Fogwater collection at El Tofo, Chile and other coastal sites in South America and Arabia(*)

Pilar Cereceda *, Robert S.Schemenauer**
* Pontificia Universidad Católica de Chile** Environment Canada, Toronto, Canada (Retired),
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Abstract: Chile pioneered the use of fog as a water resource for human consumption. For more than 6 years, since 1992, Chungungo, a small town of 300 people, obtained its domestic water supply from 75 fog collectors that yielded an average of more than 10,000 liters of water of good quality a day. Based on that work, several studies were done in other places, some with more promising results than others. The water collected from fog is being utilized for a variety of different purposes at these locations. In this paper, the methodology used at five coastal experimental sites located in Chile, Peru and the Sultanate of Oman will be discussed. The El Tofo-Chungungo site has been extensively studied for almost a decade. It is important as a research site and a place where data has been collected on a routine basis. The results are compared to those from other locations and the geographical similarities and differences discussed.

1. INTRODUCTION:

The sites discussed below have in common the fact that the predominant type of fog is advective, originating as clouds over the ocean. The formation of the cloud is related to high pressure cells in the atmosphere and cold ocean currents. This high elevation fog is present in mountain ranges located near or on the coastline. The altitude at which the fog is present is variable. The following coastal sites were studied between 1987 and 1997. The dates in brackets are the data collection years for Table 1.

Table 1: Coastal sites

-El Tofo-Chungungo	(29°27'S;71°18'W),Chile. ,(1988-1995)
-Iquique	(20°46'S-70°45'W), Chile , (1997)
-Mejía	(17°00'S-71°59'W), Arequipa, Perú , (1997)
-Cerro Orara-Ancón	(11°49'S-79°09'W) Lima, Perú (1990)
-Dhofar	(17°00'N-54°04E) Sultanate of Oman , (1989-1990).

1.1 Methodology and instruments

A study of the geographical factors based on the altitude of the stratocumulus and wind behaviour was done for each place. The study was based on meteorological data and parameters like relief, distance to the sea, and space for collectors. This research is done primarily with a map scale 1:50.000, aerial pictures, and field work (Schemenauer and Cereceda, 1994; Cereceda and Schemenauer, 1996). It is critical to consider the use of water.

The second part of the methodology consists of measurements on the temporal and spatial variations of fog and potential of fog water collection. A standard fog collector (SFC) of 1 m^2 covered by a polypropylene mesh of 35% shade coefficient was used to collect the data (Schemenauer and Cereceda, 1994). The periods of measurement at the different experimental sites, ranged from 8 years at El Tofo-Chungungo, to 6 months at Cerro Orara-Lima, Peru, and four months in Oman. The number of SFCs also varied from site to site, depending on the complexity of the terrain and the water needs.

As a general guideline, each location had a main site, and several sub-sites near it, with different altitudes, slope, orientation and microtopography. The main site had different experiments to study the relationship between fog water collection and height, type of mesh, type of collectors, and meteorological parameters such as wind speed and wind direction (Cereceda, et al., 1993). In some cases, water collection by individual trees was also measured (Table 2).

Table # 2: Instruments and experimental sites

Study area	Main site Type of instruments	Sub-sites
El Tofo	SFCs, Meteorological st., SFCs different height (75) 48 m^2 collectors	4 to 8
Iquique	SFCs and some Meteorological data	2 to 3
Mejia	SFCs, Meteorological st (20) 48m^2 collectors	8 to 10
C° Orara	SFCs, Meteorological st. 1 SFCs different meshes	
Dhofar	SFCs, Meteorological st SFCs different height SFCs different materials	5 to 8

2. Results

The discussion is based on the results obtained at El Tofo and are compared to the other locations. El Tofo is the place that has the longest data set and provides information on the changes that can occur from year to year.

2.1 Annual average

The mean annual average of fog water collection measured from 1988 to 1995 at El Tofo was 3.3 L m^{-2} d^{-1}. The highest average was 3.5 L m^{-2} d^{-1} in 1992, and the lowest, in 1994 with 2.7 L m^{-2} d^{-1}. As it can be seen, the differences between years are not high (Table 3).

Table # 3: Fog water collection

Site	Average L m^{-2} d^{-1}	Fog Season Length month	Annual Production L m^{-2} y^{-1}
El Tofo	3.3	12	1200
Iquique, Chile	7.3	5	2475 *
Mejia, Peru (850m)	11.7	12	4270
Mejia, Peru (725m)	4.8	12	1750
Co. Orara, Peru	8.5	7	1785
Dhofar, Oman	30.0	2.5	2250

* Based on data Aug.-Dec. 1997 but fog season likely extends throughout the year.

The annual production at the sites ranges from 1000 to 4000 L m^{-2}. It is interesting to note that the longest running operational project is at the El Tofo site, which has the lowest production rate. This shows the excellent potential of the other sites, if the production rates are sustained from year to year.

This information is very important because when an operational project is designed , this is the amount of water per square meter that will be available in a year by square meter. The water required will give the amount of collectors or total mesh surface needed. The number of months is an indicator of the need of reservoirs.

2.2 Monthly average

The month that recorded the best collection of fog water at El Tofo in the period 1988-1995, was September 1991 with 10.9 L m^{-2} d^{-1}. The lowest rate was in July 1989, with 0.2 L m^{-2} d^{-1}. In this period, only 5 months had less than 1 L m^{-2} d^{-1}. In designing an operational project, this information will be useful in specifying the capacity of the reservoirs, as it is essential to store all the water collected in the "good seasons" (Table 4).

Table # 4: Fog water collection: best monthly average

Study area	Month/ Year	Average L m^{-2} d^{-1}.
El Tofo	Sept. 1991	11
Iquique	Sept. 1997	27
Mejia	Sept. 1995	48
C° Orara	Aug. 1990	14
Dhofar	Aug. 1990	70

3. Discussion

3.1 Geographical Aspects

The advective fog in all the areas studied is formed by the interception of stratus or stratocumulus cloud by the coastal mountains. The altitude found as the best for water collection are the following: 700-800 m for El Tofo; 800-900 m for Iquique and Mejia; 400-450 m for Cerro Orara; and 800-900 m in Dhofar. Cerro Orara is a small hill topped at 430 m. Higher elevations were not present. However, for comparative purposes, two SFCs were placed on the Loma of Ancon at altitudes up to 730 m. The values measured did not exceed those at 430 m at Cerro Orara.

In all the cases studied, the wind was the agent that moved the cloud from the sea to the coast and inland. All the places studied, had predominant winds from the south and southwest. The only exception was El Tofo, where the relief affected the wind and channeled it by the west. The places where the SFCs were installed are moderately windy, 6-8 m s^{-2}, the Iquique site has wind speeds higher than that amount. Probably, the sustained good yield are due to that factor, because the stratocumulus in the area is not very thick (100-150 m).

In El Tofo, Iquique and Cerro Orara, the mountain range is very near the coastline (less than 6 km). In the case of Dhofar, the stratocumulus is very thick (400 m) and with a high liquid water content, so the distance from the coast is not a big factor, while in Mejía, a river valley gives the possibility of penetration of the fog, without high rates of evaporation of the water droplets.

3.2. The Presence of El Niño

El Niño is a phenomenon that occurs regularly in the coast of South America. In the last years strong El Niño has been present in the years 1982/83; 1986/87; 1991/92 and in 1997. All this years were very rainy and the last one was a one of the strongests of the decade. It is probable that the high rates obtained in September 1997 in Iquique and Mejía were influenced by it, and rain and drizzle were present.

4. Conclusions

Fog constitutes an important water resource for the developmentof those coastal villages that don't have direct water sources

Certain particular geographic conditions are needed, those thata favor the formation of stratocumulus clouds and also allow the collection of water with the instalation of large fog collectors

It is recomended to make a cientific evaluation of the resource previous to the instalation of large fog collector, reservoirs and pipelines, so has to have an aproximation to the collection "means" that are possible to obtain

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