

Fog Water Collection Evaluation in Asir Region–Saudi Arabia

Ghassan A. Al-hassan

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Abstract Based on the fact that water can be collected from fog under favorable topographical and atmospheric conditions. The small water droplets present in the fog precipitate when they come in contact with solid objects. The frequent fogs that occur in the southwestern region of Kingdom of Saudi Arabia have the potential to provide an alternative source of freshwater in this otherwise dry region if harvested through the use of simple and low-cost collection systems known as fog collectors. A fog collection project has been carried out in Asir region of Saudi Arabia. Three Standard Fog Collectors (SFC) were designed and manufactured with locally available materials and imported mesh. These SFCs were installed in April 2006. Three different sites were chosen based on topography and altitude and data from April 2006 to April 2007 were obtained. Measurements with the SFCs were made for regions with 2,260 to 3,200 m elevation. The results indicate that at highest altitudes (at Alsooda), it is feasible to obtain an average water production of 6.215 L/m² day over the studied period, and in the lower altitudes, which are in Abha city, it is possible to collect more than 3.3 L/m² day. The highest water collection was 24 L/m² day and recorded in Dec. 20, 2006 at Al-Sahab park station, and furthermore for the same site, the best average water production of 11.5 L/m² day was obtained in winter 3 months period namely (December, November and January). Data about the weather conditions has been collected for the studied region. An analysis of fog collection effectiveness was carried out and compared with international standards. The obtained results indicate that fog can be a useful source of water supply in the southwest region of Saudi Arabia.

G. A. Al-hassan
Mechanical Engineering Department, Damascus University, Damascus, Syria

G. A. Al-hassan (✉)
Faculty of Mechanical and Electrical Engineering, Damascus University,
P.O. Box 86, Damascus, Syria
e-mail: gaal hassan@hotmail.com

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1 Introduction

Saudi Arabia lies in the tropic. It is one of the driest countries in the world, with rainfall average less than 120 mm/year (Akasakal 1998), while Asir highlands in the southwest receive rainfall due to the monsoon that may exceed 255 mm/year. Saudi Arabia does not have rivers or other natural water sources, so the whole country rely for its water supply on groundwater and desalinated seawater, the volume of production capacity of the 30 desalination plants 2006 in the Kingdom had reached 2.27 billion liters per day (<http://www.buyusa.gov/saudiarabia>).

In Asir region (18.2° N Latitude and 42.5° E Longitude) which is located in southwestern of Saudi Arabia (Gandihasan and Abualhamayel 2007) and most of its settlements lay 2,200 m high on the top of mountains chain going along the eastern side of red sea costal (Abdullah and Al-Mazroui 1998) (Fig. 1).

In this area fog collection exceeds rainfall and is therefore a more reliable source of water than rainfall for the region. Fog occurs regularly throughout the year in most areas of Asir region and especially in Al-Sooda (Fig. 2) which has an atmospheric condition that is suitable to conduct an evaluation of the fog collection potential for water supply to settlements in this area.

Fig. 1 Geographical location of the study area (Asir region, Saudi Arabia)

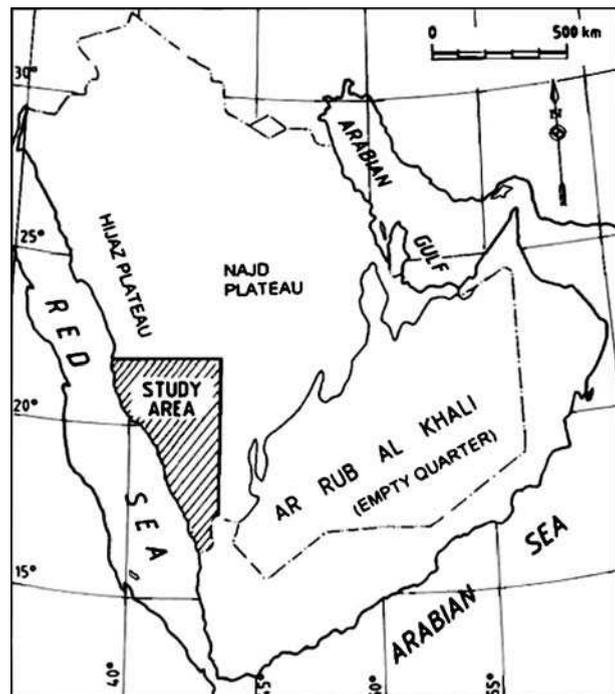


Fig. 2 Fog existing in Al-Sooda, Asir region, Saudi Arabia



Fog harvesting has been investigated for more than 30 years. Experiments conducted during the 1960s and 1970s in South Africa, but the first two fog water collection systems have been implemented in South Africa during the period 1999 to 2001 and the highest average daily recorded was 4.6 L/m^2 (Olivier and De Rautenbach 2002). The well-known fog water collection systems erected successfully in the mountainous coastal areas of Chile, clearly indicated the water harvesting potential of fog as reported in (Schemenauer and Suit 1992; Schemenauer and Cereceda 1992a, b). In Yemen (Sadaa governorate) the best sites have averaged 4.5 L of water per square meter of mesh per day over the 2 1/2-month winter period (Osses et al. 2004).

The field work was carried out using fog collection system and instrumentation that have been developed in Chile (Schemenauer and Cereceda 1994a, b) and subsequently used in many other countries.

The objective of the study was to evaluate the process of water collection from fog in Asir region–Saudi Arabia, so by first April 2006 the final locations for the three SFCs were chosen and the collectors were installed and then results of water collection were started.

2 Design and Implementation of SFCs

The potential for fog collection at the rural and urban settlements in Asir region that are designated for fog collection plans were investigated using Standard Fog Collectors (SFC). The SFC is made of a 1 m^2 , double-layer, and 35% shade coefficient polypropylene mesh and stands 2 m above the ground supported by a post at either end or arranged perpendicular to the direction of the prevailing wind (Schemenauer and Cereceda 1994a, b).

After finishing the design and manufacturing of the three SFCs, permission to erect them was obtained from the relevant local and national authorities.

Fig. 3 Fog water collection system (SFC) at Al-Sooda in the southwestern region of Saudi Arabia



Basically, as water collects on the net, the droplets join together to form larger drops that fall under the influence of gravity into a gutter at the bottom of the panel, from which it is conveyed to a storage tank. The collector itself is completely passive, and the water is conveyed to the storage system by gravity. To protect the SFC from monkeys and cows living in the area of the sites, the SFCs were guarded by metal nets with 1.75 m high from the ground as seen in Fig. 3.

3 Atmospheric Conditions in Project Area

In order to have investigate the weather conditions in the project area data has been obtained from the Saudi forecast authority in Asir region. In Table 1. There are the average values of the dry bulb temperature, wind direction and velocity, atmospheric pressure and relative humidity as recorded in 2005. It was observed especially during

Table 1 Average values of atmospheric conditions in Al-Sooda

Month	Parameter			
	Mean dry temperature (°C)	Mean surface wind and direction (m/h)	Mean level pressure (mbar)	Mean relative humidity (RH, %)
Jan.	13.2	S/14.4	794.4	100
Feb.	14.4	S/10.8	793.9	95
Mar.	16.4	S/14.4	793.6	87
Apr.	18.4	SSW/10.8	793.8	85
May	20.9	SSW/9	793.9	80
Jun.	23.2	NNE/9	792.4	70
Jul.	23.0	SSW/7.2	791.3	65
Aug.	22.5	S/9	791.8	62
Sep.	21.8	ENE/12.6	793.5	63
Oct.	18.3	E/12.6	795.1	71
Nov.	15.5	S/9	795.1	95
Dec.	13.7	S/12.6	795.1	100

the winter months that the relative humidity of the moisture air increased rapidly whereas the quick condensation of the water-vapor existing in the air.

3.1 Fog Collection Rates

The freshwater from fog has been collected daily morning by a 60 L plastic scale of measurement over 12 month's period, so that the measurements were accurate. The results of experiments with SFCs from April 2006 to April 2007 at the three sites indicate a seasonal variation in fog frequency with most fog occurring from November to February (Table 2). The data were collected and recorded daily for each site over the studied period.

The results indicate that at highest altitudes, which are at Rayda Serve and Al-Sahab Park sites, the average water production of 6.215 L/m² day over the studied period, and in the lower altitudes, which are in Abha city, it is possible to collect more than 3.3 L/m² day. The highest water collection was 24 L/m² day and recorded in Dec. 20, 2006 at Al-Sahab park station, and furthermore for the same site, the best average water production of 11.5 L/m² day was obtained in winter 3 months period namely (December, November and January).

The average water amount of fog collection for each month during the experiments period is demonstrated in Fig. 4.

The field data pointed out the fog water collection potential in Asir region. The rates are encouraging, especially for Rayda serve and Al-Sahab Park sites during the winter months (November, December, January and February).

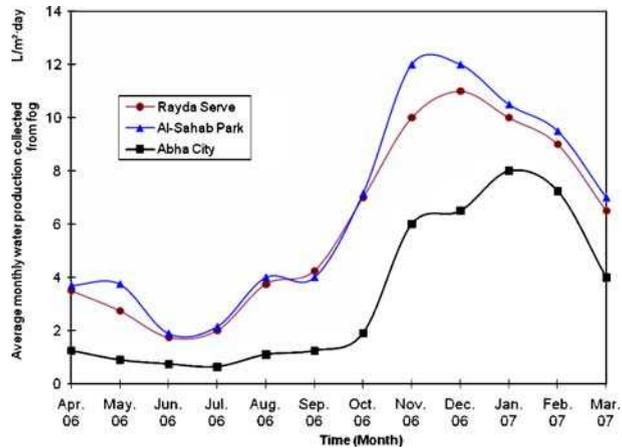
The collection rates are high for sites elevations of approximately 3,000 m or more above sea level such in Al-Sooda region where the first two collectors are located.

Most Asir villages are located at elevation higher than 2,200 m above sea level and feature good atmospheric and topographical conditions to generate fog all year long. The highlands receive variable frequently fog caused by the southwestern

Table 2 Average water production recorded from fog of the three sites for each month over the studied period

Time period (month)	Average water production collected from fog (L/m ² day)		
	Region		
	Rayda serve	Al-Sahab park	Abha city
	Elevation (m)		
	3,133	3,177	2,400
April 2006	3.5	3.7	1.25
May 2006	2.75	3.75	0.90
June 2006	1.75	1.9	0.75
July 2006	2	2.15	0.65
August 2006	3.75	4	1.10
September 2006	4.25	4	1.25
October 2006	7	7.15	1.9
November 2006	10	12	6
December 2006	11	12	6.5
January 2007	10	10.5	8
February 2007	9	9.5	7.25
March 2007	6.5	7	4

Fig. 4 Average monthly water collected from Fog of the three sites over the studied period



monsoon (Schemenauer and Cereceda 1992a, b), which brings damp oceanic winds. This humid air comes from the Red Sea is uplifted by the Asir mountains chain which are covered by Arahr trees on the way to Asir mountains and finally to inland. In analyzing and examining the data of the three sites it was found that the sites located in Al-Sooda have the best collection rates, whereas they are well exposed to winds coming from the west. The third site which is located in Abha city with elevation (about 2,200 m above sea level) harvested fewer water rates in compare with the other sites.

It was found that for the successful implementation of a fog collection project are a high incidence of fog, the presence of wind during the fog episode and a suitable site.

Comparing the values shown in Fig. 4 as collected water in the tested sites with the daily average international amounts as shown in the Table 3.

It is obviously, that the rates of collected water in Asir region is high in compare with average amount recorded in different part of the world. The reasons are high elevation, topographical and climatic conditions and the known monsoon occurs in

Table 3 Comparison between the collected average water amounts from fog in Asir with some values recorded in different locations in the world

Region–country	Time period (year)	Average amount collected from fog (L/m ² day)	Elevation (m)
Al-Sooda–Saudi Arabia	2006–2007	6.215	3,100–3,200
Hajah–Yemen (Schemenauer and Cereceda 1992b)	2003	4.5	2,000–2,200
Sahda–Yemen (Schemenauer and Cereceda 1992a)	2004	4.5	2,680–222
Calbican–S. Africa (Olivier and De Rautenbach 2002)	1997	2.314	600–1,000
Gobabeb–Namibia (Eckardt and Schemenauer 1998)	2004	3.308	408

the east coast of the read sea, so the wind reaching the highland of Asir region carrying more humidity. As a result of the temperature difference on the sea coast and the highland thus part of the air moisture then starts to condensed when reaching the dew point of the air at ambient conditions.

4 Water Quality

In general the water obtained from fog is expected to be soft, neutral water of good quality with a very low content of minerals and metals. Basically, the quality of water depends on the composition of the ambient conditions of the fog collection surface.

Chemical analyses have been conducted in the general directorate of Asir water lab for two samples of collected water from fog. The results of the test were compared with Saudi Arabian standards organization (SASO) (Saudi Arabian Standards Organization, SASO 1999), with the Standardization and Meteorology Organization of Gulf countries (SSMO) and with World Health Organization (WHO 1993).

Table 4 shows the results of the two samples that were tested. The water collected was very pure having very low concentrations of sulphates, chlorides, dissolved calcium, magnesium, sodium and potassium. No iron found in the first sample but was very low for the second one, manganese or nitrates are present. The TDS (total dissolved solids) of the collected fog water is very low and this is logic because there does not exist industrial activities close to the studied areas. As expected, no disease-forming bacteria were present in the water.

The few heterotrophic bacteria present in the samples merely reflected those occurring naturally in the atmosphere as a result of living monkeys and cows in the regions. According to Saudi Arabian standards organization, the Standardization

Table 4 Chemical analyses of fog water at Asir region (Saudi Arabian Standards Organization, SASO 1999)

Results of fog-water (mg/L)		Maximum allowed value (mg/L)		Tests
Sample (2)	Sample (1)	Unfilled water	Filled water	
0.032	0.1	1.5	0.5	Ammonia
Trace	0.26	3	3	Nitrite
8.86	39.87	50	50	Nitrate
39	180	1,000	100–500	T.D.S
22	22	250	150	Chloride
4	53.9065	250	150	Sulphate
20	104	500	200	Hardness
4.8096	40.08	–	–	Calcium
1.9456	0.9728	–	–	Magnesium
0.18	Nonexist	0.3	0.3	Iron
0	0	1.5	0.8–1.5	Fluoride
8	72	–	–	Total Alk.
77	360	–	–	Cond.
6.00	7.00	6.5–8.5	6.5–8.5	pH
Nonexistent	Nonexistent	15	15	Color unit
14.5	1.2	5	5	Turb.(NTU)
Nonexistent	Nonexistent	Nonexistent	Nonexistent	Odor
Nonexistent	Nonexistent	Part of mil.	Part of mil.	Res. CI

and Meteorology Organization of Gulf countries (SSMO) and the World Health Organization (WHO) the collected water at the three sites was found to be suitable for human consumption.

5 Conclusions

A project to evaluate the process of water collection from fog in Asir region–Saudi Arabia has been implemented since April 2006 till April 2007 and preliminary results shown that there is a great potential of atmospheric water resource. These promising results from the three studied sites in Al-Soodah (Rayda serve and Al-Sahab Park) and Abha city represent opportunities to obtain a new water resource to supply freshwater to water-poor communities in Asir regions. The best collection took place at Rayda Serve and Al-Sahab Park sites which are located at altitudes higher than 3,000 m. It was indicated that the origin of the fog, wind speed during fog events and elevation are major determinants in the volume of water that can be collected, so selection of a suitable site is vital to the success of a fog water harvesting project. Water produced by the SFCs can be collected and used directly by individual families in small 1 m³ containers. The results indicate that at highest altitudes (Rayda serve and Al-Sahab Park), the average water production of 6.215 L/m² day over the studied period, and in the lower altitudes, which are in Abha city, it is possible to collect more than 3.3 L/m² day. The highest water collection rate was 24 L/m² day recorded in Dec. 20, 2006 at Al-Sahab park station, and furthermore for the same site, the best average water production of 11.5 L/m² day was obtained in winter 3 months period namely (December, November and January), and about the same amount for Rayda Serve site while for Abha city site the average collected water for the same period (December, November and January) was more than 6.8 L/m² day. A Chilean mesh (Schemenauer and Suit 1992) with a shade coefficient of 35% was used in three sites.

Finally, the results indicate that in terms of both quality and magnitude of amount collected water harvesting could be used successfully to supply settlements of Asir region with freshwater in the fog prone regions. However, care must be taken to select a suitable site and to ensure that the orientation of the collector is perpendicular to the direction of fog bearing winds. Ideally, the site should be exposed to frequent fog bearing winds.

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