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Practical Paper

Feasibility of fog water collection: a case study from Oman

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ABSTRACT

The aim of this study was to assess different fog collectors in certain jabal (i.e. mountainous) areas in the Dhofar Region of the Sultanate of Oman which experience fog resulting from the Indian monsoons. A further aim was to provide fog collectors in the close vicinity of houses in the mountains to directly meet the needs of the local residents. Experiments were conducted using three fog collectors with different mesh materials namely; air conditioner filter (AC; 6 m × 2.8 m), green shade mesh (12 m × 3 m), and aluminum shade mesh (12 m × 3 m). The collectors were constructed close to the point of use. This reduced the costs as the installation of pipelines would not be needed to deliver the water. The results showed that all fog collectors proved to be very effective in fog water collection. Among all of them, the AC filter proved to be the most effective. The total fog water collected during the period of 77 days by AC filter, green shade mesh, and aluminum shade mesh was 995, 880, and 753 L/m^2, respectively. This paper concludes with a set of recommendations for further in depth assessment of the qualitative and quantitative aspects of this water collection technology.

Key words | Al-Khareef, domestic water supply, fog water collection harvesting, Oman

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INTRODUCTION

Fog water collected for potable water production has been reported for numerous countries (Table 1, Schemenauer & Cereda 1991). For example, each summer between June and September, the Dhofar region in the south of Oman in the Arabian Gulf, experiences an annual phenomena called Al-Khareef. This phenomena is characterized by thick fog and light rain caused by moist air brought in by the Indian Ocean monsoons. The Dhofar region is divided naturally into a coastal plain, mountains, and a desert region. The area is a major tourist attraction during the summer monsoon season. The administrative capital, Salalah, lies on the coastal plain. Behind this lies the mountain range called the Jabal, which reaches heights of 1000 meters, followed by a desert area, the Nejid, which connects to the Rub Al Khali desert.

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The actual water supplies in Dhofar come from groundwater distribution systems. However, the houses in the mountains are not connected to this distribution network. Therefore, water is transported in trucks from the valley to the houses in the mountains and this has additional risks during the monsoon due to the low visibility and the slippery road surfaces. Furthermore, as more groundwater is extracted on the mountains, less is available to the people living on the coastal plain around Salalah. This contributes to the underground intrusion of salt water on the plain (Alesh 1998). On the other hand, during the monsoon season, a thick deck of fog covers the mountains of Dhofar. This fog has the potential to provide an alternative source of water. It can be collected during the monsoon season (from mid-June to

Table 1 | Countries with arid regions where fog collection was documented either by artificial collectors or vegetation (Schemenauer & Cereceda 1991)

Country	Region	Latitude Range	Altitude Range (m)	
South America	Chile	Northern Coast	23°S–30°S	500–800
	Peru	Central and Southern Coast	11°S–16°S	350–700
North America	Honduras	Tegucigalpa	14°N	2000
	Mexico	Sierra Madre Or.	19°N	15–2400
	USA	California	34°N–40°N	50–1200
	USA	Hawaii	21°N	225–3400
Europe	Gibraltar	Gibraltar	36°N	300
	Yugoslavia	Mount Velebit	44°N	1600
Africa	Angola	North Interior	6°S	50–900
	Angola	South Coast	13°S	1600–2000
	Ascension Is.	Green Mountain	8°S	850
	Cape Verde Is.	Isla Brava	15°N	980
	Kenya	Marsabit	2°N–4°N	200–1700
	Namibia	Gobabeb	23°S	10–400
	South Africa	Table Mountain	34°S	750–1050
	Spain	Canary Islands	28°N	600–2350
	Sudan	Erkwit	19_oS	1150
Middle East	Israel	Menara	31°N–33°N	600–900
	Jordan	Kefar Etsyon	32°N	600
	Oman	Dhofar Jebel	17°N	100–1000
	Saudi Arabia	Hejaz Mountains	20°N	1200
	Yemen	Al-Mahwit Province	15°N	1500
Asia	India	Cheerapunji	25°N	1300
Australia	Australia	Mount Wellington	43°S	1270

mid-September) and can provide substantial volumes of water for domestic use and small-scale farming in the mountains.

Barros & Whitcombe (1989) conducted research into the technology of fog collection in the Jabal Dhofar. The results in the coastal mountain region indicated the feasibility and applicability of this technology for collecting water. However, in these experiments, the fog collectors were not assembled close to the mountain's residents. Hence, the installation of a pipeline was needed to deliver water to the point of use in the mountains. Therefore, the pipe costs from collectors to the point of use were one of the major infrastructure costs which made the system uneconomic and hydraulically difficult.

The aim of this work is to develop residential type fog collectors to directly meet the needs of the mountain residences during the monsoon season. The collectors will be close to the point of use. This will reduce the cost, as the installation of the pipelines will not be needed to deliver the water. The collected water then can be used directly from the storage tanks, which are installed in the houses, to irrigate plants or to supply people and animals.

METHODOLOGY

Site selection

A suitable house at Ashta in the mountains of the Dhofar Region was selected by taking into account four main factors, namely, (a) the potential for collecting large volumes of water, (b) the proximity of a water-poor community, (c) accessibility and (d) security. Construction of the fog collectors at the house commenced in June 2005 and the field measurements started on 2nd July 2005 and continued well into mid September 2005 when the fog, though less frequent, was still present. The local residents were involved in assisting with the erection of the fog water collection systems and they were responsible for taking the daily water collection readings.

Fog collection

Three large fog collectors were erected and operated simultaneously, at the selected house in Ashta, to capture the fog (Abdul-Wahab *et al.* 2006). Each collector consisted of a flat, rectangular screen supported by a rectangular steel frame and arranged perpendicular to the direction of the fog-bearing wind. The frame was supported with its base 4.5 m above the ground. Standardizing the height of the frame above the ground was important because fog collection would vary with the height above the ground (Schemenauer & Cereceda 1994). The design of these collectors was the same but they had meshes of different local materials, including AC Filter, Green Shade Mesh, and Aluminum Shade Mesh. The AC filter (Figure 1) was 6 m × 2.8 m and so it gave a collecting surface area of 16.8 m^2. The Green Shade Mesh was 3 m × 12 m (i.e. collecting surface area of 36 m^2) and was used in a double-layer. The Aluminum Shade Mesh was 3 m × 12 m (i.e. collecting surface area of 36 m^2) and was used in a triple-layer.

Each fog collector consisted of 3 m × 1.5 m sheet nets connected together with steel cables which anchored the system to the ground. Double sets of horizontal steel cables anchored the poles to each other and supported the screen. The shading nets were secured at the lower end by bolting them to sections of perforated steel plates. A gutter was attached to the lower end of the net along the bottom supporting cable. During the foggy conditions or rain episodes, small fog droplets were deposited on the screen and coalesced to form larger drops which flowed downwards under the force of gravity into the gutter fixed below the screen. The water was then channeled to a storage tank located in the house. The outlet of the storage tank was connected to a water flow meter to measure the water collection in liters per day. Moreover, a rain gage was installed in situ to measure the amount of precipitation collected on the site.

Figure 1 | Picture showing the actual AC fog collector in foggy conditions.

RESULTS AND DISCUSSION

Analysis of fog and rainwater collection data

The total water collected indicates both fog and rainwater collected daily (i.e. both rain and fog water are collected by the fog collectors). In order to make a distinction between rain and fog water in this work, the net fog collected was calculated by taking the difference between the total water collected and rainwater. The results indicated that the daily total water production by AC filter, green shade mesh, and aluminum shade mesh was almost the same during the days of July with slightly higher amounts of water produced with aluminum shade mesh, especially during the beginning of the fog collection experiments. The mean total water collected daily by AC filter, green shade mesh, and aluminum shade during July was 19.78, 19.70, and 20.69 L/m^2/d, respectively. The monthly total water produced by AC filter was 593.4 L/m^2, and that of the green shade mesh was 591.1 L/m^2, and that of the aluminum shade mesh was 620.8 L/m^2.

The daily amount of fog and rainwater collected during August was less than in July. In general, the amount of total water collected by the AC filter was the highest followed by the green shade mesh, and the aluminum shade mesh. The daily average fog and rainwater collected by AC filter, green shade mesh, and aluminum shade was 15.40, 11.90, and 7.07 L/m^2/d, respectively. The monthly total fog and rainwater collected by these three collectors during August was 477.3, 368.8, and 219.3 L/m^2, respectively. Hence, the three studied collectors showed considerable differences with respect to total liquid water collected. Moreover, larger discrepancies were found in the amount of fog and rainwater data in August than in July.

During the fifteen days of September 2005, the fog and rainwater collection was generally very low except on the fourth day in which the highest daily fluxes were observed. Again, the results of total water collection indicated that the aluminum screen collected least water of the three. During this 15 day period the average daily water collected by AC filter, green shade mesh, and aluminum shade was 1.80, 1.53, and 1.06 L/m^2/d, respectively. For the AC filter, the total water yield was 26.9 L/m^2 while the green shade and aluminum meshes yielded 22.9 L/m^2 and 15.9 L/m^2, respectively.

Analysis of fog water data

In order to determine the contribution of fog relative to the total water yield, hourly and daily rainfall data were recorded using a rain gauge placed at the project site and the weather station located at Qayroon Herity near the area of the study. It was assumed that whenever rain was recorded by the rain gauge, all the water deposited on the fog collectors originated exclusively from rainfall. On the other hand, if no rain was recorded, all the water collected was assumed to originate from fog alone. Although this technique underestimates the contribution by fog, it does give some indication of the relative contributions of fog and rainfall to the total volume of water collected. Therefore, rainwater collection was subtracted from the total fog and rainwater collection to yield the fog water collection by knowing the rain collected per unit area, and percentage of rain. Taking into account the monthly quantities of fog water collected at the site, July was the best month of the monsoon to obtain a good amount of water. On certain days of July (12 July 2005), the fog collection flux was as high as 46 L/m^2/d. On the other hand, September was found to be the least efficient month to obtain water from the fog, with only 13.3% of the days potentially suitable for fog water collection

The daily variations of fog water collected by different fog collectors during July, August, and September 2005 are illustrated in Figures 2a, 2b, and 2c, respectively. It can be seen that the daily amount of fog water produced by the AC filter, green shade mesh, and aluminum shade mesh was almost the same during July with slightly higher amounts of water being collected by aluminum shade mesh. The daily amount of fog collected in August was lower than that collected in July (Figure 2b). It is also interesting to note that the amount of fog water collected by each collector differed considerably. In general, the amount of fog collected daily by the AC filter was the highest followed by the green shade mesh, and the aluminum shade mesh. During the fifteen days of September 2005, the fog collection was very low except on day 4 when the rate of the amount of fog collected by AC filter, green shade mesh, and aluminum shade mesh was 9.71, 7.58, and 4.10 L/m^2/d (Figure 2c) respectively. Generally, in September the fog was not so frequent. This fact explained the lower amounts of fog water collected.

The total fog and rainwater collected during the whole experimental period of 77 days by AC filter, green shade mesh,

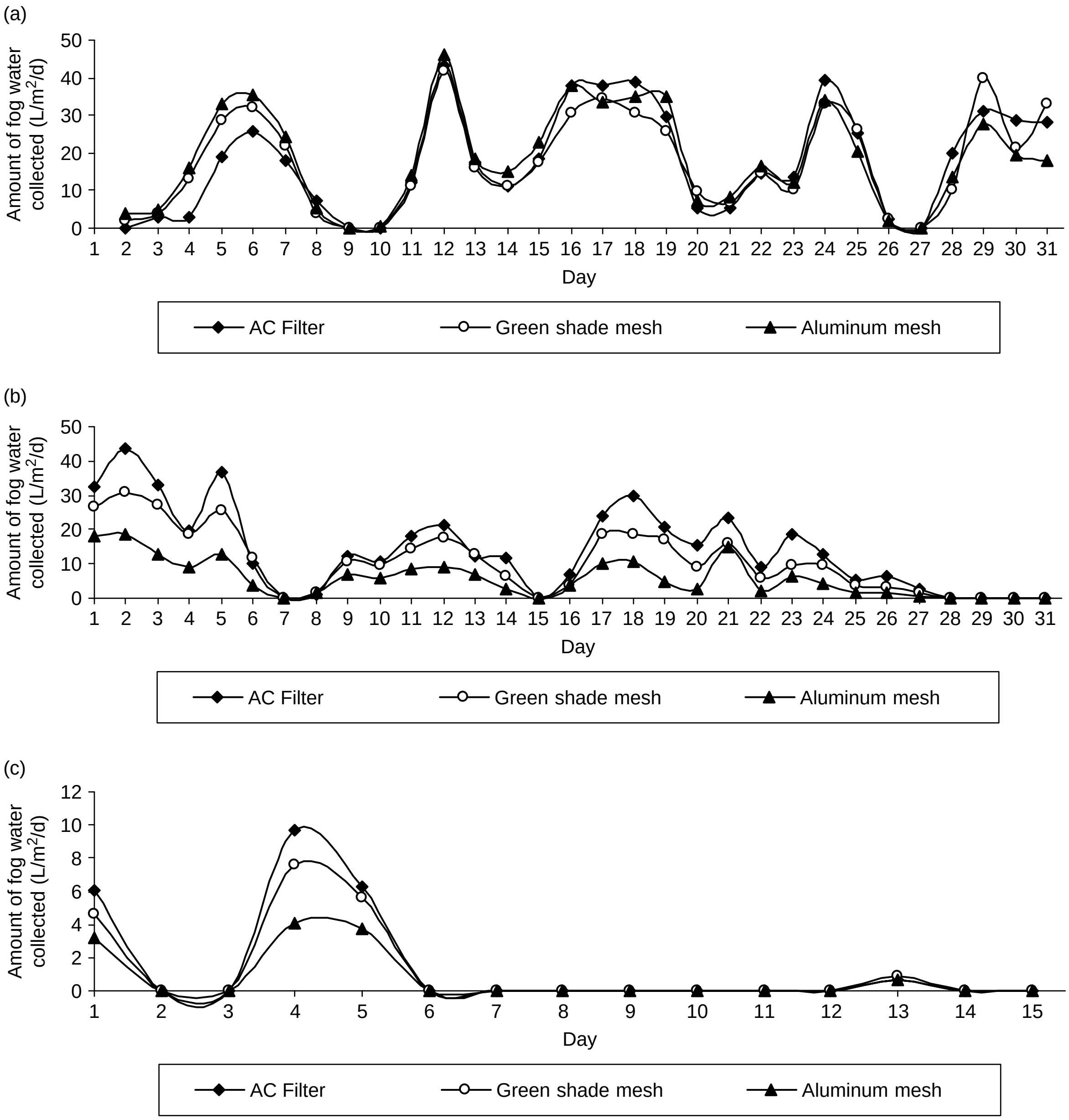

Figure 2 | a) Amount of fog water collected daily by the three fog collectors during July 2005. b) Amount of fog water collected daily by the three fog collectors during August 2005. c) Amount of fog water collected daily by the three fog collectors during September 2005.

and aluminum shade mesh was 1097, 983, and 856 L/m^2, respectively, while the total net fog water collected from these collectors was 988, 874, and 747 L/m^2. Therefore, the three fog collectors used in this study proved to be very effective in fog water collection

The fog water in the Dhofar Mountains is only available for about two months of the year. This puts limits on the use of the water. Despite the fact that the water is suitable for use as drinking water (Schemenauer & Cereceda 1992; Abdul-Wahab *et al.* 2006), the use of the water for human consumption is limited due to the requirement for long periods of storage between fog seasons. The most effective use may be for the irrigation of tree seedlings employed for reforestation. Once these trees are a meter or so tall they can be self sufficient, provided drought tolerant native species are selected (Schemenauer & Cereceda 1992). MWR (1996) reported that the high water production rate from the Khareef fog is an indicator of a high rate of fog moisture interception by natural vegetation, often observed as dripping runoff under trees and grass. This explains the high amount of water collected under the shiboo trees during 1989 and 1990 (COWIconsult 1992). Furthermore, this water would benefit grazing cattle by supplying pools of drinking water, as occurred in this case study. Future work is needed to better understand the effects of other fog collecting materials on the quantity of fog water produced (e.g. linear strands of nylon to better replicate nature and spiders' webs).

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