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# Design and testing of large fog collectors for water harvesting in Asir region, Kingdom of Saudi Arabia

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## Abstract

The region of Asir is located in the southwestern part of the Kingdom of Saudi Arabia between longitudes 41 – 45º E and latitudes 17 – 21º N. One of the main problems in the Asir region is the high demand for water during tourism seasons and there is urgent need to identify alternative sources of potable water.

Al-Sooda, situated at an altitude of about 3,015 m in the Asir region, was identified as the most suitable experimental site and two large fog collectors measuring 20 m by 2 m each were erected in 2009. The distance between the two sites is about 3 km. During the period from 27 December 2009 to 9 March 2010, a total of 3,128.4 L and 2,562.4 L of fog water were collected at Glider club and the Hotel sites, respectively. The results from the chemical analyses of three sets of fog water samples collected were analyzed for its quality to compare with World Health Organization drinking water standards and found to be potable. The study suggests a clear tendency that in terms of both quality and magnitude of yield, fog is a viable source of water and can be successfully used to supplement water supplies in the Asir region of the Kingdom.

## 1. Introduction

Water is a basic necessity of people along with food and air. Water has no substitute unlike energy sources and other essential commodities. There is no life without water. In 2007 the UN World Tourism Organization had predicted more than 7% annual growth in tourism industry in the Middle East. Flourishing tourism in the Asir region of the Kingdom of Saudi Arabia is challenged by the scarcity of water resources. It is an accepted fact that water is one of the scarcest and most limiting basic natural resources of the Kingdom. 57% of the total water use in the Kingdom relies on non-renewable water resource of deep groundwater. The use of non-conventional water resources to complement or replace the use of usual fresh water sources is important in water scarce regions such as the Kingdom. The desalinated water, water obtained by fog capturing, rainwater harvesting, groundwater harvesting, cloud seeding, etc. are included under the designation of non-conventional waters. Saudi Arabia is the world's largest producer of desalinated water with desalination meeting 70% of the country's present domestic/drinking water requirement. Capturing water from fog for household or agricultural use is a promising technology.

Fog forms in Asir Region more frequently between November and February. In the last several years, fog collection projects have been successfully implemented in arid regions of many countries in the world. In order to evaluate the effectiveness of fog water collection, three identical Standard Fog Collectors (SFCs) with two different local collection materials were designed and manufactured. Experiments were conducted in 2005 at two different locations in the area close to Al-Sooda. The study indicates that in terms of both quality and magnitude of yield, fog is a viable source of water and can be successfully used to supplement water supplies in the fog-prone Asir region in the Kingdom [1].The proposed research is devoted to investigate and identify the best site in Asir region to yield a good water production rate from the fog by constructing two Large Fog Collectors (LFCs) of 40 m² size and testing in the high yield sites. The typical experimental results are presented in the paper. Chemical analyses of the water collected are performed and also reported in this paper.

## 2. Site selection

The region of Asir is located in the southwestern part of the Kingdom of Saudi Arabia, as shown in Figure

1, between longitudes 41 - 45°E and latitudes 17 - 21°N.


Figure 1: Study area location.

The location, roads, and available infrastructure places considerable limits on the selection of sites. The final selection of two sites to erect LFCs will be based on the fact that they must be easily accessible by road and secure from vandals. In addition, the availability of observers taking the measurements and maintenance of data quality must also be taken into consideration. It is to be noted that a large area of at least 25 m of flat vacant land is needed for the erection of LFC. It is interesting to note that Al-Sooda has the highest altitude (about 3,015 m) and is about 15 km away from Abha. It was decided to erect two LFCs at the following sites in Al-Sooda area, namely Glider club site and Inter Continental Hotel site. These two sites are about 3 km away from each other.

## 3. Design and manufacture of LFCs

The size of the LFC selected for this study is 20 m wide by 2 m high with a surface area of 40 $m^2$, as shown in Figure 2 and bases 2 m above the ground to maximize the exposure to the wind [2]. The LFCs are flat rectangular nets supported by a post at both ends and arranged perpendicular to the direction of the prevailing wind. LFC panels are designed to withstand the structural stresses imposed by wind, humidity, and friction between different parts. The area around the LFC must be relatively clear to allow a free flow of wind. The LFC surface is a black

Figure 2: The LFC at the Glider club site.

polypropylene mesh with a single layer of the mesh's fibers cover about 35% of the total area. The mesh is placed tightly on the LFC frame in a double layer. The mesh is woven in a triangular pattern and has a lifespan of about ten years. The mesh should be installed in such a way that the seams lie horizontally. As water collects on the net, droplets join to form larger drops that fall under gravity toward a trough located at the bottom of the panel. The water is then flows through a PVC pipe to a storage tank capacity of 250 L located down. A suitable water supply system must be designed to transfer the water from the trough to the reservoir or storage. The supporting structure is made of noncorrodable materials so that the collected water remains uncontaminated. The pipe must be protected from the sun's rays that can damage the PVC pipe. The distance the water travelled in the pipes must be short. The reservoir must always be covered to avoid dust and insects getting in. It must be cleaned as needed and examined on a monthly basis.

In November 2009, the final locations for the 2 LFCs were chosen. Permission to erect LFCs was obtained from the Government authorities in the Asir region. After obtaining permission, the collectors were installed during November and December 2009 at these two sites to evaluate the efficiency of fog water collection. Local inhabitants were involved to assist with the erection of the LFCs. Structural cables were employed in the construction of the LFC. These cable systems are used to provide lateral and torsional stability to the structure. Operational measurements began in the last week of December 2009 using LFCs.

## 4. Results and discussion

Experiments were conducted from 27 December 2009 to 23 March 2010 but data from 27 December 2009 to 9 March 2010 are used for the analysis since there were no fog events after 7 March 2010. During

the above experimental period of 72 days, there was no fog for 27 days whereas 7 days there was fog with rain and fog water were collected on 38 foggy days from LFCs. Comparison between fog water yields in liters at Glider club and the Hotel sites for experimental period spanning December 2009 to March 2010 is given in Table 1.

Table 1: Summary of experimental results

| Period | Glider club site (L) | Hotel site (L) |
|---|---|---|
| 28/12/09 - 10/01/10 | 692.8 | 645.9 |
| 11/01/10 - 26/01/10 | 1,329.4 | 1037.7 |
| 28/01/10 - 10/02/10 | 633.4 | 529.8 |
| 11/02/10 - 22/02/10 | 185.0 | 131.0 |
| 23/02/10 - 07/03/10 | 287.8 | 218.0 |
| Total | 3,128.4 | 2,562.4 |
| Average (L/day) | 82.33 | 67.43 |
| Average ($L/m^2$/day) | 2.06 | 1.69 |
| Ratio | 1.22 | 1.0 |

At Glider club site, a total of 3,128.4 L of water collected from the LFC. This gives an average yield of 2.06 $L/m^2$/day. Similarly at the hotel site, a total of 2,562.4 L of water were collected during the same period. The comparison between yields at Glider club site and the Hotel site reveals that the fog water yield at the former site was considerably higher. This is probably due to the increase in wind speed and the higher liquid water content of fog.

Fog collection is affected by the meteorological conditions prevailing during the experimental period. Figures 3-5 show the relationships between the amount of fog water collected by the LFC at the Glider club site and the meteorological variables. When the ambient temperature is between 5 and 10ºC, the water collection rate is high. Similarly when the relative humidity is higher than about 90%, the collection rate is high and the maximum collection is produced when the relative humidity is close to 100%. When the wind speed is about 4 m/s, the yield is high.

Water quality is of vital importance when supplying water for drinking. The actual implementation of fog collection with these collection nets should always include analysis of the quality of the collected water to ensure that the collector does not impart any chemicals that would pose a threat to the health of

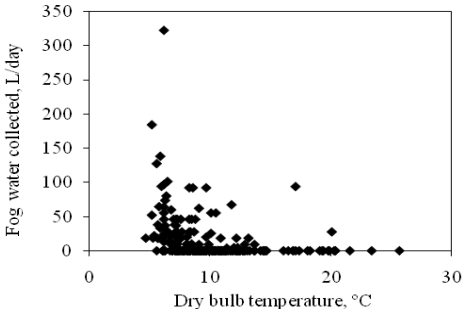


Figure 3: Fog water collected as a function of temperature.

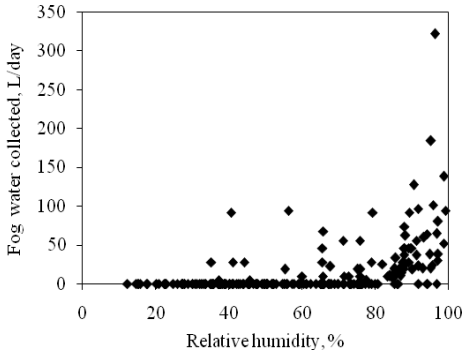


Figure 4: Fog water collected as a function of relative humidity.

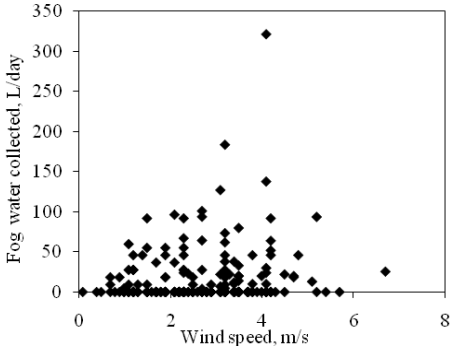


Figure 5: Fog water collected as a function of wind speed.

the users. It is, therefore, fog water quality monitoring program is carried out to identify any contaminants from the collector material and atmospheric deposition. The quality of water depends on the composition of the ambient humidity and the conditions of the fog collection surface. Chemical analysis and concentration of major cations and anions of fog-water collected were performed and the quality of water discussed in this section is based on three set of water samples collected at two different sites. The samples were analyzed for total dissolved solids (TDS), total hardness, electrical conductivity, pH, and major ions, namely, sodium, potassium, calcium, magnesium, chloride, sulphate, nitrate, fluoride, manganese, iron, etc. Samples were analyzed for anions by Ion Chromotography. Total dissolved solids and total suspended solids were determined gravimetrically. Total hardness was calculated using calcium and magnesium concentrations determined by ICP-AES. The analyses of fog water quality were assessed for its suitability [3] and are shown in Table 2.

Table 2: Chemical characteristic analysis of fog water collected (results in mg/L)

| | Sample #1 | Sample #2 | Sample #3 |
|---|---|---|---|
| pH | 7.43 | 7.42 | 7.24 |
| Cond. (ms/cm) | 0.23 | 0.40 | 0.39 |
| TDS | 158 | 278 | 318 |
| TSS | 3.0 | 34.0 | 2.0 |
| Chloride | 13.6859 | 24.5526 | 27.5375 |
| Sulphate | 40.347 | 63.200 | 71.716 |
| Flouride | 0.0508 | 0.0981 | 0.0899 |
| Nitrite | 0.554 | 1.2607 | 8.0672 |
| Nitrate | 23.003 | 49.3663 | 44.0433 |
| Carbonate | <0.020 | <0.020 | <0.020 |
| Bicarbonate | 40.347 | 63.200 | 71.716 |
| As | < 0.007 | < 0.007 | < 0.007 |
| Ca | 25.7 | 49.3 | 50.3 |
| Cd | < 0.0009 | < 0.0009 | < 0.0009 |
| Cr | < 0.0004 | < 0.0004 | < 0.0004 |
| Cu | < 0.003 | < 0.003 | < 0.003 |
| Fe | < 0.0003 | < 0.0003 | < 0.0003 |
| Hg | < 0.005 | < 0.0005 | < 0.005 |
| K | 1.62 | 2.97 | 3.47 |
| Mg | 0.966 | 1.69 | 1.64 |
| Mn | 0.003 | < 0.0001 | 0.002 |
| Na | 7.05 | 12.7 | 12.3 |
| Pb | < 0.008 | < 0.008 | < 0.008 |
| Se | < 0.011 | < 0.011 | < 0.011 |
| Si | 0.128 | 0.145 | 0.245 |
| Sr | 0.102 | 0.185 | 0.199 |
| Zn | 0.051 | 0.041 | 0.019 |

## 6. Summary and Conclusions

In spite of the fact that about three months of fog events in a year is a short time to establish meteorological average values, the results obtained to date suggest a clear tendency that fog is a viable resource in the Asir region of the Kingdom of Saudi Arabia. The maximum daily fog water collections from the LFCs are 598 L and 473.8 L at Glider club and the Hotel sites, respectively. The results suggest that Glider club site has a greater potential for fog water harvesting than the Hotel site.

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