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Review Article

PERFORMANCE EVALUATION OF TWO DIFFERENT TYPES OF MESH FO RFOG HARVESTING UNDER LABORATORY CONDITIONS

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A R T I C L E I N F O

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A B S T R A C T

An innovative technology that can aid in harnessing a clean water supply is to capture the moisture from the air. Fog harvesting technology is based on the principle that wherever mist or fog touches a metallic or net surface it condenses to form dew or droplets of precious water. The technology is innovative, environmentally appropriate, socially beneficial and cost-effective. It epitomizes the "green technology' to obtain clean, fresh water almost anywhere from the earth. An experimental investigation was performed to compare the fog collecting efficiency between two mesh structure. As a result, When the model was run for one-hour period, the rectangular and inverted triangular tapered mesh (shade net) collected a total of 6.6 ml and 4.5 ml respectively. The water run-off dynamics of both the mesh were also studied by observing the water collected at different time intervals, within 20 min in the fog flow the rectangular mesh had collected 2.4 ml of water and subsequent water collections were monitored at interval of 10 min time up to one hour and average subsequent collections was found to be 1.05 ml. Likewise, the shade net had collected 1.5 ml of water and 0.75 ml in the subsequent time interval.

INTRODUCTION

The most pressing issue of this 21st century is inclined towards the availability and accessibility to safe and clean water. A per UN report, two out of three people will be living in a country that's struggling to meet their demands for water in the next 10 years. India is one of the most water-challenged countries in the world, from its deepest aquifers to its largest rivers. With almost 54 percent of India's total area facing high to extremely high stress, almost 600 million people are at higher risk of surface water disruptions (timesnownews).

Ground water levels are falling and most of its water resources are often severely polluted. Climate change, increasing water scarcity, population growth, demographic changes, and urbanization already pose challenges for water supply systems. In the most recent case of the water crisis, Cape Town, South Africa, they're calling it "Day Zero" -- the day when the taps run dry (CNN report). A changing climate and a growing metro's population maybe two of the causes of this crisis. Options for water sources used for drinking and irrigation will continue to evolve, with an increasing reliance on groundwater and alternative sources, including wastewater.An innovative technology that can aid in harnessing a clean water supply is to capture the moisture from the air.

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Capturing water from the air and fog are often overlooked but hold great promise for a supply of clean water. Fog harvesting technology is particularly suitable for mountainous areas (400 to 1200 m) where communities often live in remote condition, capital investment and other costs are generally found to be low in comparison with conventional sources of water supply (UNEP, 1997b). Around 3800 litres per day can be collected from a collecting surface area of about 70 m^2 (**Schemenauer*et al*, 2004**).

In this technology, the water is drawn directly from the moisture present in the atmosphere. The technology is based on the principle that wherever mist or fog touches a metallic or net surface it condenses to form dew or droplets of precious water. The technology is innovative, environmentally appropriate, socially beneficial and cost-effective. It epitomizes the "green technology' to obtain clean, fresh water almost anywhere from the earth. This technology is also yielding good results in neighbouring countries such as Nepal. This technology is advantageous as a source of providing clean water which often meets WHO standards for different purposes without any adverse effects on the environment. The harvested water can then be used for irrigation purpose and also for drinking with lesser treatment. Additionally, the technology also provides an opportunity to restore natural vegetation and support agricultural practices through the sourcing of clear water for crops and livestock. Thereby recapturing all the above-cited details about the potential of fog harvesting in the hilly region of Sikkim, a performance evaluation of fog collecting effectiveness between two different mesh structures was done for a detailed study.

MATERIALS AND METHODS

The Laboratory model of Fog Harvesting Mechanisms was designed which consists of the following major parts (Fog Generator, Fan, Water container, Pipe, Collection Chamber, Mesh structure as shown in Figure. 1. A plastic water container of circular shape was used to store water upto a certain level inside the container. The two humidifiers were placed at the bottom part of the container to generate the mist. A circular pipe of 6 cm diameter (approx.) was used which protruded from the water container. The circular pipe extended upto the fog collecting chamber. A closed chamber using transparent glass walls was fabricated to maintain the required humidity for condensation to take place inside the closed chamber. At the level of the circular pipe from the water container, the mesh structure frame was fixed at two different locations inside the glass chamber. The mesh structure was fixed into a rectangular frame which has a conveying channel for the collected water to flow into the collecting tank outside the closed chamber.

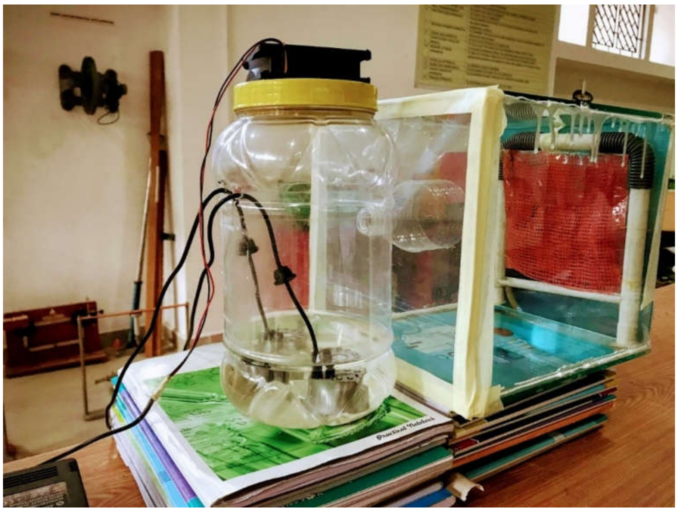

Fig 1 Laboratory Fog Harvesting Mechanism

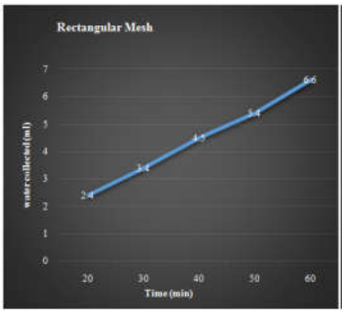

Figure 1 Water collected at a distance of 16 cm

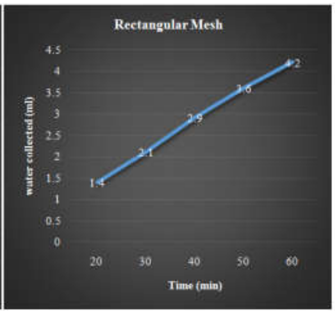

Figure 2 Water collected at a distance of 8 cm

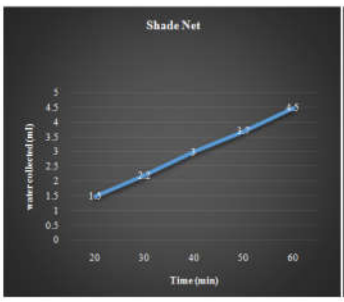

Figure 3 Water collected at a distance of 16 cm

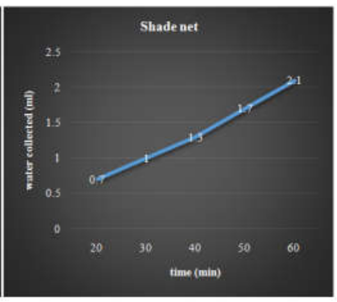

Figure 4 Water collected at a distance of 8 cm

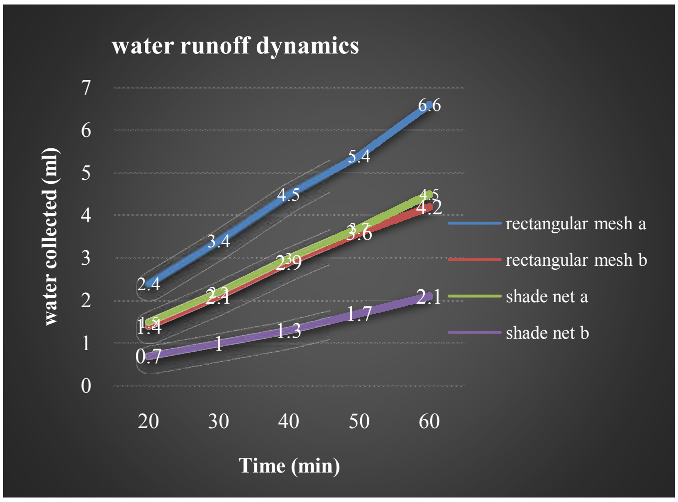

Figure 5 Water runoff dynamics of the two mesh structure at different locations.

Table 1 experimental result of water runoff dynamics of mesh structures

Sl. No.	Mesh	Distance from the end of the pipe (cm)	Water runoff dynamics over a period of one hour (ml)						Collecting rate (ml/cm^2/hr)
			20	30	40	50	60	Total	
1	A	16	2.4	1	1.1	0.9	1.2	**6.6**	**0.034**
		8	1.4	0.7	0.8	0.7	0.7	**4.3**	**0.021**
2	B	16	1.5	0.7	0.8	0.7	0.8	**4.5**	**0.023**
		8	0.7	0.3	0.3	0.4	0.4	**2.1**	**0.011**

The frame was made from a pvc pipe of 2 cm diameter. The conveying pipe at the bottom of the frame was given a small slope for easy flow of the collected water from the mess structure. Two different mesh structure, one having an effective collection area of 0.0195 $m^2$was used from reused materials. The other mesh structure (shade net) made from High Density Polyethylene (HDPE).

Development of Fog Harvesting Mechanisms

Two humidifiers were used to generate the mist flow from the water container. A plastic pipe is employed to guide this mist flow towards the closed chamber. A 12 V cooling fan was used to increase the mist flow speed. At the end of the pipe, the mist flow speed is approx.0.33 m/s, which was measured using a wind speed meter. The entire process is conducted in a closed chamber, 99 % humidity is maintained inside the chamber for the condensation process to occur and a humidity meter is used to monitor the humidity throughout a process cycle. A tested mesh is placed one at a time at a distance of 16 cm and 8 cmaway from the exit of the pipe, and a glass container is put below the mesh with the help of a conveying pipe to collect water that drains down. Two rectangular mesh were tested for their collecting efficiency initially. In case of the first tested mesh, every fibre has a rectangular collecting surface. For the second shade net mesh, it is arranged in a triangular and tapered at the bottom arrangement for the fibre.

Working condition of the model

The fog humidifier was run initially for around 25 minutes to maintain the required humidity inside the glass chamber. After the humidity reaches around 99 %, condensation occurs, thereafter the deposition of small droplets starts on the collecting surface of the mesh structure. Each mesh structure was tested for a total running time of one hour, where the observation was noted down at a uniform interval of 10 minutes. For a particular mesh structure, it was tested at two different locations inside the closed glass chamber. The collecting efficiency of each mesh structure was then calculated as Collecting efficiency (per day basis) (assuming 12 hrs of fog availability)

= volume of water collected / effective collecting area (1)

RESULTS AND DISCUSSION

Fog collection studies

The fog interception and collection capability of the two different mesh structure wereexamined using a consistent fog/mist flow with an airflow rate of 1.2km/hr and 0.6 km/hr. The individual mesh structure frame was placed at $90^0$with the protruded plastic pipe to determine the fog collecting efficiency. The size of thedeposited droplets ranged from a few 3 to 5 mm. When the model was run for one-hour period, the rectangular and inverted triangular tapered mesh (shade net) collected a total of 6.6 ml and 4.5 ml respectively. The quantity of fog water received per sq. cm for both the mesh was calculatedfrom the effective surface area used for experiments and was found to be 0.369 ml/cm^2 and 0.277 ml/cm^2 respectively. The water run-off dynamics of both the mesh were also studied by observing the water collected at different timeintervals and the obtained results are shown in Table 1.Within 20 min in the fog flow the rectangular mesh had collected 2.4mlof water incase of 16 cm distanceand subsequent water collections were monitored at an interval of 10 min time up to one hour and average subsequent collections were found to be 1.4ml for a distance of 8 cm. Likewise, the shade net had collected 1.5 ml of water and 0.75 ml in the subsequent time interval at a distance of 16 cm and 8 cm respectively as shown in Table.1.

Collection Efficiency

The collection efficiency, η, of a mesh depends on aerodynamic collection efficiency(η_{ace}), capture efficiency (η_{cap}), and draining efficiency (η_{dra}) (Rivera)

$$\eta = \eta_{ace}\eta_{cap}\eta_{dra}. \quad \text{... (2)}$$

In the study, only the capture efficiency and draining efficiency of the mesh structure was considered and results were obtained on the basis of these efficiencies. Water sample collection for each mesh structure was done at two different locations from the end of the glass chamber and are presented in Table 1. The individual, as well as comparative analysis of the water runoff dynamics of the different mesh structure, are presented from Figure 1 to 4.

The collecting efficiency of fog/moisture was compared between the rectangular mesh and inverted tapered shade net under the same range of wind velocities and humidity condition, and at two different distance. Under the similar working conditions and at two different distance considered, the rectangular mesh have performed significantly better than the shaded net. The rectangular mesh has a draining path different from that of the shaded net. The water runoff dynamics of the two mesh structure at different locations are presented in Figure 5.

On a 90^0 mesh design, the tiny droplets take time to fall, because their gravity is less than the resistance force induced by the contact angle hysteresis. Inthe case of these rectangular meshes, every fibre has a slippery surface which reduces the friction and adds to the fast movement of the water droplets. Due to gravity, large drops that are condensed on a rectangular mesh may move down from the mesh.However, tiny drops may get stuck and affect the merging of these small droplets on the filaments and thus are not harvested which may be seen in the case of shade net as per the orientation of the fibre.

SUMMARY AND CONCLUSION

In this work, we have explored the possibility of harvesting an alternative source of clean water particularly for a period where the scarcity is at the highest and aggravates with the topography also. A laboratory model was fabricated for testing the feasibility of harnessing this clean source of water by using reused materials.

- A high interdependence of wind speed variation on fog collecting efficiency was observed.
- The nature of surface, its rigidity, thickness of the fibre also affects the amount of water harvested. It was more when the surface of the fibre was slippery which is due to a reduction in the frictional surface.
- The angle of the collecting frame with respect to the ground also impacts on the movement of the collected water. A vertically oriented mess structure frame results in less water harvested under similar conditions.

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