CHEMICAL ENGINEERING TRANSACTIONS

VOL. 117, 2025

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Fabrizio Bezzo, Flavio Manenti, Gabriele Pannocchia, Almerinda di Benedetto

ISBN 979-12-81206-17-5; **ISSN** 2283-9216

DOI: 10.3303/CET25117083

Efficient Water Capture Process with Pentahedral Fog Catcher Design, n Arid Zone Lima

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Water scarcity is an increasingly recurrent problem in many parts of the world, especially in arid and coastal areas accentuated by climate change. The water resource is very accessible to populations with scarce economic resources, so finding a way to obtain this resource is a priority. Fog catchers have emerged as a viable solution for capturing water from fog; they are systems that work by condensing the moisture present in the fog through a special mesh that traps it and then channels it into a container. Although fog catchers already exist and have been successfully implemented, there is a continuous effort to improve their efficiency, a key aspect being the design of the fog catcher itself. In that sense, the research aimed to design and build a pentahedral-shaped fog catcher and evaluate its efficiency in capturing fog water compared to a traditional design. As a result, it was obtained that the pentahedral design with a panel area of 45 m^2 each, captured an average of 188 litres of water in 24 hours, compared to the traditional design that captured 34.56 litres in the same time, both installed in the same place (at an altitude of 718.6 m.a.s.l.) and in the same meteorological conditions (temperature of around 16 °C and relative humidity of 90.85 to 92.4% on average). It is established that water collection with fog catchers is a viable solution, presenting itself as a sustainable alternative for areas with water scarcity, it does not require traditional water sources nor does it need energy.

1. Introduction

Water scarcity is an urgent and pressing challenge today, with an impact that affects almost two thirds of the world's population for one month every year; this phenomenon is mainly caused by human action characterized by the inability to meet the total water demand of the population and other ecosystems (Alwarthan, et al., 2024). The main causes of this water crisis are climate change (Gardner, 23010), the inefficient use of water as in the case of agriculture where 68% of the world's water is consumed, the high contamination of water sources and the overexploitation of aquifers, industry consumes 20% of the world's water, as does domestic consumption (Alwarthan, et al., 2024).

Water scarcity has a profound impact in many ways. In the environmental sphere it causes direct impacts on public health, the economy, and can become a source of conflict within communities (Bell, 2015); it also impacts biodiversity, contamination of the food chain and the disappearance of many ecosystems (Arce and Pfister, 2016). The challenges associated with water scarcity, it is indicated, will be exacerbated by several factors resulting in unsustainable management and extraction of water sources that may be depleted in the coming decades (Rich et al., 2023).

Faced with this crisis, there are studies that seek to alleviate the problem of water scarcity; for example, research in southeaster Africa reports that water was obtained using fog as a source, also proving that it was a promising way to overcome water scarcity, highlighting its low maintenance cost and sustainability for communities with adverse water collection conditions (Zaitizila I. and Yun G., 2021). These projects on the use of fog catchers have demonstrated that fog water harvesting can be an effective and sustainable solution, especially in regions with persistent fog and limited water resources (Oktor, et al., 2024). Fog catchers are systems constructed with panels or fine meshes that capture tiny droplets of water contained in the fog and by gravity they fall and are collected reaching in some cases a volume of up to 400 liters of water per day when optimal conditions are present (Sustainability, 2023).

Paper Received: 20 December 2024; Revised: 16 March 2025; Accepted: 6 May 2025
Please cite this article as: Huaranca Paz C.M., Chavez Yalta L., Benites-Alfaro E., 2025, Efficient Water Capture Process with Pentahedral Fog Catcher Design, in Arid Zone Lima, Chemical Engineering Transactions, 117, 493-498 DOI:10.3303/CET25117083

Fog catchers have been successfully implemented in several countries, including Chile, Peru, Ecuador, Guatemala, Nepal and some African countries, in Spain, in the Canary Islands area, this technology has proven to be a viable alternative to face the severe drought affecting the region (Manzoor, et al., 2021). In Colombia, the Air Force uses fog catchers in military posts on hills with difficult access, where conventional water supply infrastructure is not easy to install, is insufficient or non-existent (Oktor, et al., 2024).
Water harvesting by means of fog catchers is a sustainable and sustainable solution that allows water care and contributes to the fulfillment of the Sustainable Development Goals, specifically referred to clean water and sanitation (Arce, et al., 2023); however, although these systems are advantageous and are a promising technology, limitations must also be considered, the most important being that the water obtained can only be used for irrigation activities, cleaning and cleaning tasks but not for direct human consumption, for which additional treatment is required, improving materials including innovative types and designs of fog catchers, among other aspects (Verbrugghe and Khan, 2023). Water purification could be done by complementary methods such as purification by progressive concentration by freezing Yan, et al, 2024).
The objective of the research was to evaluate the amount of water trapped by a pentahedral design fog trap system compared to a traditional single panel design; It is also highlighted that in small areas with fog, a greater number of fog catchers could be installed compared to the traditional single panel.

2. Methodology

2.1 Design of the fog catcher

A five-panel fog catcher with a single vertex was designed. The panels were made up of Raschel mesh panels with wooden frames on the edge of the mesh with dimensions of 3 m long and 3 m high. Raschel mesh was chosen because it is a reliable and widely used material due to the balance between efficiency, durability and cost, which can be used in low-income communities (Feld et al., 2016). It also adapts to coatings and geometric modifications to improve its efficiency (Rajaram et al., 2016). Other complementary materials used in the construction of the prototype of fog catchers under study were: gutters, polyvinyl chloride (PVC) reducers and a PVC tank for water collection (See Figure 1).

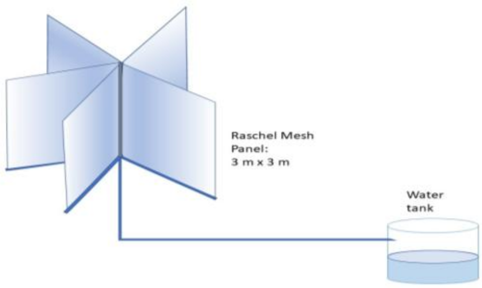

Figure 1: Pentahedral fog-catcher design

2.2. Location of the fog trap installation

The fog trap was installed in the jurisdiction of Carabayllo, north of Lima, in the sector called “Lomas de Primavera de Carabayllo”, an area with a fragile ecosystem, with the presence of very varied flora and fauna, but which in periods from August to May requires attention because it is more vulnerable due to lack of water. The fog trap was installed at coordinates 8694416N,273033E, at an altitude of 718.6 meters above sea level.

2.3. Water capture monitoring

The water capture monitoring period with the fog catcher began on May 15, 2024 and culminated on July 30 of the same year. Measurements were taken for 24-hour periods

3. Results and discussion

3.1. Meteorological conditions

During the monitoring stage, the meteorological parameters taken into account were wind speed, temperature and humidity at the site. The averages of these parameters are shown in Table 1.

Table 1: Meteorological parameters

Periods in year 2024	Wind direction	Wind speed (Km/h)	Temperature (°C)	Humidity (%)
May 15 – 31	NE	6.3	15.24	90.95
July 01 – 30	NE	4.8	16.67	90.85
July 01 – 31	NE	4.9	16.07	92.4
August 1– 15	NE	4.8	16.02	91.26

Relative humidity plays an important role in fog water collection efficiency because it influences droplet size and distribution, when this humidity is high larger droplets are formed which allows them to be captured more easily on the fog catcher surfaces as opposed to low relative humidity (Fritz, et al... 2021).Also high relative humidity means higher water vapor in the air which leads to higher fog formation, this is justified by findings where the average depression in the air is lower than the average depression in the fog catcher, 2021).Also high relative humidity means higher water vapor in the air leading to higher fog formation, this is justified by findings where fog collection efficiency decreases when the mean dew point depression (DPD) is higher than 0.2 °C or the mean liquid water content (LWC) is lower than 0.045 g/m3 (Montecinos et al., 2018). It is also important to evaluate the material of the fog trap, thus those materials that switch between hydrophobic and hydrophilic states adapt to different humidity levels improving water collection efficiency (Paris, et al., 2023).

Humidity also influences the aerodynamic behavior of fog droplets, when it is higher it generates more stable fog improving the aerodynamic collection efficiency of fog catchers, i.e. certain speed the humidity flow can influence the capture efficiency (Ukolov A.I., and Popova T.N., 2023). The place where the pentahedral fog catcher was installed has the environmental conditions conducive to capturing water by this means, where temperature and wind speed interact with humidity to obtain the collection of water with fog catchers.

In the research it was found that the wind speed was on average 4.8 to 6.3 km / h, studies indicate that the optimal wind speed ranges between 5 and 7 m / s maximize the aerodynamic collection efficiency (Carbajal, et al., 2020), high speeds can affect the structure of the fog catchers (Holmes, et al., 2015). Here it can be seen that at low speeds the formation of fog is improved by replacement by new humid air instead of old humid air, but on the contrary, at high speeds it can affect the formation of fog (Imteaz, et al., 2011); However, experiences according to the scientific literature indicate that high wind speeds generally improve fog water collection because fast winds transport more fog droplets to the mesh and can be captured (Park, 2021). In one investigation it was found that for a fog droplet size of 30 μm and a wind speed of 4 m/s, it is possible to collect at a rate of 0.65 to 9.7 L/m2 per hour when the liquid water content in the Fog (LWC) varies from 0.2 to 3 g/m3 respectively (Gandhidasan, et al., 2018).

3.2. Volume of water captured by the fog catcher

During the monitoring to see the amount of water captured by the fog catcher from the fog that occurred in the place, the volume indicated in Table 2 was found. The average reached in the period from May 15 to June 31 stands out, where 188 Liters were captured in 24 hours. This was due to a time when the temperature was lower than the following two months and with higher wind speed, despite the fact that the relative humidity was relatively lower.

Table 2: The Volume of water captured by the fog catcher

Periods in the year 2024	Volume of water captured (L)	Capture time (h)
May 15 – 31	188.00	24
July 01 – 30	160.06	24
July 01 – 31	162.00	24
August 1– 15	155.66	24

The mesh used in constructing the fog catcher panels was of the standard Raschel type at 35% shade. This material was taken based on the scientific literature which indicates that this type of material has good efficiency in capturing water droplets from the fog, there being steel meshes and three-dimensional fabric (FogHa-Tin) that can be used, but other particular characteristics that they may present must be taken into account, such as wind speed. In this regard, it is stated that stainless steel meshes coated with hydrophobic material collected more fog water than the raschel mesh at any speed, especially at higher speeds (Fernandez, et al., 2018), also cylindrical meshes are efficient for variable winds compared to traditional flat ones. (Mosa, et al., 2024).

3.3. Statistical correlation between meteorological parameters and the volume of water collected

To verify the correlation of these parameters in the research, a statistical treatment was made with the data obtained. Using the total data (92 data) on the water captured by the fog catcher and the meteorological parameters humidity, wind speed and temperature, the following was statistically demonstrated:
The normality of the data was verified. By obtaining a p-value> 0.05 for the data of all cases (Kolmogorov-Smirnov), it is established that there is a normal distribution.
Using the SPSS software, the data were subjected to correlation tests (See Table 3). Statistically demonstrating through the Pearson index test that:

- There is a significant correlation (p-value < 0.005) with a moderate positive index (0.646) between the humidity present in the site and the volume of water captured by the fog catcher.
- There is a significant correlation (p-value < 0.005) with a very high index (0.927) between the wind speed at the site and the volume of water captured by the fog catcher.
- There is a significant correlation (p-value < 0.005) with a very strong and inverse index (-0.846) between the air temperature present at the location and the volume of water captured by the fog collector.

Table 3: Pearson correlation index between the volume of water collected and meteorological parameters

		Humidity (%)	Wind speed (Km/h)	Temperature (°C)
Volume of water captured (L)	Pearson correlation	0.646**		
	sig. (bilateral)	<.001		
	N	92		
Humidity (%)	Pearson correlation	1		
	sig. (bilateral)			
	N	92		
Volume of water captured (L)	Pearson correlation		0.927**	
	sig. (bilateral)		<.001	
	N		92	
Wind speed (Km/h)	Pearson correlation		1	
	Pearson correlation			
	N		92	
Volume of water captured (L)	Pearson correlation			-0.846**
	sig. (bilateral)			<.001
	N			92
Temperature (°C)	Pearson correlation			1
	sig. (bilateral)			
	N			92

3.4. Comparison of water collection between pentahedral fog catcher and traditional design

The pentahedral design, it differed from the traditional model by using five panels joined under a single vertex, the efficiency was superior to the traditional single-panel design as seen in Table 4. After reviewing the scientific literature, no similar design has been found. In this regard, research carried out has tested "V" and concave designs, achieving aerodynamic efficiency and water collection. These designs can be improved with the geometry of the mesh and shading coefficient (Elshennawy et al., 2023), using microfiber grid types (Huang, Zhang, LI, 2024), as well as improving the chemistry and structure of the mesh surfaces (Lee et al., 2021).

Table 4: Volume of water captured by pentahedral and traditional fog catchers

	Pentahedral fog catcher (5 panels)	Traditional fog catcher (single panel)
Volume of water captured (L)	188.00	34.56
Fog catcher capture area (m^2)	45	9
Water capture index (L/m^2)	4.17	3.84

4. Conclusion

It was established that the pentahedral fog-catching design is efficient for capturing water from fog, obtaining an average of 188 L/day, more than 400% higher than the volume of water captured by a traditional single-panel model, under the same meteorological conditions and in the same place; this is due to its larger capture area and arrangement of the panels at different orientations to receive the variations of the wind with the fog. It is thus demonstrated that the pentahedral design is an alternative design to improve the obtaining of water from fog through fog-catching systems in arid areas, taking advantage of favourable environmental conditions. It is an alternative to achieve an improvement in the quality of life of populations and at a low cost, in an environmentally sustainable way.

Acknowledgments

The authors and the GITA Research Group would like to thank César Vallejo University for financial support for the publication of this research.

References

Alwarthan A., Alaskar S., Mulhim A., Hammad M., Rubayan K., Alofaisan O., 2024, Novel Approach on Utilizing Reverse Osmosis Rejected Saline Stream for Mangrove Trees Restoration & Water Conservation Management, SPE International Health, Safety, Environment and Sustainability Conference and Exhibition, HSE 2024, Abu Dhabi, Conference Proceedings, <doi.org/10.2118/220350-MS.>

Arce A. y Pfister Y., 2016, Dealing with uncertainty in water scarcity footprints, Environmental Research Letters, 11, Issue 5, <doi.org/10.1088/1748-9326/11/5/054008.>

Arce J. E., Ardila H., Mena N., Rojas, G. A., & Delgado F., 2023, Pilot fog trapping system for water harvesting on hills guarded by the Colombian Air Force, [in Spanish], International Meeting on Engineering Education ACOFI. <doi.org/10.26507/paper.2998>.

Bell S., 2015, Water scarcity, Routledge Handbook of Water and Health, Pages 360 – 366, <doi.org/10.4324/9781315693606-45.>

Crvajalñ D., Silva-Llanca L., Larraguibel D., González B., On the aerodynamic fog collection efficiency of fog water collectors via three-dimensional numerical simulations, Atmospheric Research, Vol 24515 November 2020, >doi.org/10.1016/j.atmosres.2020.105123>

Elshennawy A., Abdelaal M., Hamed A., Awad M., 2023, Evaluating Mesh Geometry and Shade Coefficient for Fog Harvesting Collectors, Water Resources, 37, Issue 15, 6107 – 6126, <doi.org/10.1007/s11269-023-03644-4>

Feld S., Spencer B., Bolton S., 2016, Improved Fog Collection Using Turf Reinforcement Mats, Journal of Sustainable Water in the Built Environment, 2, Isaue 3, 04016002, <doi.org/10.1061/JSWBAY.0000811>.

Fernandez D., Torregrosa A., Weiss-Penzias P., Zhang B. Sorensen D., Cohen R., McKinley G., Kleingartner J., Oliphant A., Bowman M., 2018, Fog water collection effectiveness: Mesh intercomparisons, Aerosol and Air Quality Research, 18, Issue 1, 270 – 283, <doi.org/10.4209/aaqr.2017.01.0040>

Fritz J., Meyer H., Tseng W., Lin N., Klenn O., 2021, Covariation of droplet size distribution and air humidity in fog: A methodological approach, Journal of HydrologyVolume 594, 125934, <doi.org/10.1016/j.jhydrol.2020.125934>

Gandhidasan P., Abualhamayel H., Patel F., 2018, Simplified modeling and analysis of the fog water harvesting system in the asir region of the kingdom of Saudi Arabia, Aerosol and Air Quality Research, 18, Issue 1, 200– 213, <doi.org/10.4209/aaqr.2016.11.0481>

Gardner G., 2010, Water scarcity looms, World Watch, 23, Issue 3, 21. ISSN 08960615.

Holmes R., Rivera JDD, de la Jara E., 2021, Large fog collectors: New strategies for collection efficiency and structural response to wind pressure, Atmospheric Research, 151, 236–249, <doi.org/10.1016/j.atmosres.2014.06.005>

Huang Y., Zhang Y., Li Y., Tan Z., Waterdrop-assisted efficient fog collection on micro-fiber grids, Chemical Engineering Journal, 481, 148423, <doi.org/10.1016/j.cej.2023.148423>

Imteaz M. Al-Hassan G. Shanableh A.Naser J., 2011, Development of a mathematical model for the quantification of fog-collection, Resources, Conservation and Recycling, 57, 10 – 14, <doi.org/10.1016/j.resconrec.2011.09.014>.

Lee J., So J., Bae W., Won Y., 2020, The Design of Hydrophilic Nanochannel-Macrostripe Fog Collector: Enabling Wicking-Assisted Vertical Liquid Delivery for the Enhancement in Fog Collection Efficiency, Advanced Materials Interfaces, 7, Issue 111, 1902150, <doi.oprg/10.1002/admi.201902150>

Montecinos S., Carvajal D. Cereceda P. Concha M., 2018, Collection efficiency of fog events, Atmospheric Research, Volume 209, 163 – 169, <doi.org/10.1016/j.atmosres.2018.04.004>

Mosa M., Radwan F., All-Ghobari H., Fouli H. Alazba A., Impact of varied fog collector designs on fog and rainwater harvesting under fluctuating wind speed and direction, Earth Science Informatics, 17, Issue 1, 617 – 631, <doi.org/10.1007/s12145-023-01195-1>.

Oktor K., Dhuol M. and Ercan M., 2024, Fog Harvesting: An Effective Solution to The Water Scarcity Problem. Sakarya University Journal of Science, 28, 4, 899-911. <doi.org/10.16984/saufenbilder.1480488>

Parisi G. Szewczyk P. Narayan Sh.Stachewicz U., 2023, Photoresponsive Electrospun Fiber Meshes with Switchable Wettability for Effective Fog Water Harvesting in Variable Humidity Conditions, ACS Applied Materials and Interfaces, 15, Issue 33, 40001 – 40010, <doi.org/10.1021/acsami.3c07044>

Park J., Lee Ch.Lee S. Cho H. Moon M. Kim S., 2021, Clogged water bridges for fog harvesting, Soft Matter, 17, Issue 1, 136 – 144, doi.org/10.1039/d0sm01133a

Qadir M, Jimenez G., Farnum R., Trautwein, Research History and Functional Systems of Fog Water Harvesting, Front. Water, 29 April 2021, Sec. Water and Hydrocomplexity, 3 – 2021, <doi.org/10.3389/frwa.2021.675269>

Rajaram M., Heng X., Oza M., Luo C., 2016, Enhancement of fog-collection efficiency of a Raschel mesh using surface coatings and local geometric changes, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 500, 218-229, <doi.org/10.1016/j.colsurfa.2016.08.034>

Rich D., Andiroglu E., Gallo K., Ramanathan S., 2023, A review of water reuse applications and effluent standards in response to water scarcity, Water Security, 20, 100154, <doi.org/10.1016/j.wasec.2023.100154>.

Sostenibilidad, 2023, Fog catchers: a solution for capturing water in times of drought, [in Spanis], <www.sostenibilidad.com/agua/atrapanieblas>

Ukolov A.I., Popova T.N., 2023, Numerical simulation of aerodynamics of a standard fog collector, Computational Continuum Mechanics, 16, Issue 2, 242 – 255, <doi.org/10.7242/1999-6691/2023.16.2.21>

Verbrugghe N., Kha A., 2023, Water harvesting using fog collectors: a review of conceptual, experimental and operational aspects, [in Spanish], International Journal of Low-Carbon Technologies, 18, 2023, 392–403, <doi.org/10.1093/ijlct/ctac129>

Yang HC, Jusoh M., Zakaria ZY, Jusoh YMM, Amran NA, 2024, Purification of rainwater collected on roofs by progressive freezing concentration, Chemical Engineering Transactions, 113, 37-42,<doi.org/10.3303/CET24113007>.

Zaitizila I., and Yun G., 2021, Fog-to-Water for Water Scarcity in Climate-Change Hazards Hotspots: Pilot Study in Southeast Asia, Glob Chall, 5(5), 2000036, doi: 10.1002/gch2.202000036.