Studies on the Efficiency of a Solar Distillation Still for supplementing Drinking Water Supplies in South West Africa

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Abstract

This investigation deals with the use of solar distillation for the desalination of brackish water or seawater in South West Africa (SWA). A suitable solar 'still' could supply the basic drinking water requirements of families living on remote farms. From various established designs, the double inclined roof still was chosen for evaluation under local climatic conditions. Special attention was given to simplicity of construction, minimum capital outlay, long life and ease of operation. Investigations were carried out on the glass thickness used in the roof structure, construction features and performance of the still under various climatic and environmental conditions. Annual distillate production of the experimental stills varied from 6–27 ℓ/d at an estimated total cost of R1,40/m^3.

Introduction

South West Africa has little surface water and domestic, agricultural and livestock requirements generally depend on subsurface supplies. The quality of these waters often does not conform to drinking water standards (WHO, 1970) owing to the high concentration of dissolved mineral salts. This may include relatively high concentrations of toxic substances such as nitrates and fluorides (Department of Water Affairs, SWA, 1974). Before selecting a particular type for further study and development many experimental solar distillation units were built in various designs and sizes. These included inclined tray stills, semi-inclined roof stills and double inclined roof stills with numerous modifications to each type. Evaporation surface areas varied between 1,25 and 9,30 m^2. Some of the experimental units suffered from structural defects while others were too costly to consider for further study. The decision on the most suitable design for local use was based on efficiency, not necessarily the highest distillate production. After considering construction cost, availability of raw materials, ease of construction, life span, maintenance and operation by unskilled labour, a double inclined roof still was selected for further study.

Performance of a Double Inclined Roof Solar Distillation Unit

The experimental still consisted of a shallow basin covered by a double inclined glass roof (Figure 1). Mineralized water in the basin is heated by solar radiation penetrating the glass cover and vapour condenses against the overlying glass surfaces from

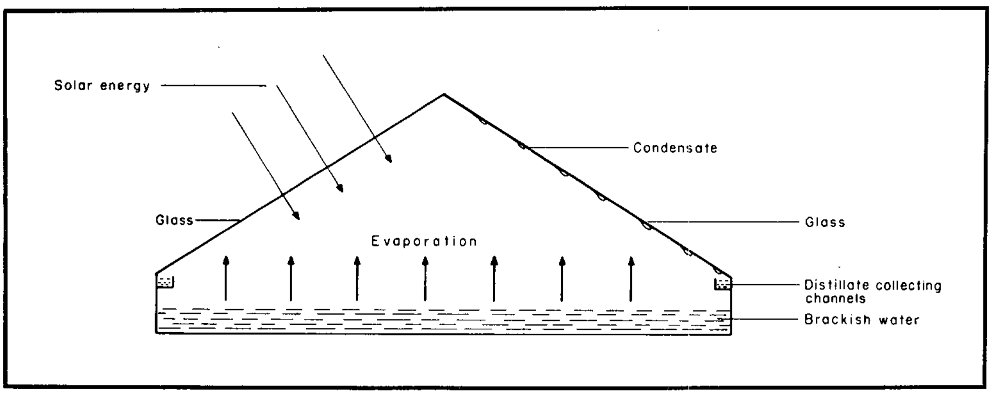

Figure 1
A double-inclined roof still

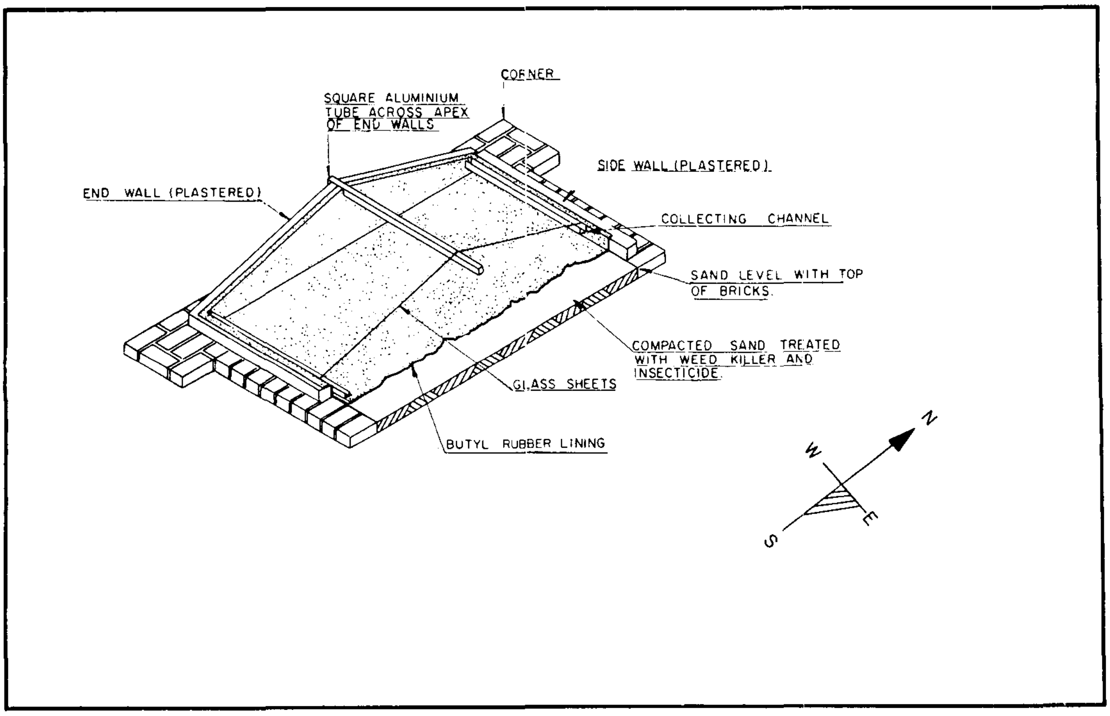

Figure 2
Isometric view of distillation unit in section

which it runs into collecting channels. Factors affecting the efficiency of this unit include sun intensity, orientation of the unit, wind, ambient temperature, transparent cover material, glass thickness, mineralized water temperature, temperature difference between mineralized water and condensation surface, salt concentration of mineralized water, insulation of the unit, depth of the mineralized water in the evaporation basin, internal lining of the evaporation basin and the sealing efficiency of the unit.

Structural Details of Experimental Model

The unit was erected with its longitudinal axis in an east-west direction (Figure 2). The tilted roof walls on the east and west sides of the unit and both side walls on the north and south sides respectively were constructed from masonry and mortar. The floor of the evaporation basin was filled with sand, treated with weedkiller and insecticide and then compacted. All plumbing consisted of plastic PVC piping. The inside of the

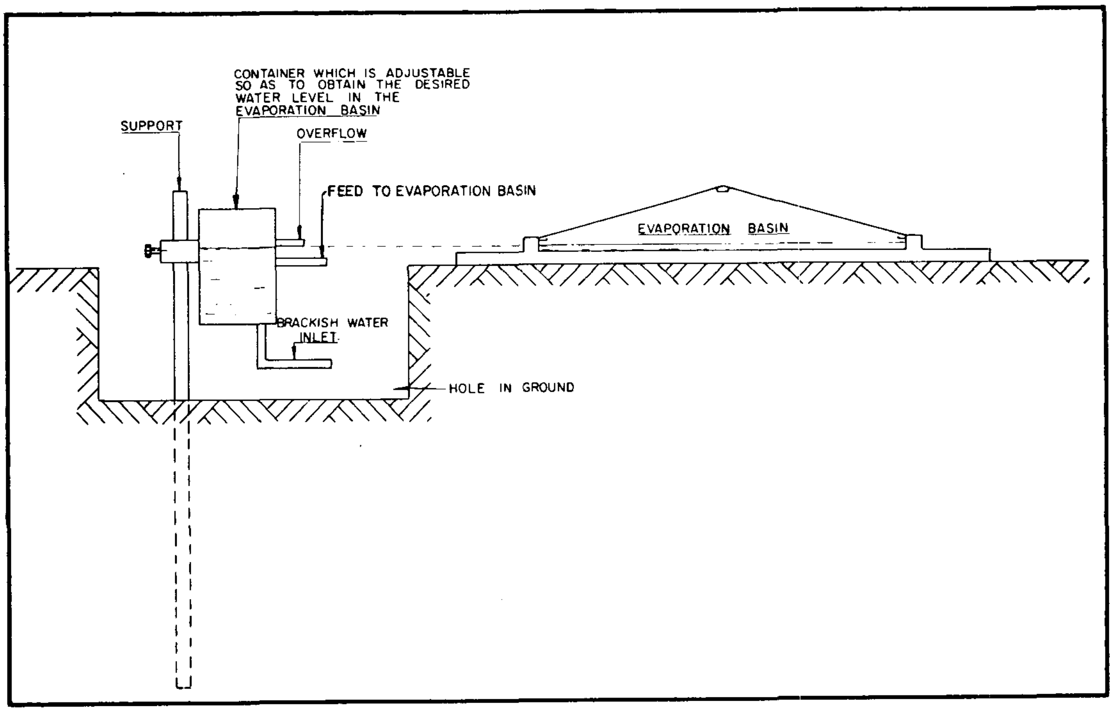

Figure 3
Controlled water feed system

unit was lined with 1,02 mm thick butyl rubber sheeting held in position with the aid of an adhesive solution. Dimensions of the evaporation basin were 2,44 m × 2,03 m (4,95 m^2). Distillate collecting channels were made of aluminium as was the square tubing across the apex of the end walls. The unit was covered by six sheets of 2,94 mm thick glass which were installed at 15° from the horizontal (Yellot, 1963) and coincided with the slope of the two end walls. All seams between glass and glass and rubber and glass were sealed with silicon adhesive.

Raw Water Supply System

Raw water was supplied to the still either by batch feeding or by using a system, shown in Figure 3, which continuously replenished the amount of water lost by evaporation. The latter system involved the provision of a supply tank, whilst a certain amount of raw water went to waste. This system had on the other hand the advantage of needing the minimum of attention. The depth of the water in the evaporation basin was kept at approximately 25 mm. Previous experiments indicated that depths greater than 25 mm reduced distillate production. Depths less than 25 mm were not practical due to the formation of dry spots on the basin floor.

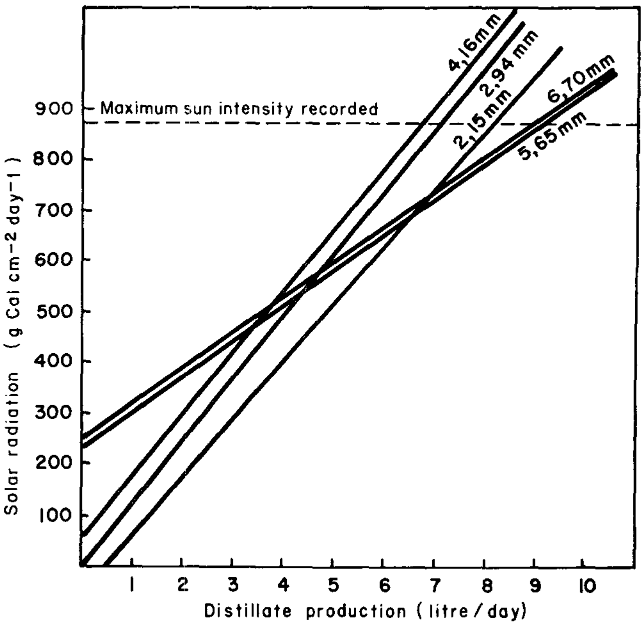

Figure 5
Variation of distillate production with solar radiation and glass thickness in the double inclined roof still

The influence of glass thickness

Varying the thickness of the glass which covered the distillation unit had a significant effect on the performance of the still (Figure 4). Maximum distillate production was obtained with

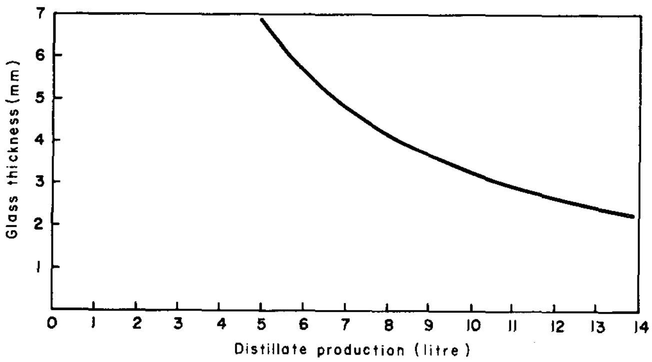

Figure 4
The effect of glass thickness on distillate production of the double inclined roof still

glass 2,15 mm thick but, due to its weakness, 2,94 mm glass was used on all the experimental stills.

Distillation commenced at a sun intensity of less than 100 g cal cm^{-2} d^{-1} with 2,15 mm, 2,94 mm and 4,16 mm glass while distillation only commenced above 200 g cal cm^{-2} d^{-1} with 5,65 and 6,70 mm glass (Figure 5).

Evaluation of Five Experimental Units

Results from five similar experimental units at different locations in SWA are summarized in Figure 6 and discussed below:

Windhoek. The still was built in the grounds of the Department of Water Affairs to facilitate surveillance. With the exception of a few cold and overcast winter days, the minimum distillate production was about 6 ℓ/d. A maximum of 27 ℓ/d was recorded in the summer. The water treated was local tap water with a total salt content of 600 mg/ℓ.

Aroab. The still was built on the flat and barren countryside just outside the town which lies in an arid region about 160 km east of Keetmanshoop. Although this area is known for extreme temperature variations and heavy winds during the winter, minimum production figures were similar to those in Windhoek. During November 27 ℓ/d was produced on various occasions and it seems likely that this figure may be exceeded during the hotter months of December and January when no tests were done. Borehole water with a total salt content of about 3 000 mg/ℓ was treated.

Ondangua. This area had the warmest climate of the five experimental sites. The still was located in flat surroundings where reflection of heat from the soil (fine white silt) was high. During the summer months distillate production was appreciably more than 27 ℓ/d and during winter, production was rarely less than 12 ℓ/d. Raw water used in these experiments was Ondangua drinking water with a total salt content of about 700 mg/ℓ. Distillate values for the months April, May and December were not reported due to inadequate supervision of the unit during this period.

Möwe Bay. The still was located on a sandy and rocky slope about 500 m from the sea. The area is windy throughout the year, with winds ranging from breezes to gale force. Mornings, up to 10h00, and afternoons from 16h00, are usually characterized by fog. During the winter months days may go by without any sunshine. Distillate production from sea-water, with a total salt content of about 35 g/ℓ varied from 4 ℓ/d to 18 ℓ/d during the year of testing. Values for April and May are not reported for similar reasons as those given for Ondangua.

Rössing. The experimental site was on top of a small outcrop in a mountainous area, 80 km east of Swakopmund. The days are

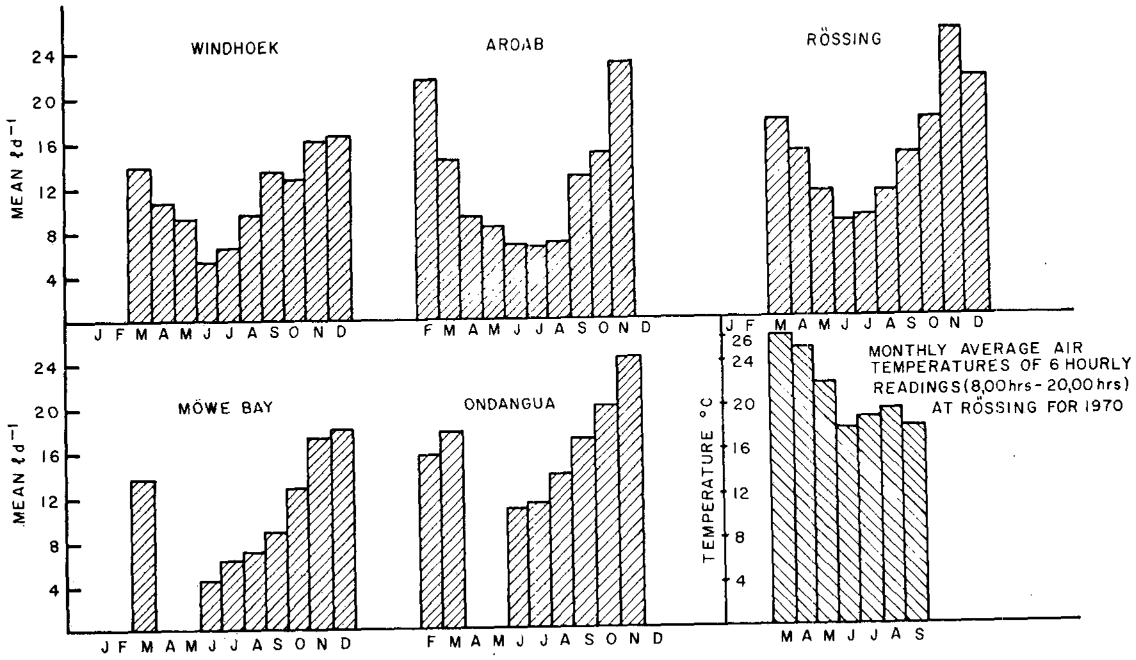

Figure 6
Distillate production of the double inclined roof still operated in different localities in SWA (1970)

usually warm and bright with a cool wind blowing in the afternoon. During the experimental period, average monthly air temperatures never dropped below 17°C. Distillate production from water extracted from a pit, dug in a dry river bed (Kahn River), with a total salt content of about 6 g/ℓ, varied from 7 ℓ/d to 27 ℓ/d during the year of testing.

Discussion and Conclusions

The double inclined roof still proved to be a most suitable type of solar still for application in SWA. It may for instance be used to supply the essential drinking water requirements for families living on remote farms. Certain other still designs (not discussed here) had higher distillation efficiencies but this advantage was outweighed by the simplicity of construction, low cost, long life and convenient operational features of the experimental double-inclined roof still. The cost of material for the still was about R48 (1970 prices) and the total construction cost about R79. If the total cost is written off over the expected lifetime of 15 years at an interest rate of 7 per cent, and estimated production rate of 3,4 ℓ/m^{-2} d^{-1} would cost R1,4 m^{-3}.

Findings obtained at different localities indicated that wind speed coupled with ambient temperatures did affect the performance of the still. This is illustrated by the observation that distillate production was higher at Rössing, which has a higher wind speed but lower ambient temperature than Windhoek. Similarly, distillate production was about equal at Windhoek and Möwe Bay, while sun duration and intensity were considerably lower but wind speed much higher at Möwe Bay than at Windhoek. The dominant parameter in solar distillation is the intensity of the sun. Distillate production for a known sun intensity by the inclined roof still can be evaluated from Figure 7. This still was designed to operate in the northern latitudes of SWA. Optimum efficiency at more southernly latitudes may require an increase in the angle of the glass roof. A construction and operation guide for the double inclined roof still has been published previously (Department of Water Affairs, 1973).

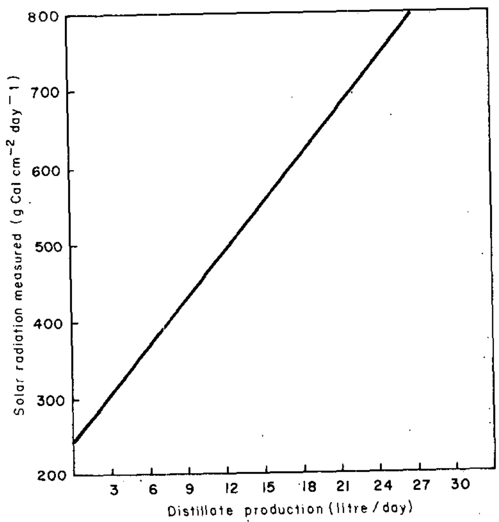

Figure 7
Estimated distillate production of the double inclined roof still at a range of solar radiation intensities.

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