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Dew plant for bottling water

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ABSTRACT

In a context of climate change and increasing need of fresh water in the world, rain and dew water can have a significant impact as new sources of water, especially in arid and semi-arid areas. The aim of the paper is to demonstrate that atmospheric moisture can be harvested and processed into safe drinking water comparable in quality and price to reverse osmosis processed water available in the market. The paper describes the construction and functioning of a water production plant in northwest India (Kothara). Rain and dew are collected; for dew special attention has to be taken. In particular, special condenser architecture (ridges) is designed using Computational Fluid Dynamics simulation and improved condensing surfaces are operated. Dew yields are estimated from the meteo data and using simulation. From the figures an economic model is derived; it comes out that water passively harvested from atmospheric moisture may be cheaper than that from reverse osmosis and does not pollute the environment, supporting the importance of dew and rain resources to provide supplementary supply of potable water in arid and semi-arid environment.

1. Introduction

The increasing need of fresh water in the world and especially in arid or semi-arid regions led recently to seriously consider rain and dew precipitations as new source of water. Collecting rain water is simple, but harvesting dew is more challenging. Although long ignored, dew water offers indeed a renewable complementary source of potable water for arid or isolated areas. There are many legends that report dew harvesting as noted by Beysens and Milimouk (2001) and Mylymuk-Melnytchouk and Beysens (2016). It is only recently that dew condensers have been constructed on accurate physical grounds, enabling dew to be collected with a sufficient yield.

What is dew? Dew is produced from air water vapor condensation on a substrate that gets cooled because of nocturnal negative radiation balance between the substrate and atmosphere. Yields are primarily limited by the available cooling energy, which does not exceed 100 W m^{-2}, leading to a theoretical maximum yield of the order of 0.8 L m^{-2} per night. Practically, due to heat losses with wind, cloud coverage and limited air humidity, the maximum yield is rather 0.6 L m^{-2} per night as observed by Clus et al. (2009). In the last decades systematic investigations of high yield radiative materials with hydrophilic properties for water condensation at small supersaturation and improved drop recovery have been performed (see the review by Tomaszkiewicz et al. (2015)). The simplest condensers are planar panels made of high emissivity plastic film insulated underneath that are oriented 30° with horizontal, the "best" angle as determined by Beysens et al. (2003). The above film has been elaborated by Nilsson (1996) and is manufactured by OPUR (2016). Its color is white; it is made of low density polyethylene (LDPE) film containing a few percentages of TiO_2 and $BaSO_4$ micro-particles with high infra-red emissivity. It also contains food proof, water insoluble surfactant, which enhances dew drops collection. Such condensers can harvest 15–20 mm of dew water in the season at the dew plant site (see below, Section 4).

Other condensing architectures have been elaborated. Conical

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shapes have been used by Berger et al. (1992), Kounouhewa and Awanou (1999) and Clus et al. (2009). Similar to cones, inverted pyramids have been generated by Jacobs et al. (2008). Sharan et al. (2011) produced a serie of ridges. High yields have been obtained by Beysens et al. (2013) with periodical structures of origami shapes. Roofs condensing dew water have been built and operated successfully by Beysens et al. (2007) and Sharan et al. (2007a; 2007b). Large dew condensers have been developed and field-tried in India in the recent years by Sharan (2011) and Sharan et al. (2011). Three different models were developed for large scale applications – condenser-on-roof, condenser-on-ground and condenser-on-fence.

The said experimentation is carried out in a village called Kothara of the district Kutch situated in the north-western India, in a hot semi-arid zone. Kothara receives an average of 200–300 mm rainfall in a year. Pan evaporation is as high as 2000 mm due to the lack of vegetation cover of the land. This extremely high evaporation process causes almost all water bodies, large and small, go completely dry immediately after 2–3 months of rainy season. Despite being a semi-arid zone where there is acute problem of drinking water, rain water harvesting is not popular among the households in this region. This is due mainly to the fact that rainfall besides being low is also concentrated over just a few days in a year, making large storage structure necessary. Therefore groundwater remains the only source of water, which is unsuitable not only for drinking purpose but for irrigation also at times. Shortage of potable water is chronic and widespread in Kutch. It is especially of concern in villages near the coast. They get water on tanker-trucks daily from long distances. It is practically untenable to depend on these municipality run tankers for drinking water because the supply is limited and scarce. It forces residents to all sorts of alternative arrangements for drinking water. One of them is production of potable water from brackish groundwater through reverse osmosis (RO) filtration. RO comes with its own environmental threats. It causes groundwater level going down year on year. Pumping out this ever depleting groundwater has become increasingly costlier. Potable water obtained from RO is only about 50% of the total processed. The rest, which has too high dissolved solids, is disposed off in the surrounding, leading to accelerated degradation of top soil and groundwater quality. It has negative impact on flora and fauna of the region. Although the technology of RO filtration has been becoming more efficient and increasingly less expensive, RO process is not a sustainable solution of drinking water problem in the long run. Unregulated disposal of reject water from households and commercial vendors is leading to degradation of surroundings, top soil and ground water.

Greater use of atmospheric moisture - dew and rain water - can reduce dependence on RO process. The Kutch region gets ~300 mm of rain over 15–20 days during the monsoon season, June to September, in a very erratic way. During some years, rain does not happen. Dew occurs from October to May with 100–115 dew-nights and 20–25 mm of dew water over the season. While the condensers are specifically engineered to condense dew, rain can be routinely harvested using the same surface. Thus, a suitably designed plant can potentially harvest 320–325 mm of atmospheric moisture during the year.

Kothara (Fig. 1) has 2200 households and a population of 7000. It has piped supply pumped out from 135 m depth. Water is not potable – Total Dissolved Solids (TDS) vary over the months from 1500 ppm to 2800 ppm. It is used for wash and also given to cattle.

In this paper are described details of a drinking water production plant designed to harvest atmospheric moisture and process it into drinking water for local sale. Its functioning with respect to local meteorological conditions is characterized by Computational Fluid Dynamics (CFD) and modeling from meteorological data.

2. Quality of dew water

Chemical and biological tests had already been performed by Sharan (2011) and Sharan et al. (2011) in four locations around the Kothara dew plant site: Suthari (13 km), Sayara (111 km), Panandhro (82 km) and Satapar (420 km). The results are shown in Table 1, with Suthari the most representative site considering the distances. The data show that dew is safe and potable according to Indian regulation. Studies in other parts of the world found that dew water is potable once disinfected (see Tomaszkiewicz et al., 2015 and refs therein).

3. Dew plant

The plant is constructed in Kothara, a village which is in the Kutch district of Gujarat state of India. The project started in August 2013 and the construction work a few months later. The plant is situated at 23°07′36.08″N 68°55′50″E (Fig. 1).

This dew harvesting plant is rated to process on an average 500 L of water daily. It has four main components (Fig. 2): (i) catchment where moisture is harvested, (ii) sand filter (iii) raw water cistern for storage and (iv) purifier and packaging unit. The catchment is erected on level wall compacted ground over a rectangular, $40 \times 16\ m^2$ plot. In appearance it is similar to an array of solar panels of solar power installations. First, angle iron mounts are grouted to the ground at carefully marked locations as shown in Fig. 2a. Seen from longitudinal end each row has an 'M' profile with gutter in the middle. Mounts have side slope of 30° from horizontal. This angle is the "best" angle to enhance dew droplet recovery by gravity while not diminishing the radiative cooling, as demonstrated by Beysens et al. (2003). This form was selected (over others) to make the facility compact and to provide more condensing area per unit land area. There are 15 modules or rows of the mounts (Fig. 2b). There is a 50 cm wide access walkway between two adjacent rows for cleaning and repairs. Each of the fifteen rows of panels, made of two planes inclined at 30° from horizontal facing each other, are separated by a distance of 0.225 m. The distance between the top of each "V" is 0.5 m. Each plane of the "V" is 1 m wide, 18 m long and 0.025 m thick; it is a sandwich with 0.025 m styrene foam board in the middle and plastic film wrapped around. The total surface area of all these 15 V-shaped rows of mounts is, hence, $540\ m^2$ ($2 \times 15 \times 18 \times 1\ m^2$). This is the overall catchment area of this facility.

The condenser panels are prepared at the site and installed over the mounts (Fig. 2c). The top and lower edges of the panels rest on the top (ridge) and lower purl (eve) of the mounts. The installation of the panels is a painstaking task. It is done with a team of skilled workmanship. The lower edge of the panel is first fastened into grippers starting from one end to the other in small stretches at a time. The process is then repeated for the top edge. Condenser panels are installed first on one half of each row. This process is then repeated for the other half of the rows. This procedure ensures that there is enough room to maneuver for the team of installers. Partially finished condenser field can be seen in Fig. 2a–c. The gripper assembly (channel and zig-zag springs) used is similar to those being used in the greenhouses (Fig. 2d). This procedure ensures that the panels remain planar to permit rapid draining, and also remain tight to overcome wind pressures. It has been observed that wind gusts do not lift or depress the panels appreciably. This is the most crucial point of the erection of the plant for the throughout. Top surface of the panels forms the catchment. This procedure also guarantees easy removal and replacement as and when needed.

All fifteen primary gutters (running from left to right) drain into the one common secondary gutter. This gutter runs to the nodal