community), operational care required, operation and maintenance costs, involvement of women in operation, and appreciation of benefits.

#### **Cost**

The cost aspect is important for the replicability. The costs of the technology should be affordable for the families. Furthermore their willingness to spend the money very much depends on their appreciation of the potential benefits (see later). In the demonstration phase the project could consider to subsidize the costs of the systems to be demonstrated. However, eventually all costs should be borne by the users. Transportation costs of filter material could be subsidized.

The filter systems comprise a used oil drum, some piping, bibcock, putty and filter material. The oil drum (cleaned and painted) may cost around R 30 each, the piping R 10, and the bibcock R 20-40. The gravel for the filter has to come from Ruacana, with transport costs of about R80/m<sup>3</sup>, while the aggregate may costs around R20/m<sup>3</sup>; total aggregate cost R 100/m<sup>3</sup>. The coarse and filter sand can be found locally (some sieving using mosquito mesh is required).

The cost of the gravel filter will be around R 100 excluding filter transport and installation. Instead of a bibcock for collection of water, a small gutter can be used. The cost of the sand filter will be around R 80 excluding filter transport to the homestead and installation. If smaller containers or traditional baskets are used, the prices will be less.

The cost of the batch coagulation barrel (200 l) will be around R 50, excluding transport. The solar radiation disinfection does not involve any cost as plastic and glass bottles are abundant in Namibia.

#### **Availability of materials and spares**

Filter material is not available in Uukwaludhi district except the filter sand which needs sieving for the coarse sand layer of the gravel filter. The gravel is to be transported from the Ruacana Crusher. The common Kalahari sand is too fine for the sand filter; however, the local people know locations where coarser sand can be found.

Piping and bibcocks can be bought from hardware shops in Oshakati. Old oil drums are sometimes available at the market but as many drums may be needed other suppliers (harbour, chemical industries) are to be found. Smaller plastic containers are available from shops and in the market.

#### **Technical production capacity**

The technical capacity to produce the filters has not been assessed in detail. Reference is made to the consultancy report of Stephen Hussey (April 1993). The production does not require special skills, neither are many tools required (chisel, hammer, shovel, pliers). Any mechanical workshop or small workshop run by men or women (income generating project) could produce the filters. A short training may be useful to highlight important features of the filter.

#### **Need for extra support**

Limited support from outside the community is needed in the long term. The production workshop and the trained Community Health Workers are capable to cover all technical, operational and hygiene aspects. Support is needed in terms of monitoring, advice and refresher training, as well as on communication and education/promotion materials. Support in the start-up phase may be useful in transporting filter media to the production workshop. Transport of filters to the site may use donkey-carts.

#### **Operational care required**

The operational care of the sand filter is the scraping of the upper 1.5 cm of the sand bed when the water production is become very low (frequency less than once a month), and resanding the filter when the sand bed thickness is less than 25 cm (less than one a year). General information on operation can be found in Visscher and Veenstra (1986) and in IRC Training Series 5. It is important that the flow of effluent water is continuous. The production of a short pamphlet illustrating the steps in cleaning and resanding is needed. The upflow gravel filter may need cleaning by downwashing once or less a month. Details or given in section 5.2.3 of this report. The production of water is in small portions (10 litres) when raw water is poured in the inlet.

The operational care of solar disinfection is the daily filling (early morning) and placing in the sun of the bottles.

The availability of the advisory support of the health workers to the households is crucial.

**Operation and maintenance costs**

The operation and maintenance costs are very low to nil as there are no consumables. Replacement of bibcock and other parts is not expected within five years of use.

**Involvement of women in operation**

In Owambo, women and children are usually in charge of collecting water, and may spend a substantial part of the day in this activity. Their role in the common household activities is outstanding as the men and the boys spend much time with the cattle. The role of the daily operation of the water treatment is clearly an extension of water collection and close to the household activities. For instance, the sand filter has a continuous operation and the gravel filter in small volumes of 10 litres a time, and solar disinfection is a daily routine. In most situations these tasks will be taken up by the women. It will slightly increase the load of the women.

**Appreciation of benefits**

It is presently unclear how people (women, mothers, men) appreciate clear and safe water. As mentioned in section 4.1 it is important to get comprehensive understanding of the local practices on which further developments should be built. Hygiene education through CHWs can stress the importance of safe water in the reduction of health risks. Monitoring and reporting to the people of potential and actual reduction in water-related diseases can be considered.

## 6. Desalination

In many locations in Uukwaludhi district, the only water available during a large part of the year is saline well water. Many wells draw water from the discontinuous perched aquifer which may be very small. Then the salt water aquifer is hit and saline water is the only reliable source of water (See figure 4).

Extrapolation of TDS values of a number of boreholes in Owambo have resulted in a map (appendix 11) for expected TDS levels of groundwater in Owambo (ref. Groundwater Consulting Services). This excludes the discontinuous perched aquifers and the fresh water lenses (see figure 4).

According to the WHO Guidelines for Drinking Water Quality (1984) water with a TDS level above 1000 mg/l is not acceptable. However, people and stock in Owambo may drink water with TDS levels up to 10,000 mg/l.

There are several options to address the problem of lack of fresh water:

- \* desalination of the salt water
- \* rainwater harvesting for drinking water
- \* bringing in piped water for human consumption only through communal water points
- \* trucking drinking water
- \* other methods

### 6.1 Desalination techniques

Although the technology of desalination of water is highly developed, almost all methods are inappropriate for use at household level in rural areas. Two methods have been extensively tested and introduced in rural areas:

- \* wood-fuelled still
- \* mexican solar-powered still

In India, a solar-powered still has been recently developed, but only limited information is available.

Most information in this section is retrieved from *Solar-Powered Desalination* by Yates, Woto and Tlhage (1990).

In some areas, people do not like the flat taste of distilled water. Mixing with for instance rainwater would increase the acceptability.



### 6.1.1 Wood-fuelled still

In Botswana a wood-fuelled still was developed and field-tested. The still consists of a three-legged cast iron cooking pot covered with a lid with condenser, see figure 18.



a.

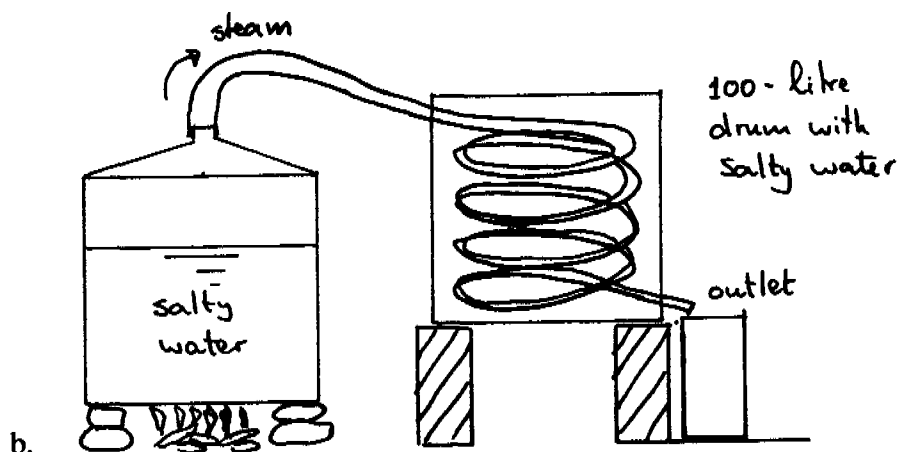


Figure 18: Wood-fuelled stills: a. kudu-horn b. Ghanzi still (source: Yates et al., 1990)

The kudu-horn still was not accepted by the people as its yield was very low: 0.7 l/h, the fuel consumption high and the danger for accidents with children was also high.

The Ghanzi still was not a success at village level because the salt residue was not flushed out resulting in scaling and corrosion, the firewood in the vicinity got depleted, and fair distribution of water appeared to be impossible. The yield was 33 l/h.

### 6.1.2 Mexican solar-powered still

The principle is that a glass-covered basin filled with salty water is placed in the sun, the water evaporates and condensates on the glass. The condensed water flows into a gutter that into a small container.

The model is schematized in figure 19.

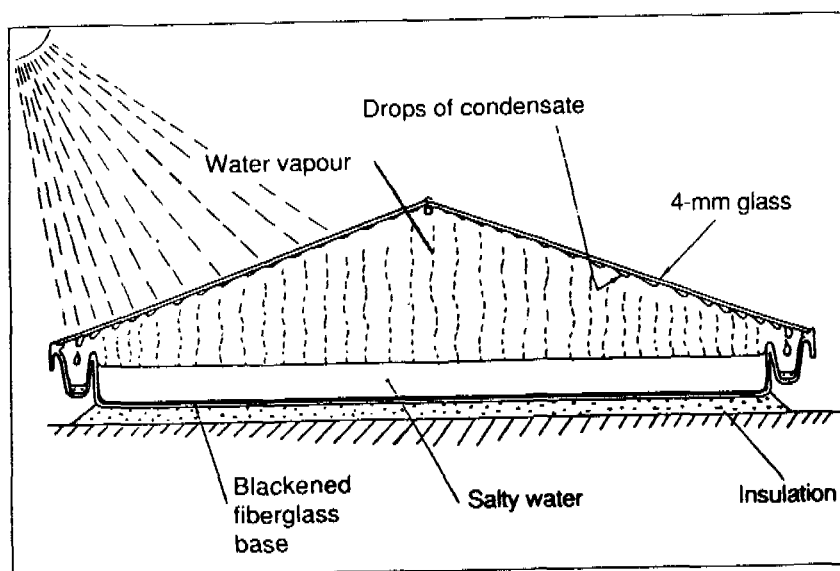


Figure 19: Mexican still developed by Rural Industries Innovative Centre (source: Yates et al., 1990)

The yield of the Mexican still depends on the solar radiation. Maximum yield obtained 4.4 l/m<sup>2</sup> equivalent to 8 l/day for the standard solar still. Typical summer yields were 7 l/day and in winter 2.5 l/day (night temperature up to minus 9 centigrade).

Cost of the still in Botswana (1985) was US \$ 340 per still.

The yield is too low for one household's drinking water consumption.

Desalination using solar stills was the topic of research initiated by the Water Research Commission of South Africa before independence. Field investigations and trials were also done in Namibia but not very successful (Götze, personal communication). The WRC Pretoria published a report on this research.

### 6.1.3 Indian solar still

A researcher of the Indian Institute of Technology in New Delhi developed recently a solar still comprising of sheets of black polythene sandwiched between sheets of black jute (New Scientist, 1993). The principle is schematized in figure 20. Data on costs, production and efficiency are not known as yet.

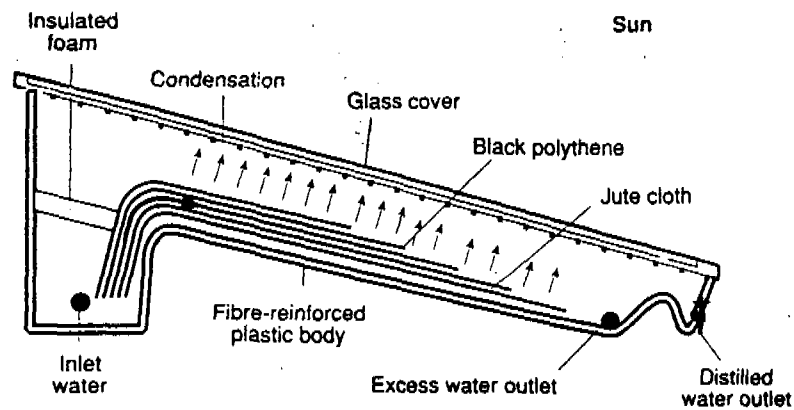


Figure 20: Solar still developed by Indian Institute of Technology (source: Coghlan in New Scientist, 1993)

## 6.2 Rainwater harvesting

This option has been extensively discussed in section 4.2. The issues limiting this option are the low rainfall (around 300 mm/year) in these specific areas with high TDS concentrations in groundwater; and the high investment costs if rainfall harvesting has to meet all household water demands.

## 6.3 Piped water supplies

The reticulation network does not have to be very dense; households can use donkey transport and perhaps aqua-rollers to ferry the fresh water. An acceptable maximum distance between any household in this particular area and a water point may be 10 km, or a return trip of 4 hours by donkey. Issues as willingness and capacity to pay, as well as other consumer-related management issues are to be addressed prior to any decision. This option should be further studied by DWA and UNICEF on feasibility and sustainability. The introduction of cost recovery of O&M costs of rural water supply planned by DWA should be taken into account. Furthermore, extensive hygiene education is then to be part of the promotion and education campaign.

## 6.4 Trucking of water

Yates (1992) viewed trucking as the simplest, most expensive and least reliable solution to the fresh water supply problem in Botswana. This option is not worth the consideration.

## 6.5 Other methods

Reverse osmosis is the process whereby salt water is put under high pressure against a membrane, which allows water through but not the salt molecules.

Small reverse osmosis units with a production capacity of 30 l/day are available. The common problem is the clogging and damaging of the membrane because of poor raw water quality. Possibly required pretreatment of the raw water augments the complexity of the technology, and so reduces its feasibility and sustainability. The cost of membranes is high, and availability in Namibia is not known. The required power could be produced by hand or pedals. The technology is not low-cost but may be worth the consideration. In the western part of Namibia DWA experimented with fog collection. These experiments were not continued.

## *7. Institutional aspects related to rural water supply development*

The Department of Water Affairs (DWA) is responsible for the bulk water supply for stock and human consumption. According to the present planning, DWA will take over the Rural Water Supply activities from the Directorate of Rural Development in the Dept. of Agriculture. Within DWA a new directorate is planned for Rural Water Supply. The administrative handing-over has not yet taken place. The new directorate has to establish policies, strategies and guidelines on how to work on rural water supplies with the communities. This applies both for community-managed piped water supplies as for point water sources, such as shallow wells and boreholes, and for small dams and reservoirs. Also information and support structures on the development of rainwater catchment and simple water treatment systems will probably be the responsibility of the directorate of Rural Water Supply. For the management of public standposts of the piped water supply, water committees will be established. Recently, the DWA established 8 committees in the Okahau water supply line.

The activities carried out during this consultancy and follow-up activities proposed ought to be discussed with DWA's Rural water supply directorate for integration in their programme of activities. UNICEF's water activities could achieve more if they are being done in collaboration with the agency responsible for rural water supply activities. Closer cooperation and consultation with DWA in the development and implementation of feasible water supply and water treatment technologies is recommended.

## 8. *Conclusions and recommendations*

### 1. Water quality characteristics

The quality characteristics of water from oshanas, omifima and other surface water sources is very poor in physical and bacteriological terms. This is primarily caused by the dissolving and re-suspension of salts from the soil during runoff of the rainwater. Little can be done to prevent this occurring. The water quality usually worsens due to evaporation. Both physical and bacteriological quality can be improved. In certain locations in the district well water, the common water source, is very saline.

### 2. Existing water sources for human consumption

- A wide range of water sources is used: rainwater, groundwater (traditional shallow wells or omifima, hand dug shallow wells, hand dug pits in the oshana, boreholes), surface water (oshana, dams, circular dams, omufima, borrow pits, canals) and piped water supply
- People in Uukwaludhi use mainly the convenience criterion in selecting their water source, which means that the closest water source is used for all purposes. However different sources are used during the year as source capacities diminish towards the end of the dry season.

### 3. Potential drinking water sources for rural Uukwaludhi

- For the selection of most potential source and best technology several aspects have to be considered, including community and consumer-related aspects (such as distance and convenience), institutional aspects and technical aspects.

**Recommendation:** to conduct a participatory community survey to collect required data on relevant aspects and to collect other required information on technological and institutional aspects (see section 4.1).

Considering the quality, quantity, accessibility and reliability rainwater and omifima are the most potential water sources for human consumption in rural Uukwaludhi. For rainwater the technologies recommended are roof and surface catchment, and for omifima the infiltration well. Both technologies seem feasible and sustainable, although investment costs and subsidizing mechanisms for both have to be worked out.

**Recommendation:**

- (i) to further develop the potential options
  - (ii) to introduce the options in pilot areas
  - (iii) to discuss with DWA their interest in the options and their possible contribution in investment costs and technical support on short- and long-term basis.
- The ultimate water supply source will remain "imported" water from the canal and the piped water supply system. Improved water transport systems for instance using donkeys, should be considered.

**Recommendation:**

- (i) to discuss with DWA the capacity of the piped supply for this option and the arrangements for community management of the water points.
- (ii) to experiment and promote the use of donkeys in transporting water.

4. Low-cost water treatment systems for household level application

- Experiments with pretreatment through upflow gravel filtration were very satisfactory in terms of quality improvement, and promising for water production and filter run length.

**Recommendation:**

- (i) to continue with experiments with omufima raw water and increased production to 60-90 l/d.
  - (ii) to install some filters in households of community health workers for field pilot testing on acceptance, appreciation, functioning and performance, and costs.
- Experiments with pretreatment through coagulation with alum were successful. Alum is presently not marketed in small quantities.

**Recommendation:**

- (i) to follow up availability and cost of alum
  - (ii) to install some batch systems in households of community health workers for field pilot testing on acceptance, appreciation, functioning and performance.
- Substantial water quality improvement was observed in dams and borrow-pits through purification mechanisms of water plants and possible bio-chemical activities.

**Recommendation:** to approach scientific institution for possible interest in further investigations on this feature.

- As the suggested pretreatment methods do not produce a bacteriologically safe water, subsequent treatment can be sand filtration, UV radiation, chlorination, or boiling. As most feasible and sustainable method is slow sand filtration or UV-radiation recommended.
- The present sand filter did not function properly because of poor raw water quality and design faults.
- Experiments with modified old sand filter were very unsatisfactory.
- Experiments with new sand filter design were satisfactory in terms of effluent quality but a failure for water volume production and filter run length.

**Recommendation:** to start new sand filter using pre-treated water from upflow gravel filter, and monitor its functioning and performance.

**Recommendation:**

- (i) to test option of UV-radiation using pre-treated water
- (ii) to introduce option with community health workers

## 5. Desalination

- The following options for desalination have been reviewed: wood-fuelled still, Mexican solar-powered still, Indian solar-powered still and reverse osmosis. None of the methods have a great potential for household water treatment because of low yield, high fuel demands, high investment costs, high O&M costs, and present non-availability of spares.

**Recommendation:** to investigate potential for reverse osmosis at neighbourhood level (medium scale)

- Other potential options for household water supply in those parts of Uukwaludhi where people now depend on salt groundwater are:
  - \* rainwater harvesting for drinking water
  - \* bringing in piped water for human consumption only through communal water points
  - \* trucking drinking water

The first two options have potential but investment costs are high and for piped water supplies people may have to collect water from quite some distance for which they may have to pay.

**Recommendation:**

- (i) to determine the potential for rainwater harvesting in terms of quantity of water versus costs, acceptance and O&M capacity of people
- (ii) to discuss the potential for the piped water supply option with DWA, and with the rural people their views on required efforts and costs.

## 7. Institutional development

**Recommendation:**

As soon as the relocation of Rural Water Supplies in DWA has been effectuated, UNICEF could establish closer cooperation and consultation links with DWA.

## 9. Plan of Action

Several important points needing further and more attention came to the surface which could be included in the Plan of Action for the coming period. The most important areas of attention are:

- participatory community survey
- rainwater harvesting at household level
- omifima with filter and collector well
- household water treatment systems
- piped water supplies
- training and promotion
- monitoring and evaluation

### **Participatory Community Survey**

From informal discussions with people in Uukwaludhi and other information the programme staff received, people expressed the problems they face with water, more specifically the problem of poor availability of water. Reducing the burden of water collection is apparently among their top priorities of problems to get solved. It remains somehow unclear whether water quality is also one of their major concerns. Introduction of household-based water treatment should not be done from the project's perception but respond to a felt-need and priority expressed by the community.

It is therefore recommended to conduct a participatory community survey on the people's view on water use, practices, problems, priorities, ideas etc. A number of issues have been mentioned in section 4.1. Appropriate participatory methods have been developed to be used in such a survey including pocket chart, mapping, puppet chart, discussions etc. (Srinivasan, 1990).

The survey should be well-designed and survey teams trained in a practical way. Specific tools and materials (like area-specific puppet charts, illustrations for pocket charts) should be developed during the workshop with the help of local illustrators.

This activity may take up to four weeks and the assistance of a consultant familiar in participatory techniques may be considered. The survey team is to be composed of health, water and community development staff from the district. It is suggested to have this activity carried out as soon as possible as it gives the basis for further development directions.

### **Rainwater Harvesting**

Rainwater harvesting has a high potential in Uukwaludhi. The roof catchment systems for institutions (schools etc.) are well developed in the project; designs, costs etc. are known and documented.

Development of smaller storage systems, their construction techniques and costs should be looked into, e.g. the 200 litre non-reinforced tank. Underground tanks collecting water from roof and surface catchment have to be developed; examples are available in the literature (e.g. Lee and Visscher, 1992).



Experiments have to continue simultaneously with introduction in the community, of more efficient surface catchment designs. All are to be done before the next rains. The use of oshipale and other suggestions on surface catchment are given in section 4.2.

If these experiments are successful, further introduction in the community through CHWs can be done. The involvement of the private sector and training of artisans is then to be planned.

### **Collector Well with gravel/sand filter**

This option has high potential for the period directly after the rains until the omifima get dried up.

The activities to be carried out are:

1. investigations on existing collector well in Onangalo; i.e. for presence and composition of possible filter, depth of well etc.
2. discussions with the users of the well in Onangalo on management, appreciation, problems etc.
3. discussion with DWA Rural Water Supply Division on their interest in this option and their possible contribution in investment costs, construction material supply and technical support on short- and long-term basis
4. introduction of the option in a few potential omifima, preferably near a CHW's home, and after having the system and its testing discussed with a group of users
5. monitoring of functioning (e.g. quantity of water), performance (quality improvement), acceptance, appreciation, problems etc. of the supply/treatment option

Activity 1 and 2 can be carried out when the omufima is dry (October/November), and will take one to two days.

Activity 3 can be done before October, in order to allow sufficient time for their participation in the introduction of the option in November, before the rains.

Activity 4 can be done when the potential omifima are dried up, say in November; and will take two weeks.

Activity 5 starts as soon as the rains have started, the omifima is filling up and water can be drawn from the well.

### **Piped water supplies**

If even people living far away from the piped supplies system would make more use of this source of water, then the management of the standposts would become urgent. Management would include controlling the amount of water collected and the hygienic conditions around the standpost. The formation of water committees is the responsibility of DWA, as well as policies on management and cost recovery.

These issues could be kept high on the agenda in discussions with DWA.

The accessibility of this water supply will be increased when people living far away from the supply system use donkeys for transport. The project should experiment and promote the use of donkeys in transporting water by giving options how donkeys can carry the water.

This activity can start directly.

## Household water treatment systems

### Upflow gravel filter

The started experiment on household treatment systems using the upflow gravel filtration can go on. IABP Project staff, already involved can do the testing, coordinated by the WES consultant. Filtration volumes can be increased (after one week running on 30 litres/day) to 60 litres per day and then after one month to 90 litres per day. Simple turbidity tests can be carried out at the spot. Records should be kept daily of time and volume filtered, influent and effluent turbidities, and filtration days till end of filter run. An example of the form format is appended 10.

Cleaning by downwashing is to be done as soon as the effluent turbidity increases steeply. Turbidity of last downwash water is to be recorded; if turbidity is higher than influent turbidity, extra water is to be added from the top of the filter. Records on results have to be kept.

If the experiment is viewed as successful (say after 2 months functioning, perhaps with two cleanings), some filters can be installed in homes of CHWs and fieldtesting on acceptance, appreciation, functioning and performance can be done by them.

An experiment using a smaller container (50-60 litres) can be started at the Garden Centre, using the same filter characteristics but a smaller output of 20 litres per day. Drawing of water should be done in batches of not more than 5 litres a time.

### Coagulation

Using 200 litres drums can be seen as a communal system, as every day 150 litres of clear water can be produced, sufficient for 75-100 people.

At household level smaller containers (50 litres) will provide about 40 litres of clear water, sufficient for 2 days drinking water for 10 people.

This can be introduced in the homes of some CHWs when the supply and way of dosing of alum has been secured. Dosage can be determined using the bottle test. Monitoring can be done by them.

### Slow Sand filtration

An experiment in the Garden Centre can be started using the present slow sand filter arrangement after thoroughly cleaning all filter media. The volume of water to be filtered per day can follow the output of the upflow gravel filter, which water is used as influent, so 60 to 90 litres per day. Effluent of slow sand filter is to be tested for turbidity, and once a month on bacteriological quality (faecal coliforms or E-coli).

When the experiment with the smaller gravel filter starts, a smaller sand filter can also be installed, using the output of the smaller gravel filter. Filter characteristics remain the same as for the larger sand filter.

If first experiment is successful, introduction at a few CHWs' homes of the smaller sand filter can be done. They have then to monitor the functioning, performance etc. of the sand filter using a special scaled plastic tube for turbidity measurement.

### UV-radiation

This option can be further tested at DWA using the effluent water coming from the upflow gravel filter and coagulation barrel, and also using raw omufima water for comparison. Plastic bottles of 2 litres, abundantly available in Windhoek, can be used for this experiment.

DWA Oshakati is the best place as there bacteriological water analysis (E-coli or faecal coliforms) are carried out. Sampling in Tsandi would mean that samples have to reach Oshakati within four hours on the days that DWA scheduled to do bacteriological analysis.

Discussions and arrangements with DWA Oshakati have to be made.

Simultaneously, the introduction of the UV option can be done at CHWs' that have upflow filters or coagulation jars.

### **Other water supply and water treatment activities of lower priority**

#### Collection of additional data

Apart from community data and views of the people, information is to be collected on institutional and technological aspects. This can be done by project staff and may make two weeks to have these data/information collected and processed.

#### Effect of water plants on turbidity reduction

It is suggested that a scientific institute is approached for possible interest in further investigations of this potential capacity of plants.

The water from such locations has to be treated further (sand filter, filtering through cloth) as much water fauna is present.

#### Reverse osmosis for desalination

Information on small scale reverse osmosis from other countries and projects facing the same problem is to be collected.

If potential for this technology as seen from other experiences is high, an experiment at neighbourhood level can be considered.

#### Piped water supply into areas with only saline groundwater

This option is to be discussed with DWA as soon as their responsibility for rural water supply has become effective.

#### Income-generating projects

Some activities could be considered to be taken up by income-generating groups depending on their success in the demonstration/introduction phases:

- \* repacking and sale of alum
- \* production and sale of household filters (different sizes)

### **Training and promotion**

- \* introduction potential best water sources for human consumption and potential water treatment technologies in courses of health workers, especially CHWs and HAs/HOs
- \* strengthening (introduction) health aspects of adequate and safe water in health and hygiene education activities of health workers (CHWs, HAs/HOs etc.)
- \* development of training material on above issues for these courses and sessions
- \* development of promotional and technical information material (guidelines for O&M) on water sources and water treatment
- \* training artisans on surface catchment of rainwater

### **Monitoring and evaluation**

Monitoring and evaluation of improved water supply and water quantity using established indicators on a.o. acceptance, appreciation, problems, functioning, and performance. The CHWs who will receive demonstration plants will do part of this monitoring, for which specific indicators have to be established.

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## APPENDICES

1. List of persons met
2. Terms of Reference
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4. IABP-Unkwiludhi Project Area
5. Photographs
6. Water analysis of samples taken and data from three oshanas west of Oshakati
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8. Pamphlet on "Safe Water for Health"
9. Sieve curves of sand of new sand filter, gravels and coarse sand
10. Instructions for housewives on solar disinfection of drinking water
11. Total Dissolved Solids for groundwater in Owambo
12. Record for monitoring performance upflow gravel filter

**APPENDIX 1**

**List of persons met**



**LIST OF PERSONS MET****APPENDIX 1**

Ms Frances Chinemana	UNICEF Project Officer IABP Windhoek
Mr Stephen Adkisson	UNICEF Programme Officer Windhoek
Mr Andreas Nakanyala	UNICEF driver Windhoek
Tataati Simon Shilekah	UNICEF Project Coordinator IABP Tsandi
Yambila Mhone	UNICEF WES Consultant Tsandi
Francis Sibe	UNICEF Ass. Project Officer IABP Tsandi
Ms Alina Itamalo	UNICEF Community Mobilization IABP Tsandi
Ms Mary T. Joseph	UNICEF Community Mobilization IABP Tsandi
Ms Ndapewa Shangala	UNICEF Comm.Health Worker Consultant Tsandi
Mr Abraham Ipinga	UNICEF Field Assistant Tsandi
Ms Esther	UNICEF secretary Tsandi
Garden Group	IABP activity Tsandi
Hans Götze	DWA Regional Water Engineer Oshakati
Isaac Ashepala	DWA Regional hydrogeologist Oshakati
Dieter Lucks	DWA Head Water Quality Windhoek
Adrian Cashman	DWA Media Liaison and Public Relation
Tjeerd Dijkstra	DWA Planning Office Windhoek
Fillepus Benjamin	DWA Water plant operator in Ogongo
Peter	DWA Water Plant Operator in Ombalantu
Ms Rachel Nathaniel	DBC Public Relation Officer Windhoek
Arto Suominen	Water Supply and Sanitation Project in Ohangwena Region (FINNIDA-supported)
Hannu Pelkonen	Water Supply and Sanitation Project in Ohangwena Region (FINNIDA-supported)
Amon Mkonto	Project officer, DAPP
Viv Stuart-Williams	Groundwater Consulting Services Windhoek
Ms Zoe George	Groundwater Consulting Services Ongwediva
King and Queen Taapopi of Tsandi	

**APPENDIX 2**

**Terms of Reference**

**UNICEF NAMIBIA**

**TERMS OF REFERENCE FOR  
INTERNATIONAL WATER AND SANITATION CENTRE**

**MAY 1993**

**Purpose:**

To assist UNICEF Namibia in the investigation and development of appropriate and effective low-cost methods for:

- (a) water filtration and
- (b) desalination,

suitable for dissemination in the Integrated Area Based Programme (IABP) in Uukwaluudhi District, Omusati Region, Northern Namibia.

**Main Tasks:**

1. Search and review of literature on present experiences in small-scale and household-based water treatment systems using the IRC documentations holdings, and preparation of a written report, giving an overview of potential systems, based on the literature review.
2. Review and assessment of documentation on WES activities in the IABP area to-date.
3. On-site assessment of the current filtering technologies under experimentation in the IABP area.
4. Design and development of an appropriate filtering system which would:
  - be suitable for community-based maintenance;
  - be constructed of locally available materials and/or be suitable for local manufacture in fairly large numbers at low cost;
  - be effective in eliminating pollutants, organic matter, etc, and be effective in eliminating smell.
5. Provision of full specifications and guidelines for the design and construction of the filtration system, including testing procedures and performance indicators.
6. Elaboration in full of a plan of action, with the project team, and in particular, with the WES Consultant and the WES Assistant Project Officer, for the introduction of the system into the community and households, with guidelines for appropriate field testing parameters and equipment, follow-up procedures, maintenance, etc.

7. Investigation of, and preparation of recommendations on, the possibilities for suitable and effective desalination systems which could be used/tested in the IABP project area.

#### **Working Methods:**

1. The IRC consultant will work under the supervision of and in close consultation with the Project Officer/IABP, UNICEF-Windhoek.
2. The IRC consultant will work closely with all members of the project team based in the IABP office in Ukwaluudhi, and will co-ordinate his work in the field through the Resident Project Co-ordinator.
3. The IRC consultant will work directly with the WES Consultant based in Ukwaluudhi, the Assistant Project Officer/WES in the UNICEF-Windhoek office, and with other UNICEF staff and consultants engaged in WES activities. In addition, efforts will be made to include in discussions and field visits, a staff member from the Department of Water Affairs.
4. The IRC consultant, in accomplishing the tasks, will observe the need for full and on-going consultation with community organisations and promoting community participation for the development of the programme.

#### **Timetable of Activities:**

Prior to arrival in Windhoek:	Review of IRC documentation and preparation of overview (4 days at IRC)
Tuesday 11 May:	Arrive Windhoek; briefing with PO-IABP, APO-WES, etc
Wednesday 12 May:	Briefing in Windhoek continued, review of documentation, etc.
Thursday 13 May:	Travel to Oshakati/Tsandi (by air): fieldwork in IABP area through to Saturday 22 May
Sunday 23 May:	Return to Windhoek (by car)
Monday 24 May:	Debriefing to staff in UNICEF-Windhoek, and other interested parties; finalising report
Tuesday 25 May:	Departure from Namibia

**APPENDIX 3**

**Itinerary**

## ITINERARY MISSION ON SMALL-SCALE WATER TREATMENT OPTIONS

UNICEF-Namibia

10-26 May 1993

Monday	10 May	Departure from the Netherlands
Tuesday	11 May	Arrival in Windhoek, Namibia  Briefing meeting with Ms Frances Chinemana  Consultation information sources in UNICEF-Windhoek
Wednesday	12 May	Meeting with Mr Adrian Cashman, Public Relations in Dept. of Water Affairs  Meeting with Mr Viv Stuart Williams of Groundwater Consulting Services  Meeting with Mr Tjeerd Dijkstra, Planning Office Dept. of Water Affairs  Meeting with Mr Dieter Lucks, Water Quality Division in Dept. of Water Affairs
Thursday	13 May	Travel to Oshakati by air and to Tsandi by road  Short visit to laboratory of DWA in Oshakati  Briefing in UNICEF office in Tsandi
Friday	14 May	Discussion on detailed programme with Consultant WES in Tsandi  Assessment of old household filters at IABP-garden in Tsandi  Re-starting old filter; arrangements for new filters and testing  Field visit to oshana near Tsandi, rainwater catchment at school Oshinamba, household filter at King's place, other non-functioning household filter and earth-lined canal

Saturday	15 May	<p>Arrangements for new filters and testing at IABP-garden in Tsandi</p> <p>Field visit to and sampling of omifima, shallow dug wells, school rainwater catchment system, excavated reservoir with collector well</p> <p>Starting up design-1 household filter at IABP-garden</p> <p>Analysis of water samples</p>
Sunday	16 May	<p>Tests at household filters in IABP-garden</p> <p>Visit to canal water treatment plant in Ogongo</p> <p>Analysis of water samples in Ogongo</p>
Monday	17 May	<p>Tests at household filters in IABP-garden</p> <p>Arrangements for design-2 household filter (upflow filter)</p> <p>Meeting with Mr Hans Götze, Regional Water Engineer in Oshakati</p> <p>Meeting with Messrs Arto Suominen and Hannu Pelkonen, Water Supply and Sanitation Project in Ohangwena Region, FINNIDA-supported project</p>
Tuesday	18 May	<p>Meeting with Mr Tataati Simon Shilekah (Resident Project coordinator) and Yambila Mhone (WES Consultant) on progress and programme</p> <p>Arrangements for design-2 household filter (upflow filter)</p> <p>Tests on design-1 household filter</p> <p>Inspection old filter after stopping filter run</p> <p>Visit and interview three families around Tsandi on water practices</p>
Wednesday	19 May	<p>Visit to Ombalantu Water Treatment Plant (batch system)</p> <p>Start test on household-based batch water treatment using coagulant (source 1 water)</p> <p>Start design-2 household filter (upflow filter) with water from different source (2)</p>

Stop filter run of filter 1, inspection filter and scraping of upper sand layer

Re-start filter 1 with water from source 2

Investigation on effects of water plants on natural clarification process of colloidal waters

Thursday 20 May Tests on filter 1 and filter 2 (water from source 2)

Test on batch coagulation with water from source 2

Field observations on effects of water plants on natural clarification process of colloidal waters

Reporting

Friday 21 May Brief meeting with WES Consultant Yambila Mhone

Tests on filter 1 and filter 2 with water from source 3

Tests on batch coagulation with water from source 3

Turbidity analysis on all samples

Discussion with DWA Regional Water Engineer Hans Götze

Saturday 22 May Visit to environmental sanitation activities of the DAPP project and meeting with Amon Mkonto, project officer

Tests on filter 2 with water from source 3

Sunday 23 May Travel by road to Windhoek

Monday 24 May Discussions at UNICEF Windhoek

Water and sand/gravel samples for analysis to DWA

Debriefing at UNICEF Windhoek

Tuesday 25 May Report writing

Departure from Namibia

Wednesday 26 May



**APPENDIX 4**

**IABP-Unkwaludhi Project Area**





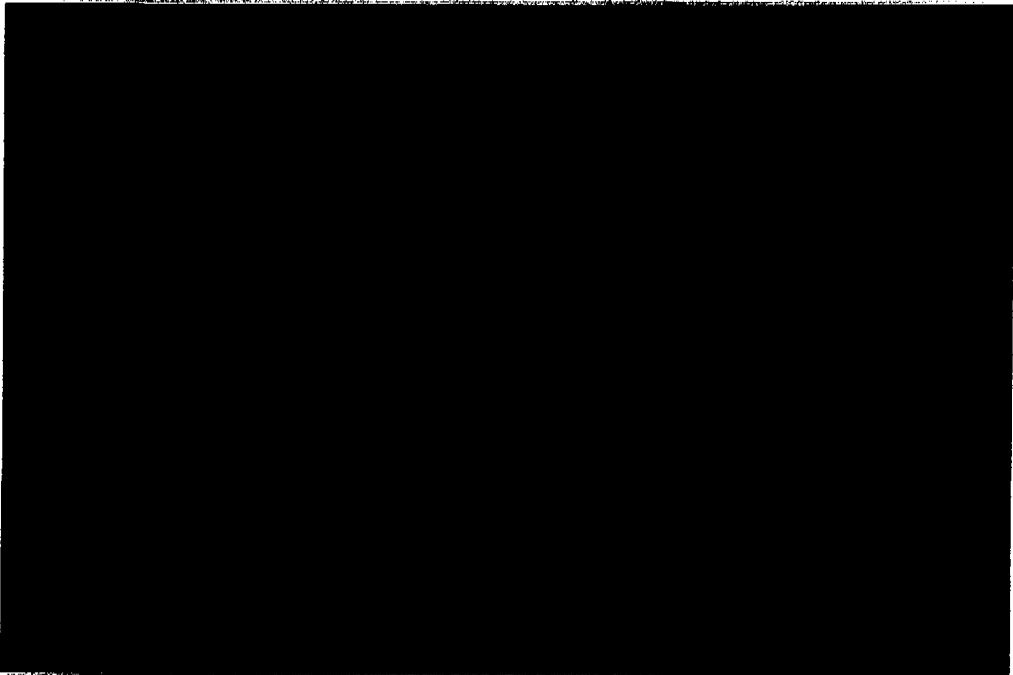
**APPENDIX 5**

**Photographs**

WATER SOURCES



Oshana

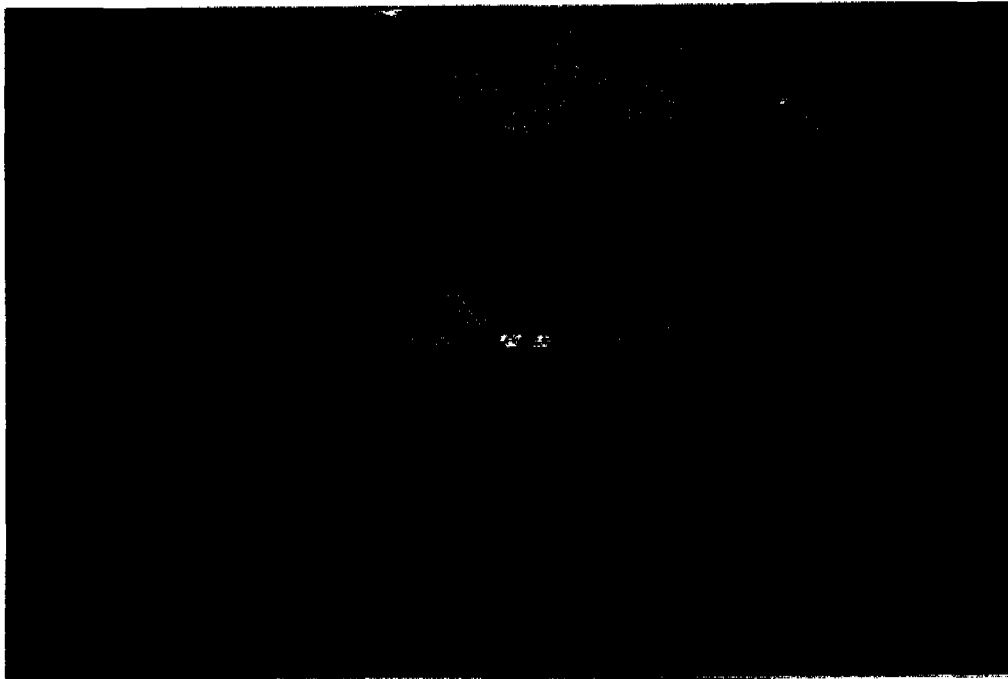


Omifima

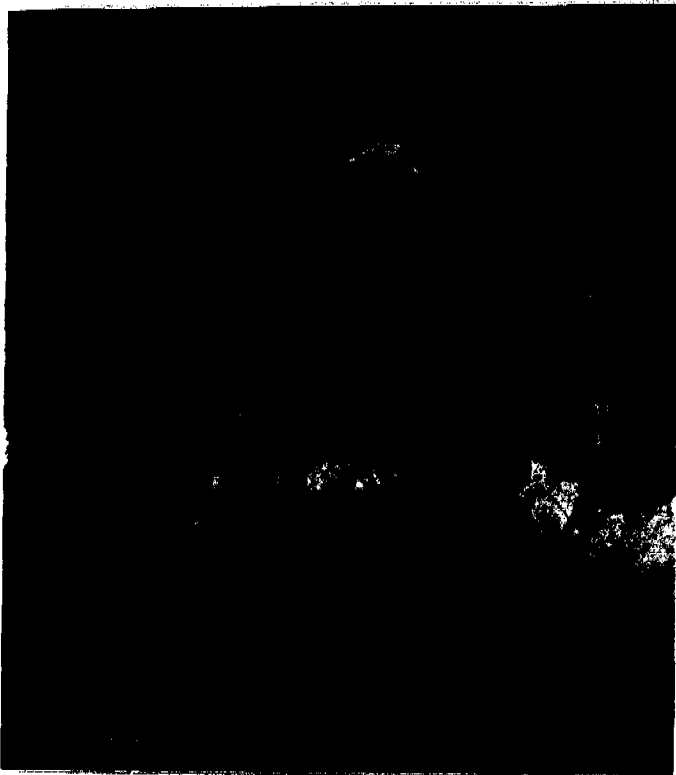


Flooded  
omifima

WATER SOURCES CONTINUED



Omufima  
with  
collector  
well

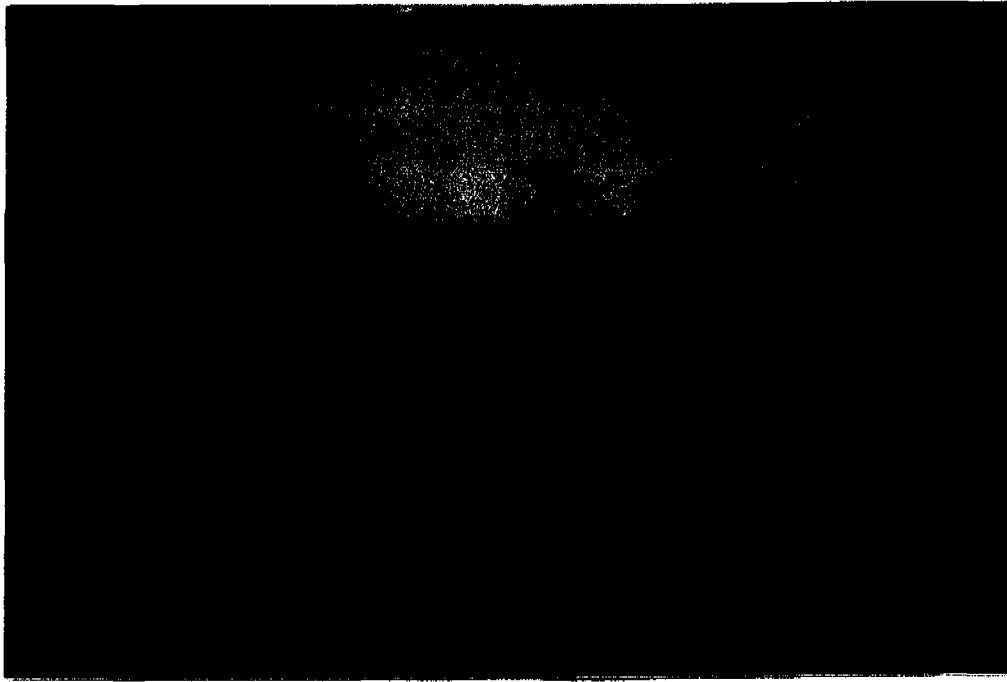


Dug well



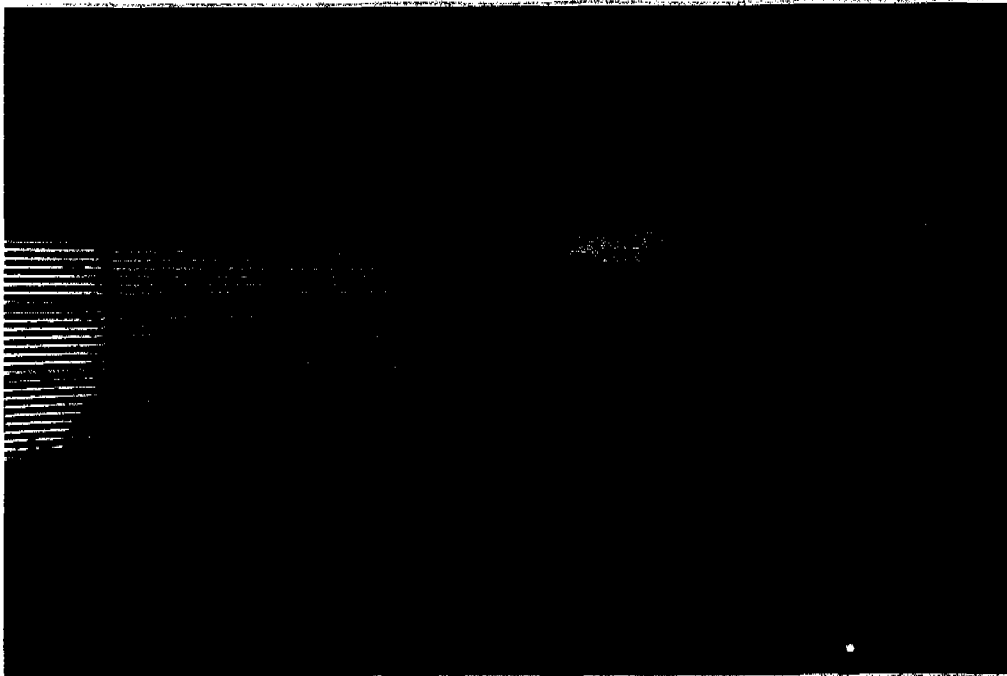
Earth-lined  
canal

WATER SOURCES CONTINUED

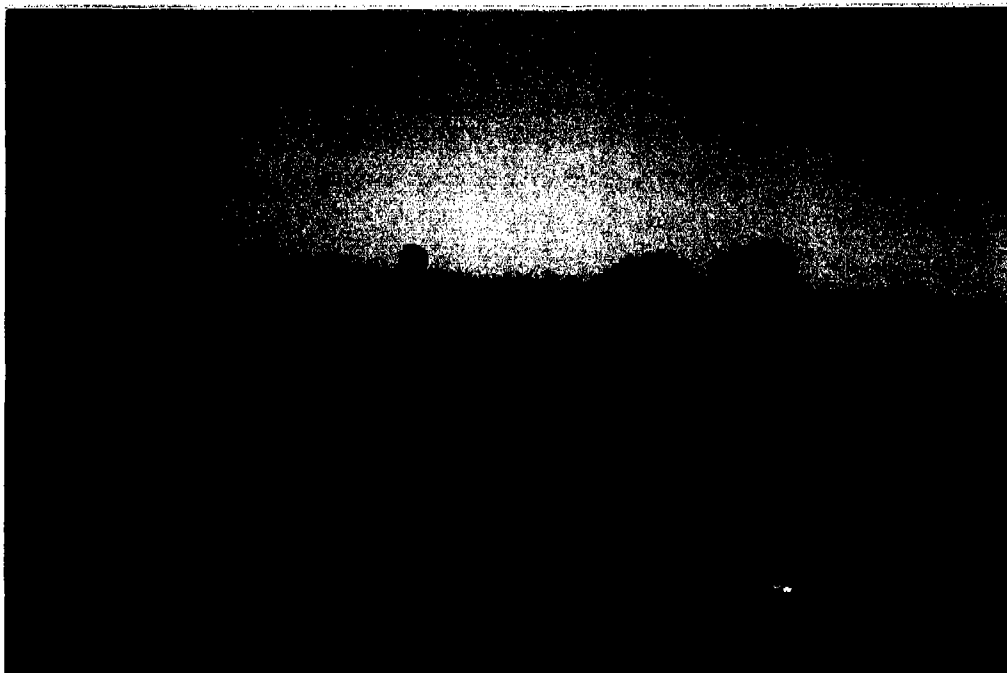


Piped water supply

Public Standpost  
and  
Cattle trough



Rainwater  
Harvesting  
System



Water  
Transport with  
donkey-cart

# WATER TREATMENT

Household  
Water Treatment  
Systems:  
left: Modified Sand Filter

middle:  
Upflow Gravel Filter

right: Batch  
Coagulation Barrel

Aggregates of  
Upflow Gravel Filter

Turbidities of water:

left: raw oshana water

next: coagulated oshana  
water (24 hrs)

next: coagulated oshana  
water (24 hrs)  
with sediment

right: filtered water  
(sand filter)



**APPENDIX 6**

**Water analysis of samples taken and data from three oshanas west of  
Oshakati**

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66440  
File number : 10/4/3/1  
Sender : Mr. Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Pits 2

Date sample taken : 1993-05-15  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : Omufima near Tsandi (Onangulo)  
Time : 11:45

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH	8.1	A Excellent
Conductivity	24.3 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity)	160 mg/l	
Sulphate as SO <sub>4</sub> :	7 mg/l	A Excellent
Nitrate as N:	0.5 mg/l	A Excellent
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	<0.1 mg/l	A Excellent
Chloride as Cl:	13 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	87 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na:	5 mg/l	A Excellent
Potassium as K:	8 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	87 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	8 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	96 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	12 mg/l	
Turbidity	11.0 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : A

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C1-S1

Low salinity. Suitable for most plants on most soil types.

Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = 0.2 Scaling

Ryznar Index = 7.8 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 0.3 Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : D. Lucks

Sample number : CH66440

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66441  
File number : 10/4/S/1  
Sender : Mr. Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Onangalo : excavated omufima

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : sample number 4a  
Time : 15:05

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	7.8	A Excellent
Conductivity :	16.0 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity) :	106 mg/l	
Sulphate as SO <sub>4</sub> :	26 mg/l	A Excellent
Nitrate as N:	<0.5 mg/l	A Excellent
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	<0.1 mg/l	A Excellent
Chloride as Cl:	21 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	46 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na:	22 mg/l	A Excellent
Potassium as K:	7 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	32 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	16 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	49 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	2 mg/l	
Turbidity :	330.0 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : A

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C1-S1

Low salinity. Suitable for most plants on most soil types.

Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = -0.8 Aggressive

Ryznar Index = 9.5 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 1.2 Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : D. Lucks

Sample number : CH66441

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66442  
 File number : 10/4/3/1  
 Sender : Ms Chinemana (Unicef-WHK)  
 Origin : AREA ( Investigation )  
 Sampling point : OVAMBO  
 Location description : Onangalo : collector well near excavated omufima  
 Date sample taken : 1998-05-24  
 Date sample received : 1998-05-26  
 Date sample analysed : 1998-06-03  
 Comments : sample number 4b  
 Time : 15:05

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	8.0	A Excellent
Conductivity :	21.9 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity) :	145 mg/l	
Sulphate as SO4:	13 mg/l	A Excellent
Nitrate as N:	<0.5 mg/l	A Excellent
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	<0.1 mg/l	A Excellent
Chloride as Cl:	13 mg/l	A Excellent
Total Alkalinity as CaCO3:	78 mg/l	
Phenolphthalein Alkalinity as CaCO3:	0.0 mg/l	
Sodium as Na:	16 mg/l	A Excellent
Potassium as K:	7 mg/l	A Excellent
Calcium as CaCO3:	55 mg/l	A Excellent
Magnesium as CaCO3:	12 mg/l	A Excellent
Total Hardness as CaCO3:	67 mg/l	A Excellent
Silicate as SiO2:	10 mg/l	
Turbidity :	35.0 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : A

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C1-S1

Low salinity. Suitable for most plants on most soil types.  
 Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

STABILITY OF WATER WITH RESPECT TO CaCO3 :

Langelier Index = -0.2 Aggressive  
 Ryznar Index = 8.4 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 0.4 Corrosive

ANALYST : E Kaambo for PERMANENT SECRETARY : D. Lucks  
 Sample number : CH66442

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66443  
File number : 10/4/3/1  
Sender : Ms Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Okasheidhi: open dug well

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : The sulphate value is suspiciously high.  
sample number 5  
Time : 00:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH	8.2	A Excellent
Conductivity	273.0 mS/m	B Good
Total Dissolved Solids (calculated from Conductivity)	1802 mg/l	
Sulphate as SO <sub>4</sub>	1580 mg/l	D Higher Risk
Nitrate as N	<0.5 mg/l	A Excellent
Nitrite as N	<0.1 mg/l	
Fluoride as F	0.3 mg/l	A Excellent
Chloride as Cl	52 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub>	156 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub>	0.0 mg/l	
Sodium as Na	62 mg/l	A Excellent
Potassium as K	11 mg/l	A Excellent
Calcium as CaCO <sub>3</sub>	462 mg/l	B Good
Magnesium as CaCO <sub>3</sub>	128 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub>	590 mg/l	B Good
Silicate as SiO <sub>2</sub>	41 mg/l	
Turbidity	16.0 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : D

**INFORMATION CONCERNING C OR D GROUP DETERMINANTS :**

**SULPHATE:** Guideline values for sulphate are based on taste considerations. Water containing high concentrations of sulphate can have a laxative effect which is enhanced when consumed in combination with magnesium. Metal corrosion and degradation of concrete and asbestos cement may be increased by high sulphate levels.

STOCKWATERING : Unsuitable

**IRRIGATION CLASSIFICATION : C4-S1**

Very high salinity. Generally unsuitable for irrigation.  
Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

STABILITY OF WATER WITH RESPECT TO  $\text{CaCO}_3$  :

Langelier Index = 1.1 Scaling

Ryznar Index = 5.9 Scaling

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 11.0 Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : *D. Lucks*

Sample number : CH66443

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66444  
File number : 10/4/3/1  
Sender : Mr. Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Okasheidhi: fresh water

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : sample number 6  
Time : 00:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH	8.5	A Excellent
Conductivity	220.0 mS/m	B Good
Total Dissolved Solids (calculated from Conductivity)	1452 mg/l	
Sulphate as SO <sub>4</sub> :	405 mg/l	B Good
Nitrate as N:	10.0 mg/l	A Excellent
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	0.5 mg/l	A Excellent
Chloride as Cl:	185 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	438 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	24 mg/l	
Sodium as Na:	245 mg/l	B Good
Potassium as K:	9 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	87 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	474 mg/l	C Low Risk
Total Hardness as CaCO <sub>3</sub> :	561 mg/l	B Good
Silicate as SiO <sub>2</sub> :	102 mg/l	
Turbidity	3.7 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : C

**INFORMATION CONCERNING C OR D GROUP DETERMINANTS :**

**MAGNESIUM:** Magnesium concentrations greater than 420 mg/l give rise to an unpleasant taste. Magnesium, in association with sulphate, may have laxative properties, but the human body can adapt to this effect in time.

STOCKWATERING : Suitable

**IRRIGATION CLASSIFICATION : C3-S2**

High salinity. Only suitable for plants with good salt tolerance and soils with very good drainage.

Medium sodium content. Suitable for coarse-textured or organic soil with good permeability. Hazardous for fine-textured soils with high cation-exchange capability unless gypsum is present.

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

STABILITY OF WATER WITH RESPECT TO  $\text{CaCO}_3$  :

Langelier Index = 1.2 Scaling

Ryznar Index = 6.2 Scaling

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 1.6 Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : *D. Lucks*

Sample number : CH66444



DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66445  
File number : 10/4/3/1  
Sender : Mr. Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Oshona water

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : sample number 8  
Time : 00:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	7.6	A Excellent
Conductivity :	191.9 mS/m	B Good
Total Dissolved Solids (calculated from Conductivity) :	1267 mg/l	
Sulphate as SO <sub>4</sub> :	53 mg/l	A Excellent
Nitrate as N :	1.0 mg/l	A Excellent
Nitrite as N :	<0.1 mg/l	
Fluoride as F :	<0.1 mg/l	A Excellent
Chloride as Cl :	500 mg/l	B Good
Total Alkalinity as CaCO <sub>3</sub> :	78 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na :	360 mg/l	B Good
Potassium as K :	18 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	37 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	29 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	66 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	21 mg/l	
Turbidity :	145.0 NTU	
Total Suspended Solids at 105 deg.C :	10282 mg/l	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : B

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C3-S4

High salinity. Only suitable for plants with good salt tolerance and soils with very good drainage.

Very high sodium content. Generally unsuitable for irrigation.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = -0.8 Aggressive

Ryznar Index = 9.3 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 9.7 Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : D. LUCKS

Sample number : CH66445

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66447  
File number : 10/4/3/1  
Sender : Ms Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Dam water : source 2

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : sample number 10  
Time : 00:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	7.9	A Excellent
Conductivity :	31.3 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity) :	207 mg/l	
Sulphate as SO <sub>4</sub> :	30 mg/l	A Excellent
Nitrate as N:	0.5 mg/l	A Excellent
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	<0.1 mg/l	A Excellent
Chloride as Cl:	23 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	106 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na:	41 mg/l	A Excellent
Potassium as K:	9 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	47 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	16 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	64 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	19 mg/l	
Turbidity :	520.0 NTU	
Total Suspended Solids at 105 deg.C:	2701 mg/l	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : A

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C2-S1

Medium salinity. Suitable for plants with moderate salt tolerance provided a moderate leaching of salts from soil occurs.

Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = -0.2 Aggressive

Ryznar Index = 8.4 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 0.6 Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : *D. Lucks*

Sample number : CH66447

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66446  
File number : 10/4/3/1  
Sender : Mr Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Omufima near Tsandi: source 3

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : sample number 9  
Time : 10:30

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	7.7	A Excellent
Conductivity :	53.2 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity) :	351 mg/l	
Sulphate as SO <sub>4</sub> :	30 mg/l	A Excellent
Nitrate as N :	<0.5 mg/l	A Excellent
Nitrite as N :	<0.1 mg/l	
Fluoride as F :	<0.1 mg/l	A Excellent
Chloride as Cl :	136 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	106 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na :	92 mg/l	A Excellent
Potassium as K :	59 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	37 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	25 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	62 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	15 mg/l	
Turbidity :	450.0 NTU	
Total Suspended Solids at 105 deg.C :	2697 mg/l	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : A

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C2-S1

Medium salinity. Suitable for plants with moderate salt tolerance provided a moderate leaching of salts from soil occurs.

Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = -0.6 Aggressive

Ryznar Index = 8.8 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 2.1 Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : D. Lucks

Sample number : CH66446

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66448  
File number : 10/4/3/1  
Sender : Mr. Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Sample filter 2

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : sample number 11  
Time : 09:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	7.6	A Excellent
Conductivity :	51.1 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity) :	337 mg/l	
Sulphate as SO <sub>4</sub> :	34 mg/l	A Excellent
Nitrate as N:	<0.5 mg/l	A Excellent
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	<0.1 mg/l	A Excellent
Chloride as Cl:	31 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	200 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na:	52 mg/l	A Excellent
Potassium as K:	9 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	97 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	45 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	143 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	21 mg/l	
Turbidity :	15.0 NTU	
Total Suspended Solids at 105 deg.C:	50 mg/l	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : A

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C2-S1

Medium salinity. Suitable for plants with moderate salt tolerance provided a moderate leaching of salts from soil occurs.

Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = 0.0 Scaling  
Ryznar Index = 7.5 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 0.4 Corrosive

ANALYST : E Kaambo for PERMANENT SECRETARY : D. Lucks  
Sample number : CH66448

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66449  
File number : 10/4/S/1  
Sender : Mr. Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Sample filter 1

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : sample number 12  
Time : 09:30

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	8.4	A Excellent
Conductivity :	184.3 mS/m	B Good
Total Dissolved Solids (calculated from Conductivity) :	1216 mg/l	
Sulphate as SO <sub>4</sub> :	140 mg/l	A Excellent
Nitrate as N:	10.5 mg/l	B Good
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	<0.1 mg/l	A Excellent
Chloride as Cl:	270 mg/l	B Good
Total Alkalinity as CaCO <sub>3</sub> :	304 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	8 mg/l	
Sodium as Na:	305 mg/l	B Good
Potassium as K:	49 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	105 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	66 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	171 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	36 mg/l	
Turbidity :	0.5 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : B

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C3-S3

High salinity. Only suitable for plants with good salt tolerance and soils with very good drainage.

High sodium content. Can cause harmful sodium concentration in most soil types. Requires special soil management.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = 1.0 Scaling

Ryznar Index = 6.4 Scaling

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 1.7 Corrosive

ANALYST : E Kaambo for PERMANENT SECRETARY : D. Lucks  
Sample number : CH66449

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66450  
File number : 10/4/3/1  
Sender : Mr. Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Sample filter

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : sample number 13  
Time : 14:45

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	8.4	A Excellent
Conductivity :	153.4 mS/m	B Good
Total Dissolved Solids (calculated from Conductivity) :	1012 mg/l	
Sulphate as SO <sub>4</sub> :	220 mg/l	B Good
Nitrate as N:	14.5 mg/l	B Good
Nitrite as N:	6.5 mg/l	
Fluoride as F:	<0.1 mg/l	A Excellent
Chloride as Cl:	140 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	118 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0 mg/l	
Sodium as Na:	225 mg/l	B Good
Potassium as K:	40 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	80 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	54 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	133 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	32 mg/l	
Turbidity :	4.8 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : B

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C3-S2

High salinity. Only suitable for plants with good salt tolerance and soils with very good drainage.

Medium sodium content. Suitable for coarse-textured or organic soil with good permeability. Hazardous for fine-textured soils with high cation-exchange capability unless gypsum is present.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = 0.5 Scaling

Ryznar Index = 7.5 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 3.6 Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : *D. Lucks*

Sample number : CH66450

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66451  
File number : 10/4/3/1  
Sender : Ms Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Eputu : borrow pit

Date sample taken : 1998-05-24  
Date sample received : 1998-05-26  
Date sample analysed : 1998-06-03

Comments : sample number 14  
Time : 08:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	8.3	A Excellent
Conductivity :	23.0 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity) :	152 mg/l	
Sulphate as SO <sub>4</sub> :	<1 mg/l	A Excellent
Nitrate as N:	<0.5 mg/l	A Excellent
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	<0.1 mg/l	A Excellent
Chloride as Cl:	5 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	86 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na:	17 mg/l	A Excellent
Potassium as K:	6 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	37 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	12 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	50 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	9 mg/l	
Turbidity :	20.0 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : A

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C1-S1

Low salinity. Suitable for most plants on most soil types.

Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = -0.0 Aggressive

Ryznar Index = 8.3 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 0.1 Non-Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : *D. Lucks*

Sample number : CH66451

DEPARTMENT OF WATER AFFAIRS  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH66452  
File number : 10/4/3/1  
Sender : Mr. Chinemana (Unicef-WHK)  
Origin : AREA ( Investigation )  
Sampling point : OVAMBO  
Location description : Onajehma : borrow pit

Date sample taken : 1993-05-24  
Date sample received : 1993-05-26  
Date sample analysed : 1993-06-03

Comments : sample number 15  
Time : 00:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH	: 8.8	A Excellent
Conductivity	: 23.0 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity)	: 152 mg/l	
Sulphate as SO <sub>4</sub> :	15 mg/l	A Excellent
Nitrate as N:	<0.5 mg/l	A Excellent
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	<0.1 mg/l	A Excellent
Chloride as Cl:	15 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	84 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	10 mg/l	
Sodium as Na:	34 mg/l	A Excellent
Potassium as K:	6 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	22 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	12 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	35 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	13 mg/l	
Turbidity	: 680.0 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : A

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C1-S1

Low salinity. Suitable for most plants on most soil types.

Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = 0.3 Scaling

Ryznar Index = 8.3 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 0.4 Corrosive

ANALYST : E Kaambo

for PERMANENT SECRETARY : D. Lucks

Sample number : CH66452



DEPARTMENT OF FISHERIES AND WATER  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH59512  
File number : 10/4/3/1  
Sender : C.J. Hay  
Origin : AREA ( Research )  
Sampling point : OSHAKATI AREA  
Location description : Locality 5 (Oshona west)

Date sample taken : 1991-02-21  
Date sample received : 1991-02-27  
Date sample analysed : 1991-04-15

Comments : Source = Oshona  
Temperature = 28 deg.C  
Time : 15:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH	7.3	A Excellent
Conductivity	90.6 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity)	598 mg/l	
Sulphate as SO <sub>4</sub> :	36 mg/l	A Excellent
Nitrate as N:	<0.5 mg/l	A Excellent
Nitrite as N:	<0.1 mg/l	
Fluoride as F:	0.4 mg/l	A Excellent
Chloride as Cl:	169 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	128 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na:	160 mg/l	B Good
Potassium as K:	4 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	30 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	12 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	42 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	20 mg/l	
Turbidity	301.0 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : B

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C3-S2

High salinity. Only suitable for plants with good salt tolerance and soils with very good drainage.

Medium sodium content. Suitable for coarse-textured or organic soil with good permeability. Hazardous for fine-textured soils with high cation-exchange capability unless gypsum is present.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = -1.0 Aggressive

Ryznar Index = 9.3 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 2.2 Corrosive

ANALYST : R.M. Roels

for PERMANENT SECRETARY : *E. Champion*

Sample number : CH59512

DEPARTMENT OF FISHERIES AND WATER  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH59510  
File number : 10/4/3/1  
Sender : C.J. Hay  
Origin : AREA ( Research )  
Sampling point : OSHAKATI AREA  
Location description : Locality 13 (17 km west)

Date sample taken : 1991-02-25  
Date sample received : 1991-02-27  
Date sample analysed : 1991-04-15

Comments : Source = Oshona  
Temperature = 30 deg.C  
Time : 13:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP
pH	: 6.7	A Excellent
Conductivity	: 54.2 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity)	: 358 mg/l	
Sulphate as SO <sub>4</sub> :	116 mg/l	A Excellent
Nitrate as N:	10.5 mg/l	A Excellent
Nitrite as N:	0.2 mg/l	
Fluoride as F:	0.1 mg/l	A Excellent
Chloride as Cl:	79 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	76 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na:	100 mg/l	A Excellent
Potassium as K:	8 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	37 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	33 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	70 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	23 mg/l	
Turbidity	: 200.0 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : A

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C2-S1

Medium salinity. Suitable for plants with moderate salt tolerance provided a moderate leaching of salts from soil occurs.

Low sodium content. Suitable for almost all soils and crops except those very sensitive to sodium.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = -1.7 Aggressive

Ryznar Index = 10.1 Aggressive

CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 3.1 Corrosive

ANALYST : R.M. Roeis for PERMANENT SECRETARY : E. Champion  
Sample number : CH59510

DEPARTMENT OF FISHERIES AND WATER  
Private Bag 13193, Windhoek, 9000, Namibia  
REPORT ON ANALYSIS OF WATER

Sample number : CH59511  
File number : 10/4/3/1  
Sender : C.J. Hay  
Origin : AREA ( Research )  
Sampling point : OSHAKATI AREA  
Location description : Locality 10 (6 km west)

Date sample taken : 1991-02-25  
Date sample received : 1991-02-27  
Date sample analysed : 1991-04-15

Comments : Source = Oshona  
Temperature = 25 deg.C

Time : 10:00

DETERMINANT:	RESULT:	DRINKING WATER GROUP:
pH :	6.9	A Excellent
Conductivity :	101.4 mS/m	A Excellent
Total Dissolved Solids (calculated from Conductivity) :	669 mg/l	
Sulphate as SO <sub>4</sub> :	36 mg/l	A Excellent
Nitrate as N:	<0.5 mg/l	A Excellent
Nitrite as N:	0.2 mg/l	
Fluoride as F:	0.3 mg/l	A Excellent
Chloride as Cl:	250 mg/l	A Excellent
Total Alkalinity as CaCO <sub>3</sub> :	102 mg/l	
Phenolphthalein Alkalinity as CaCO <sub>3</sub> :	0.0 mg/l	
Sodium as Na:	194 mg/l	B Good
Potassium as K:	7 mg/l	A Excellent
Calcium as CaCO <sub>3</sub> :	22 mg/l	A Excellent
Magnesium as CaCO <sub>3</sub> :	33 mg/l	A Excellent
Total Hardness as CaCO <sub>3</sub> :	55 mg/l	A Excellent
Silicate as SiO <sub>2</sub> :	37 mg/l	
Turbidity :	340.0 NTU	

CLASSIFICATION FOR CHEMICAL QUALITY OF DRINKING WATER : B

STOCKWATERING : Suitable

IRRIGATION CLASSIFICATION : C3-S3

High salinity. Only suitable for plants with good salt tolerance and soils with very good drainage.

High sodium content. Can cause harmful sodium concentration in most soil types. Requires special soil management.

STABILITY OF WATER WITH RESPECT TO CaCO<sub>3</sub> :

Langelier Index = -1.6 Aggressive

Ryznar Index = 10.1 Aggressive

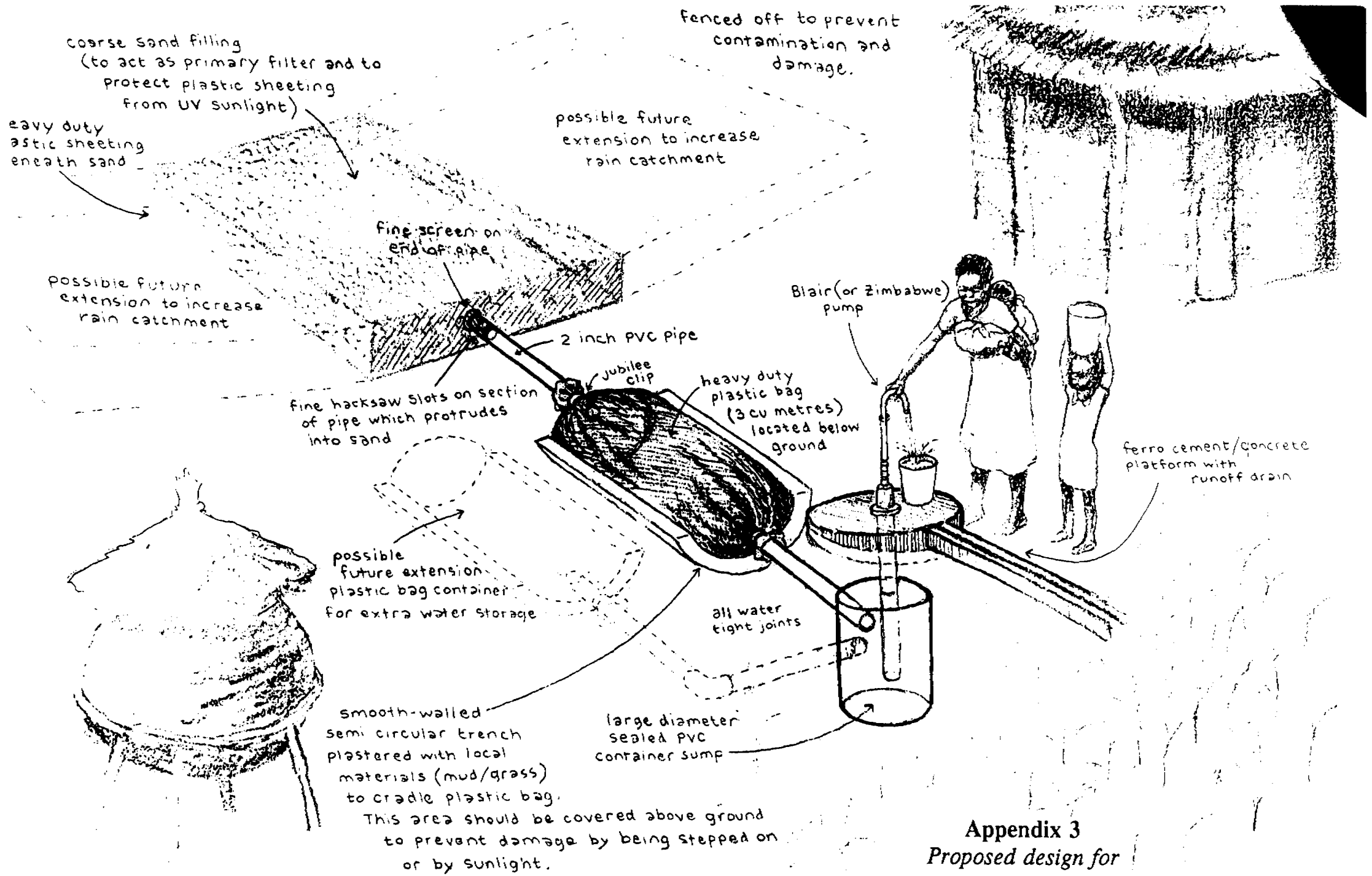
CORROSION POTENTIAL OF WATER TOWARDS STEEL :

Corrosivity Ratio = 3.8 Corrosive

ANALYST : R.M. Roëis for PERMANENT SECRETARY : *E. Champion*  
Sample number : CH59511

**APPENDIX 7**

**Proposed design for Household Rainwater Harvesting in Namibia  
(by B. Doyle)**



Appendix 3  
Proposed design for

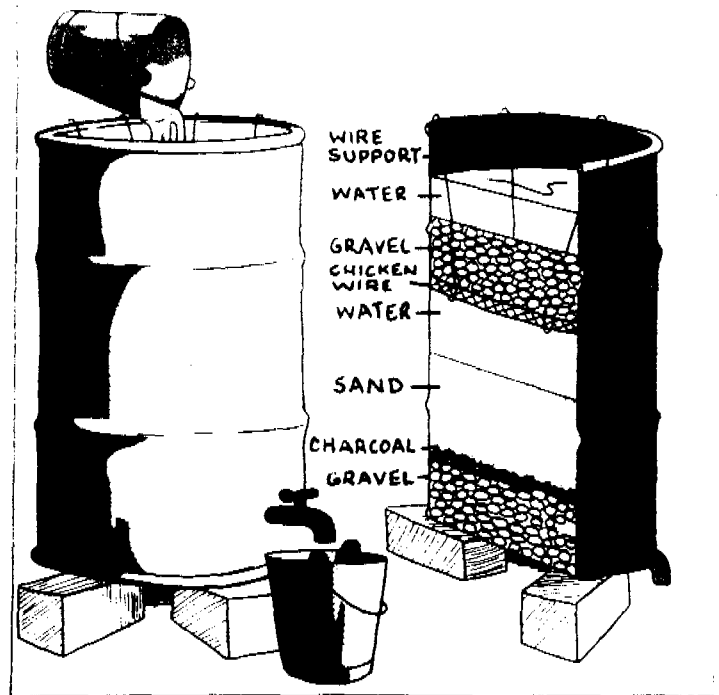
**HOUSEHOLD RAINWATER HARVESTING**  
in Namibia

**APPENDIX 8**

**Pamphlet on "Safe Water for Health"**



Produced by Water Affairs, Namibia  
in collaboration with UNICEF



### 3 Ways to make water safe

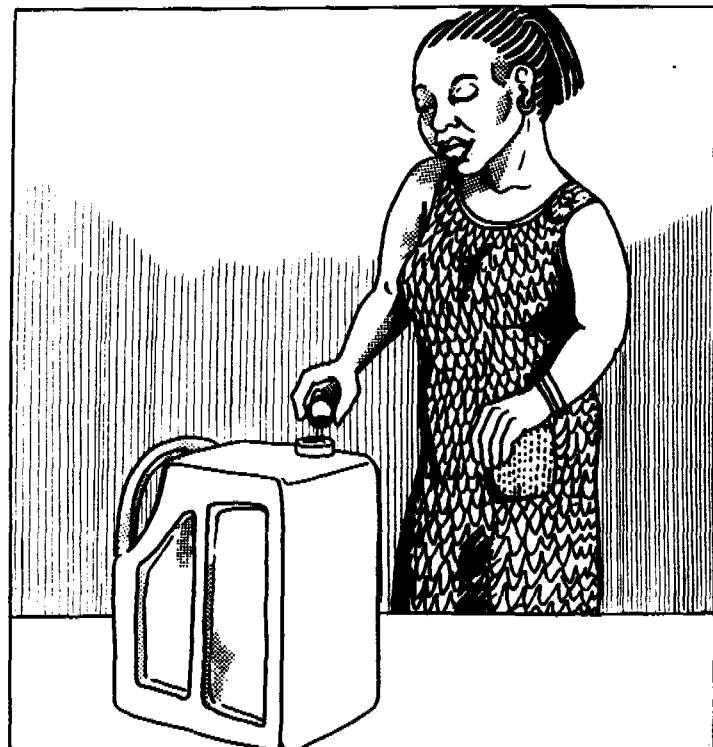
#### 1. Filter water in a sand filter

Many people sieve water to remove dirt. The sieves they use can only remove the dirt the eye can see. This sand filter removes all the dirt, including the germs that cause diseases.



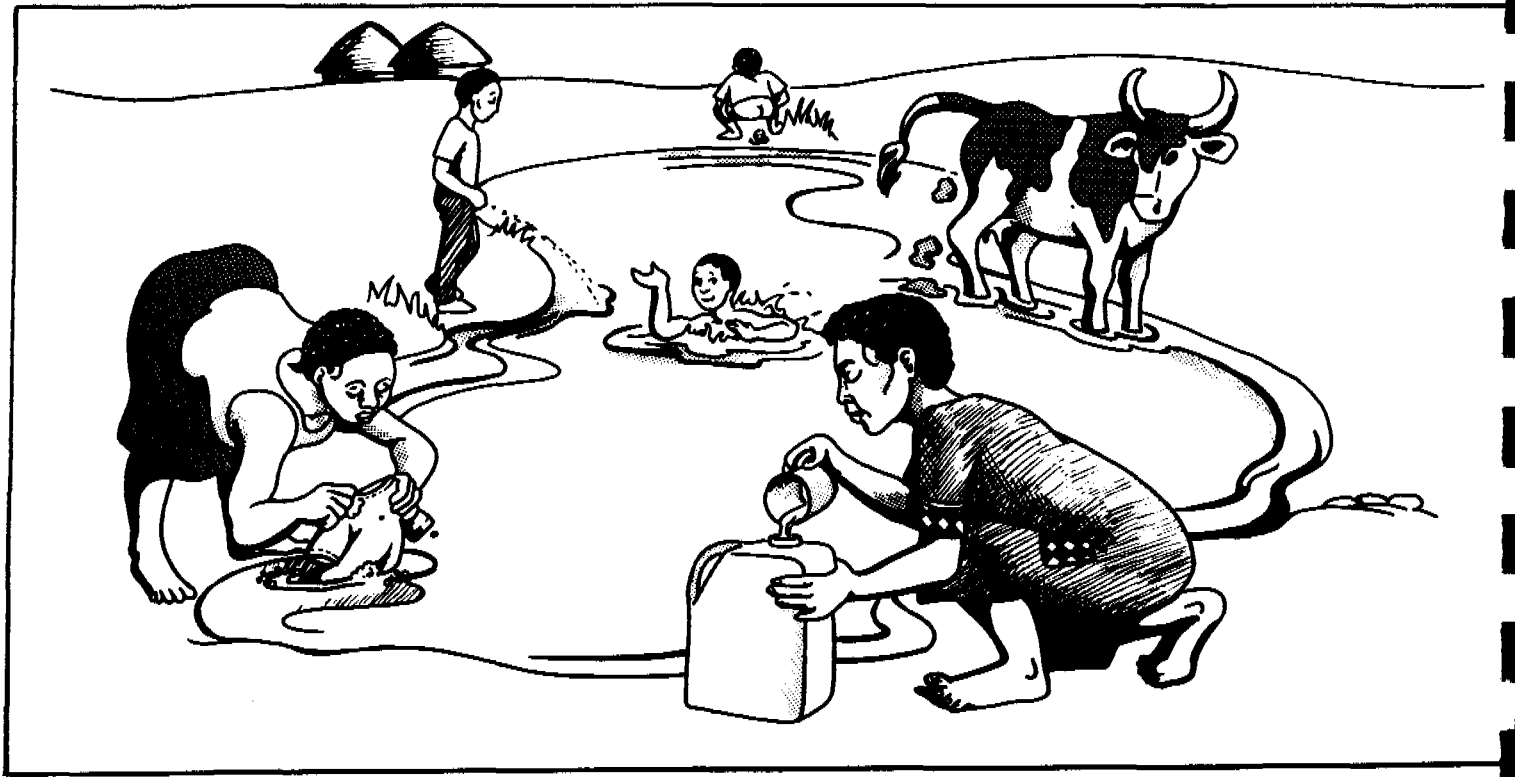
#### 2. Boil water to kill germs

After boiling, allow the water to cool. Store the clean top water in a covered container for drinking. Boiled water is not only for children, the sick and the weak. It is for all people who want to remain healthy and strong.



#### 3. Add chlorine, tablets to the water to kill germs

Use chlorine tablets according to instructions. Then allow the water to stand for one night before it is used.



**This water is unsafe.**

Water from dirty sources is not safe. It is dangerous. Do not use it because it spreads diseases.

Water from pools, oshanas, open canals, earth dams, open water tanks and rivers is unsafe. If you must use it, filter it first.

**Water becomes unsafe:**

- When storm water flows into it. Storm water brings dirt with it. The dirt may include human excreta.
- When harmful insects and germs grow and multiply in it. Mosquitoes may breed and multiply in water. Bilharzia, diarrhoea and cholera germs are carried from one point to another by water.
- When people bring dirt into it as they wash clothes, bathe or drop rubbish or human waste in or near the water.
- When animals are allowed to urinate and excrete in it.
- When it is stored in containers which are not securely covered or are rusty.
- When it is stored or drunk from dirty containers.



Even water from wells can be unsafe when wind and storm water bring dirt in it.

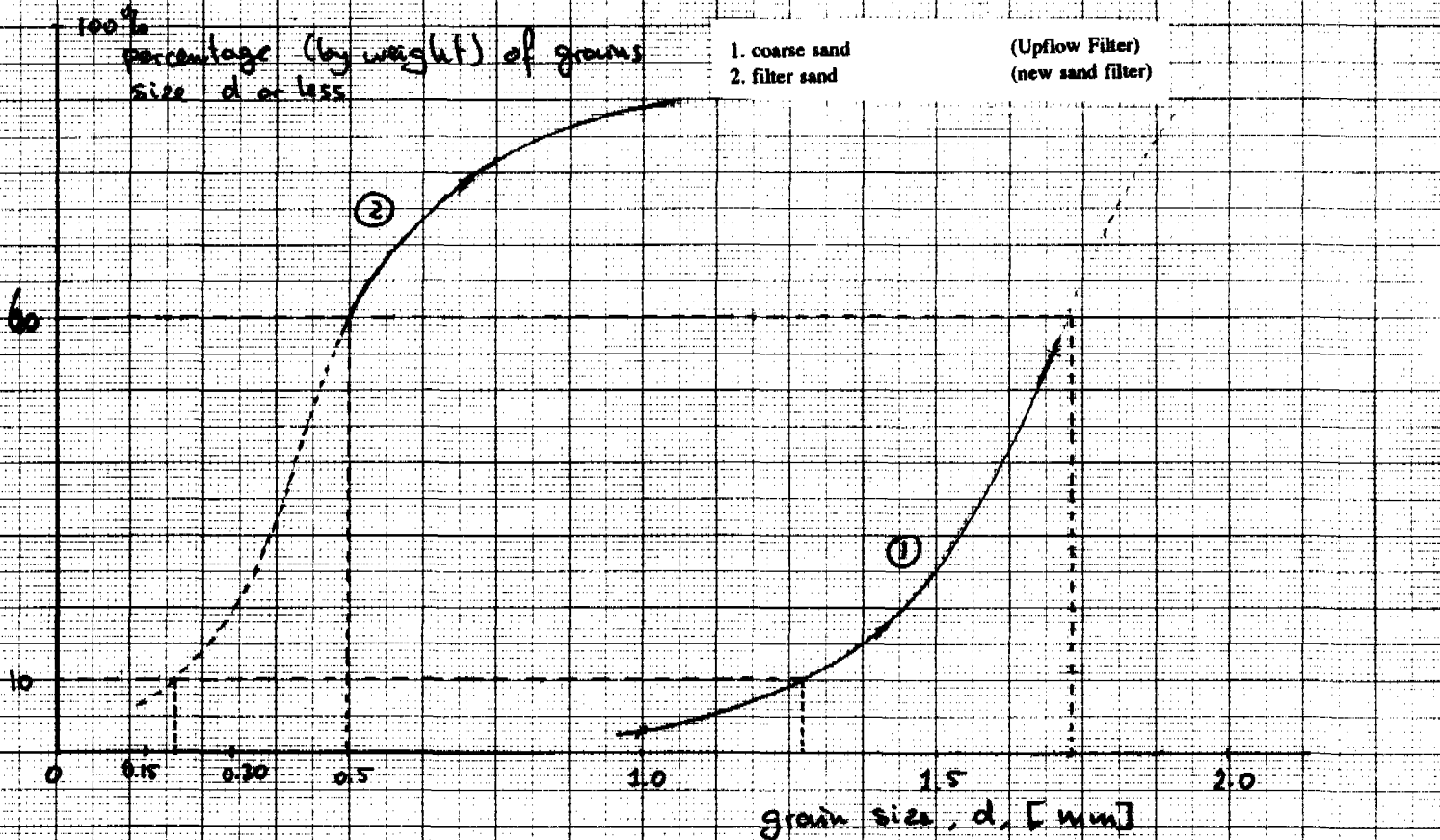
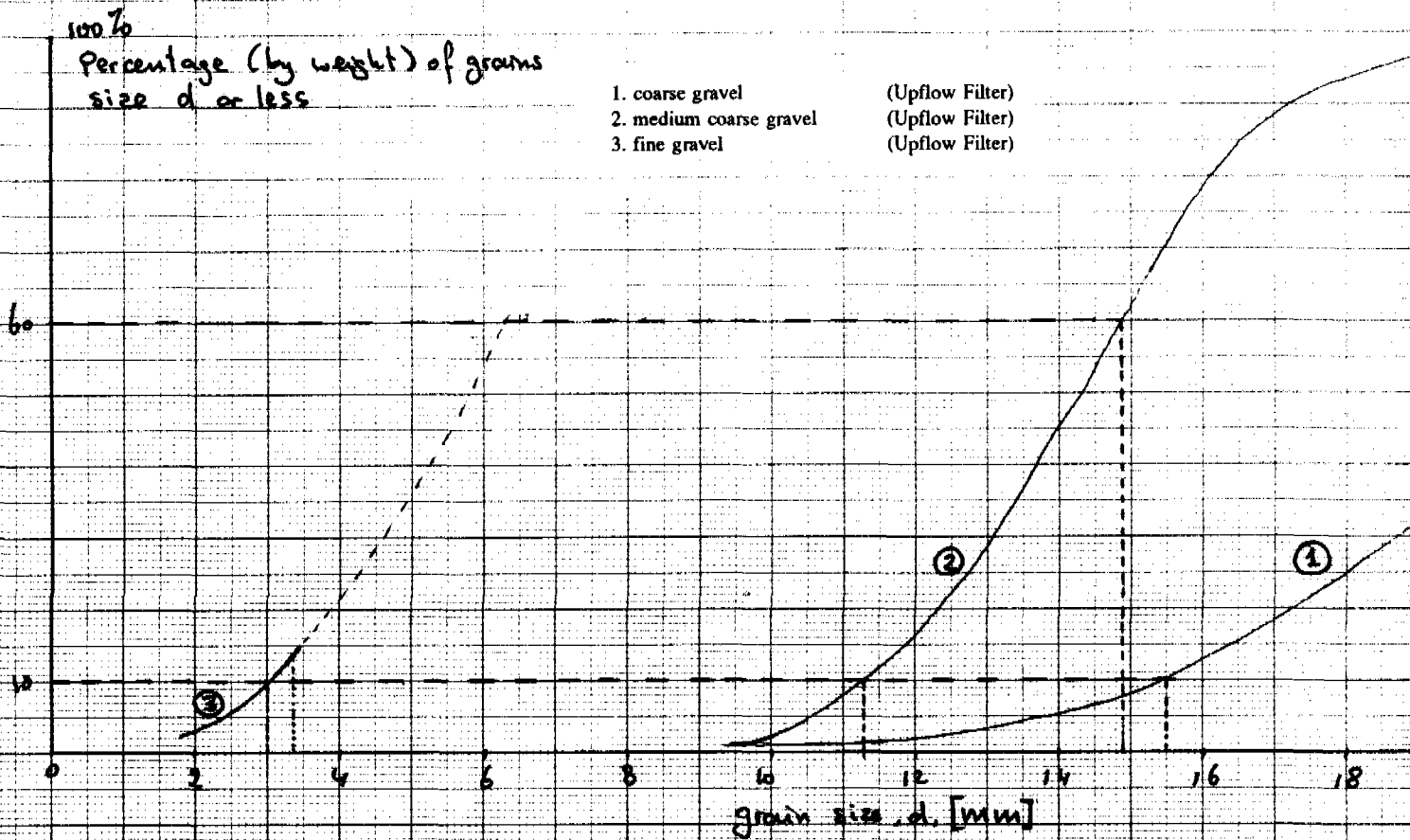


**APPENDIX 9**

**Sieve curves of sand of new sand filter, gravels and course sand**

# Sieve analysis

by Dept. of Water Affairs



SENDER: UNICEF  
Mr Chinemana  
P O Box 1706  
WINDHOEK  
Namibia

DATE SAMPLE RECEIVED: 24-05-1993

SIEVE TEST

SIDE: BLACK STONE GRAVEL :	GS 6121:	> 19 mm :	67,32 %
		> 9,5 mm :	31,85 %
		< 9,5 mm :	0,83 %
SITE: BLACK FINE GRAVEL :	GS 6122:	< 2 mm :	2,80 %
		> 2 mm :	9,94 %
		> 3,35 mm :	87,26 %
SITE: WHITE STON GRAVE :	GS 6123:	> 19 mm :	3,87 %
		> 9,5 mm :	94,90 %
		< 9,5 mm :	1,23 %
SITE: FINE SAND :	GS 6124:	< 0,5 mm :	58,61 %
		> 0,5 mm :	23,94 %
		> 0,85 mm :	6,79 %
		> 1,0 mm :	10,66 %
SITE: COARSE SAND :	GS 6125:	< 1,0 mm :	3,17 %
		> 1,0 mm :	13,44 %
		> 1,4 mm :	38,56 %
		> 1,7 mm :	44,83 %

DATE : 26-05-1993

ANALYST : *Giess* G. J. KAMPE

**APPENDIX 10**

**Instructions for housewives on solar disinfection of drinking water**

# INSTRUCTIONS FOR HOUSEWIVES SOLAR DISINFECTION OF DRINKING WATER

## GENERAL INFORMATION

The following instructions are intended primarily for the benefit of housewives in rural areas in developing countries where safe community water supplies are not available. It is assumed that in these areas water-borne diseases are endemic or sporadic.

These instructions concern the procedure to be adopted on a routine basis for the proper disinfection of drinking water for household use. The procedure involves exposure to sunlight of water from the usual community source for a minimum period of time in available transparent containers such as colourless or blue-tinted glass or plastic bottles.

In order to save time and effort, it is highly desirable for a housewife to make her own arrangements to carry out the routine disinfection operation regularly once a day, or once every other day. For this reason, a housewife should ensure enough containers that would hold the desired quantity of drinking water estimated by her to meet the needs of the family for one or two days.

At the end of the sunlight exposure period, a housewife could then transfer indoors the whole set of containers for use. To avoid recontamination, the already disinfected water should preferably be kept in the same containers used in the solar exposure operation. However, if there is a shortage of small containers, then the disinfected water could be transferred from each exposed container to a clean large container reserved for bulk storage of processed water.

Once a set of emptied containers becomes available after usage, the refilling and exposure procedures are repeated. If the containers are maintained in a good state of cleanliness, then there would be no reason for having to clean them repeatedly each time they are to be re-used.

## PROCEDURE

### 1. Containers:

- From among those found at home, or purchased from the local market, select a number of containers made of colourless or blue-tinted glass or transparent plastic estimated to hold an amount of drinking water sufficient for household consumption for one or two days. The selected containers could include ordinary bottles, jars, or any other types of vessels provided they are transparent to light. Coloured containers other than blue, or greenish-blue should not be used as they are not as satisfactory.
- Remove any detachable paper labels from bottles, and wash all the containers with water (and soap, if necessary) to remove dirt and any residue from the previous contents.

Fetch water in the usual manner from the common village supply (stream, well, pond, reservoir, etc.). If the water is highly turbid, then clarify the water by allowing the suspended particles to settle. Decant the clear water into other vessels.

Carefully fill each of the containers hereafter reserved for the solar disinfection operation with the clarified water.

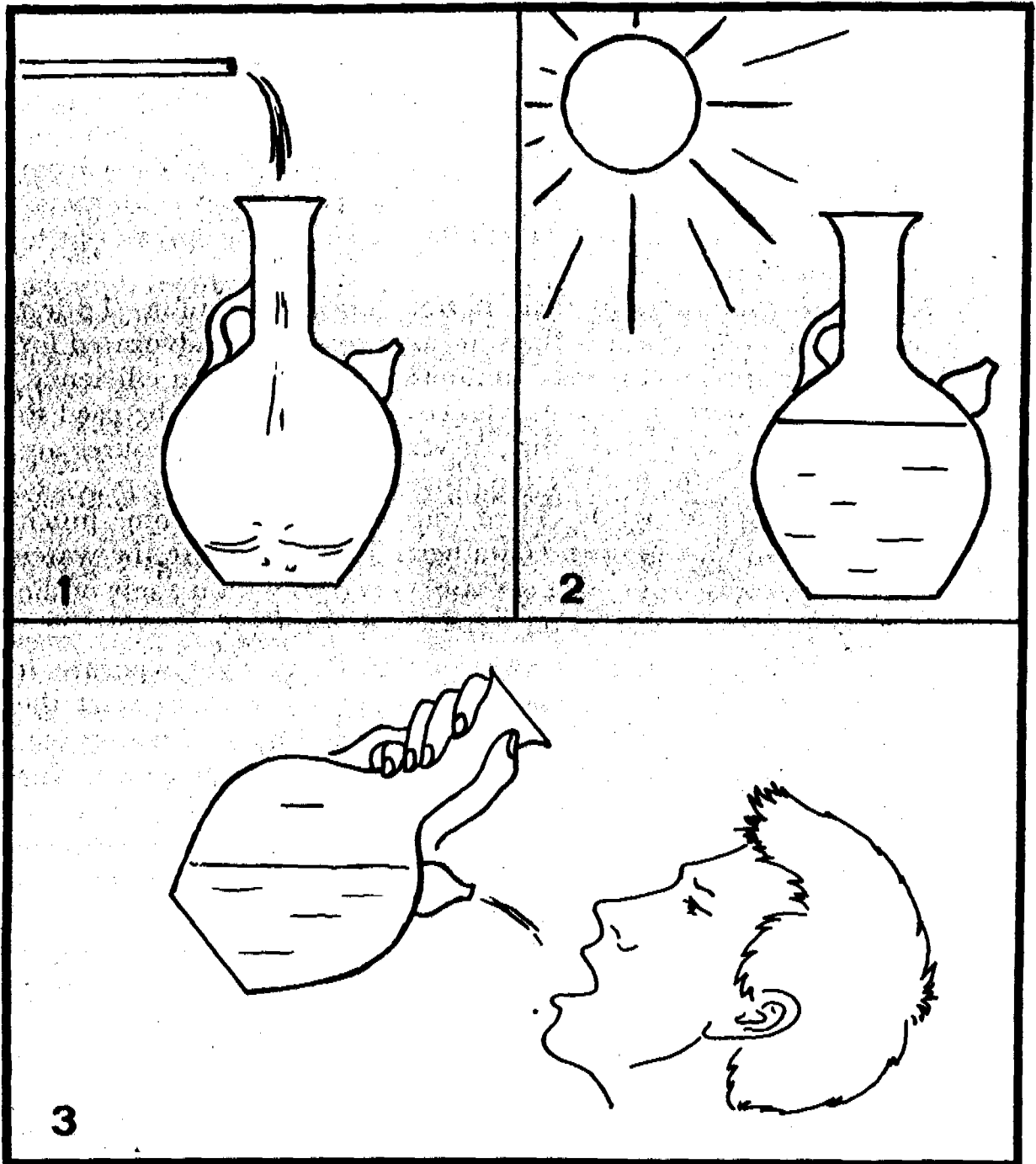
Place the containers outdoors in an open space where sunlight cannot be obstructed by houses, walls, trees, or bushes throughout the day. Porches, balconies, roofs, or window sills would be satisfactory if open land is not available. Select places away from dust, children, domestic animals, and pets to avoid contamination and mischief. Individual containers should be spread out to avoid shadows.

Keep the containers in their normal upright position. Tilting them at an angle towards the sun (as is commonly advocated for other solar appliances) may diminish the disinfection efficiency. Stoppers for bottles, and original covers for jars may be used to prevent the entry of dust, dirt, or vermin. But, such closures are not essential for the disinfection process. In fact, water exposed to bright sunlight in tightly closed containers could become much warmer than that in open containers. This is because the water vapour escaping from open containers carries with it some of the heat acquired by the water exposed to sunlight.

Since it is futile to maintain an exact time for sunlight exposure, it would be a wise arrangement on a routine basis to start the sunlight exposure operation at a convenient time in the morning, and to keep the containers exposed until the late afternoon. The exposed containers may then be kept in place overnight to allow the water to cool, or they may be transferred indoors in readiness for use. However, in such emergencies as when a family runs short of disinfected drinking water, an exposure period of about two hours, especially at noontime, should be adequate for proper disinfection. These practical suggestions will ensure satisfactory results even under moderately cloudy conditions. It would not be practical to carry out the operation under conditions of heavy rainfall.

After use, the empty containers can be re-used without the need for rewashing unless they accidentally become dirty. The cycle can now be repeated from the stage of refilling with water through the stage of sunlight exposure. With time and experience, the whole operation becomes a matter of routine.

It should be noted that these instructions need to be modified or simplified further by health educators and primary health care promoters to suit local conditions, provided the essential requirements are not altered in any way.

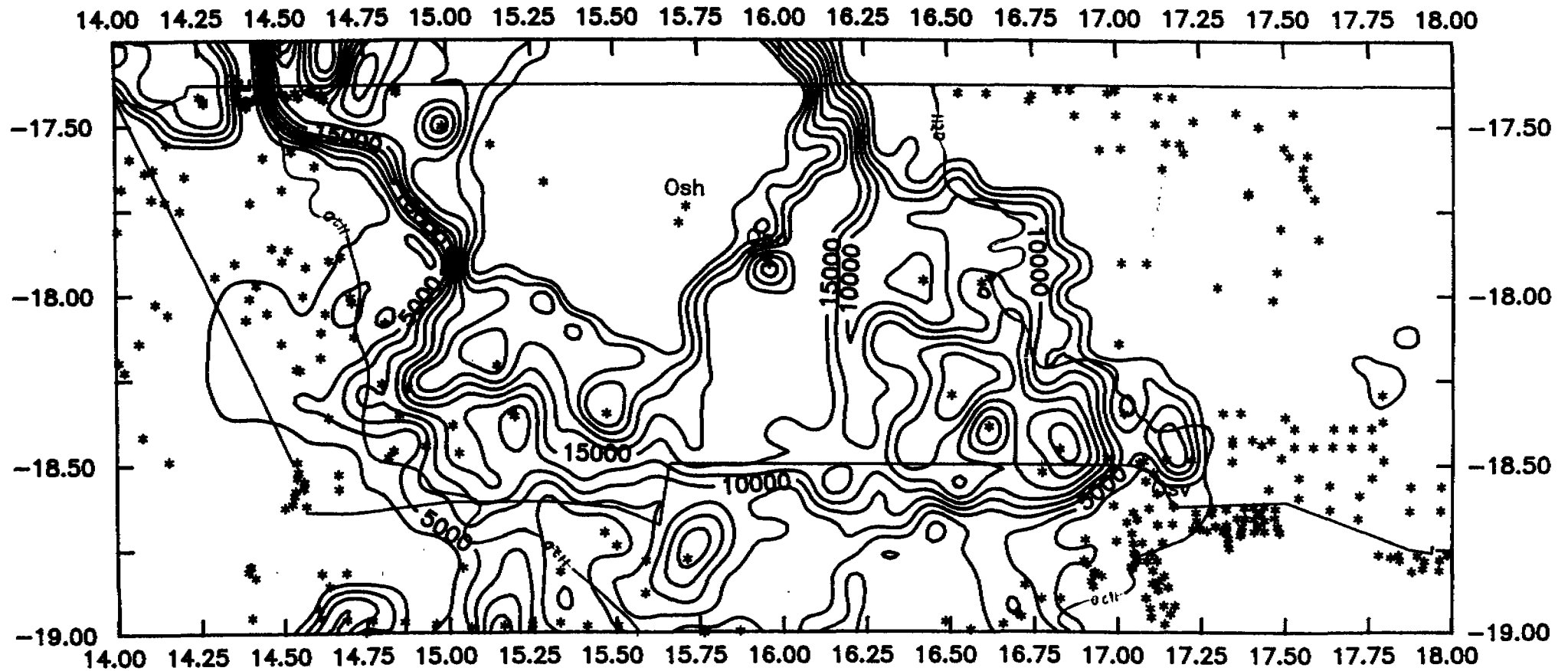


**APPENDIX 11**

**Total Dissolved Slids for groundwater in Owambo**



# OWAMBO TOTAL DISSOLVED SOLIDS - (OUT3.PLT)



**APPENDIX 12**

**Record for monitoring performance upflow gravel filter**

