IFDA2019

IFDA2019-6 abstracts

14 Jun 2019 08:37:14

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-4-1

The Social Contexts of Fog-Water Project Success and Failure

Byron Bignell, Anthony Makepeace, and Nicolás Zanetta Colombo

The authors have conducted a detailed analysis of the project state, community mobilization and history of fog water projects in Kolbung in Eastern Nepal and Tojquia in Guatemala. The goal of the research is to more clearly understand the patterns of behaviors that contribute (positively or negatively) to project adoption and sustainability within the local cultural, social, religious and economic contexts of the communities in question and, by extension, to other environments in which fog collection projects are being evaluated. The authors undertake an exhaustive examination of the formal, informal and technical behaviors of the two communities regarding the introduction, maintenance and current state of fog collection projects. The authors proceed to deconstruct and analyze the contexts of project success and failure, discussing the causal and supporting factors leading to the current state of fog collection projects in their respective environments. This paper focuses on two project areas and surrounding communities; Tojquia in Guatemala, and Kolbung, in Eastern Nepal. FogQuest (FQ), a Canadian non-governmental organization (NGO), along with local and international partners has operated and developed fog-water projects in the research areas. This research focuses on recent projects; between 2008 and 2018. The researchers were prompted to undertake the research as a direct result of witnessing first-hand the decline and failure of the LFC installation at Kolbung, a process that began in 2010 and continued to until 2017, at which point the physical structure of the LFC began to fail and the collector was no longer capable of collecting water. The decline of the projects in Nepal, while the projects in Tojquia were thriving raised many questions pertaining to theories of change, the introduction of technology as they might affect program adaption to local socio-cultural and socio-economic behaviors and expectations as compared.

Keywords: Fog-water, Nepal, Guatemala, Water, Success, Failure, Comparative Analysis, Cultural, Religious, Economic, Ethnic, Political

8th International Conference on Fog, Fog Collection and Dew
Taipei, Taiwan, 14–19 July 2019
IFDA2019-24-1

Harvesting industrial fog and in situ removal of organic pollutants from collected water

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Industrial make-up water accounts for about 95% of the overall fresh water consumption globally, and an efficient fog water harvesting will provide a relief to the increasing fresh water stress. Like the atmospheric fog harvesting, industrial fog harvesting, i.e. tapping fog water from industrial cooling tower (CT) plumes or circulating water outlet, can be a viable alternative source of freshwater. Industrial fog harvesting from vertical cooling tower plumes offer a few additional challenges over the traditional atmospheric fog harvesting because of the relative orientation of the fog nets with the fog plume, CT fan rotation and gravity. We used stainless steel wire meshes in different frame sizes with varying pore density (shade coefficients) and surface wettability. Fog collection is characterized under different angles of orientation of the fog nets with the upward moving fog stream. Factors influencing the aerodynamic, deposition and drainage efficiencies are identified and recommendations for improvement of fog capture efficiencies are made. Making the surface superhydrophobic is found to minimize mesh clogging, but it also increases premature dripping of water from the mesh. Superhydrophilic surfaces are found to offer more clogging than their superhydrophobic counterparts. The dimension and shape of the fog nets are also found to influence the collection efficiency.

Besides the CTs, large loads of industrial fog are also found to appear in several industrial premises, e.g., in paper mills or other process plants where evaporative removal of process water needs to be performed as a process protocol. Large amount of fog are produced in such plants, which are often loaded with pollutants like volatile organic compounds (VOCs). Harvesting this industrial fog (e.g., from the exhaust hoods of the plant sheds) and re-using of the collected water requires that the collected water is freed from the pollutants. We demonstrate the use of an advanced mesh design that, besides capturing the fog, also degrades the VOCs present in the fog. We use stainless steel meshes, electrophoretically coated with TiO_2 nanoparticles that act as catalyst to degrade the VOCs in the fog water. Methylene blue (MB) particles are seeded in the fog as a surrogate of VOCs for characterizing the performance of the mesh. The organic molecules degrade in presence of weak UV light or very low visible light sources (395nm-405nm) as the fog deposits on the mesh. MB concentration recorded from the collected water shows in situ degradation of MB. Once the meshes are UV-activated, the VOC-breakdown continues (albeit at a reduced magnitude) for several hours even after the removal of the UV light. The research shows avenues of collection and purification of water from industrial fog.

8th International Conference on Fog, Fog Collection and Dew
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Dew-Fog as a supplementary source of water in the hilly terrain of Meghalaya, India

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Meghalaya State (meaning: the abode of clouds) in North-East India is located 4,267 feet above sea level receives the highest rainfall in the world. Today, Sohra, a district in Southern Meghalaya is known as the wettest desert on earth. With no trees or big reservoir to hold the runoff, rainwater runs down into Bangladesh. Sohra faces acute water shortage, especially during winter and tankers supply water in the lean months - from November to March - and sell water at 15 Indian rupees (about 20 cents) for a big bucket. Women walk for miles to collect drinking water from government-installed pipelines. The situation remains the same in many other districts in Meghalaya.

There is high moisture in the mountainous region of Meghalaya. To understand the true potential of Dew and Fog in the region as a supplement as a source of water in hilly terrain, an Action Research was undertaken in 2018. A hybrid model of Dew condenser (1 x 1 m) and Fog- condenser (1 x 1 m) was designed as a single unit named as standard Dew-Fog Condenser (SDFC). Both Dew and Fog yield can be monitored independently with this single unit.

SDFC were installed at two locations – Ram Krishna Mission School, Sohra district (N 25°17.159’, E 91°42.982’) and Phlangwanbroi district (N 25°15.260’, E 91°29.930’). The installation work started in July 2018 with completion in September 2018. The study team has prior experience of working and installing 800 m2 large Dew condensers on the ground at Kutch, India in 2005 with support from World Bank and technical guidance from OPUR, France.

At Sohra site, Dew was received for 52 times out of 62 nights with highest of 800 ml/m2/night while, Fog was observed on one night with a yield of 200 ml/m2/night. At Phlangwanbroi site, dew was received 40 times out of 51 nights were observed with highest dew yield of 210 ml/m2/night. While dew yield results are quite positive, we are still waiting for the fog to come in the study area.

The initial results show the potential of Dew-Fog both in the region that can be tapped and utilized as a supplementary source of water. The low-cost dew-fog systems would be designed and installed at school sites to make water available in lean season. The low-cost system in villages will be integrated with traditional bamboo irrigation system and low-cost bamboo green-house to cultivate vegetable in offseason and support the livelihood of small farmers.

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Redwood-Inspired Fog Harps

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Virtually all real-life fog harvesters are comprised of mesh netting, which suffers from dual constraints: coarse meshes cannot efficiently capture the micrometric fog droplets suspended in the wind, while fine meshes become clogged which disrupts the aerodynamics of the fog stream. Coastal redwoods obtain 34% of their water from fog drip, as fog droplets are able to effectively slide along the parallel needle arrays to fall onto the soil. Inspired by the redwood trees, we develop “fog harps" comprised of an array of fine, vertically oriented wires that bypasses the clogging constraint of conventional meshes. The lack of horizontal cross-wires allows captured droplets to slide unimpeded at small Bond numbers, which prevents clogging even when using micrometric wires. We observed up to a three-fold enhancement in the fog harvesting rate for scale-model harps compared to equivalent mesh netting. The water harvesting rate of our fog harps increased as the wire diameter decreased from 1.3 mm down to 250 μm. A theoretical model predicts that the fog collection efficiency plateaus for the wire diameter of 250 μm, indicating that the smallest wires tested here may be approaching the performance ceiling. Large fog harps (1 m $\times$ 1 m) were fabricated using a spinning frame, inspired by the bobbin winding mechanism of sewing machines. For field tests, the large fog harp and an equivalent mesh frame were installed at a local farm that experiences abundant fog. Preliminary results showed that the fog harp harvested up to five times more water compared to the mesh over a three-day period. The enhanced water collection rate of our redwood-inspired fog harps should increase the number of regions where fog harvesting is economically viable.

We gratefully acknowledge GreenShift Corporation for providing financial support.

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Electrospun fibers with controlled surface properties for fog collectors

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The fog collectors are produced with various designs to increase their efficiency in collecting water. Currently, one of the directions to make them more effective is increasing their surface area by incorporating electrospun polymer fibers. Electrospinning is becoming the main production method of nano- and microfibers with scaling up possibilities. This is a cost-effective method as fiber's properties can be controlled with the experimental setting avoiding any additional postprocessing or chemical treatments. We are able to control the wetting of fibers via their roughness [1], which can be also tuned to biomimic spider webs known to be natural fog collectors [2]. In our research, we present a few strategies to increase the efficiency in single step electrospinning to obtain the hydrophobic and hydrophilic properties of fiber networks with single and double nozzle set-up. To verify the wetting phenomena, we use advanced microscopy technique to visualize the contact angles at nano- and macro scale [3] and mechanical testing stage for analysis of their mechanical properties. Our studies show the potential of including electrospun fibers in existing fog collector structures.

Acknowledgments:
The study was conducted within the funding from SONATA BIS 5 project granted by the National Science Centre in Poland, No 2015/18/E/ST5/00230

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Mesh-induced variability of fog water collected in Central California

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We currently have (or have had) multiple deployments of standard fog collectors using a variety of mesh types in order to glean comparisons on the relative effectiveness of the fog water collection potential of these materials under different meteorological conditions. Specifically, this study examines water volumes collected from (i) standard fog collectors constructed with a double layer of 35% shade coefficient coresa raschel mesh; (ii) a standard fog collector constructed with a single-layer of coresa raschel mesh; (iii) a standard fog collector constructed with a triple-layer of coresa raschel mesh; (iv) standard fog collectors constructed with German FogHa-Tin mesh; (v) a standard fog collector with a double-layer of coresa raschel mesh coated with a hydrophobic substance generated at NbD Nanotechnology; (vi) a standard fog collector with FogHa-Tin mesh coated with a hydrophobic substance generated at NbD Nanotechnology, and, finally, (vii) a standard fog collector with a double layer of mesh purchased from a local hardware store a single layer of which has an approximately 50% shade coefficient.

The results of these comparisons illustrate the differences between different fog events that illustrate the lack of universality of any single-event comparison. In other words, some types of mesh appear to function more effectively for fog water capture in different types of fog events or under different meteorological conditions. Whether one mesh performs better than another, therefore, is predicated upon which conditions a given site experiences in general, but we need to acknowledge that there is a variance in the relative performances of the different types of mesh.

One unique result of this study is that we observe that there appears to be a tendency for the mesh that is most productive to respond more quickly in terms of producing measurable water. Since this implies that there will be less blockage from the accrued water, this result supports other work that indicates that mesh blockage from undrained droplets may tend to hinder air flow and, consequently, capture less fog.

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Fog water yields in the hyper arid coastal Peruvian desert

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Background. The "The Chilean-Peruvian arid coastal fog ecosystems under climate change: understanding biosphere-atmosphere interactions to support biodiversity conservation (2016-2019)" project analyzes the relationship between fog and the Tillandsia which is the predominant bioindicator in the Atacama Desert in Chile and the Pampa del Toro Desert in Peru. The Pampa del Toro is a hyper arid coastal desert, located in the SW of Peru, 16º south, and receives annual rainfall of less than 5.0 mm but it has the possibility of fog providing humidity and water. The origin of this fog is the cloudiness of the Pacific Ocean anticyclone that becomes advection fog when it comes into the continent.

Aim. To study the spatio-temporal variation of the fog and the amounts of fog water collected.

Method. The hourly data from two standard fog collectors (SFC) connected to Thies automatic weather stations are analyzed. The Thies weather stations, measure the following meteorological parameters every 10 minutes: temperature, humidity, wind speed and direction, rain and pressure, humidity in the soil and the fog water collected in the SFCs. Both stations are installed 15 km from the coast, at 1,055 m and 980 m a. s. l. In addition, two other SFCs connected to Davis stations, located at 980 m and 1,080 m a.s.l., are used to delimit the capture potentiality of the upper and lower layers of cloudiness. The study period is from August 2018 to June 2019. We work on an event scale (a "fog event" here is defined as a continuous recording of water from fog within a 60 minute interval, so a fog event can last many hours, but which can be interrupted for 50 minutes for example, and then continue, OSSES, P. et al., 2018).

Results. In the preliminary analysis, there are notable differences in collection data between September, with only 5.6 L/m2, and October with 89.5 L/m2. The greatest presence of fog is from 4 to 9 a.m. and the lowest is during hours around midday. The environmental conditions change when there is fog: the temperature decreases 2ºC and the wind speed goes down to 2 m/s. There are a mean average of 35 fog events per month. The fog events collect a mean average quantity of water of 30.0 L/m2; the longest event lasted 18 hours and 8.5L/m2 was collected.

Conclusions. Knowledge concerning the behavior of the fog in this desert is of vital importance because it is practically the only available water resource for the survival of the existing ecosystem.

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An investigation on the potential for fog water harvesting from Table Mountain, South Africa

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The fog cloud that frequently appear over Table Mountain in South Africa could serve as a supplementary source for Cape Town that is located in the dry semi-arid Western Cape Province. Fog clouds over the mountain is mostly associated with moisture advection from the south-easterly ocean, driven by south-easterly winds, during the austral summer and winter seasons. However, during the winter season, northwesterly winds that originate from rain bearing cold frontal systems contribute to a significant portion of table fog events, and in addition, also brings precipitation to the mountain. In this study, the potential of harvesting fog water as a supplementary water source from the fog cloud on Table Mountain is investigated. This investigation formed part of a range of strategic studies by the City of Cape Town aimed at determining the potential of adding water from alternative sources to the water budget of the city. The study firstly consisted of a comprehensive analysis of all historical and currently collected meteorological data on Table Mountain, as well as in the vicinity of the mountain. Subsequently, the characteristics of fog clouds over Table Mountain were investigated, with a detailed analysis of how fog cloud density is affected by mountain terrain features – within the limitations of the data available. The mountain terrain was also used as an indicator of the most suitable places on Table Mountain for erecting both pilot and longer term fog water harvesting systems. Included was an Environmental Impact Assessment (EIA). Specific regions on Table Mountain were found to be most suitable for fog water harvesting, taking into consideration terrain, tourism, accessibility and its influence on the environment, keeping in mind that Table Mountain is a World Heritage Area. In conclusion, estimated water yields from fog cloud harvesting were provided.

8th International Conference on Fog, Fog Collection and Dew
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Possibility of dew use and better utilization in the Serbia

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The Republic of Serbia has an area of 88,361 km2, but the need for drinking water grows every year. Serbia has, for the time being, waters from the biggest rivers systems and lakes. According to climate change, Serbia may stay without drinking water in some mountains and plains. Especially, the north part of the country is more vulnerable. With the help of satellite data and numerical GIS methods, we estimated total capacity of dew volume at the whole territory. Multi-criteria GIS analysis and satellite detections with methods such as kriging and semi-kriging gave satisfactory results of this research. Ordinary kriging method was employed through QGIS and SAGA (GIS) of Spatial Analyst. Although there are a few other methods, the priority is given to ordinary kriging and Global kriging because it includes autocorrelation or the statistical relationship among the measured points. Thus, with this method, the weights are based not only on the distance between the measured points and the prediction of location but also on the overall spatial arrangement of the measured points and it minimizes the variance of the error of estimation. When we downloaded satellite data, these data were compared with meteorological data of precipitation, evaporation and temperature. All results were presented on the maps of dew distribution across the country. We got very precise grid in 1x10 of longitude and latitude. Also we derived relief of dew distribution according to the estimation of elevation. These maps could be interpreted and implemented in new projects for better utilization of dew use in Serbia. The advantages of this approach are in the application of three dimension analysis. The estimated total capacity of dew potential of Serbia is 10000 cubic kilometer or 10x1016 liters. Comparing the obtained data for Serbia this type of water is not large but it is enough for farming or using of drinking water in semi-arid and arid areas. This type of water will be more used in Serbia according to climate change effects and drought influence.

Key words: Serbia, dew capacity, GIS analysis, Satellite detection, Maps