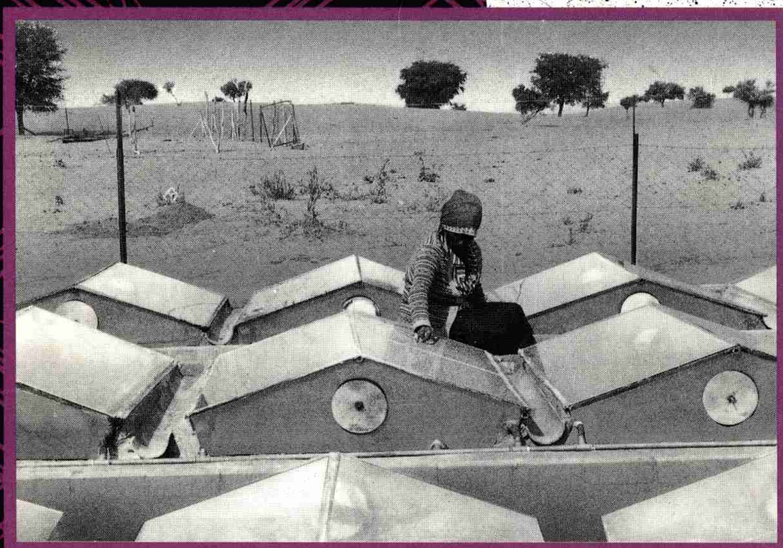
SOLAR-POWERED DESALINATION



A case study from Botswana

R. Yates, T. Wöto, & J.T. Tlhage

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by

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Abstract

In Africa, chronic drought conditions are reducing access to and the quality of drinking water. In Botswana, recurring droughts have left 80% of the population reliant on water from boreholes. Drilling such boreholes is an expensive proposition and the water is often scarce or saline. One possible solution to this dilemma is solar desalination. The Solar Energy Section of the Rural Industries Innovation Centre (RIIC) in Kanye, Botswana, has been studying solar distillation methods since 1977. This book summarizes the results of an intensive 3-year field study carried out by RIIC, with the support of IDRC (International Development Research Centre), on the technical performance and suitability of various small-scale desalinators. Their findings indicate that small-scale desalinators can provide a clear, palatable distillate; that certain models can provide a constant and adequate supply of potable water when the distillate is added to salty water from traditional sources; and that the technology is readily acceptable to remote area dwellers (RADs). The study also highlights the importance of including intended beneficiaries in the management of a new technology, in this case, the siting, construction, operation, and maintenance of the desalinators.

Résumé

En Afrique, la sécheresse chronique réduit la quantité et la qualité de l'eau potable. Au Botswana, les sécheresses répétées ont contraint 80 % de la population à compter sur les forages pour leur eau. Coûteux à réaliser, ces forages souvent sont presque secs ou contiennent une eau salée. Le dessalement solaire offre peut-être une solution à ce dilemme. La Section de l'énergie solaire au Rural Industries Innovation Centre (RIIC, Centre d'innovations industrielles rurales) à Kanye, Botswana, étudie les méthodes de distillation solaire de l'eau depuis 1977. Dans cet ouvrage sont résumés les trois années de travaux intensifs réalisés par le RIIC avec l'aide financière du CRDI (Centre de recherches pour le développement international) sur le rendement technique et la pertinence de divers petits alambics. La conclusion des travaux est que ces appareils peuvent fournir un distillat limpide et agréable au goût; que certains modèles produisent une quantité d'eau potable constante et suffisante lorsque le distillat est ajouté à l'eau salée puisée aux sources habituelles et que la technologie serait bien accueillie par les habitants des régions reculées. L'étude souligne aussi l'importance d'inclure les bénéficiaires visés dans la gestion d'une nouvelle technologie, dans ce cas-ci le choix de l'emplacement, l'aménagement, l'exploitation et la maintenance des installations de dessalement.

Resumen

En Africa, la sequía crónica está reduciendo los suministros de agua y su calidad. En Botswana, sequías recurrentes han hecho que el 80% de la población dependa del agua de pozos, la perforación de los cuales es muy costosa y el agua de los mismos escasa y salina. Una posible solución a este dilema es la desalinización solar. La Sección de Energía Solar del Rural Industries Innovation Centre (RIIC, Centro de Innovación de Industrias Rurales) en Kanye, Botswana, ha estado estudiando los métodos de destilación solar desde 1977. Este libro resume los resultados de un estudio de terreno

intensivo de 3 años, llevado a cabo por el RIIC con apoyo del Centro Internacional de Investigaciones para el Desarrollo (CIID). El estudio se centró en el rendimiento técnico y lo apropiado de varios desalinizadores de pequeña escala. Los resultados del estudio indican que los desalinizadores de pequeño calibre pueden destilar un agua clara y aceptable; que ciertos modelos pueden proporcionar un suministro adecuado y constante de agua potable cuando el destilado se añade al agua salada proveniente de fuentes tradicionales; y que la tecnología ya se acepta por pobladores de áreas remotas (PAR). El estudio subraya también la importancia de incluir a los beneficiarios objeto del proyecto en la gestión de una nueva tecnología, en este caso el asentamiento, construcción, operación y mantenimiento de los desalinizadores.

Contents

Foreword

Chronic drought conditions in Africa are reducing access to, and quality of, drinking water, particularly for those living in arid regions. Surface water sources and shallow wells are not being replenished naturally. Drilling boreholes to access deep, subterranean water tables is expensive and requires sophisticated drilling and pumping equipment. Transporting water supplies to remote communities is difficult and expensive. Consequently, per capita water consumption is severely restricted. Also, water from shallow, hand-dug wells, abandoned boreholes, and surface water sources is often brackish and salty. The lack of sufficient and potable water can only adversely affect the health of arid region dwellers.

Since 1977, the Solar Energy Section of the Rural Industries Innovation Centre (RIIC), a nongovernmental organization (NGO) located in Kanye, Botswana, has been carrying out research on solar distillation methods. The objective of their program is to improve the quality and increase the quantity of drinking water for people living in remote areas, particularly for the remote area dwellers (RADs) in the Kalahari Desert. The findings of RIIC's initial studies indicated that desalinators provide a clear and palatable distillate.

In 1983, RIIC approached IDRC (International Development Research Centre) for financial support to carry out an intensive, 3-year field study on the technical performance of small-scale desalinators and their suitability to the RADs. The results of the project confirmed that

- if properly constructed and maintained, certain desalinator models provide a constant and adequate supply of potable water when the distillate is added to salty water from traditional sources, and

- the technology is readily acceptable to the RADs.

The project also highlighted the need to account for managerial aspects related to the promotion and maintenance of the technology, particularly the active participation of the intended beneficiaries in siting, constructing, operating, and maintaining the desalinator units. If the intended beneficiaries are not involved, the technology will not be used correctly, or perhaps not used at all; community members will continue to perceive the technology as a gift from, and therefore a responsibility of, the government.

IDRC believes that the findings of this project provide useful insight into the use of small-scale desalination methods, particularly for government agencies and NGOs involved in planning and promoting the use of such devices. The publication of this report is intended to increase knowledge in these areas, so as to improve the planning and execution of similar projects designed to increase accessibility to drinking water for communities located in arid regions of the developing world.

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Introduction

Obtaining water is one of the major occupations of rural peoples in Africa. In the desert areas, especially during the last 6 years of drought, it has become, for many, a preoccupation. In Botswana, for example, water is scarce and costly at the best of times. Annual rainfall averages from 250 mm in the southwest to 650 mm in the extreme north, the national average, under normal circumstances, being 450 mm. The recurring droughts have left an estimated 80% of the population reliant on water from boreholes, many of which yield poorly or are saline (Botswana 1985).

In areas where saline sources have been tapped by boreholes and the water is too salty for humans to consume without serious consequences, the introduction of desalination promises to enhance the quality of life and to improve health standards, including infant survival. The technology, therefore, seems particularly suitable for the Kalahari Desert.

This thinking prompted the Rural Industries Innovation Centre (RIIC) in Kanye, Botswana, to investigate small-scale desalinators, with the objective of increasing the available drinking water for people living in remote areas of the Kalahari. RIIC adapted designs of solar stills and tested their use in three communities: Khawa, Lokgware, and Zutshwa.

Installations at two of the settlements have proved successful; the local people participated in making the system work and continue to operate, maintain, and benefit from the stills. The stills are popular in these areas, and they have contributed to the community spirit. In Khawa, for example, there is now less social chaos related to water use than before, and a social conscience as well as cautious use of potable water has emerged.

Although it is still too early to evaluate the overall impact of desalination, the future of settlements with only saline water is no longer bleak, and such areas are now seen as habitable. According to official figures, 80% of Botswana is covered by the Kalahari sands. This whole area is said to be drained by a system of dry rivers that rarely carry any water even during years with good rainfall. In certain areas, shallow depressions (pans) retain rainwater for brief spells after heavy thundershowers. The only reliable source is groundwater accessible through boreholes or hand-dug wells. Such water is being tapped despite the thickness of the sand layers.

According to the National Development Plan 1985–91 (Botswana 1985, p. 200):

> Ground water can be found beneath the Kalahari sandbeds, but generally only at large depths (100 metres is not unusual) and with low yields that can support only a few people and livestock. The water is sometimes saline due to lack of recharge from rainfall. Water is found nearer the surface in areas of calcrete, silcrete and ferricrete formations.

Both the public and the private sectors develop water supplies by drilling of deep boreholes, many of which turn out to be blanks or saline. The result has been a call for new techniques such as desalination to render the salty water drinkable.

The Department of Water Affairs (within the Ministry of Mineral Resources and Water Affairs, which oversees development of the national water resources) drills and equips boreholes and hands the systems over to district councils (which fall under the Ministry of Local Government and Lands) to operate and maintain. The desalination units introduced by RIIC now come under the auspices of the Kgalagadi District Council. The district councils decide which villages are priorities for the water program.

In the private sector, the two major industries — cattle and mining — have funded the search for water. The government has granted drilling rights to cattle producers in the sandveld, as cattle are second only to diamonds as a source of foreign exchange. At the same time, mining companies have drilled their share of boreholes and have had an impact not only on the availability of water but also on employment and mobility patterns in the desert. Many San, and others who have traditionally been hunter gatherers, have settled. In Lokgware, for example, settlers have taken over a site with a borehole abandoned by a prospecting company.

As the Kalahari's traditional water sources such as sip-wells, melons, and wild tubers have dried up and disappeared, the people have converged around boreholes, some of which are privately owned and are delivering salty water. The cattle farmers who financed the drilling monopolize the potable sources. Few are willing to share their water; they see the provision of water as a responsibility of the government. At

Khawa, for example, several boreholes in the surrounding 10–20 km deliver potable water, but the council was forced to truck water from Middlepits into Khawa — about 90 km.

Since 1979, water consumption per person in the 17 biggest villages has remained steady for standpipe users (15 L/day) but has doubled for people with private connections, going from 40 to 80 L/day (Botswana 1985, p. 200). The water is used for drinking, washing, cooking and in some cases gardening. In contrast, in remote settlements, the target is about 2 L/day per person, and water is supposed to be used strictly for drinking and cooking. Although the target for supply of water is small, the schemes for remote communities tend to be expensive to set up and operate.

New technologies such as desalination offer a means to use more of the available water for human consumption. According to the sixth National Development Plan (Botswana 1985, p. 205), "salinity of water is increasingly becoming a problem and has sometimes necessitated drilling of several boreholes in a village [or settlement]...." The lack of rainfall during the past few years has practically halted groundwater recharge, and many boreholes that once delivered water suitable for human consumption have been abandoned because the salt in the water has increased. The lack of reliable water sources hinders development immensely and has the worst effect on people who live in remote areas.

The Kalahari remote area dwellers

Only 20% of Botswana's population can be realistically seen as permanent residents of the desert. Of this group, a minority are in remote areas. Those living outside organized villages such as Tsabong and Hukuntsi are termed remote area dwellers, living in permanent and semipermanent settlements. In Kgalagadi District, about 15% of the population is living in remote areas and a majority of this group (3 633) live in recognized settlements.

The nomadic bands of traditional hunter gatherers are no longer found in Botswana. They either are in the process of settling or have already settled. Since 1977, when the Remote Area Development Programme (RADP) was instituted, government has promoted permanent settlements. The justification has been the relative ease in providing services such as food, education, water, and health care to permanently settled communities. Up to 14 remote settlements in Kgalagadi district alone have come under the program, and, elsewhere, the government is introducing "feeding points" in the hope that they will become settlements. Most settlers have historical links with the areas in which they settle and view the land as their home.

An ethnic perspective

The government has defined remote area dwellers as all the people outside organized villages; this definition encompasses members of several ethnic groups. Until 1977, the only program that served remote area dwellers was the Bushmen Development Programme. The government that emerged after independence realized that groups other than the San (Basarwa) were living in remote corners of the country and were equally underprivileged.

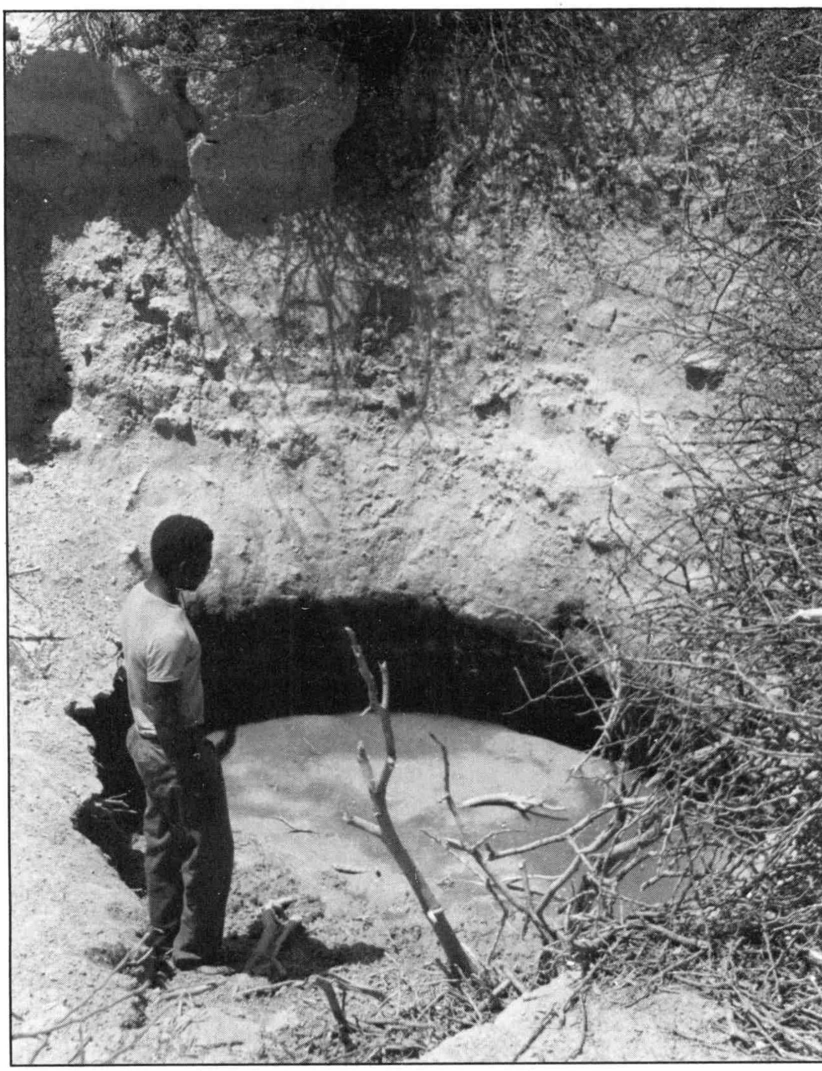
The transition from the Bushmen Development Programme to the current RADP was not easy. One reason was anthropological interest in the San as a distinct society. David Stephen (1982) wrote in his report *The San of the Kalahari*,

> Many people, with very different perspectives, campaign for the San from outside Botswana: some wish to maintain the image of the San as "noble savages" — to maintain a form of human zoo in Botswana; others are interested, as writers or film-makers, in perpetuating a romantic image of primitive people.

Pressure came from academically oriented individuals to resist developmental policies that would change the lifestyle of the San.

The policies introduced in the late 1970s were a negation of the colonial notions embodied in the Bushmen Development Programme. As Egner (n.d.) in his evaluation of RADP put it, "to counter allegations of 'Separate development' and ethnic bias by those who deprecate any form of special assistance for narrowly defined groups of the poor, the ... Basarwa Development Programme was changed to Remote Area Development Programme in 1978 and its target group [to]... all people living outside organised village settlements."

Surveys carried out in four settlements in the Kgalagadi District in 1984–85 indicated people residing in areas designated as remote settlements were from mixed ethnic backgrounds. In Khawa, where no Basarwa had settled, the population comprised Bakgalagadi (4%), Bakgothu (8%) (Hotentots), Batlharo (56%), mixed races (20%), and others (12%); Ncaang was made up of 12.5% Basarwa and 87.5% Bakgalagadi, whereas both Lokgware and Zutshwa were solely Basarwa.



Existing water supplies in settlements are often hand-dug wells that become badly polluted by animals despite being protected by thorn fences.

Non-Basarwa remote area dwellers have always been a part of the country, but have only been covered by the government development program since 1978. Conversely, the pockets of Basarwa living in and around big villages no longer are covered by the program and have no access to its benefits. Many are marginalized sectors of the rural population and live under abject poverty.

Fundamentals of RADP

For the past decade, the Botswana government has devoted much effort to restructuring and strengthening RADP. This program falls under the hegemony of the Ministry of Local Government and Lands, with most of the responsibilities for administration and implementation falling under district councils. Since its institution in 1977–78, RADP has worked toward social, economic, and political objectives for remote dwellers:

- the extension of basic social services such as education, health care, water supply, feeding programs for vulnerable groups;
- the opening of access to land, water rights, and income-earning opportunities; and
- the fostering of self-reliance, social integration, and awareness of rights.

Although RADP is only a decade old, it has had considerable success in Kgalagadi, especially in implementing the first objective relating to the provision of social services. It has set up transportation for children to go to primary schools in bigger villages (Werda, Hukuntsi, Tshane, Lehututu, and Kang) where they are housed and fed. In the meantime, private schools up to fourth year in primary school are being started in the settlements and will be staffed by council- or government-paid teachers.

All the settlements are served by a mobile health clinic from the nearest village while health posts are being built locally. The posts that have been erected are currently staffed by family welfare educators; however, as soon as it is feasible, the posts will be better equipped and some qualified nurses will be provided. The clinics are responsible for feeding programs for preschoolers, pregnant women, and destitute individuals. Other feeding programs that RADP underwrites are emergency aid for whole communities (drought-relief rations) and meal programs at local schools.

Although some settlements in this district have potable water, others receive drinking water brought into the communities by trucks or obtained through small-scale desalination. Desalination has tended to promote self-reliance, which is not a feature of government schemes to deliver potable water by trucks. The future of such settlements is uncertain and is totally dependent on securing a reliable water supply.

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Choosing a technology

Governments in developing countries have a variety of possibilities to provide water for remote settlements in the desert: drilling, reticulation, trucking, resettlement, and desalination, among others. Drilling is the most satisfactory in the long term, but in the desert it involves high investment. In Botswana, for example, drilling costs 70 BWP/m, and boreholes are often drilled more than 250 m before they are abandoned as dry (in May 1990, 1.87 Botswana pula [BWP] = 1 United States dollar [USD]). Casing adds another 50 BWP/m to the cost, and screens a further 1 200 BWP.

Salt water is found more often than fresh water. Even with sophisticated prospecting techniques, it is difficult to tell whether underground water will be sweet and whether it will have a significant yield.

At least 55% of boreholes drilled in Kgalagadi District are salty or dry. Once a borehole has been drilled, cased, and equipped, there is no guarantee that it will remain sweet or that its yield will stay the same. In many areas, it is unlikely that any sweet water will ever be found.

Another major constraint to drilling is the lack of rigs and experienced drillers to do the work in developing countries. Even after plans have been made, several years may go by before drilling is completed. Settlements that are fortunate enough to tap ample quantities of sweet water tend to attract new settlers and their livestock. The settlements are often in areas of good grazing, used by livestock only in the rainy season and attracting wild game throughout the year. Few of the people from the settlements have livestock and they often depend on the wild game for their survival. When new settlers bring in cattle, the balance is upset, wild game is driven away, and the local people end up working for the cattle owners for little pay.

The extent to which people migrate to sweet boreholes is illustrated by experience in Kedia, Botswana. Fewer than 50 people lived there in 1984 when rumours of drilling began. In a few months the population had risen to 800. No water was discovered during drilling, so the government began to reticulate water there instead of forcing people to move yet again.

Reticulation

Reticulation is the process by which water is brought from a borehole to the end user by pipeline. This is very satisfactory if a suitable borehole is not too far away. The costs are not excessive and construction of a pipeline is very labour intensive. The total cost of laying a 63-mm pipe is about 2 700 BWP/km. However, the technology is suitable for distances of only about 5 km. For longer distances, 90-mm pipe must be used at a cost of 4 435 BWP/km. The system is simple to maintain and reliable, although leaks may go undetected for some time. The main obstacle to reticulation is that most remote settlements do not have access to sweet boreholes within 40 km and, where the boreholes exist, their output is usually in use.

Trucking

Trucking water is the simplest, most expensive, and least reliable solution to the problem. To administer a water-trucking program is relatively undemanding. A driver is simply told to take a truck and deliver water to a particular settlement. But the operation depends on the availability of transport, and to have trucks permanently being used to deliver water detracts from other developments.

The roads to remote settlements are poor, and the trucks often travel at less than 15 km/h for distances up to 200 km. Because of the sandy roads, loads of water must be kept relatively small, the trucks often having to return several times to fill storage tanks in the settlements. The traffic makes bad roads worse. Breakdowns and other unforeseen circumstances prevent reliable deliveries, so settlements may wait 2–3 weeks after one tank of water is finished before the next is delivered.

In many instances, the tanks leak, so people tend to grab as much water as they can before it is lost. People with containers for water storage at their homes are better off, and the poorest people suffer. Once water reaches a household it is seldom given away.

Commonly, a truck, with driver and two assistants, leaves its base at lunchtime and arrives at a settlement about 6 h later. In the morning, 20 or so 200-L drums are loaded onto the truck, although several leak from damage during off-loading and transit. Having loaded the drums, the crew drive for about 3 h to a council borehole and fill the drums at the only available standpipe. Yield is usually low, and filling takes several hours. Late that evening the truck arrives back in the settlement and the water is pumped into holding tanks. The process is repeated the next day, and by the time the truck returns most of the water delivered the night before has been used. The process is repeated for 4 or 5 days before the truck leaves the drums and goes back to base. Within a week, all the water will be finished.

Control over the system is difficult, and the drivers at times persuade their supervisors that particular settlements need water if they have personal reasons for going there. Yet, trucking is the only supply of potable water to about 70 settlements around Botswana.

Desalination

Desalination of water can be done in many ways; the main requirement is a reliable supply of salt water. If the water source is a hand-dug well, then it must be public property or the owner may claim preferential use.

Shallow-basin solar stills have proved to be simple to construct, reliable and cost effective, but they are also labour-intensive to operate and low yielding, particularly in the winter. Other types of solar distillation can produce more water per square metre than shallow-basin stills, but they are much more complicated.

For example, a small multi-effect solar still, which uses the heat of condensation of the water, can produce three times the output of a shallow-basin still (Heschl and Sizmann 1987). However, this type needs much more water to be pumped, the recovery rate is low, and the system susceptible to breakdowns. It is also unsuitable for very salty water. Multistage flash desalination is efficient but is suitable only for large-scale plants; to power the process by solar energy would require massive investment.

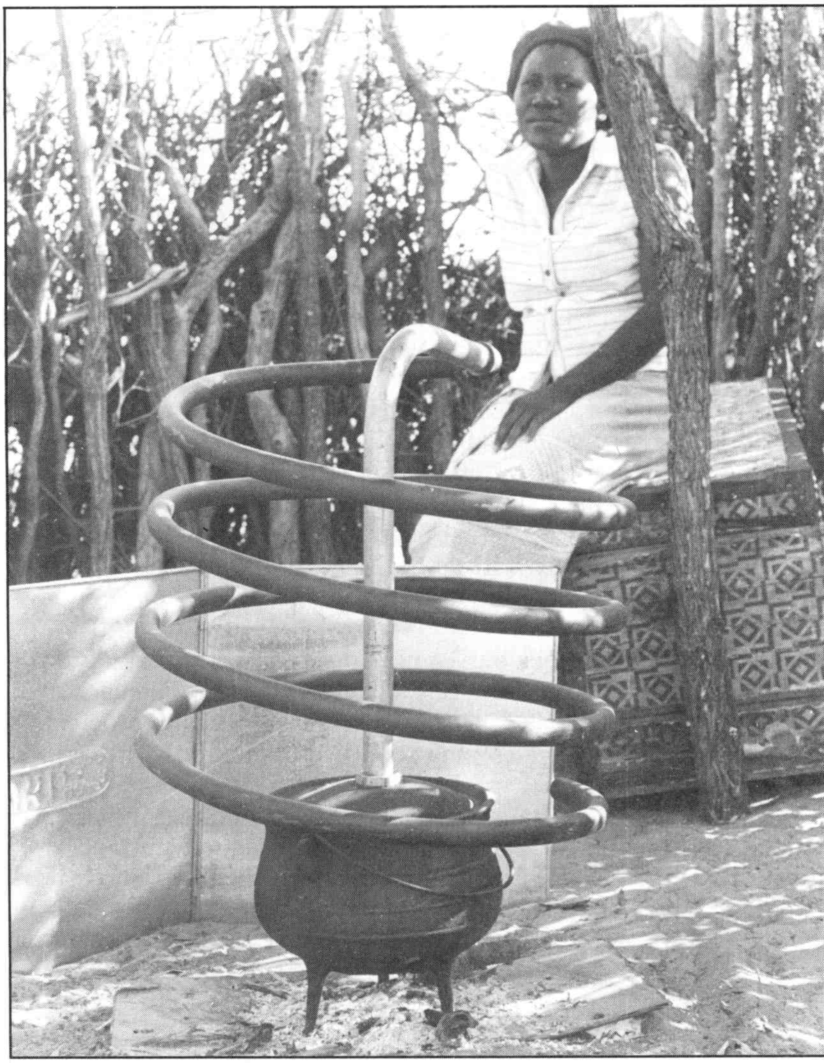
Reverse osmosis, however, can be carried out on a small scale. Salty water is forced at high pressure against a membrane that allows water through but not salt molecules. Large reverse-osmosis plants can produce hundreds of cubic metres of water a day; yet small units, about 30 L/day, are available. The only power needed is to pump and pressurize the water, and this can be supplied by hand or pedal for very small units. The drawback is that the process is sensitive to the quality of raw water, and the membranes easily become clogged or damaged. To clear them requires special procedures that would be unmanageable in remote settlements. Replacement membranes are expensive and not easily available in Botswana. Therefore, in the event of a membrane failure, a settlement could be out of water for months. As the only indication of failure is a reduction in output, people tend to use the system until it totally fails.

Also, the power requirements of reverse osmosis rise with salinity of feed, and the proportion of sweet water recovered is often low. Reliable pretreatment of the water is another requirement, including filtration, coagulation, balancing of pH, removing free chloride ions and any traces of oil. If pretreatment is not properly managed, with regular sampling, the membranes will fail at some stage. Given the scarcity of skilled labourers in remote settlements, these techniques are impossible to organize.

A network for supply of filters and chemicals would have to be put in place, as well as trained people to support the operators. Such a sophisticated technology would be feasible only in larger and more widespread applications. As a consultant funded by the Swedish International Development Authority concluded in a report on desalination for the Department of Water Affairs (Dahlberg 1981), "the installment of solar stills rather than reverse osmosis is ... recommended."

Using wood as a fuel for desalination over the long term was never seriously considered in Botswana; however, it was seen as a suitable measure to deal with emergencies, for example when water trucks failed to arrive. Firewood is plentiful in many areas of northern Kgalagadi, so wood supply is not a critical problem. Fires are lit at night in every household in the area, so an attempt was made to introduce stills that consisted of modified lids for the traditional three-legged pots. A hole was drilled in the lid, and a blackened copper pipe connected to it to act as a condenser. Cooling was to be provided by radiation and air convection. Early models used a coiled pipe (called the "kudu horn" by users), but this was difficult to transport and tended to be heated directly by the fire. Later models used a straight pipe, 3 m long, coming away from the fire. These stills were difficult to use, produced little water (0.7 L/h) and could not be left unattended in case they were knocked over by children. Although they were politely accepted (once they were given away together with a pot), they were seldom used.

A larger model was designed to use water as the coolant instead of air. Called the Ghanzi still, this model had a copper coil immersed in a cool drum of salty water. Water was boiled in a separate 100-L drum and the steam piped to the coil to be condensed. The yield was 17 L/h.



A prototype wood-fueled still, called the "kudu horn," was rejected because of low yield.

When introduced into a village, the Ghanzi still proved unsuitable for several reasons. The salt residue in the boiling drums was not flushed out as recommended so the drums quickly became scaled and corroded. Also, the firewood in the immediate vicinity became depleted when the still was regularly used. And it was virtually impossible to distribute the water fairly. Those with donkeys were able to bring wood, but they had exclusive rights to the water produced. Thus, those without donkeys had to beg for water.

Nevertheless, two Ghanzi stills on one fire could, in 3 h, with less than a donkey-cart of wood, provide 100 L of distilled water, enough for the daily drinking requirements of 50 people. Therefore, the stills were used.

Solar stills

The principle behind solar stills is simple: salty water is left in the sun in a glass-covered basin that is airtight and has a black base to absorb radiation; the water evaporates, the air inside the unit soon becomes saturated with water vapour, and condensation occurs on the coolest available surface — the glass. If the glass is set at an angle so the condensing water flows down, rather than forming drops and falling back into the basin, then the water can be collected in gutters at the lower edge of the glass and can be directed into storage tanks. If the still is insulated, the water will get hot quickly on a sunny day. The salt molecules remain in the basin and can be collected.

Solar desalination is an obvious choice for the remote areas of Botswana as it is reliable and easily maintained. The challenge is to design a still that is simple (even at the expense of some efficiency), uses local materials and gives long service with minimal care.

In the remote areas, local materials for construction are hard come by. Even the sand is poor for building, as the particles are small and uniform. Few local people have skills in construction, so any project to introduce desalination must include a training component not only for operation but also for erection and installation. One must assume that the stills will at some time be left to dry out, so materials used in construction of the stills must be robust and resistant to corrosion by salt and degradation by heat and ultraviolet radiation.

Botswana has its own construction industry and has access to materials manufactured in South Africa and, thus, can avoid materials that must be ordered from North America or Europe. Fibreglass and brick, both of which can be produced in Botswana, are the main materials chosen for the stills introduced. The fibreglass unit is a modified Mexican still, which derives its name from the place it was first used.

Fibreglass is an ideal material for this application. It is strong, flexible, and does not corrode or leave a taste in the water. It can be made extremely resistant to damage from ultraviolet rays and is stable at temperatures up to 95°C wet and 185°C dry. The moulded surface is extremely smooth and hence can be easily kept clean. The basin can be coloured black, for optimum efficiency, the pigment being added to the resin so no amount of scraping will remove it. Other materials, such as steel bracing and nylon nipples can be bonded into the moulding without problems.

Since first introduced in Botswana, the Mexican still has been developed into a very efficient and effective design. Performance is high and the stills are robust, easily installed, and easily maintained. If a sweet borehole is drilled in an area, the fibreglass units can be removed and reinstalled elsewhere, so the capital outlay is not lost.

Their one disadvantage is cost. Between 1985 and 1987 the price of fibreglass materials increased by 250%, so cheaper alternatives have been sought. Bricks and mortar — the brick still — proved acceptable, although much less durable and portable than the fibreglass unit. Trials with asbestos cement boards and ferrocement as the main materials were not successful.

Different configurations of stills were also tested, some of which performed well but were not practical for remote areas. For example, a "cascade" still, consisting of several basins like a set of steps covered by a single piece of glass, keeps the water surface close to the glass and, thus, has a minimum of air within it and is efficient. However, it cannot be cleaned easily and it uses an inconveniently large sheet of glass.

Basic survival stills can be made by covering holes in the ground with plastic sheet, but they are unsuitable for use in Botswana despite their low cost. They have to be dismantled for access to the distillate, and their performance depends on minor details. Although they were thought to be a means for pastoral peoples to obtain water while at sites other than settlements, the only sources of water, including brackish water, are settlements.

3

Designing stills for harsh conditions

A solar still consists of a basin with a sloping glass cover; the walls are low and it looks like a house with a glass roof. At the bottom edge of the glass, on the inside, runs a gutter. The bottom of the basin is black and is well insulated.

Salty water (30–40 mm deep is optimal) is introduced in the basin, heats up when the sun shines, and evaporates. The heat is absorbed by the black surface, and the hotter the basin becomes, the faster the evaporation. The insulation prevents the heat from being lost to the earth.

The air inside the unit becomes saturated, and then water vapour condenses on the coolest available surface, the glass. The water flows down the inside of the glass as a thin film and collects in the gutter. From there, it is directed to a storage tank. The glass must be set at an angle, be kept clean and be free of cracks so that the water does not form droplets that fall back into the salt water.

Each still has access doors so that the inside can be properly cleaned. However, when the doors are closed, the unit must be airtight for optimal operation.

Mexican stills

The Mexican solar stills (MK II) of the Rural Industries Innovation Centre in Kanye are made of fibreglass and resin mixtures. They are designed to withstand transport over unpaved roads and to operate under the harsh conditions in rural Botswana. They differ from the MK I models in that they do not have false bottoms packed with insulation and the gables are lower than the earlier model.

The moulded basin has 1.6 m^2 of evaporator area, two gutters for collection of the distillate as it runs down the glass, and gables that support the glass. The shape is like a tent with two pieces of glass for the roof (Fig. 1 and blueprint, pp. 16–17). The fibreglass is strong and resistant to salt, heat and sunlight; it is dyed black before it hardens.

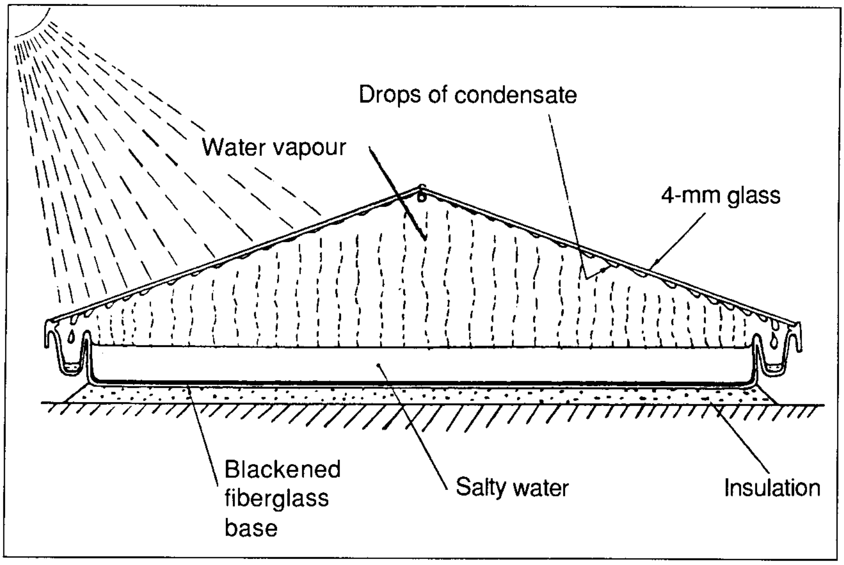
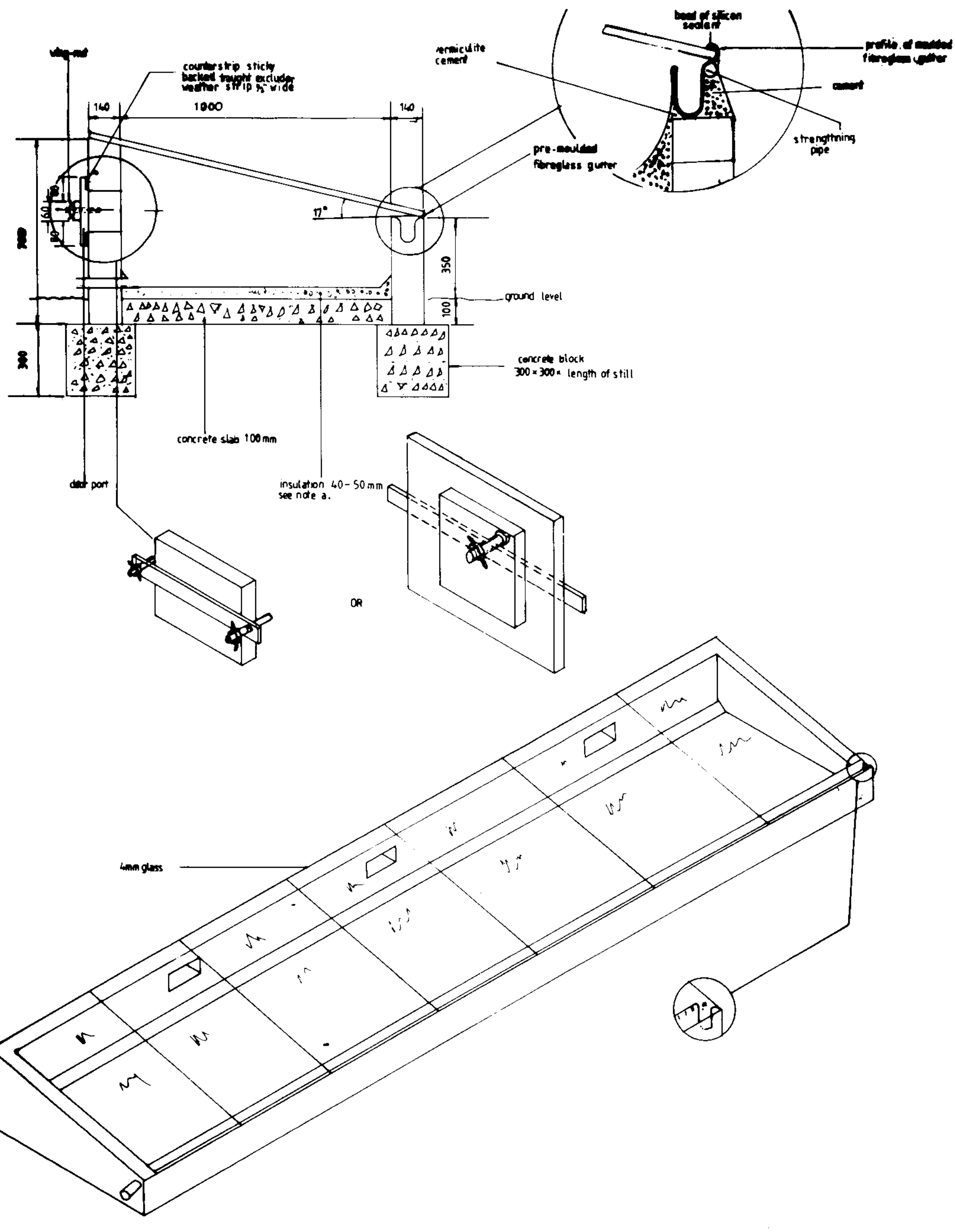
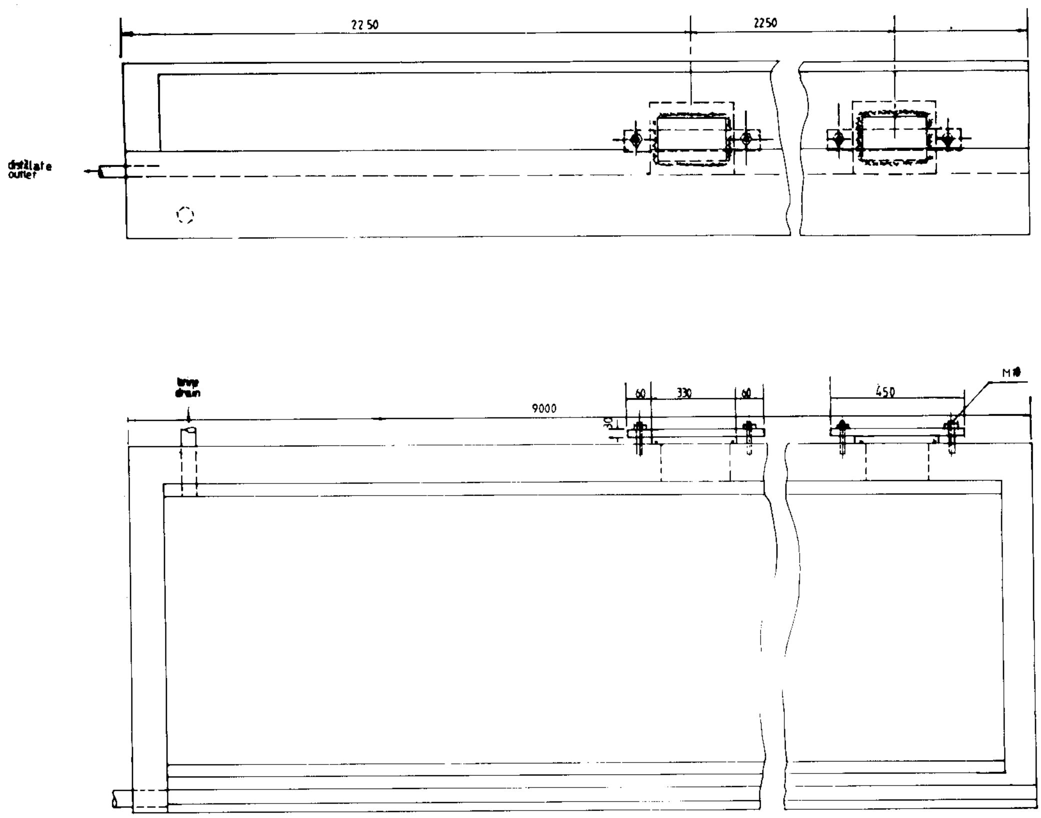


Fig. 1. The Mexican still is simple, reliable, and efficient.

The stills are relatively small and can easily be carried on Landcruisers® or similar vehicles commonly used in the desert. A larger prototype (with 1.9-m^2 evaporator area) has been built because in Botswana most transport of such materials is on 7-t trucks. The high cost of making moulds, however, has put the larger types on hold. For easy transportation the stills are designed with recessed outlet and drain nipples and slightly sloping gables so that they can be stacked. Early models used to vibrate down until they nestled so tightly that the corners split. To prevent this, support blocks were incorporated into the mould.

Originally, the stills were tried with both glass and plastic glazing. The plastic used was "Tedlar" polyvinyl fluoride sheet. This was found to give about 15% less production because condensation occurred as drops rather than as a film, hence reducing the transmission of light. Tedlar was also very difficult to fasten to the still, and even harder to make taut. With time, it tended to stretch and flap in the wind, so drops of distillate fell back into the brine. To allow the condensate to run down the Tedlar under normal circumstances, the designers introduced a glazing angle of 20°. Once the problems of Tedlar had been identified, it was decided, in accordance with other literature (Durham 1978), to use only glass.


counterstrip sticky backed draught excluder weather strip ½" wide
140
1000
140
bead of silicon sealant
vermiculite cement
cement
strengthning pipe
pre-moulded fibreglass gutter
17°
350
100
ground level
300
concrete block 300 × 300 × length of still
concrete slab 100 mm
insulation 40 – 50 mm see note a.
OR
4mm glass



ACTUAL LENGTH OF STILL AS REQUIRED.

NOTES

a insulation is made of vermiculite cement mix 6:1 50mm at far end from drain 40mm at drain followed by cement screed, painted with black epoxy enamel (3 coats)

b. ordinary brick-block to be used for foundation, for wall use compressed vermiculite cement block

c square holes must be equally spaced 210 × 170

d. fibre-glass gutter must slightly ~~slope~~ towards the outlet

e. glass is used for covering, using sealant around edges avoid silicon sandwiched between glass and window. Lay glass first then silicon.

Scale	1 : 25	SOLAR	
Design		MARK III INSULATED BRICK STILL	
Drawn	D. Phetlhu [illegible]		
Checked	[illegible]		13/4[illegible]A

The glass could be kept at an angle of 15°, with an improvement in efficiency, possibly because the distance between the water surface and the glass was lower and, hence, the energy required to lift the water vapour to the glass was reduced. The reduction in angle also meant that a smaller piece of glass could be used. A standard 4-mm window glass is used and has been found to be satisfactory. It is easily obtained within Botswana and is strong enough to withstand hail storms. Thinner pieces (3 mm) broke during hail storms and became brittle when the still was left dry and overheated. Originally, one sheet of glass was used on each side of the still, but this was increased to two each, half the size, to ease transport and replacement problems.

To transport the glass on bad roads, it was essential to carry it stacked on edge in a strong crate, padded underneath and fastened on top to prevent movement. The crate was stored as far forward in the vehicle as possible, and packed across, rather than along the chassis.

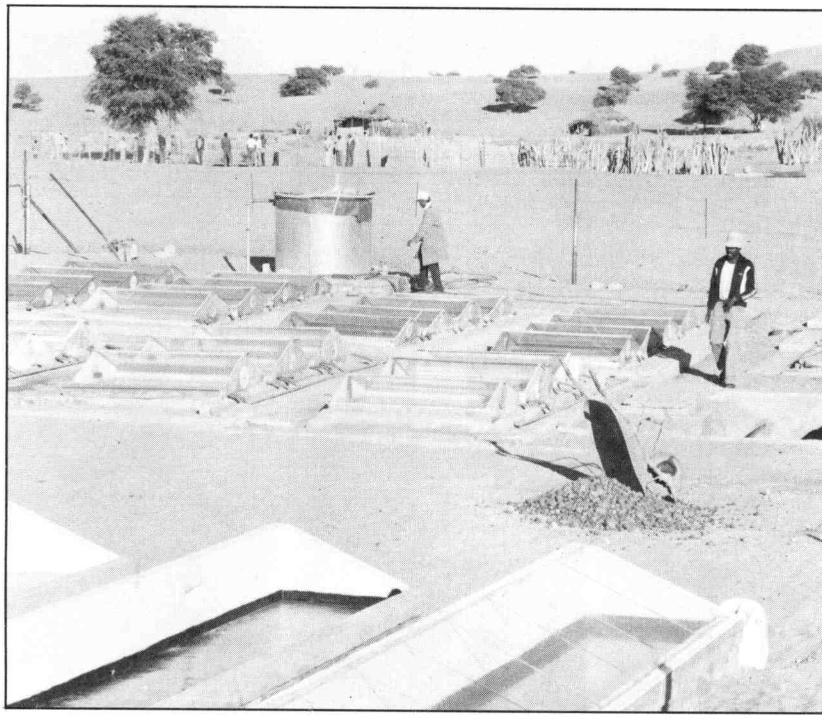
When a site is ready for the still to be installed, the glass is fastened to the still with a silicone sealant. By putting the glass in place and then applying the silicone around it rather than sandwiching the silicone between the glass and the fibreglass, one can remove the glass later without breakage.

Outlets for distillate and a drain for brine (which could also be used for filling) are made by bonding nylon nipples into the mould. Galvanized iron nipples were used at first, but they soon corroded on their cut ends.

For efficient operation, good insulation is essential. Early attempts to make a polyurethane-filled false bottom in the stills failed because the false base did not bond properly to the moulded form. Polyurethane was found to be the most effective insulator. It could simply be laid under the still. However, it is very expensive and difficult to transport. So for normal installations, a 6:1 mixture of vermiculite and cement is recommended, 50 mm thick. This is cheap and effective, serving as a foundation to hold the stills in place.

For access to the still basin, two holes exist in the gable ends and are covered with moulded plastic caps. The caps are held in place by fibreglass batons fastened with brass bolts. A seal is created by a sticky-backed piece of foam weatherstripping.

If the fibreglass basin is pulled from the mould before it has fully cured, it tends to shrink and distort. The distortion, in turn, causes the lower glazing edges to bend inwards. The edges can be braced so that



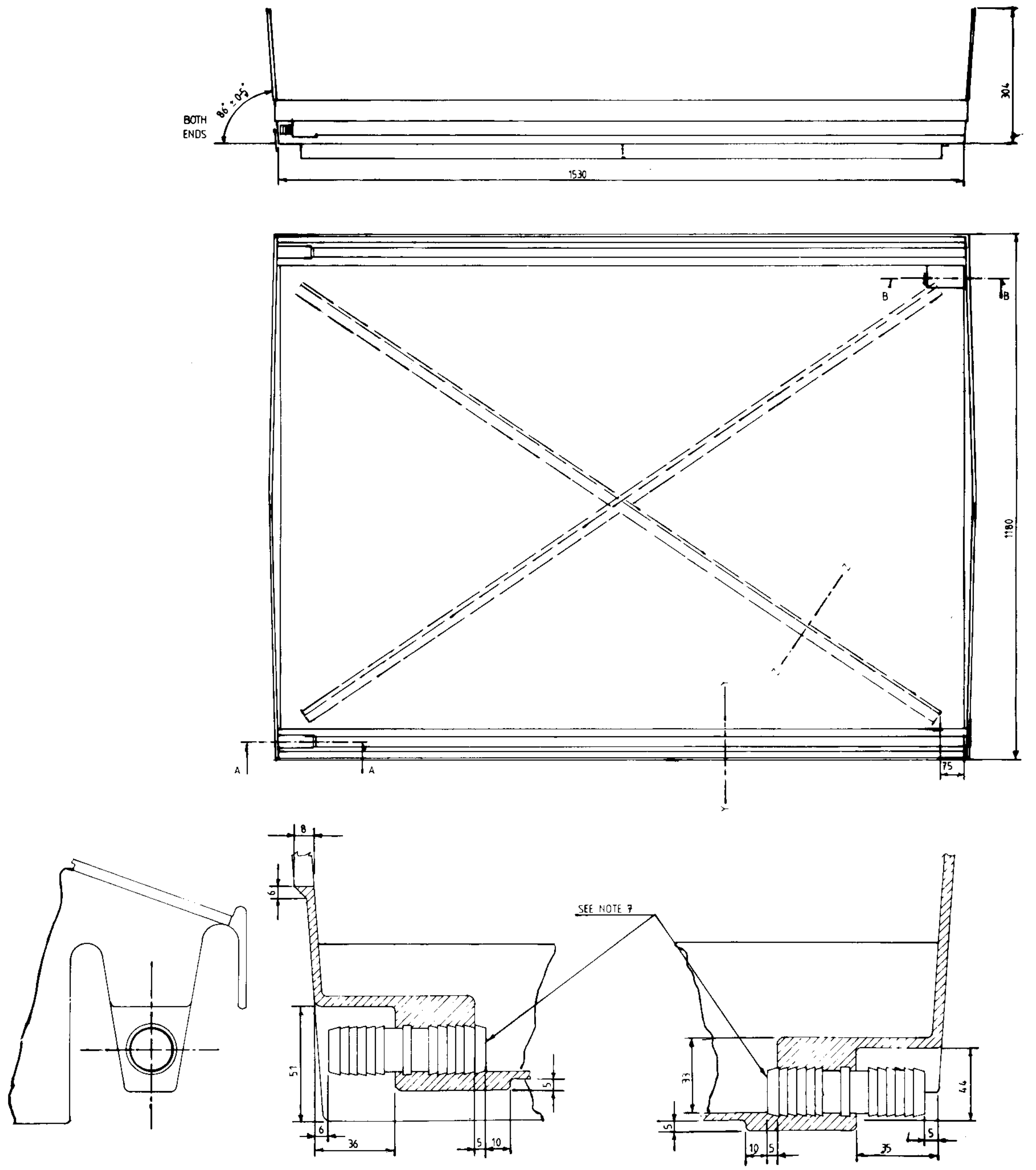
At Khawa, Botswana, brick (foreground) and Mexican stills have been installed.

they remain straight, but the solution is to keep the stills longer in the mould. A fold of fibreglass has been incorporated into the design to further strengthen the edges of the still. Angle iron is bonded onto the base to hold it flat, because warps in the basin result in dry areas that reduce efficiency.

A galvanized iron pipe is used as a ridge pole to support the apex of the glass. Although it reduces production slightly, as it heats the adjacent strip of glass and prevents condensation, no other material has been found to be as satisfactory and easily obtainable.

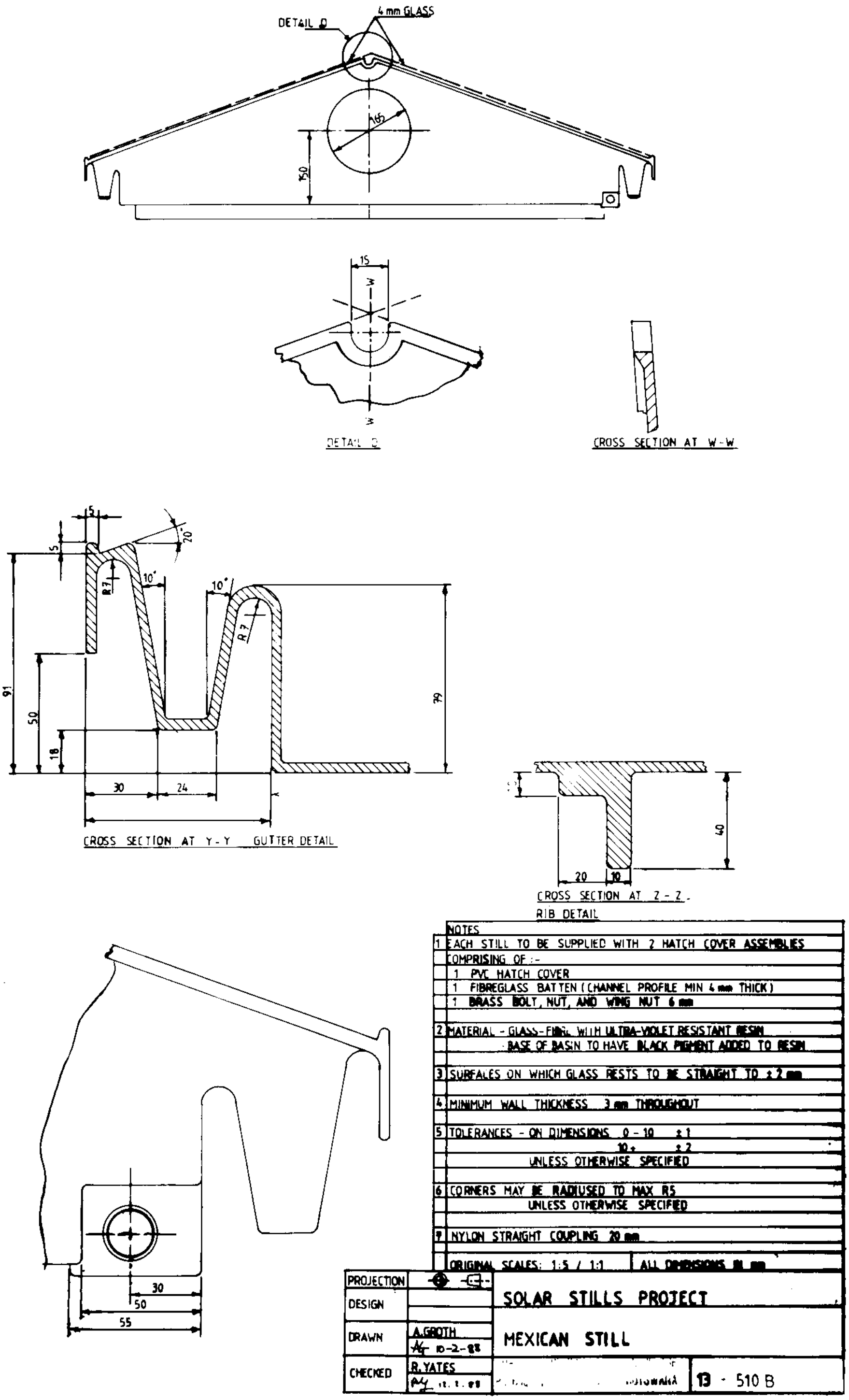
Brick stills

The brick stills consist of a long, insulated concrete basin covered with a single sloping glass roof that is supported on brick or block walls (blueprint, pp. 20–21, and Fig. 2). A single gutter runs along the bottom



SECTION A A GUTTER OUTLET DETAIL
(OTHER SIDE SYMMETRICAL)

SECTION B B BASIN DRAIN DETAIL


DETAIL D
4 mm GLASS
DETAIL D
CROSS SECTION AT W-W
CROSS SECTION AT Y-Y GUTTER DETAIL
CROSS SECTION AT Z-Z
RIB DETAIL
NOTES
1 EACH STILL TO BE SUPPLIED WITH 2 HATCH COVER ASSEMBLIES
COMPRISING OF :-
1 PVC HATCH COVER
1 FIBREGLASS BATTEN (CHANNEL PROFILE MIN 4 mm THICK)
1 BRASS BOLT, NUT, AND WING NUT 6 mm
2 MATERIAL - GLASS-FIBRE WITH ULTRA-VIOLET RESISTANT RESIN
BASE OF BASIN TO HAVE BLACK PIGMENT ADDED TO RESIN
3 SURFACES ON WHICH GLASS RESTS TO BE STRAIGHT TO ± 2 mm
4 MINIMUM WALL THICKNESS 3 mm THROUGHOUT
5 TOLERANCES - ON DIMENSIONS 0 - 10 ± 1
10 + ± 2
UNLESS OTHERWISE SPECIFIED
6 CORNERS MAY BE RADIUSED TO MAX R5
UNLESS OTHERWISE SPECIFIED
7 NYLON STRAIGHT COUPLING 20 mm
ORIGINAL SCALES: 1:5 / 1:1
ALL DIMENSIONS IN mm
PROJECTION
DESIGN
DRAWN
A.GROTH
10-2-88
CHECKED
R.YATES
SOLAR STILLS PROJECT
MEXICAN STILL
B - 510 B

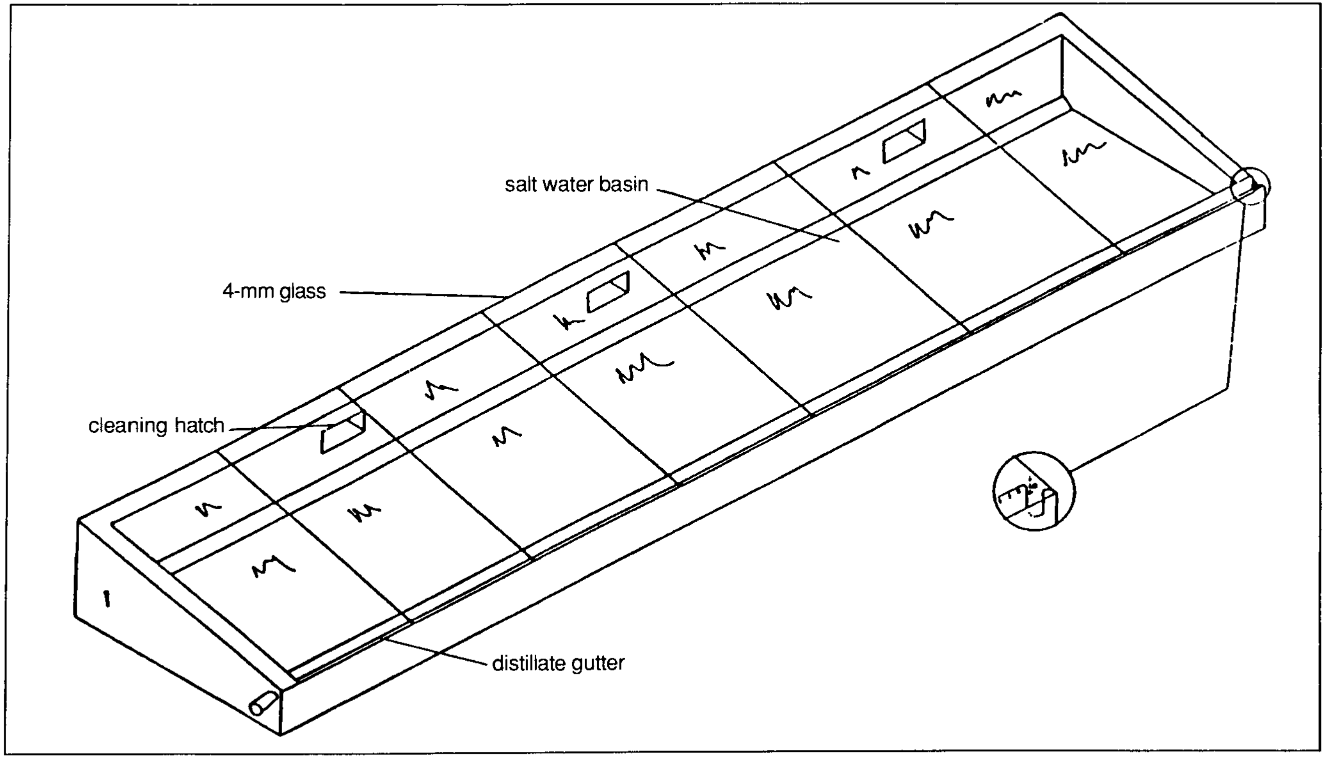


Fig. 2. Stills with walls of bricks and mortar are efficient but liable to crack near the cleaning hatches.

edge of the glass to collect the distillate. Large brick stills can be constructed much more cheaply than the fibreglass variety. The floor of the still is a reinforced concrete slab, topped by a 50-mm layer of vermiculite–cement insulation, and finished with a thin screed of strong cement mortar. The recommended maximum for the reinforced concrete slab is 5 m because of the risk of cracking. Brickforce reinforcement is used between each course. The basin (slab) is painted black with epoxy enamel, which is resistant to salt and heat.

A single, north-facing glass has been used in the installations to date in Botswana. The span of the glass is 1 m, as experiments with a longer span have shown that the glass breaks. No extra supports are needed between each sheet of glass. As in the Mexican still, the glass is set at about 15°.

Bituminous black paint was tried but found to taint the distillate even 2 years after construction. It also was easily damaged during cleaning as it softened in the heat. Although more expensive, the epoxy enamel forms a strong smooth surface. It is easily cleaned and does not tear when scraped. Some chalking of the paint is caused by sunlight, although it does not seem to affect performance. The basin needs repainting after about 3 years. The still must be left for several weeks to cure before being painted. A fibreglass gutter with an integral lip to support the glass catches the distillate. The addition is expensive but effective. Attempts to form a cement gutter only led to problems with the poor quality of sand available in the field.

The walls are either standard cement/sand blocks or blocks made from vermiculite–cement. The latter give slightly improved performance but, if exposed to water, will absorb it. Hatches are constructed in the back wall for cleaning and filling purposes. The method of sealing is the same as for the Mexican stills. The spaces in the brickwork cause problems of cracking as the stresses in the wall concentrate at their corners. Precast concrete lintels can be used over the spaces but, at this stage, cracking is still a problem. The walls inside need to be plastered before being painted, and the corners between walls and floor are rounded with cement to avoid leaks. The low quality of available sand in the field in Botswana has made plastering difficult and again cracking often occurs. Given skilled labour and a supply of reasonable sand, these stills can be recommended for long-term installation, but some further development is necessary before they can be more simply and reliably constructed. A butyl rubber lining in the basin and the gutter might overcome the problem of cracking.

4

Installing and operating the stills

A good and effective installation takes time, and all the steps are equally important. People in remote areas should have the necessary materials and tools before beginning the task. They should be aware of what the stills can do and be prepared to participate in the construction as well as in the regular use of the stills. Despite the commitment of the community, developers of desalination must have access to enough funds to pay labourers and must be available to supervise the work closely.

Initially in Botswana, the stills were installed with the help of volunteers. However, voluntary labour proved inconsistent, so a group of about 10 labourers were employed for each installation and paid the same wage as they would have received under a drought-relief scheme.

The Mexican stills were specifically designed to avoid the need for skilled labour, as this is scarce in the desert. Very quickly all the workers learned the various jobs. Solar desalination is simple, so they quickly understood what was needed and how to solve problems as they occurred.

The Mexican stills were, in effect, assembled as kits, with virtually no construction on the stills themselves. A standard layout was established, with 16 stills (four rows of four stills each) on a raised foundation or plinth.

Once the stills are installed, one member of the community must be hired to operate and maintain the stills; in Botswana, the local council employs the operator, and the position has been designated "council pumper." Besides overseeing the still's operation and the distribution of water, this person will be expected to carry out monthly inspections according to a checklist, repair the equipment, and keep the site free of debris. If funds permit, an assistant should be hired; otherwise, there will be times when the stills are unattended. In Botswana, for example, the council pumpers must leave the settlements to shop and to hunt; also, absences may be caused by illness or injury.

The Rural Industries Innovation Centre can provide technical backup, but the steps detailed in this chapter should be sufficient for installation and operation of stills in most circumstances.

Installation

Materials and tools

The materials can be bought locally in Botswana (Table 1). The installation starts with cleaning and fencing the site; the number of tools depends on the number of people doing the installation and the size of the installation. For a bank of 16 Mexican stills, the minimum tools will be

- 1 hacksaw and 10 blades;
- 2 measuring tapes: 5 m and 15 m long;
- 2 silicone guns;
- 2 pairs of gloves;
- 1 chisel;
- 2 spirit levels: a short one and a long one;
- 1 roll of fishline (building line);
- 1 wheelbarrow;
- 3 shovels and 1 spade;
- 2 building trowels;
- 2 gauging trowels;
- 1 building square;
- 2 glass cutters;
- 1 pair of pliers;
- 2 adjustable spanners (small ones);
- 4 paint brushes (2 small and 2 bigger ones);
- 2 trimming knives; and
- 2 flat screwdrivers.

Site selection and fencing

Any site that has a reliable source of salt water is suitable — the nearer a community the better. A privately owned source of water is suitable only if the owner can be persuaded to relinquish any preferential rights to the water. The best site is the centre of the community.

Obviously, the steps in obtaining approval for use of the site differ in each country; in Botswana, the authority lies with the Landboard.

Installing Mexican stills at Khawa, Botswana.

The site is marked and cleared of bushes. The stills need a shadow-free area so that they receive maximum radiation. Any trees that will interfere with the functioning of stills should be eliminated. Fencing to keep out animals, thieves, or anything that may damage or misuse the stills, especially the glass, must be a minimum of 1.5 m high, with two lines of barbed wire at the top and one line of barbed wire at the bottom.

Local people can be engaged to build the fence; wood or iron poles are suitable. The enclosure needs two gates — one for pedestrians and one for farm vehicles; a lock is essential for each gate.

Constructing the plinth

The plinth is the base for a group of stills. It consists of a low rectangle, the walls of which are brick, with concrete footings. The space within the walls is filled with impacted sand.

The area on which the plinth is to be constructed should be measured and the corners marked by pegs. The first peg is placed in one corner of the fenced area so that there will be room for expansion in future. The standard area for a plinth to support 16 Mexican stills is 10 m × 6 m. This provides enough room for four stills in a row (each still is 1.6 m^2 and has two gutters of 110-mm diameter each — one in front of

Table 1. Materials needed to install a Mexican still.

Item	Purpose	Supplier in Botswana
Vermiculite–cement	Insulation under the still	Garden Centre or Hydrocon — Gaborone
Cement	Concrete, building plinth, moulding bricks, etc.	Any dealer for construction materials
Still basins	Distilling water	Hydrocon — Gaborone
Silicone sealant	Glazing stills	Haskins Hardware, Hydrocon — Gaborone
Fibreglass mat	Patching stills	Hydrocon
Resin resistant to ultraviolet rays	Repairing damaged stills	Hydrocon
Gutters	Collecting rainwater and brine from stills	Builders Merchants Botswana — Gaborone
Polypropylene pipes	Collecting distillate	Hydrocon
Nylon joints	Connecting the pipes to the still	Hydrocon
Clamps, 15–20 mm	Fastening pipes to joints	Hydrocon
Hatch hole covers	Closing and opening stills	Hydrocon
Weatherstrip	Sealing the hatches for airtightness	Builders Merchants Botswana, Haskins Hardware
Brass bolts 6 mm diameter, nuts and wingnuts	Holding the hatch hole covers	Haskins Hardware
Fibreglass baton	Holding covers inside the stills	Hydrocon
Galvanized pipes	Poling for glass support	Builders Merchants Botswana, Haskins Hardware
Glass sheets, 4 mm thick	Glazing the stills	Any glass dealer

the still and the other at the back of the still). In other words, an area 15 m^2 should be allocated to each set of four stills.

Between the pegs, a trench is dug 450 mm deep and 250 mm wide and is leveled. This width of trench will accommodate a wooden frame for footings that are to be 150 mm × 200 mm thick. The footings are a mixture of cement, sand, and water in a ratio of 1:3:6. After being poured, they are leveled by a wooden straight edge. They are left to harden for 3 days, during which they are regularly sprinkled with water so that they are strong slabs when dry. A wall of bricks, 500 mm high or five courses above ground level is sufficient to keep sand and dust away and to protect against flooding during heavy rains. Stock bricks, with a smooth finish, can be used and in fact are best because they can be obtained easily. The smooth finish is needed because the outside of the wall will not be plastered. The space within the holding wall is filled with sand and tamped down. The sand must be at least 30 mm below the top of the wall.

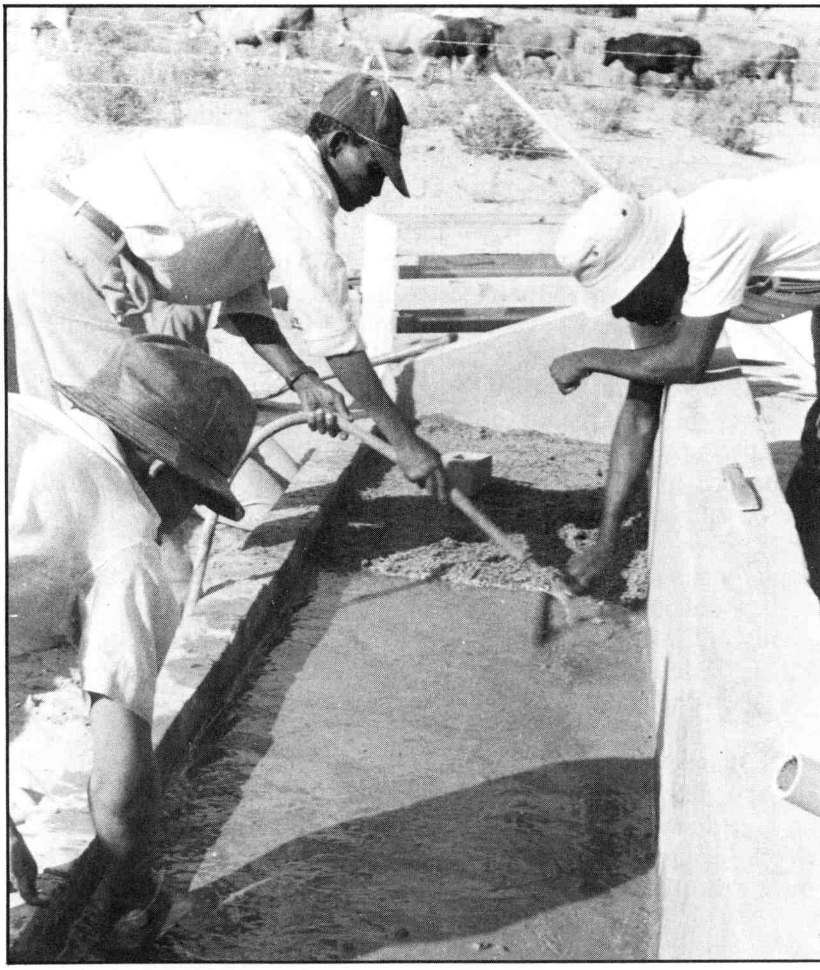
The stills should be set in position and the area for each one clearly marked; they are then removed to allow the insulation to be installed. The entire area under each still is to be covered with insulation so that the heat accrued during the day will be partially maintained and will enable night operation. The insulation is essential for continuous production. The material can be polyurethane, vermiculite–cement, sawdust, etc.

In Botswana, vermiculite–cement, either dry or mixed with water and cement, has been the most cost-effective material tried to date. The risk in using dry vermiculite–cement is that water will eventually find its way into the insulation.

The next step is to set the still basins on their bed of insulation and make sure they are level. This will ensure that no area within the basins becomes dry during regular operation.

Gutters are to be installed in front of and behind the stills to collect rainwater and, when the stills are flushed out, the reject brine. Between the bottom of the still basin and the gutter, the space will be covered by concrete so that the entire plinth serves the function of rainwater catchment.

PVC (polyvinyl chloride — plastic), asbestos, or cement can be used for the gutters, as can any other material that is resistant to damage by ultraviolet rays, is durable, and is locally available. For normal installations in Botswana, PVC gutters are put in place after they have



Workers level the vermiculite–cement insulation on a brick still.

been dipped in glue and then gravel, so that they bond to the concrete that is poured later (the concrete will cover all the space within the plinth that is not occupied by stills and gutters). Asbestos gutters were used in the past, but they broke easily and were difficult to transport. Also, the dust from the asbestos cut in the field was a health hazard to workers.

The underlying aim is for rain to flow down the glass roofs of the stills and over the concrete into the gutters. The gutters all slope toward one corner of the plinth so that the water will run gently into a tank set in the ground. To flush out the stills, one just opens the drain nipple on the basins and the brine runs into the gutter and can be directed, like the rainwater, into a tank or into a soakaway. The joints on gutters should be sealed with either epoxy resin/hardener mixture or some similar compound.

Space between the gutters will serve as walkways but should slope slightly toward the gutters. When the gutters are put in place, all the areas that are not covered by either gutters or basins will be sand. This sand is stamped down and compacted as much as possible so that it does not crumble when covered with concrete. The mixture for the concrete covering is cement, sand, and water in a ratio of 2:3:6 (depending on the quality of the sand). After the concrete has been poured over all the exposed areas of sand within the walls of the plinth, it is tamped down and made smooth. A wooden plastering trowel is recommended for smoothing the surface; a shining trowel renders the surface so smooth that it is slippery when wet.

Once the concrete has been added — in front of, behind, and between the stills — all the surfaces of the plinth are impermeable to water and thus will contribute to water collection. The concrete has to be left to harden for at least 2 days before it can bear any weight; it should be heavily sprinkled with water for at least 3 days.

The stills have two plastic outlet nipples, each 20 mm in diameter, to which pipes have to be fitted for collection of distillate. A third outlet nipple is a drain and is 25 mm in diameter. In early installations in Botswana, galvanized iron nipples were used, but these have now been replaced with plastic ones.

Polypropylene pipes are used to channel the distillate in Botswana because they are ultraviolet-resistant, are simple to cut, are flexible, and do not rust, although when new they do give the distillate a slight smell. Also, they tend to warp when they get hot and the bends can hinder and even prevent the flow of water to the tank (Fig. 3). The pipe should be held in place by holderbats and should be lain in a snaking fashion so that any warping takes place sideways not up and down (Fig. 4).

The pipes are attached to each other and to the outlet nipples by jubilee clips that fit 15–20 mm. The tools needed for this part of the installation are a sharp knife, flat screwdriver, and a measuring tape.

Pipes are used to join the two distillate outlets from each still, all the stills in a row, all the rows, and all the plinths. One needs to have

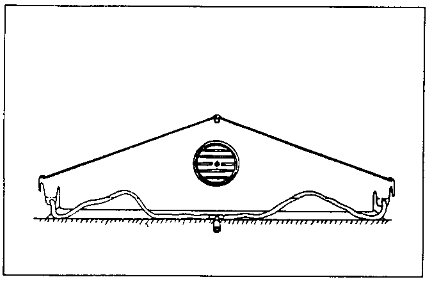


Fig. 3. Warping of the pipe can prevent flow.

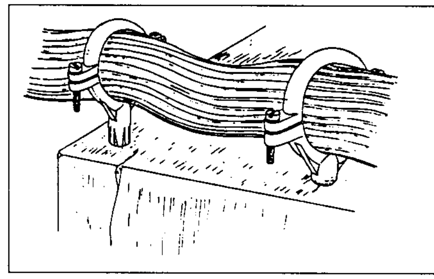


Fig. 4. Holderbats keep the pipe in place.

20-mm elbows, 20-mm T-joints, and nipples to make the necessary connections, but the aim is to have a single pipe entering the tank collecting the distillate so that the tank can be properly covered. Every site needs a tank for distilled water sunk below the level of the stills. In Botswana, 2 000-L rubber-lined tanks are used for distillate collection. If possible, the distilled water will be pumped out, but if no pump is installed the water should be removed with a plastic not a metal container. The tank should remain covered. Sites also have a rainwater catchment tank and saltwater storage tank. In Botswana, the rainwater tank is built of bricks and plastered inside, a coat of waterproof paint being applied to the plaster to reduce cracking. All the tanks should be kept covered.

Plastic pipe, 75 mm in diameter, should be used to direct the rainwater from the gutters into the tank. The pipes coming from the gutters of the plinths should be covered at this opening with wire net or garden net to blockade dirt. The same size pipe should be used for the drain outlets that lead to soakaways. The soakaways should not be constructed near trees, as the salty water will damage the roots and kill the trees.

The standard Mexican still is 1.6 m long and 62 cm high. Four sheets of 4 mm thick glass are used to glaze one still. For easy handling and transportation, glass sheets of 800 mm × 620 mm are used. The 4 mm thick glass can withstand hail and travel over rough roads. Joints (or cracks) across the glass will cause the distillate to fall off and drop back into the brine, whereas cracks running vertically do not affect the production of the distillate (Fig. 5). When the glass is being installed, the following precautions must be taken.

- Never leave glass out in the sun, as overheating will affect the performance. Also, do not leave glass anywhere it can get blown over by the wind.

- Avoid leaving fingerprints on the inside surface of the glass. Handle the glass by its edges.

- If the glass to be fitted needs cleaning, wipe it gently with a soft cloth. Wipe up and down the glass, not in a circle or across it.

- If any glass is broken, clean up the pieces and bury them immediately.

An average of 1.5 bottles of clear silicone sealant is enough to glaze one still. Silicone sealants come either in plastic bottles (315-mL cartridges) that fit into a gun for application or in pressurized aluminum canisters (210 mL). For ease in use, it is best to cut the plastic nozzle at about 45° (Fig. 6).

Stills have at the top of their gables two slots for the ridge poles. The ridge poles can be made from 15 mm thick galvanized pipe. Their purpose is to support the glass. Below the ridge poles are two openings called the hatches, which are used for cleaning and filling the still. They are fitted with a weatherstrip so that the still becomes totally airtight. The best material for use as a sealing strip is black foam weatherstrip. This has an adhesive backing and the optimum size is about 1.3 cm (0.5 inches) wide and 1 cm (0.375 inches) thick. There is a cheaper grade of white weatherstrip available but this is not durable. If no weatherstrip is available, then a ring of plastic tube about 10 mm thick can be fixed on with silicone. The sealing strip can be fixed either to the still or to the hatch cover itself. In fact, it has been found best to fasten the weatherstrip to the door, as this prevents it from getting soaked when the still is being cleaned. If a plastic tube is used, it can be fastened to the still wall.

The covers for the hatches are made of plastic and are shaped like shallow basins with a hole in the middle. A fibreglass baton is joined by a 6-mm brass bolt, nut, and wingnut; the baton fastens the hatch cover to the still.

Although the orientation of the stills is not critical, the problems of drifting sand are reduced in Botswana when the gables face north–south. A small hut completes the installation, serving as a place to store tools and spare parts, particularly glass.

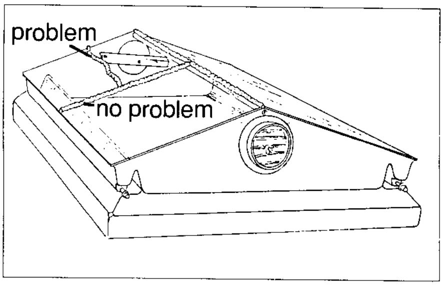


Fig. 5. Vertical cracks in the glass do not interfere with the distillate's flow.

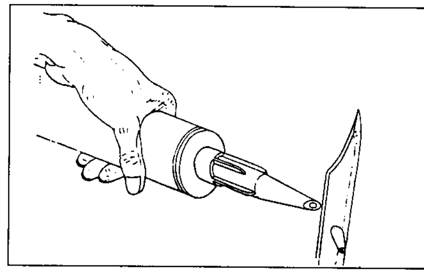


Fig. 6. The tip of the silicone sealant canister is cut at about 45.°

Monitoring and operation

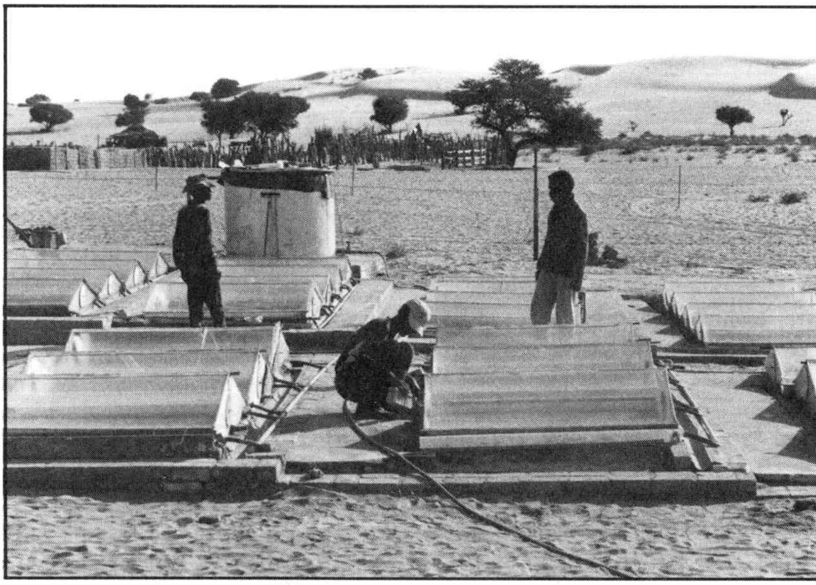
When all the steps of installation have been completed, the stills should be filled and the operation carefully monitored. The monitoring involves checking for vapour and distillate leaks. The output should be monitored for a minimum of 5 days, 24 h/day (typically 20% of a day's production occurs at night). If the results show discrepancies, then the setup should be thoroughly inspected for leaks. Sometimes leaks occur on the glass joints; the silicone sealant may not take well to the glass or it may shrink when the still heats up and cools. Joints on pipes should be checked and jubilee clips adjusted as necessary to stop leaks.

Filling the stills

The stills are filled with salt water to a depth of 40 mm (two fingers width), closed and left in the sun. At no time should any part of the basin be allowed to dry out. It is best to fill the stills early in the morning when the water is already cold so no production is lost because of the cooling effect of the newly introduced water. This practice was recommended to operators in Botswana, but they seldom followed the recommendation and, at any rate, the water heated up quickly.

The stills are topped up with water every 2 days (more often if dry areas appear in the basin). The maximum depth for water in the Mexican stills is 70 mm; if more water is added, it leaks out the cleaning hatches.

To fill the stills, the operator loosens the wingnut on the hatch so that



Filling the stills at Khawa, Botswana.

the cover falls open without damage to the sealing ring. If the operator slides the cover off, the sealing strip will likely tear (Fig. 7). A hose is introduced into the hatch for filling, after which the hatch is resealed.

Monitoring output in the field continually is unrealistic in areas where people are few, relatively widely scattered, and unfamiliar with the concepts and rationale. In Botswana, the data from regular monitoring proved unreliable so all still designs were monitored in Kanye to assess performance and durability and for short times in the field. As one of the main benefits in measuring output is to ensure the proper

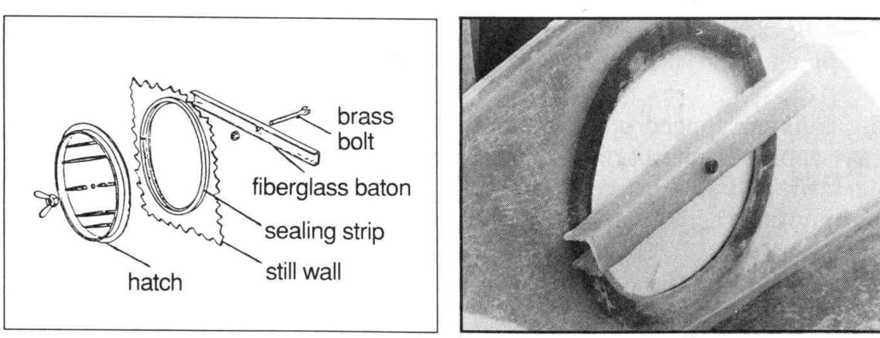


Fig. 7. The cleaning hatch.

functioning of the system, which was designed to be sturdy and simple (with leaks being readily apparent), monitoring the output during the first 5 days and annually (during inspection by officials of the ministry or council in charge) is probably sufficient.

In Botswana, a solarimeter is used to measure incident radiation, and the results are combined with figures for the output of the stills in an equation to determine efficiency (Alward 1985):

$$\text{efficiency (\%)} = \frac{(\text{daily production in L/m}^2)(0.69\ \text{kWh/L}) \times 100}{(\text{daily solar radiation on the horizontal in kWh/m}^2)}$$

where 0.69 kWh is the amount of heat required to bring 1 L water to its evaporating temperature and then to evaporate it. This equation has been used for measurements throughout the year in Botswana, and the efficiencies of the stills are clearly lower in winter.

The theoretical maximum efficiency for a single basin solar still is 60%, and the maximum obtained for the Mexican still in tests over 24 h in Botswana was 55% (production 4.4 L/m^2, insolation 5.56 kWh/m^2 in October 1985). Maximum yield from the Mexican still was more than 8 L/day, but typical summer yields were 7–7.5 L/day, or 4.4–4.7 L/m^2 per day. In winter, yield dropped to as little as 2.5 L/day. This level of output occurred during the coldest months when nights of −9°C are not uncommon. Unfortunately, in Botswana, winter is also the driest time of year, and this level of production is insufficient. Using this minimum as a standard in designing a system would be uneconomic; it is better to acknowledge that until suitable water storage and distribution systems have been established, a small amount of water may have to be delivered in the winter.

In the longer term, storage for rainwater should be constructed to augment water supplies in winter. Each block of 16 stills (10 m × 6 m) gives a useful rainwater catchment of 50 m^2. Given 250 mm annual rainfall and a collection rate of 60%, the yield is 7 500 L of water — an increase of 30%.

Performance of the stills in summer was unaffected by the orientation of the glass, but in winter stills oriented along a north–south axis had higher output than others.

As expected, performance of the stills decreases when the colour of the base changes from black to white with salt encrustation. The difference between stills filled with deep water (70 mm) and those with shallow water (30 mm) is only about 3%, with the efficiency of production being higher when the water was kept at about 30 mm.

The brick stills are not as efficient as the Mexican stills, but the drop in production during winter is somewhat lower (50% as opposed to 60% for the Mexican stills). A maximum of 3.8 L/m^2 per day was obtained in summer for brick-walled stills, and 4.3 L/m^2 per day for stills with walls of vermiculite blocks.

The volume of water to be consumed is augmented somewhat because the distillate must be mixed with some salt water so that the total dissolved salts (TDS) meet the mineral requirements of the human body. The World Health Organization recommends a TDS of 100–1 500 mg/L. Distilled water is salt free, whereas the water from boreholes in Botswana varies from 6 000 mg/L in Khawa to 235 000 mg/L in Zutshwa (seawater is about 35 000 mg/L). In practice, people in Botswana drink water with up to 4 000 mg TDS/L, but the health of young and old is adversely affected at this level of consumption.

Before distribution of the water, the operator mixes the distillate with appropriate quantities of salty water. This step is essential and may demand considerable effort from extension workers, as the amount of salt water in mixtures is site-specific and the operators may view the task as superfluous or self-defeating. Persuading people of the value in adding salt water is simplified by the fact that distilled water does not quench thirst, but the extension effort should not be underestimated. In Lokgware, Botswana, one man said the distillate "makes the blood thin," but extension staff still had to devote a large amount of time to ensuring that the operators carried out the mixing before distribution of the water.

5

Maintaining the stills

The stills, plinth, pipes, glass, etc. should be regularly maintained. Both the still basin and the glass can easily be mended. Fibreglass mat, resin and hardener are used for leaks in the basin, and pieces of glass can be cut to mend broken panes.

Cleaning the basin

At least once a fortnight, the stills should be drained completely, flushed out, scrubbed clean with a soft brush or rubber scraper, and then refilled. If salt forms crystals in the basin, the stills should be cleaned sooner. After being cleaned, the basin should appear black when wet. At the installations in Botswana, it was very unusual for the stills to be properly flushed out until they needed a major clean.

In fact, if the basins were flushed out with plenty of salt water every week, then salt deposits seldom appeared in them. Nevertheless, salty water is a scarce commodity and is not used wastefully. Given that the filling and flushing were done during the day, it was probably more efficient only to fill and not to flush. When the stills were cleaned, the salt solids were taken out by hand through the hatches.

In Zutshwa, the water was so saline that the salt sometimes crystalized as a film over the water surface. This prevented evaporation and greatly reduced output. The operators learned to break the film with a stick and the salt crystals fell to the bottom of the basin and were later withdrawn and sold.

Cleaning the glass

The glass should be wiped clean every week. If available, a commercial window-cleaning product should be used. If washed with salty water, the glass must be squeegeed carefully with a rubber scraper before it dries; otherwise the water will leave salt traces. A small amount of distillate can be used to clean the glass quickly.

In Botswana, the operators have been cautioned to take care of the glass, to avoid rubbing it with sandy cloth and pressing against it. They receive a certain amount of help from villagers to clean the glass and to remove windblown sand. In Zutshwa, all those receiving water must first give some of their time; this approach has proved useful, particularly in the winter when many quelea birds are attracted to the stills and leave their mess behind. These deposits have to be scraped off with sticks, a time-consuming task, which scratches the glass.

Glass breakage has not been a problem during normal operation in Botswana, although many sheets have been broken during installation and removal for renovation. A few have been broken by stones from catapults fired at the birds attracted to the stills and some of the 3 mm thick glasses used originally in the country's installations broke during hailstorms. Others have been broken because of carelessness, and in one case a tank cover blew onto a still and broke the glass.

To avoid having the glasses blow out during high winds, the operators were told to open the cleaning hatches to equalize pressure inside with that outside. However, in the desert, if the hatch covers were removed in a storm, the stills would fill quickly with sand. Also, the operators were cautioned that anything in the yard that may be blown into the stills during a storm should be removed. Sheets of corrugated zinc are regarded as particularly dangerous and if used to cover the tanks should be well weighed down.

The most common problem was that stills were left to go dry. Operators were asked to leave the hatches open if the stills had to be left dry for any reason. If the stills were to be unused for long times, then the operators were to remove the glass and store it out of the wind and sun.

Despite the cautionary notes, in practice, the stills sometimes dry out. This soon causes a baked-on crust of salt, small vapour leaks through the silicone, and overheated glass, characterized by condensation forming in droplets rather than as a film. This change in the glass reduces the amount of energy passing through and hence lowers performance. Overheated glass can be retreated by adding ammonia to the salty water. The vapour renews the glass surface, but the distillate is undrinkable while ammonia is in the still. The technique caused suspicion among people in Lokgware, Botswana, who had to be told to avoid the poisoned distillate. In developing countries where water is in such short supply and the level of education in rural areas is low, it may be better, except in extreme cases, to leave the glass to recover with time.

Cleaning the hatches

It is best to leave one hatch untouched and to do all filling and cleaning through the other one. The hatches should be sealed so they are airtight.

Inspection and repairs

Every month the operators are expected to inspect the whole installation. A checklist of questions and steps to remedy problems follows and pertains to each component of the setup, beginning with the most fragile part — the glass.

- Are there any traces of water leaking along the bottom edge of the glass? If so, cut away the silicone around the leak, dab the area dry with a cloth then reapply silicone.

- Are there any vapour leaks around the sides of the glass or the end of the ridge pole? Look for any traces of sand inside the still, as these show where leaks are. Watch for any changing patterns of vapour on the glass as these also imply leaks. Once it is obvious that there is a leak, look very carefully from below to see exactly where it is, then reseal with silicone. If sealing between two sheets of glass, run the silicone gently over the joint and check again closely for leaks.

- Are any glasses broken? To replace them, cut away silicone around the old glass and remove it. Scrape all the surfaces on the still clear of old silicone. Lay a new piece of glass in place then reapply silicone around it. Avoid pressing the silicone between glass and still; instead try to seal around the edge of it with a bead of silicone direct from the canister (Fig. 8). If possible, cut the broken glass parallel to the sloping (62 cm) edge so that the result is a rectangle and the piece can then be stored for use in future repairs (Fig. 9). After replacing a glass, look carefully for leaks at the next inspection, as the silicone will initially shrink.

- Is the water forming droplets instead of a thin film on the glass? This indicates that the glass has been overheated, with the result being reduced efficiency. The stills have probably been left to go dry (Fig. 10). Overheated glass will go back to normal with time and use. In extreme conditions, add a small amount of ammonia to the brine and do not use the distillate until the glass has been

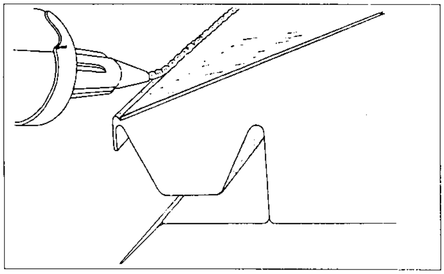


Fig. 8. Applying the silicone around the glass for ease in removal later.

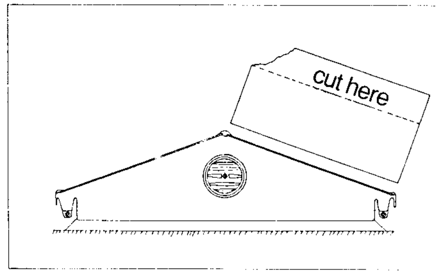


Fig. 9. Cutting broken glass.

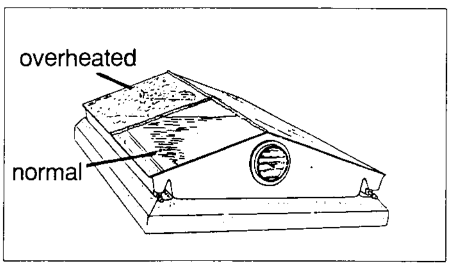


Fig. 10. Overheated glass is brittle but will recover elasticity with time.

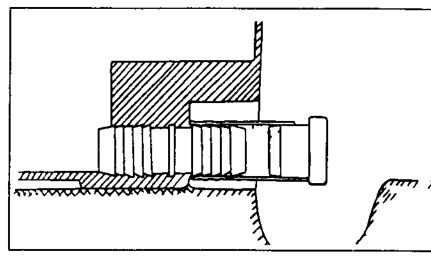


Fig. 11. Extending the outlet nipple ensures drainage into gutter.

restored to normal and the still has been flushed out. Alternatively, gently wipe the glass with up and down strokes using a mild abrasive cleaner.

- Are the hatches properly sealed?
- Is the sealing strip still stuck to the hatch cover?
- Do the threads on the brass bolt need grease?
- Is the brass bolt securely fastened in the fibreglass baton?
- Are there leaks of distillate around the outlet nipples?
- Are all the nipples securely fastened? If any are loose, use fibreglass resin or epoxy resin to reset them.
- Are the outlet nipples extended from the recessed position under the stills so that any salt water drained from them goes directly

into the gutter (Fig. 11)? Slow leaks from the end of the outlet nipples are not important as the salt will tend to seal them automatically. Any leaks that allow water to go under the still are to be sealed immediately to prevent the insulation from being soaked.

- Are the joints in the piping free of leaks?

- Are the pipes warped upwards and preventing flow to the tanks? If any of the distillate gutters on the stills are full, a pipe is probably holding up the flow. If so, move the pipe around until water can flow again. If this is not successful, then look for a blockage in the pipe.

- Are the gutters blocked by sand or debris?

- Are the joints between the gutter sections intact? If there is a gap so water is leaking through, clean the area well and seal with epoxy resin or cement mortar.

- Are there any gaps between the stills and the concrete? If so, water may leak down, soak the insulation, and reduce efficiency. Seal gaps with strong cement mortar or epoxy resin.

- Is sand building up around the stills or the plinth? If so, clear it away.

- Are there gaps under the fence? If so, block them.

- Are there breaks in the fence? Mend any damaged wires immediately.

- Are any of the tanks leaking?

- Has rubbish fallen into any of the tanks or gutters?

- Is there any structural damage to the still? Mend it as soon as possible. If the damage is inside the still, then begin by draining and drying the basin and removing the glass. Clean the damaged area thoroughly and, if possible, wipe with acetone. Next cut a piece of glass fibre mat to cover the damaged area. Mix enough resin to soak this mat with just one or two drops of catalyst (Fig. 12). Mix well; then begin work immediately. Depending on the amount of catalyst, the mixture will harden in a few minutes to a few hours. Apply a layer of resin with a brush over the area to

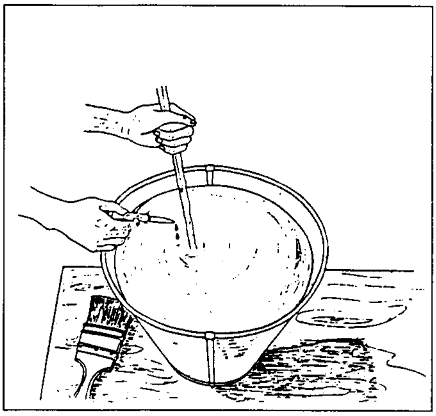


Fig. 12. A few drops of catalyst speeds the hardening of the resin.

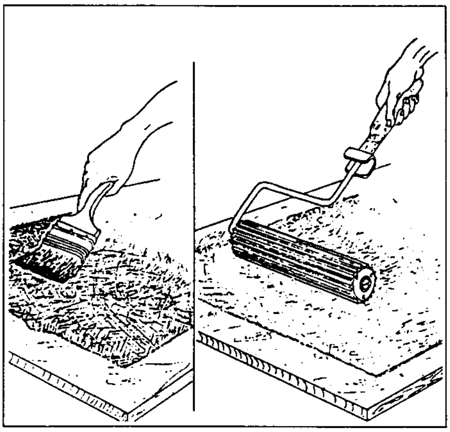


Fig. 13. Once the fibre mat is in place, the bubbles can be pressed out with a roller.

be patched; put the patch over this; then cover the mat with more resin and leave it to cure. Make sure the glass fibres are smoothed down in the resin and that any air bubbles are forced out of the mixture (Fig. 13). Acetone should be used to clean brushes, tools, and hands after the work.

- Has the black coating on the still basin peeled off? Nothing can be done to replace the colour in the Mexican stills. Efficiency of the unit will drop slightly, but the unit will continue to work. A coating of black enamel paint can be applied to the outside of the still and the blackness will show through the resin. For the brick stills, the black paint inside the basin will tear or flake, a signal that the whole still should be unglazed, stripped, and repainted. This should be especially checked by water unit staff every year. If any repairs have been made to the brickwork, the new cement or concrete should be left for at least 1 month before being repainted because any moisture that comes out of the cement will be trapped under the paint and will cause blistering.

6

Comparing costs of alternative technologies

Solar desalination is not a cheap technology, but the options for supplying water to remote areas are often even more expensive. Where feasible, reticulation is likely to be cheaper than desalination. Cost comparisons between trucking and desalination are impossible to generalize. Each site has different water salinity and, hence, mixing ratio of distillate to salt water. The distance that a water truck has to travel from its base, and the distance from the settlement to water source are also variable.

To date in Botswana, the desalination system most successfully implemented uses fibreglass Mexican stills, which are very expensive but are simple, reliable, and appropriate. Under the current circumstances in the country, drilling will likely be pursued at all settlements in the next 6 years, and the investment in stills is not wasted when sweet water is found, as the stills can easily be moved to another site.

The installation of these stills at one site (Zutshwa) in Botswana gives some indication of the costs (Table 2). Total cost per still was 639.41 BWP. The cost of materials excluding that for fencing was 387.86 BWP/still or 61%; the cost of all materials was 430.25 BWP/still or 67%. The cost of materials and labour was 481.75 BWP/still or 75% of the total, and cost of transport was 157.66 BWP/still or 25%.

For comparison purposes, the costs of desalination and trucking have been detailed for Khawa, Botswana (Table 3), which is 200 km from the district centre and 100 km from a borehole supplying sweet water. At one trip from the base to the settlement and five trips to the borehole, the trucks would travel 1 400 km/month to supply water to the settlement. The data show that desalination pays for itself in about 2 1/2 years. Cumulative costs for trucking and desalination in the first year are respectively 38 378 BWP and 81 684 BWP; in the second year 74 556 BWP and 86 568 BWP; by the end of 10 years, desalination would have saved 230 000 BWP compared with the cost of trucking. Desalination also supplies more water and on a more regular basis. These calculations do not take into account the rainwater catchment possibilities, which would provide at least another 50 000 L/year. (To

Table 2. Costs (BWP) of installing 32 Mexican stills at Zutshwa, 1985.[a]

Quantity	Material	Unit cost	Total cost
	Stills		
32	Fibreglass basins	205.00	6 560.00
70 m	Glass, 4 mm thick	28.26	1 978.20
8	6-m lengths, 20-mm galvanized pipe	8.55	68.40
37	Silicone sheet	9.55	305.60
6	Rolls weatherstrip (3-m × 0.5 inch)	13.00	78.00
	Total		**8 990.20**
	Foundation		
74 bags	8-kg bags vermiculite	10.00	740.00
2 000	Bricks	0.20	400.00
65 bags	50-kg bags cement	6.50	422.50
75 lengths	Asbestos gutter	8.25	618.75
2 kg	Epoxy resin and hardener	19.00	38.00
	Total		**2 219.25**
	Piping		
22 lengths	20-mm galvanized pipe	8.55	187.00
64	Nipples	0.25	16.00
64 units	20-mm tee joints	1.17	74.88
10 units	20-mm elbow joints	0.83	8.30
8 units	20-mm unions	2.05	16.40
2	2-m (2 000-L) rubber-lined tanks	450.00	900.00
	Total		**1 202.58**
	Fencing (30 m × 30 m)		
	Bolts and fastenings	–	50.00
2	Gates	60.00	120.00
6	Corner poles	28.50	170.00
8	Supporters	10.00	80.00
4 rolls	Mesh wire	47.00	188.00
56	Poles	9.50	532.00
1 roll	Barbed wire	70.00	70.00
2 rolls	8-gauge wire	73.00	146.00
	Total		**1 356.00**
Total materials			**13 768.03**
Total labour			**1 648.00**
	Unskilled (@ 2.00 BWP/day)		508.00
	RIIC staff (@ 10.00 BWP/day)		1 140.00
Total transport			**5 045.00**
	Materials from Kanye (@ 0.75/km)		3 420.00
	Water and bricks from Hukuntsi (@ 0.75/km)		1 625.00
Total installation			**20 461.03**

[a] Fibreglass basins now cost 390 BWP; asbestos gutters have been replaced by polypropylene pipe in more recent installations; the fencing and tanks at the Zutshwa installation were used for a further 32 stills; and transport would cost less since procedures have been streamlined.

Table 3. Cost comparisons for desalination and trucking to supply potable water to Khawa, Botswana.

	Trucking	Desalination
Water supplied (L/year)	242 400	
Summer		210 816
Winter		43 920
Costs (BWP)		
Capital	**4 200**	**76 800**
On-site tanks × 3	4 200	0
Mexican stills × 128	0	76 800
Annual recurrent	**30 998**	**4 884**
Transport 1500 km/month	21 600	0
Tank replacements, liners	3 600	600
200-L drums × 40	2 600	0
Government wages/per diems	4 560	0
Maintenance @ 5%	0	3 940
Contingency @ 10%	2 818	444

Note: Costs were calculated based on a population of 270 given a daily demand of 2.5 L/person (242 400 L annually), a ratio of 2:1 for distillate-to-saltwater mixture, installed cost of 600 BWP/still, distillate production of 3.5 L/day for 9 months and 2.5 L/day for 3 months, a distance of 200 km to base (Tsabong) and 100 km to sweet water (Khuis), and transport costs of 1.20/km for a 7-t truck, 1985.

date, no successful system has been established to save the additional water for winter use.) The calculations also do not take into account inflation, as it is so difficult to predict. Chances are that it would affect the price of trucking as much as or more than that of desalination. Not only inflation but also population changes, and all the calculations were done in 1985.

Given the experience in Botswana, cumulative costs of trucking and of reticulation over different distances have been compared with those for desalination (Table 4). The data show that brick stills, if they can be built reliably, are an attractive alternative financially even where distances for trucking are relatively short.

For a settlement such as Khawa, the investment for standard Mexican stills is repaid in fewer than 3 years. Brick stills, at 100 BWP/m^2, would pay for themselves inside the first year. However, the skills required to build brick stills are not readily available in remote areas of most developing countries, and, in Botswana, the instability of the land and the quality of local sand militate against reliable performance of brick stills. As the number of saline boreholes increases, more attention

Table 4. Cumulative costs (BWP) of different methods of providing water to settlements in remote areas of Botswana, 1985.

	Year						
Method	**1**	**2**	**3**	**4**	**5**	**10**	**20**
Trucking (km/month)[a]							
1500	37 860	75 720	113 580	151 440	189 300	378 600	757 200
1000	27 960	55 920	83 880	111 840	139 800	279 600	559 200
500	18 060	36 120	54 180	72 240	90 300	180 600	361 200
200	12 120	24 240	36 360	48 480	60 600	121 200	242 400
100	10 140	20 280	30 420	40 560	50 700	101 400	202 800
50	9 150	18 300	27 450	36 600	45 750	91 500	183 000
Desalination							
Mexican stills[b]	78 820	80 839	82 859	84 878	86 878	96 996	117 192
Brick stills[c]	30 990	31 980	32 970	33 960	34 950	39 900	49 800
Mexican, extra long[d]	76 162	78 125	80 087	82 050	84 012	93 824	113 448
Reticulation (km)[e]							
5	14 472						
10	46 676						
20	93 353						
30	140 029						
40	186 706						

[a] Trucking kilometrage is calculated at 1.20 BWP/km.
[b] Cost of 128 Mexican stills is assumed to be 600 BWP/still installed.
[c] Cost of 300 m^3 brick stills is assumed to be 100 BWP/m^2.
[d] Cost of 106 extra long Mexican stills is assumed to be 700 BWP/still installed, with an evaporating area equal to 128 regular Mexican stills.
[e] The cost of drilling is not included in these figures.

will need to be paid to installing the brick stills, for the investment will be repaid quickly even in quite accessible settlements. But for remote places that have some possibility of future access to a sweet borehole, the fibreglass stills are economically attractive.

7

Conclusions

In arid countries, where salt water is commonly found when digging wells and drilling boreholes, solar-powered desalination should be an integral part of the overall strategy to supply potable water to remote areas. In the long term, the technology is simple and less expensive than trucking water into settlements. It promotes self-reliance on the part of communities and is a relatively permanent solution to the water shortage. It purifies water sources that otherwise would be undrinkable and, thus, improves the potential return on investments in drilling.

In Botswana, the government is currently engaged in drilling boreholes and transporting water by truck to settlements throughout the countryside. It has not yet incorporated desalination as one of its essential tactics. Given the potential for desalination, however, the government can now drill boreholes in or near settlements, knowing that striking salt water need not be a disappointment.

The experience with solar stills indicates the feasibility of introducing the technology in remote communities, as long as a supply of salt water is accessible and plentiful. The results merit follow-up, and funding agencies may well support desalination projects as part of drought-relief or water-development programs.

In Botswana, RIIC will provide technical support and is looking forward to working with district councils that wish to pursue desalination as a means to improve the reliability of water supplies in remote areas. The district councils take responsibility for dealing with members of settlements to identify sites and install units. They also must raise funds for additional installations, supplement desalination in the winter by trucking water into settlements where necessary, supply tools and spare parts, and regularly inspect equipment and sites.

The central government also has a role in promoting desalination, as it continues its drilling operations; saline sources, when tapped, should be equipped with pumps and handled in much the same way that sweet sources are. Desalination should be budgeted for and encouraged. The government successfully coordinates a major effort for drought relief and is well organized in its approach to agencies for financial support.

Given these strengths, it could easily further the adoption of solar desalination.

RIIC envisages the use of stills to supply water not only to villages but also, in smaller installations, to schools, garages, clinics, etc. The hope is that this booklet will encourage setups and that the information it contains will be useful to developing countries other than Botswana. The staff at RIIC (Private Bag 11, Kanye, Botswana) would appreciate feedback from readers and would be pleased to assist groups embarking on similar work.

Afterword

The original IDRC-supported project on small-scale desalinators carried out by RIIC took place from October 1984 to October 1987. At the end of the project period, the research team handed over to the Kgalagadi District Council responsibility for the operation and maintenance of two pilot small-scale desalination plants, one at Khawa and the other at Zutshwa.

During the winter (May–June) of 1989, the research team carried out a postproject evaluation, also with the support of IDRC. The team assessed the state of the technology following the time during which the District Council Water Unit was responsible for operation and management. The evaluation methodology consisted of interviews with end users in Khawa and Zutshwa and with local and central government and nongovernment officials. Also, the performance and physical status of the desalinators were assessed.

Findings of the postproject evaluation

Technology acceptance

The number of local and central government officials familiar with desalination technology had increased significantly from the end of the original project period. Over 95% of respondents had visited at least one of the settlements and viewed the solar-powered desalination plants at least once between 1987 and 1989.

The policy of the Department of Water Affairs favours drilling for developing water resources for remote communities. Four attempts at drilling are made in each community before opting for an alternative means of providing water. Over the past several years, successful drilling efforts have been few: dry holes and holes with brackish water have been commonplace. As alternatives, government officials favoured desalination techniques (43% of respondents); 30% of those interviewed favoured resettlement of communities and 9% favoured transporting water by truck to remote communities.

Of those favouring desalination, the majority preferred simple solar-powered desalination technologies, such as those assessed during the project. Only a few respondents preferred large-scale, mechanical desalination systems. Those who preferred the more simple technologies highlighted their low operation and maintenance requirements, and the ease of dismantling, transporting, and reassembling the plants.

Critics of simple desalination technologies argue that the yields of distilled water do not meet the water requirements of RAD communities. Government of Botswana policy states that each citizen is entitled to a minimum of 40 L of water per day. As mentioned in Chapter 4 (p. 35), the maximum yield from the Mexican still was more than 8 L/day. Whereas average summer yield was 7–7.5 L/day, in the winter, yield dropped to as little as 2.5 L/day. In contrast, technologies such as reverse osmosis can produce up to 15 m^3 (15 000 L) of distillate per day.

In the postproject evaluation, the research team points out that, although mechanical technologies such as reverse osmosis can produce higher yields of distillate, they require a highly trained technician and spare parts must be imported and purchased with foreign exchange. The simple solar-powered stills installed under the RIIC project can be assembled in remote areas using local labour and, using to a large extent, locally available materials. They have also been shown to be a locally manageable technology.

Water availability

The research team visited eight RAD settlements in the Kgalagadi District during the postproject evaluation. Water availability was assessed under three situations: settlements where boreholes that yield potable water have been successfully drilled; settlements where solar-powered desalinators are in use and the water supply is supplemented by water transported by truck; and settlements where water trucking is the principle means of supplying potable water.

The results of this asscssment indicated the following:

- Where borehole drilling has been successful, there was a marked increase in the number of community-development activities by local government (e.g., construction of schools, health posts) and private entrepreneurs (small shops).

- In communities using desalinators, settlement infrastructure has also improved, albeit at a slower rate than in settlements with functional boreholes. Although the distillate yield is insufficient to meet all the water requirements of the settlement, the desalination plants are viewed as elements that enhance the development of a social infrastructure. Water trucking to these settlements is highly irregular because of the unavailability of transport, the time required, and the lack of available labour.

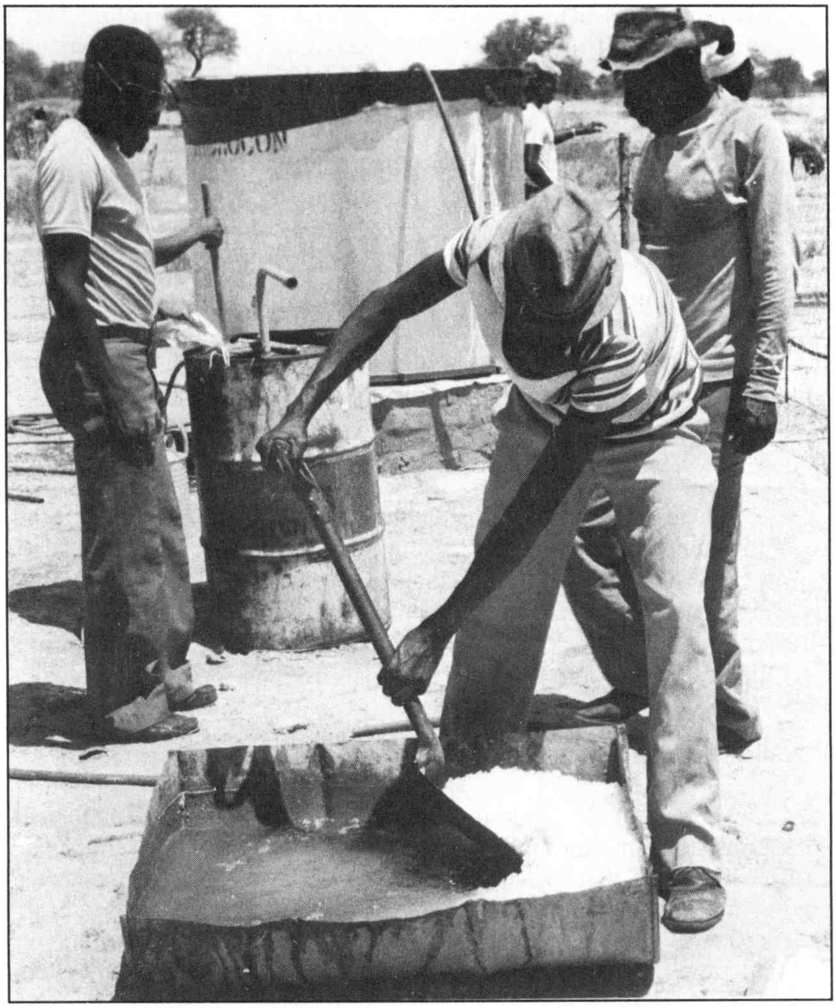
- The most underdeveloped of the RAD settlements were those that relied exclusively on water transported by truck. These settlements have the most rudimentary social infrastructure. On average, water is delivered once per month. The research team described the standard of living of RADs living in these settlements as one of abject poverty and perpetual suffering.

The research team concluded that, although government officials tend to give a low technical rating to the simple, solar-powered desalination technology, RADs assign a high social value to the technology. Respondents from the RAD settlements with desalinator plants indicated that, without the stills, people would have migrated to other settlements with reliable water sources.

Technology management and community involvement

The management of the stills by community members was found to be not as consistent or thorough as planned or required. The postproject appraisal indicated that desalination plants are not cleaned regularly, many of the basins have a salt residue (significantly reducing operating efficiency), the rainwater gutters are not cleared of sand, distillate-collection pipes are not connected, and hatch covers are not attached properly (if at all).

Individuals that had been identified during the project as responsible for operation and maintenance carried out their tasks sporadically and inconsistently. In the original project, community members were responsible for maintaining the pilot desalination plants. At the end of the formal project period, this responsibility passed from the RAD settlements to the Kgalagadi District Council. The research team proposed two factors as affecting the correct operation and maintenance of the stills: lack of supervision and lack of accountability. As stated previously, many government officials were not convinced of the benefit of the small-scale desalinators.



At Zutshwa, salt, after being collected from the stills, is washed before being loaded on trays to dry.

Based on the results of the postproject evaluation, the research team believes that the propensity to operate and maintain the stills correctly may be related to cultural and socioeconomic factors. This hypothesis is based on the fact that the stills in Zutshwa were functioning more effectively, and had been maintained better, than those in Khawa. Socially, Zutshwa is more socially and ethnically cohesive than Khawa; Zutshwa is also more established and permanent. In Zutshwa, those assisting in the maintenance of the stills receive a quantity of salt produced by the still. This salt is used in cooking and in tanning hides, or is sold on the open market. Also, drinking water rations were substantially higher for those involved in maintenance than for those who were not.

The research team concluded that the success of solar-powered, small-scale desalinators depends largely on the degree of community involvement and sense of ownership. Unless the community perceives the technology as an important element in survival, their willingness to maintain the stills will remain low.

Conclusions

Following the postproject evaluation, the research team concluded that no clear consensus exists in Botswana on the future of small-scale, solar-powered desalination technology. As the distillate yield does not meet the water demands within RAD settlements, many perceive the technology as a failure, and argue that more research should be directed toward more sophisticated, higher yielding technologies, such as reverse osmosis.

Supporters of small-scale desalination highlight its impact on the development of the social service infrastructure within RAD settlements, its ease of maintenance and operation, and its use of available water resources. They hold that its shortcomings can be alleviated through improvements in design and by modifying to the management structure and process, particularly with greater involvement and support of local government officials.

The decision to introduce and experiment with small-scale desalination plants was taken as a means of supporting the survival of RADs and their settlements. The transportation of water to these settlements by truck is costly and irregular. Conditions in the Kalahari Desert are harsh. The experimental units were not designed to meet entirely the potable water requirements of the RAD settlements. Rather, they were designed and installed on an experimental basis to test their performance and social acceptability. The failure of the stills to meet local water requirements was exacerbated further by the migration to the RAD settlements that occurred after the stills were installed.

The researchers propose further study of desalination technologies and their impact on RAD settlements. More research is required on design options, with particular reference to size and materials. Different operation and management schemes should also be studied. It must also be determined whether small-scale desalination, in its current state, is appropriate for RAD settlements, which are characterized by significant immigration. The costs involved to increase the number of stills or expand their volume to meet the increased demand for water, and the related maintenance requirements, may prove to be greater than the cost of alternate means of providing water to such communities.

Perhaps the following citation (Woto 1989) from the postproject evaluation report best summarizes the potential of small-scale desalination as a means of improving and increasing water supply to remote settlements in arid areas:

> Desalination should not be seen as an end in itself, but as a means to the end. It should be viewed as a way of creating a base for other development initiatives in a settlement. Moreover, it should be seen as complimentary to other water-related technologies. Future initiatives relating to desalination should be geared to the long term, and not perceived as a short term solution.
>
> While small-scale desalination has a limited role to play in the future, consideration should be directed towards using this technology to alleviate the suffering prevalent in RAD settlements, particularly in those where drilling bore-holes has not, and will not in the short to medium term, take place.

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In Memoriam

Amy Chouinard, who had devoted much time and effort to this book as a freelance editor, passed away suddenly early in 1990. Her contributions and comments were highly appreciated, and her presence in the publishing world will be sorely missed.

J.B.C.

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From 1984 to 1988, Roger Yates managed the Solar Research Section of the Rural Industries Innovation Centre in Kanye, Botswana. During this time he supervised the development, testing, and introduction of solar stills to remote settlements in the Kalahari Desert. Following this work, he helped the Department of Fisheries in the Sudan develop trial solar stills for use in remote fishing camps. Mr Yates has lectured in the Netherlands, Canada, Botswana, England, and Germany, and has done several interviews with the BBC World Service. He has recently completed his Master's research on "Water and Waste Engineering for Developing Countries" at Loughborough University in England.

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