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Feasibility and sustainability of fog harvesting

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ABSTRACT

Knowing that the fog harvesting is a non-conventional method for the production of freshwater, the sustainability of a fog collection project is studied. Sustainability and feasibility of fog harvesting collection projects is the focus of this Paper. A sustainable operation of fog harvesting projects which provides numerous sites worldwide with sufficient amounts of fresh water worldwide is presented. The key characteristics of fog harvesting system are considered including the physical process; the fog collectors; and the mesh types.

Sustainability aspects of fog collection projects are investigated including fog water quantity and quality. The feasibility of fog harvesting collection projects is evaluated, compared with other sources for freshwater supply including the corresponding infrastructure; the cost of water; the operational costs; and the amortization periods for expenses. The vision of implementing a fog collection project including the decision-making criteria is presented as a logical process. The community involvement analysis and the social impact are analyzed in the light of the existing freshwater resources and needs. The most important environmental factors that affect the volume and the frequency of water are evaluated. The Paper concludes that prior to implementing a fog water harvesting program; a pilot-scale assessment of the collection system should be executed.

1. Introduction

The collection of fog for the purpose of the production of clean water has attracted increasing attention over the past few decades. One of the most exciting aspects of this resource is that in many regions the supply of water will be limited only by the number of collectors one chooses to install. Fog has the potential to provide an alternative source of freshwater in semi-arid and arid regions if harvested through the use of simple and low-cost collection systems known as fog collectors. Fog-water collection is a resource that should be seriously examined in certain semi-arid and arid regions of the world. It is particularly attractive in areas where conventional sources of water are nonexistent or are disappearing. The fog collection projects worldwide, to analyze factors of success, and to evaluate the prospects of this technology is reviewed (Otto Klemm et al., 2012). An SFC fog collection has been record for 14 years, with average fog collection rates of about 6 L/m^2 of mesh per day [or (6 L m^{-2} day^{-1})], in Alto Patache fog oasis in the Atacama Desert which is a site primarily used as a platform for ecosystem and climate research in Chile (Calderón et al., 2010).

There are fog collection projects in Africa. In Eastern Africa, in Eritrea, there are about 700 km of mountains along the Red Sea, where the winds advect moist air from the sea and form advection and orographic fog on the highlands. Twenty large fog collectors LFCs were installed in the villages of Nefasit and Arborobo to increase access to drinking water for schools and 120

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families. Results showed a good production of fog water. The project subsequently faced some significant challenges on its management since the collectors needed high maintenance and close supervision during high wind conditions. The fog collectors now serve as a demonstration of the potential for fog collection for the whole of Eritrea. There is also a large evaluation project underway in Tanzania and some work has been done in Ethiopia (www.fogquest.org). On the Northwest coast of Africa, fog water collection has been investigated since 2006. In Morocco and the Canary Islands, the station Anaga (842 m above MSL) on Tenerife Island exhibited the best collection rates 10 L m^{-2} day^{-1}, (Marzol et al., 2010). The efficiency, good performance, and the availability of continuous hourly data for more than 14 years has enabled this station to be used as a model site for studying the characteristics of fog on the island of Tenerife and for comparison with other places (Marzol et al., 2010). Boulaalam-4 km from the coast and 300 m above MSL, and Boutmezguida-30 km from the coast and 1225 m above MSL, were chosen as the two experimental sites in a pilot project. Data obtained after 2 years of investigation indicate that the interior was the more efficient site with more than 7 L m^{-2} day^{-1} compared to only 1.9 L m^{-2} day^{-1} on the coast (Marzol et al., 2010).

There are fog collection projects in the Arabian Peninsula. In Yemen, the potential to collect fog water for fresh water production was investigated in the mountains near Hajja, north of the capital city of Sana'a and inland from the Red Sea in 2003 (Schemenauer et al., 2004). The best sites averaged 4.5 L m^{-2} day^{-1} over the 3-month dry winter period, justifying a large project with 25 LFCs be implemented in January 2004. In Oman, a major fog collection experiment was undertaken in the summers of 1989 and 1990. In the upper elevations, from 900 to 1000 m above MSL, very high average collection rates of 30 L m^{-2} day^{-1} for the monsoon period were obtained. More recent work by Abdul-Wahab et al. (2010) confirmed the productivity of the fog. Abualhamayel and Gandhidasan (2010) report on 3 months of measurements in the Asir region with encouraging fog collection rates of about 2 L m^{-2} day^{-1}.

Southern Europe is also a region with severe water resources problems. Croatia was the first country in this region to collect fog water. Since 2000, a SFC has been collecting fog water on Mount Velebit, 1594 m above MSL near the Adriatic Sea. The results show that fog has the potential of being an important source of water, especially during the dry summer season, when collection rates of up to 4 L m^{-2} day^{-1} can be achieved (Mileta and Likso, 2010). In Spain, a fog collection network has been maintained since 2003 on the eastern fringe of the Iberian Peninsula, covering an area nearly 800 km long. Twenty-four fog collectors are installed at 19 different locations. Fog water is collected with handmade cylindrical passive fog collectors (i.e., omnidirectional collection efficiency), made of either nylon wire or Raschel mesh, in combination with additional meteorological sensors. Fog can play an important role in the hydrological system in this area, with total values reaching 7 L m^{-2} - day^{-1} at some locations (Estrela et al., 2008). Table 1 presents the evaluation project of Fog harvesting for the production of fresh water in arid or seasonally arid regions.

2. Material and methods

2.1. Fog harvesting

Fog is composed of liquid droplets. Fog, in the simplest of terms, is a cloud which is touching the ground and the type of fog is then determined by the physical process which has created the fog. When a cloud, with a base some distance above the sea or the land, moves over a mountain, the mountain is covered by fog. Fogs produced by the advection of clouds over higher terrain tend to have higher liquid water contents than fogs at the land or sea surface. These high elevation fogs are of primary interest for the production of water in arid lands. The frequent fogs that occur in the arid coastal areas fogs have the potential to provide an alternative source of freshwater in this dry region if harvested through the use of simple and low-cost collection systems known as fog collectors. In meteorological definitions of fog, it is further stated that it is composed of tiny water droplets and that it is present when the visibility is below 1 km. The collection of fog droplets depends on the diameter of the droplets, the wind speed and the nature of the collection surface. Fog droplets are typically from 1 to 30 μm in diameters.

2.2. The standard fog collector (SFC)

The collection rate of a fog collector is determined by the wind speed, the fog liquid water content (LWC), the size distribution of fog droplets, and the size and arrangement of the mesh material. A fog collector is simply a frame that supports a section of mesh in a vertical plane. The large, operational fog collectors are typically made of two supporting posts, and cables on which the mesh is suspended. In addition, there is a network of guy wires to support the posts, a plastic trough to collect the water, and pipes to move water from the troughs to a reservoir or cistern. The large collectors are usually 12 m long and 6 m high. Fig. 1 shows a large fog collector together with the water tanks in Spain. This LFC is 18 m^2 flat-panel fog collectors located at Mount Machos, Spain.

The standard fog collector (SFC) is used in feasibility studies to evaluate the amount of fog water that can be collected at the given sites. The construction and use of this flat mesh panel is described in detail in Schemenauer and Cereceda (1994a). The SFC has a 1×1 m^2 surface, with a base 2 m above ground and is installed perpendicularly to the wind direction that is associated with the occurrence of fog. It has now been used to measure fog fluxes in about 40 countries. The large fog collector (LFC, Schemenauer and Cereceda, 1994b) has been widely used for fog collection. The principle is identical to that of