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Investigating the Effect of Mesh Structure and Mesh Retaining Module on the Rate of Fog Harvesting

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ABSTRACT: Nowadays, the impact of water scarcity is felt more than ever due to population growth, environmental changes, and increased industrial as well as agricultural developments. Thus, it is imperative to harvest water from every available source such as fog. The process of harvesting water from fog which is a cost-effective method has attracted the attention of many researchers trying to increase the efficiency of this method in various ways. In this research, a practical test system is presented to investigate the influence of the mesh and the mesh retaining module on the rate of fog harvesting. 6 sets of modules and meshes were exposed to the fog flow and after taking the results, the most effective factor between the meshes and the module was determined. All factors affecting fog harvesting were kept constant during the test, and only the effects of the mesh and module were examined. Teflon yarns mesh which increased the fog harvesting by 23 to 77%, was chosen as the best mesh, while the Modular Funnel-Large Fog Collector module which increased the rate of fog collection by 7 to 9 times was considered as the best module. This unique effectiveness should be attributed to the aerodynamic property of the MF-LFC module, which uses the rate of fog flow effectively in order to increase water harvesting.

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1- Introduction

Today, population growth, accelerated agricultural and industrial developments to meet the demands of the people, and climate change has caused the problem of water shortage to be felt more than ever. Therefore, high-efficiency methods are required for potable water supply, and some countries have resorted to water distillation and desalination processes, which require high energy and operating costs, and more non-renewable energy sources are required for these methods 1]]. However, not all countries are able to use these methods. One of the low-cost and low-energy methods is water collection from fog, which has been studied extensively to increase its efficiency2]]. Studies have shown that many plants and animals are able to collect water from fog, which has inspired many researchers to develop high-efficiency meshes to mimic the same approach to water collection3]]. Moreover, to increase the fog harvesting rate, it has been observed that the mesh material has a significant effect on the fog harvesting rate, which is achieved by hydrophobic and superhydrophobic coatings4]].

In recent years, most studies on increasing the rate of water collection from fog have been based on the construction of hydrophilic and hydrophobic two-part meshes, even though their positive impact on increasing the rate of the collection is far from meeting the actual real life requirements. The limitations are based on the high cost of manufacturing the meshes and setting up the processes as well as the difficulty to scale up the production from laboratory to industry level. However, the process of collection of water from fog depends on several factors such as wind flowrate, the configuration of the module, the structure of mesh, the material of mesh, etc. It is imperative to focus on the effect of these parameters since mesh material is only one of the effective parameters in increasing the collection rate.

In this project, the effect of the structure of mesh and the mesh retaining module on the water collection rate will be compared; In this way, other effective factors such as mesh material, moisture content of the fog flow, and the fog flowrate are kept constant and by changing the module and structure of mesh, the rate of water collection is measured. Finally, the effect of changing the module and changing the mesh structure on the water collection rate will be determined and the most effective factor will be selected between the two. Since in this project the effectiveness of the mesh and the module should be compared with each other, modules should be designed in such a way that causes the least structural disturbance to the fog flow. Therefore, two Modular Funnel - Large Fog Collector (MF-LFC) and double cylindrical modules were designed and built. The logic used in the design is based on the results presented in scientific publications [5,

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Fig. 1. Experimental setup. Upper picture: Schematic setup. Lower picture: Real setup

6]. By building these two modules at a laboratory scale, we can move forward in line with the project goal.

2- Methodology

In this research, the effect of mesh retaining module and mesh structure on increasing the fog harvesting rate was investigated experimentally. Hence, the pieces of equipment used in this experiment include a humidifier, 3-way chamber, a double cylindrical module with hexagonal mesh, a double cylindrical module with Teflon yarns mesh, a double cylindrical module with Rachel mesh, a Modular Funnel - Large Fog Collector (MF-LFC) Module with Hexagonal mesh, MF-LFC with a Rachel mesh, MF-LFC with a Teflon yarns mesh, a water collection tank and instruments for measuring temperature, relative humidity and the amount of water collected. In this experiment, the ambient temperature is 20±2 ºC, the relative humidity is 80-90%, the fog flowrate is 550 ml / h and the distance of the humidifier from the mesh is 8 cm. A schematic and realistic diagram of the test layout is shown in Fig. 1:

Each set of meshes and modules is placed in a 3-way chamber (according to Fig. 1) and exposed to fog flow for 1 hour. Then the amount of water collected in the tank is measured and finally, by analyzing the results, the degree of effectiveness of meshes and modules on the fog harvesting rate is determined. It should be noted that the repeatability of the experiments was investigated and the experiments have shown reasonable repeatability.

Table 1. Averaged amount of collected water

Module	Mesh	Fog harvesting rate (l/m^2.day)
Double cylindrical	Teflon yarns	7.28
Double cylindrical	Hexagonal	5.06
Double cylindrical	Rachel	5.62
MF-LFC	Teflon yarns	62.58
MF-LFC	Hexagonal	35.38
MF-LFC	Rachel	50.07

3- Results and Discussion

The average amount of water collected from each set of meshes and modules is presented in Table 1:

According to Table 1, it can be seen that the Double cylindrical module with Teflon yarns mesh and a collection rate of 7.28 l/m^2.day delivers 44% better performance than the hexagonal mesh and 23% better performance than the Rachel mesh. In the MF-LFC, the Teflon yarns mesh with a collection rate of 62.58 l/m^2.day, has 77% better performance than the hexagonal mesh and 25% better performance than the Rachel mesh. Thus, Teflon yarns mesh has the best performance and hexagonal mesh has the weakest performance among the meshes. Moreover, the MF-LFC has 7 to 9 times better performance than a double cylindrical module.

The better performance of Teflon yarns meshes compared to other meshes can be explained by the fact that the density of water droplets formed on Teflon yarns is higher than those on hexagonal and Rachel nets and the droplet nucleation is better. Nucleation and formation of larger droplets with proper guidance of the nuclei have a significant effect on the fog collection rate. The one-way direction of the nuclei also affects the rate of fog collection [7]. For those reasons, the Teflon yarns mesh showed better performance than other meshes.

The better performance of the MF-LFC module versus the double cylindrical module can be explained by the fact that the drag force of the MF-LFC module against fog flow (wind) is greater than the drag force of the double cylindrical module since fog velocity decreases at the mesh surface and water droplets do not pass through the mesh easily and the collection rate increases. In general, by focusing on the aerodynamic structure of the mesh retaining modules and the optimal use of fog flowrate, the fog collection rate can be significantly increased [5].

4- Conclusions

In this project, the effects of mesh and mesh retaining modules on the fog collection rate were investigated. The results showed that the Teflon yarns mesh was better than other meshes due to its high nucleation capacity and the unidirectional flow of nuclei in this mesh, which led to the faster formation of large water droplets. In other words, Teflon yarns mesh showed 44 to 77% and 23 to 25% better performance than hexagonal and Rachel meshes, respectively. On the other hand, the MF-LFC module, due to its unique aerodynamic structure, provided impressive statistical results and increased the rate of fog collection by 7 to 9 times. The results clearly show that in addition to the mesh material, by focusing on the aerodynamic structure of the modules, the rate of water collection from fog can be significantly increased.

References

[1] M.A. Imteaz, G. Al-Hassan, A. Shanableh, J. Naser, Development of a mathematical model for the quantification of fog-collection, Resources, conservation and recycling, 57 (2011) 10-14.

[2] D. Song, B. Bhushan, Enhancement of water collection and transport in bioinspired triangular patterns from combined fog and condensation, Journal of colloid and interface science, 557 (2019) 528-536.

[3] H. Bai, T. Zhao, X. Wang, Y. Wu, K. Li, C. Yu, L. Jiang, M. Cao, Cactus kirigami for efficient fog harvesting: simplifying a 3D cactus into 2D paper art, Journal of Materials Chemistry A, 8(27) (2020) 13452-13458.

[4] J. Knapczyk-Korczak, P.K. Szewczyk, U. Stachewicz, The importance of nanofiber hydrophobicity for effective fog water collection, RSC Advances, 11(18) (2021) 10866-10873.

[5] R. Holmes, J. de Dios Rivera, E. de la Jara, Large fog collectors: New strategies for collection efficiency and structural response to wind pressure, Atmospheric Research, 151 (2015) 236-249.

[6] M. Mousavi-baygi, The implementation of fog water collection systems in Northeast of Iran, International Journal of Pure and Applied Physics, 4(1) (2008) 13-21.

[7] V. Sharma, H. Ali-Löytty, A. Koivikko, K. Yiannacou, K. Lahtonen, V. Sariola, Copper oxide microtufts on natural fractals for efficient water harvesting, Langmuir, 37(11) (2021) 3370-3381.

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