ANALYSIS OF DIFFERENT TYPES OF MESHES ON THE PERFORMANCE OF A FOG HARVESTING PROTOTYPE

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ABSTRACT

Fog harvesting is a important method which helps harvest water from fog. It is primarily utilized in areas where the fog exists excessively such as hilly areas and is a sustainable low-cost solution to recapture water vapour from the atmosphere. High rise residential areas have cropped up in Malaysia of late with a high-water footprint, and no water usage mitigating strategies. While there has been an effort to mandate rainwater collector in these high-rise apartments, the use of fog collectors especially in hilly areas has mainly been ignored. The facile nature and low cost of these fog water collectors can curb the dependency on the main water supply by harnessing the dormant potential and reclaiming the water vapour abundant in nature. This paper sought to determine the causality between the different mesh types utilized in a fog water collector and its efficacy in implementation. In the project various parameters which affected the fog water collector performance were scrutinized to determine the link between the different mesh result and its causality. The main factor affecting the fog water collector performance is the collector's mesh size and mesh's capability to expel water into the drain collector. The best results were obtained from the stainless-steel mesh collector due to its hydrophobic nature, which aided the water droplet collection.

Key words: Shade coefficient; mesh; fog harvesting, thermal, Polypropylene.

INTRODUCTION

Water is a scarce resource which needs to be protected as it remains as one of the prerequisites for life. Freshwater especially is a limited commodity as it is not abundantly available, especially in the certain parts of the world. Fog is present in mountain areas where the effects of the terrain lead to the rise of humid air, which in turn with decreasing pressure due to altitude causes it to form.It is also referd to as adiabatic cooling or condensation. (Brimelow and van Heerden, 1996; Cereceda et al., 2002; Marzol-Jaen et al., 2010) Fog harvesting is utilized to fulfill the daily water consumption in certain areas of Africa and Latin America that suffer from drought conditions (Klemm et al., 2012; Fessehaye et al., 2014). The fog collects in a fine plastic mesh screen that stretches between two supporting poles, which captures some of the water droplets mainly by the impaction mechanism (Regalado and Ritter, 2016). The droplets once they are sizable, roll into the tank through the drainage as the mass of the droplet causes it to fall via gravitational force. Typically, fog-water collection is more feasible in windy areas at middle zone, due to the low-pressure air currents there. However so, one of the major issues surrounding the fog water collector are the efficiency of the system and the robustability of the fog collector element used. This paper is about the construction and performance analysis of fog harvesting model by using fog collector elements or mesh from stainless steel and polyproplene. Through this work the influence of surface morphology, length, hydrophobic, wettability and woven density of the mesh together with its water collecting capabilities is studied. We focus the work on studying the hydrodynamic and surface wetting model to calculate the fog gathering efficiency of the mesh. Appropriate amendments of the mesh, for example absorption qualities of the mesh surfaces, reduced diameter of the wire, and altering the wire spacing helps in a major yield to fog collection.

FOG

Fog (camanchaca;in spanish) are very similar to clouds except for the fact that it reaches the lower atmospheric surface, unlike clouds. Clouds tend to align themselves above the atmospheric surface. While a cloud moves through the wind and flows over and around a mountain, the fog is present any place the cloud touches the terrain. To a meteorologist, the presence of a fog is constituted by visibility about 300. The fog consists of tiny liquid water droplets from 1 to 40 micrometers (μm) in diameter. An ordinary droplet diameter is 10 μm. Fog can be found anywhere even in the most arid and desolate location such as deserts. The altitude and location determine its liquid water content (LWC), and its ease of collection depends on the air moisture content in an area. day in a living environment. In areas near to the sea,it has been a source of freshwater (Linares et al., 2014).Moreover, in arid deserts such the Atacama Desert, Chile which has not seen rain fall in a long time has seen a crop of fog collector installations in Padre Hurtado (31.5◦S) (Osses et al.,2000) provide the local community with freshwater supply.

SHADE COEFFICIENT(SC)

The shade coefficient of a fog collector mesh is the percentage of the whole mesh location that can collect water droplets (de Dios Rivera, 2011), and the mesh material base area is divided throughout the entire region spanned by means of the mesh. The polypropylene mesh generally utilized in fog collectors has a 35 % shade coefficient. However so, the usage of the mesh in thick layers brings the shade coefficient closer to 50 %, depending on the configuration of the thick layers arrangement.

TYPES OF FOG COLLECTORS

Fog collector are used in a variety of ways to do fog harvesting, and as such comprise of many different types,each suited to its location and terrain.The most commonly used collectors are the Raschel mesh,though nowadays they have been replaced by the polypropylene mesh.A study compared the relative water harvesting efficiency of the raschel mesh and its polypropylene counterpart.It discovered that polypropylene had better durability and elastic recovery as opposed to its counterpart.(Tan et al., 2019).

Standard fog collector (SFC) and large fog collector(LFC) are among the main category of fog collectors used today for fog harvesting.Fog harvesting yields differ between sites Namibia (Shanyengana et al., 2002), Jordan (Al-Jayyousi and Mohsen, 1999), South Africa (Olivier and De Rautenbach, 2002), Oman (Abdul-Wahab et al., 2007; Abdul-Wahab and Lea, 2008) Canary Islands (Jaen, 2002) and Saudi Arabia (Gandhidasan and Abualhamayel, 2007; Gandhidasan et al., 2018) accordingly.The fog collector mesh nets that are being used to investigate in this experiment will be from stainless steel frame mesh (Mesh A), Polypropylene 50% SC (Mesh B) and the final one which is Polypropylene 73 % SC (Mesh C.) as indicated in Table 1 below.

Table 1: Fog collecting mesh used

Net Structure	Name and Characteristics
a) Mesh A 	- Single layer mesh - 50 % SC -Stainless-Steel
b) Mesh B 	- Single layer mesh - 50 % SC -Poly-propylene
c) Mesh C 	- Double layer mesh - 73 % SC -Poly-propylene

FOG HARVESTING FROM NATURE

For the most part, when researchers seek nature for motivation, they look to mimick or replicate the process which occurs there within a controlled environment towards an enhanced yield. Fog harvesting is similar, as it is inspired by desert plants and creatures, seeing what unique structures they may need to collect haze water. Hence, it was astounding when a haze gathering disclosure originated from a far wetter source: the noses of shorebirds. Furthermore, it signals a radical overhaul of fog collectors apparatus. Most haze accumulation is finished utilizing netarea texture, where the Standard Fog Collector, utilized everywhere throughout the world since Robert Schemenauer's first paper on it in 1994, comprises of a texture area 1 square meter in size and faces the breeze like minimal punctured sail. As the breeze blows fog through the gadget, water beads gather on the area and drop down into a trough, from which they stream down a cylinder into a compartment. Another strategy is reproducing a desert plant's haze gathering. But the method which interest researcher now are the shorebirds action dunking their mouths into the water while swimming, catching their little prey in water beads held between their bills. At this point, they open and close their snouts more than once to transport the prey- containing beads into their mouths. The winged creature’s open-and-close strategy could be adopted in fog collectors, whereby to bridle the haze to catch water from air. Two pivoted plates that meet up and after that move separately, serve to mirror the development of the shorebirds' bills. Beads of fog that gather on the plates are transported to the pivot each time the plates clip down and afterward independent. The area configuration is additionally better ready to withstand the solid breezes present in many fog- heavy areas than a solid plate would be. There are many other factors that affect water collection yields. The most important factor is wind velocity, and other factors include fog LWC, mesh characteristics, and droplet size distribution (Cereceda and Schemenauer, 1991).

Net Materials and its Properties

Polypropylene (PP) became famous in 1954 and won a strong recognition right away because it has the lowest density amongst other goods packing plastics. It also has an almost perfect packing resistance and can be processed through many procedures like injection moulding and extrusion. However so, its primary strength is the high temperature resistance which makes PP particularly suitable for gadgets along with trays, funnels, pails, bottles, carboys and device nets. Polypropylene is a free-colour fabric with important mechanical properties and it's far better than polyethylene. The polymer is produced by a technique of monomer connection known as addition polymerization. Through this process, heating, radiation or mediums (catalyst) are supplemented to join monomers together. As a result, propylene atoms and molecules are formed into lengthy polymer chemical chains. There are four different specific methods of the polymerization. They are solution polymerization, suspension polymerization, bulk polymerization and gas-phase polymerization. However, polypropylene properties change in method with procedure situations, copolymer components, atomic weight and molecular weight distribution. Polypropylene is a vinyl polymer in which each carbon atom is connected to a methyl organization and can be described as shown in Figure 1.

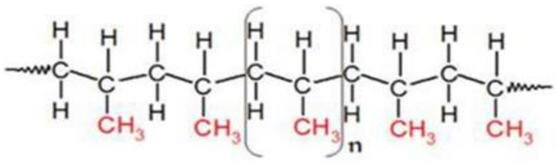

Figure 1: Polypropylene structure (Hisham A. Maddah, 2016)

Setup and Design of Prototype

The prototype was set into 3 different meshes as planned earlier using Stainless Steel frame mesh (Setup A), Poly-propylene 50% SC (Setup B) and the final one which is Poly-propylene 73 % SC (Setup C.)

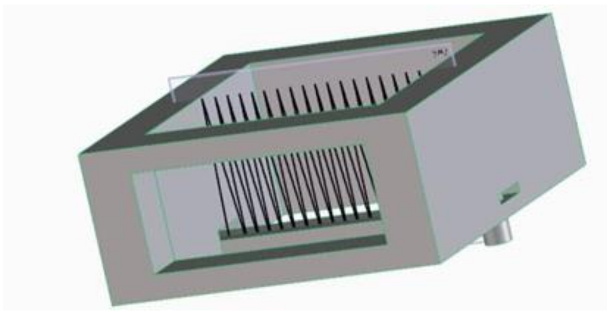

Figure 2: Design of the prototype

Overall Collection Efficiency

The effectiveness of haze water accumulation has been important to three components (Ghosh et al., 2015), to be specific water content in the fog, wind and total area and the haze water from the area to the trough. The general collection efficiency($\eta coll$) can be communicated as (de Dios Rivera, 2011; Ghosh et al., 2015):

$$\eta coll = \eta ae \times \eta cap \times \eta dr \qquad (1)$$

where ηae, ηcap and ηdr are the aerodynamic, catch and drainage efficiency, separately. Aerodynamic effectiveness (ηae) indicates the water bead in the fog that may crash into the mesh area. The portion of genuine fog bead that encroach on the area strands and gets saved is termed as the catch productivity (ηcap).The drainage efficiency (ηdr) refers to the fog water that enters the canal in the wake of crashing into the area. The fog water channel from the area relies upon the size of the bead, bead surface pressure and the distance across of the area base. The reason for twofold layering in the area is that with this structure, the gathered water dropletes loses are minimized in a solitary layer plan (Schemenauer and Joe, 1989; Schemenauer et al., 2005; Klemm et al., 2012). All the fog water caught by the area may not flow into the trough since a portion of the water might be lost because of high wind and might be spilled before gathering into the trough. Consequently, the drainage productivity is characterized as the real part of the water caught that enters the trough. In order to limit the drag, the trough must be situated appropriately to catch fog water. These drags are hard to assess because of the irregular breeze nature and must be represented through the seepage effectiveness.

Aerodynamic Efficiency (ηae)

The aerodynamic effectiveness relies upon two coefficients, the pressure coefficient (Co) and the drag coefficient (Cd). The pressure loss coefficient relies upon the area attributes, its strands and their weave. This speaks to the weight drop over the area and is straightforwardly identified with the shade coefficient. For a vertical area it is given by (Rivera, 2011):

$$Co = 1.3\ SC \quad (2)$$

where Co is the weight drag coefficient and SC is the area shade coefficient. The stream obstruction offered by the whole area get together is accounted by the drag coefficient. It differs with the angle proportion of the area yet autonomous of the shade coefficient of the area. The perspective region is characterized as the proportion of the width of the area to the tallness of the area utilized in the
authority. An estimated condition to foresee the streamlined productivity is given by (de Dios Rivera, 2011):

$$\eta_{ae} = \left(\frac{SC}{1 + \sqrt{\frac{C_o}{C_d}}} \right) \quad (3)$$

Deposition Efficiency (ηdep)

The drainage productivity is hard to assess because of fog re-entrapment and untimely drainage of beads. In this manner, the affidavit productivity is characterized as the division of haze beads that are really kept from the haze loaded breeze towards the area filaments. The testimony effectiveness speaks to the result of impaction efficiency and the seepage productivity. It is given by (Park et al., 2013):

$$\eta_{dep} = \frac{St}{\left(St + \frac{\pi}{2} \right)} \quad (4)$$

The overall collection efficiency can be simplified as,

$$\eta_{coll} = \eta_{ae} \times \eta_{dep} \quad (5)$$

where ηcoll, ηae, and ηdep are the overall collection, aerodynamic, and deposition efficiency, respectively. The amount of fog water captured by the mesh can be predicted by Walmsley et al. (1996) and Ritter et al. (2008):

$$Q = 3.6\ (LWC)\ \eta_{coll} V A_{tot} \quad (6)$$

Where Q is the rate of fog water gathered, LWC is the liquid water content in the fog, ηcoll is the general collection efficiency, V is the wind speed and A tot is the total area of the mesh. From the above condition the measure of water caught depends upon the LWC, the aerodynamic effectiveness as parameterized through the shade coefficient, weight drop and drag and the deposition productivity as parameterized through the Stokes number.

RESULTS AND DISCUSSION

Based on the experimental work carried out with the prototype fog collector we obtained several different results as expected.We tsrated by looking at the comparison of the theoretical and obtained humidity at the installation site, as indicated by figure 3. From our theoretical calculation we see that the humidity is under the super-saturation region where the water droplets are converted into fog instantaneously and therefore the water collection rate should be high. However,our experimental data proves that the humidity range is actually below saturated level therefore, the rate of water collection is lower than the theoretical expectation,at our site. Moreover, theoretical calculation show that the flow rate is higher than the experimental data, due to frictional losses. The efficiency calculationof the meshes are similar to the experimental data and prove to be a better comparison method in comparing the theoretical and experimental performance of the fog water collectors,as seen in figure 4 and 5.

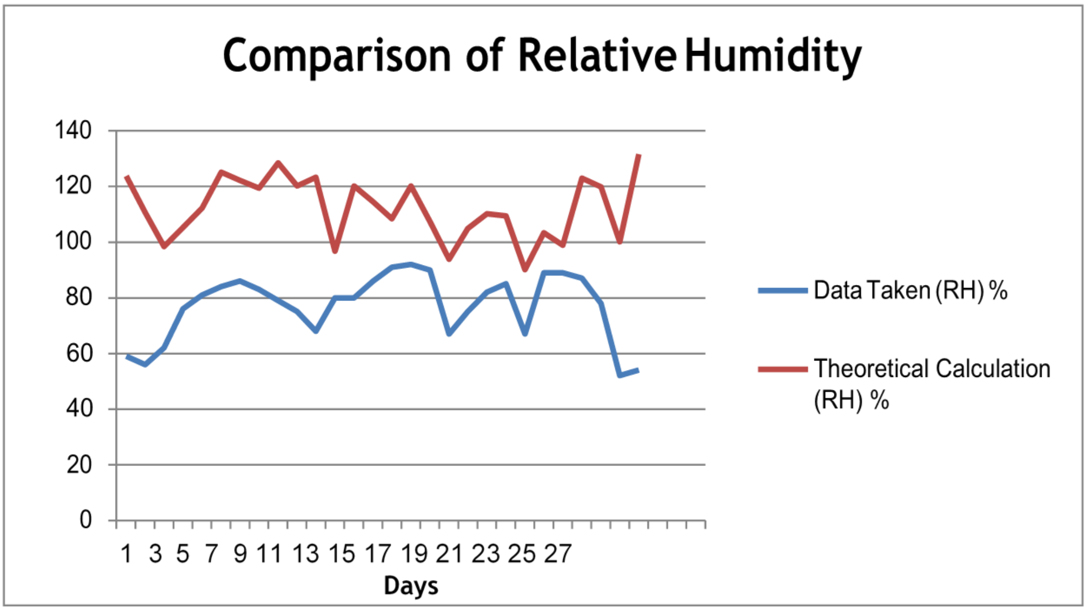

Figure 3: Comparison of Relative Humidity

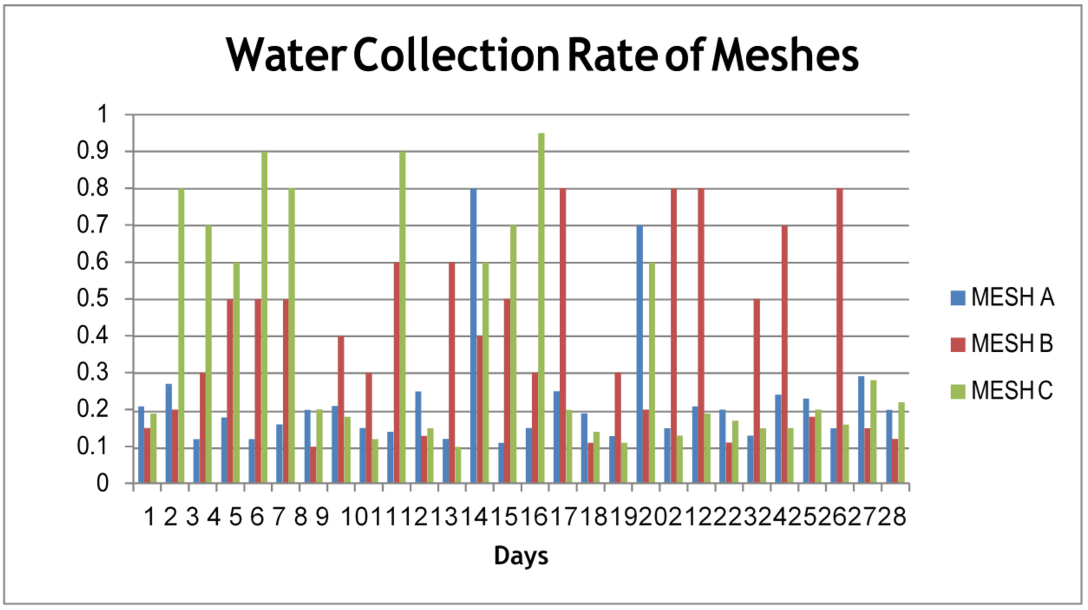

Figure 4: Rate of water Collected

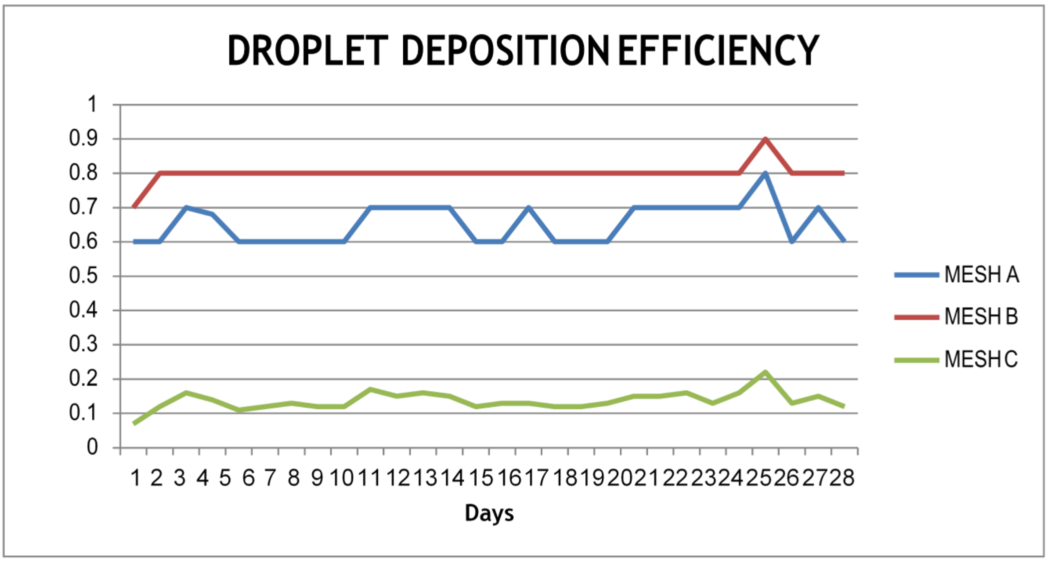

Figure 5: Droplet Deposition Efficiency

CONCLUSIONS

The fog harvesting prototype designed and investigated did functionally well and its purpose of study was fulfilled. The prototype did not encounter any serious maintenance problems rather than just minor fix for the meshes like re-adjusting and fixation. It design was little complex but the cost of producing the prototype was way cheaper than the predicted amount. The structure and meshes withstood the temperature and natural heat very well and proved to be a durable construction. With regard to the data obtained a large fog collector protype could be planned next to build upon the findings obtained.The results obtained clearly show that most important factor in the performance of the standard fog collector would be the fog collector element or mesh used.A hydrophobic materials facilitates and increases the water volume collected, and has a more prominent role that the shading coefficient.Based on these findings, the body of knowledge on fog collector can be expanded to include either more robust material like stainless steel,or explore the feasibility of incorporating hydrophobic material to coat the fog collector element.Moreover, compared to previous fog collector research which primarily investigated open air fog collector models where the elements or meshes were exposed to the air circulation ,our work focused on an enclosed model. In the typical open air systems once the air passes through the meshes, the water particle deposition doesn't occur again. However in this experiment, the model built as an enclosed environment prototype in which the air flowing into the box are swept therough the meshes twice in which the water deposition reoccurs and the recycling of air flown increases the water deposition percentage.This enclosed model could be further developed by the industry to see the potential of enclosed fog water collectors.Finally,the fog collector elements or meshes selected for the experiment was robust and able to withstand high temperature as the model is exposed to direct heat (sun). Furthermore, the model was placed in a high rise area, therefore certain minimum load bearing capabilities was designed into the prototype so that it would not be uprooted by strong wind and that the wind will not affect the experiment being conducted.As such these findings can be further incorporated and improved in future work.Based on the results of this experimental study we hope it will guide fog collector mesh selection for future studies. In conclusion, the yield of water collected proved that the fog harvesting method is a reliable method to accumulate water in residential high-rise areas. Technologically in future, this fog harvesting system can be enhanced into a better large, scaled project. Besides that, this project can be utilised in domestic purposes and irrigation water systems to be used in plantation and implemented in rural areas.

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