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Potential of harvesting water from fog and dew water over semi-arid and arid regions in Syria

Majd M. Khalil[a,*], Ahmad Kara-Ali[a] and Mohamad Assad[b]

[a] High Institute of Marine Research, Tishreen University, Lattakia, Syria
[b] Chemical Engineering Department, Faculty of Chemical and Petroleum Engineering, AlBaath University, Homs, Syria
*Corresponding author. E-mail: majd.khalil86.mk@gmail.com

MMK, 0000-0002-7445-393X

ABSTRACT

Water is a significant primary resource on the Earth's surface. Fresh water is essential for human beings and for the stability and sustainable development of any nation. Many regions in the interior of Syria have an insufficient water balance. This has caused severe shortages of freshwater as a result of climate change. Syria's main source of fresh water, rivers and groundwater, suffers from low levels due to the lack of rainfall amounts. The war in Syria exacerbated water stress, in particular the effects of the war on water sources such as the Euphrates River and the 'Feijah' source that feeds the capital Damascus. All of this has prompted us to seek other non-traditional sources such as atmospheric water, which is a renewable and relatively clean source. This paper is considered to be the first of its kind in Syria. Experimental results from semi-arid and arid regions have shown good potential for harvesting dew and fog water as a supplementary and complementary source to the existing freshwater supply.

Key words: atmospheric water, dew, fog, Syria, water harvest

HIGHLIGHTS

- The main purpose of the research is to test the possibility of obtaining water from the air in a traditional and simple manner.
- Research is new over the 2019–2020 timeframe.
- Syria suffers from water scarcity and research is the first of its kind in Syria, particularly in its arid areas.
- Syria is a country plagued by fierce war, and the population needs every drop of water possible.

INTRODUCTION

Freshwater makes up approximately 2.5% of our planet's total water. About 1.74% of it consists of snow and glaciers, 0.79% lakes, 0.03% rivers and 0.76% groundwater (Bhushan 2019). The shortage of freshwater is one of the greatest challenges of sustainable development, water and food security in any country. The problem of fresh water is clearly visible in Syria because it is located in arid and semi-arid regions, about 75% of its surface is considered arid despite the positive trend towards increasing some annual rainfall rates and characteristics, such as intensity, frequency and continuity, over certain periods. Syria has been suffering from a general decrease in precipitation rates for half a century, given the current climate changes (Eissa 2013; Mawed & Alshihabi 2014). Changes in drought patterns in Syria were evident in terms of increased drought intensity during the rainy season. Changes in drought characteristics were evident in terms of the increased intensity of rainy season drought caused by the increase in spring and winter droughts. The frequency of extreme droughts increased while the frequency of extreme droughts in the spring decreased (Skaf *et al.* 2017). Population and industry growth are projected to increase water demand from 1,900 million cubic meters in 2010 to 3,150 million cubic meters in 2050. While the average share of fresh water per inhabitant has decreased from 12,185 cubic meters in 1992 to 809 cubic meters in 2012. It will decrease to 440 cubic meters in 2050. Furthermore, climate change will have a serious impact on water resources, resulting in a reduction in surface and ground water by 1,300 million cubic meters, and an increase in the evaporation of water bodies of 190 million cubic meters by 2050. Consequently, the water crisis will worsen if it is not corrected in the near future in the light of population growth and the evolution of irrigation projects in order to guarantee the requirements of food security and industrial development. This could constitute a major threat not only to water

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security, but also to the national security of an entire country. In addition, traditional freshwater sources have been vulnerable over the past decade to major impacts arising from political and military conflicts in Syria. Among the examples, which deserve to be noted, the low level of the Euphrates comes from Turkey and its direct negative effects on the economy and development of all the eastern region of the country. In addition are the grave threats that struck the source 'Feijah' feeding the capital Damascus (Mourad & Berndtsson 2011; Mahmoud & Alsayegh 2017; Selby *et al.* 2017).

In this paper, we study fog and dew harvesting as unconventional freshwater sources, using passive fog collectors. In addition, we tested some adjustments in order to make it more suitable for the climatic conditions in Syria. Fog and dew harvesting may provide an alternative source or supplement in areas where access to freshwater sources is difficult, especially in the east of Syria. This approach is becoming more importance due to recent studies, which pointed to the possibility of ongoing conflict and the growing drought that afflicts Syria (Abualhamayel & Gandhidasan 2010). This will bring about significant changes in the amount and type of current water sources. Changes in the hydrologic cycle of ecosystems are also expected in response to climate change. Moreover, these transformations include the reduction of annual rainfall in the Mediterranean region. Climate forecast predicts an increase in atmospheric moisture levels for the Mediterranean region by 27% during the summer months by 2080 (Kaseke *et al.* 2017; Kaseke & Wang 2018). These changes will increase the need for nonconventional sources of fresh water, especially water in the atmosphere.

The atmosphere contains an estimated 13,000 trillion liters of freshwater. Atmospheric humidity is naturally and periodically regenerated in a renewable and durable water resource. Additionally, the atmospheric water collection process, a simple and inexpensive technology, does not produce harmful effects or by-products that are harmful to the environment. However, the majority of atmospheric water collection studies have not been subjected to an independent critical study of the performance, functions and realistic limits placed on atmospheric water collection systems. This has resulted in significant differences in claims and claims regarding the performance and capabilities of water harvesting operations to meet commercial needs. While the project to harvest water from fog and dew is seen as a case study as part of an innovative and comprehensive approach to addressing the complex challenges of water scarcity and sustainable development. Much of this type of research is cross-cutting in fields such as applied engineering, materials science, meteorology, climate science and environmental science. Moreover, this type of water meets World Health Organization (WHO) standards, according to numerous studies. Fog and dew act as air washers, so the chemical state of this water depends on air quality and heterogeneous interactions between the gas, liquid and solid in the surrounding area, which may be used in air pollution studies (Bagheri 2018; Kaseke & Wang 2018).

MATERIALS AND METHODS

Location and duration

To test the ability fog and dew collection under semi-arid and arid climate conditions, two sites were selected according to the climatic classification of land according to Syrian Directorate General of Meteorology (SDGM) Figure 1(b) (7 September 2020. http://www.mod.gov.sy/index.php?node = 556&cat = 7937&). **St$_1$** (East of Homs-Hama highway, N 35°′02′42 E 36°′ 45′40, 476 masl) determined as a point in the semi-arid medium. **St$_2$** (N 34°′36′59 E 36°′52′51, 420 masl) determined as a point in a very arid environment Figure 1(a). This study took an entire year between September 2019 and September 2020.

Design of the water-collecting device

Two models of the device were established. The first model (A) has a fog-collecting area of 1.00 square meters and was set up such that its base is 2 meters above the ground and its top is 3 meters above the ground. The polypropylene mesh support itself and is made from 3 cm metal pipe, as the spacers, as are the spacers. The support legs are made out of 3 cm metal pipes. A trough, which is 15 cm wide and whose bottom slants downward across the base of the mesh, routes any water collected to one side of the collector for 40-liter plastic container (Figure 2). The second model (B) is a cylindrical fog collector, which has two bases for fixing on the top and bottom sides. Mesh is placed on a sheet of metal (stainless steel) slightly concave. From the bottom, there is a metal tube fixed to a pipe ending in its rotation with a plastic container of 40 liters.

In both models, seven mesh types were employed in the first step. (1) Polypropylene single mesh with shading coefficient (SC) 35%. (2) Double polypropylene mesh with SC 35% for each layer. (3) Polypropylene single mesh with SC 50%. (4) Double polypropylene mesh with SC 50% per layer. (5) Polyethylene (PE) single net with SC 60%. (6) Double polyethylene (PE) meshes with SC 60%. (7) Metal mesh with (SC) 40%. In the second stage, each of the previous meshes were coated with a mixture of hydrophobic silica particles and methylphenyl silicon.

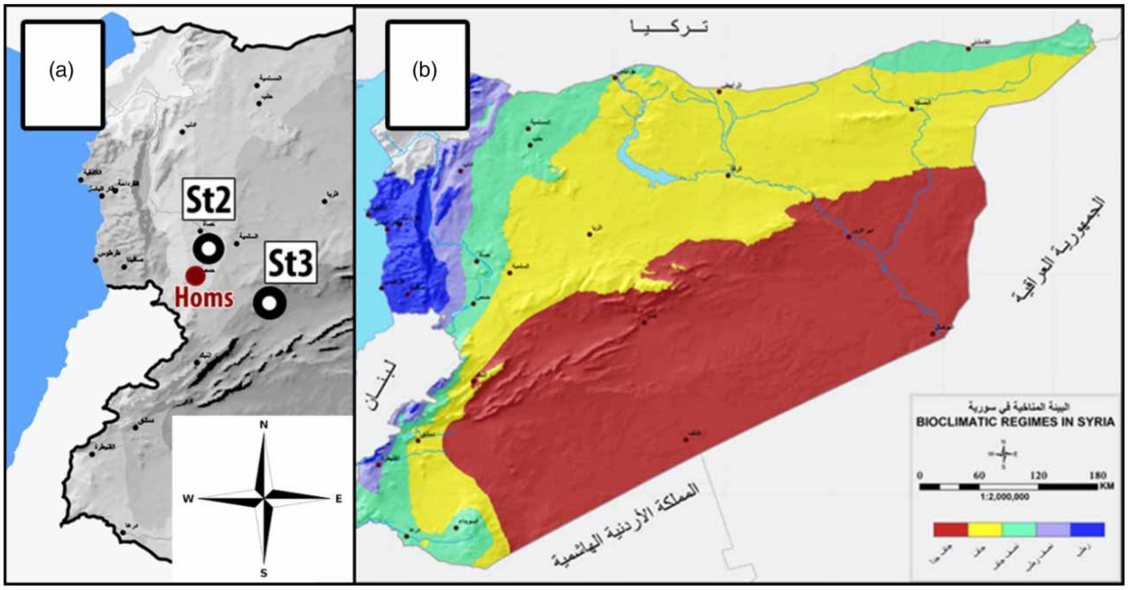

Figure 1 | (a) Location of test sites. (b) Distribution of climatic environments in the Syrian Arab Republic according to the classification of the General Directorate of Meteorology. Blue color stands for a humid environment. Light violet for semi-arid. Green for semi-arid. Yellow for arid. Red for very arid. Please refer to the online version of this paper to see this figure in colour: http://dx.doi.org/10.2166/ws.2021.229.

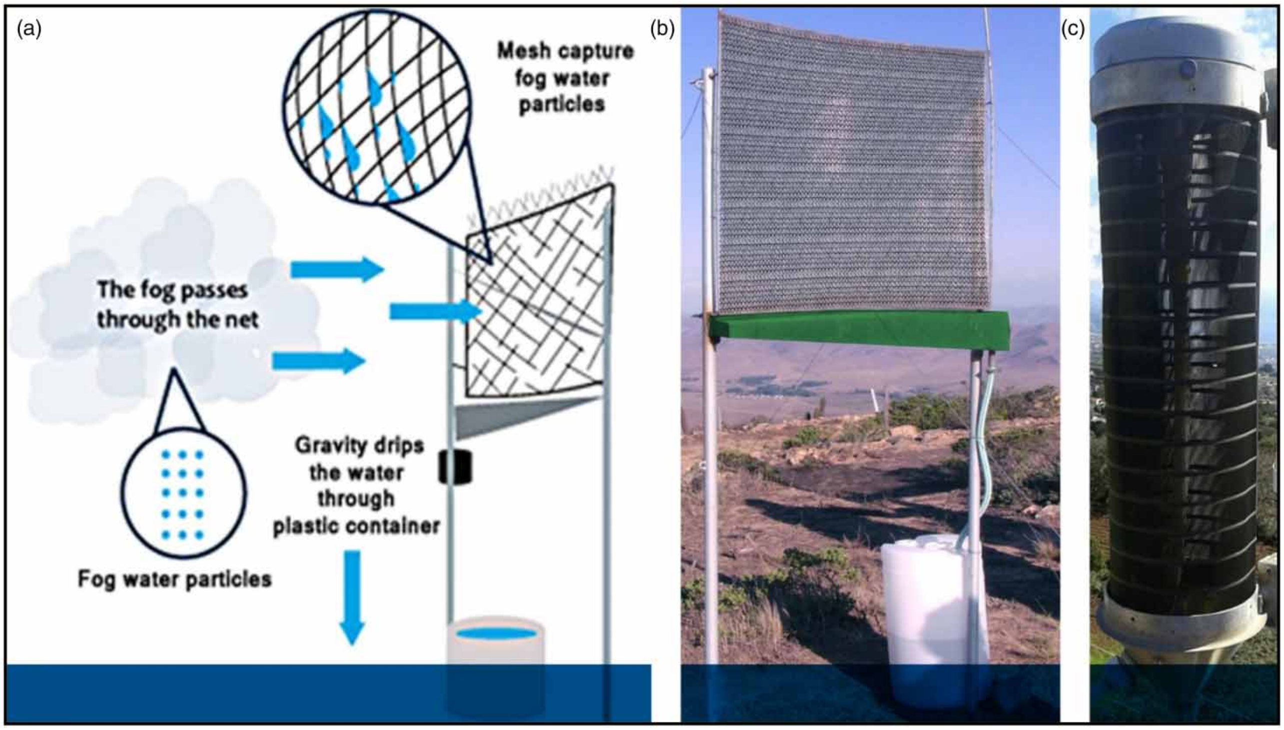

Figure 2 | (a) Water fog collection mechanism. (b) Standard fog collector. (c) Cylindrical fog collector

Shading coefficient calculation

The mesh shade coefficient (SC) represents the capturing capability of droplets, as only part of the mesh can catch droplets; it is defined as shown in Equation (1) (Gandhidasan *et al.* 2018):

$$SC = 1 - (A_{op}/A_{tot}) \tag{1}$$

SC mesh shade coefficient is given in percentage. A_{op} and A_{tot} are the opening and the total area of the mesh, respectively. Meshes with SC 35% obtained the best results in the collection of ambient air water in numerous studies and they recommended using a double mesh with SC 35% polypropylene (Molina & Escobar 2008). Other studies have reported different results with the same mesh size and SC. This led us to experiment with different types of mesh with different SC and different materials to get the best possible results of the water collection process through these meshes.

Mesh coating

In order to improve the efficiency of the water collection process, we increased the resistance of the network to the corrosive climatic factors, and obtained high mechanical stability, the meshes were sprayed with a special coating for this purpose. The coating was prepared by dissolving a mixture of solid SiO_4 (silicon oxide) with methylphenyl silicone $(C_7H_8OSi)_n$ in a solvent of mixture containing 40% tetrahydrofuran, 60% isopropyl alcohol, at following proportions 1: 5: 12 for silicon oxide, silicon methylphenyl, and solvent, respectively (Bhushan 2019).

Climate and environment factors

Atmospheric water collection using this method is dependent on the dominant environmental, climatic and synoptic factors. Rainfall, air temperature, wind direction and velocity, relative humidity, absolute humidity, ground surface temperature, dew point temperature, and air water content (Olivier 2014), (Tables 1–4).

These data were collected via field measurements, along with data from the General Directorate of Meteorology. Absolute humidity, dew point temperature and air content of water were calculated using Equation (2) (Davis *et al.* 2016; Dahman *et al.* 2017):

$$AH = \frac{6.112 \times e^{\left[\frac{17.67 \times T}{T+243.5}\right]} \times RH \times 2.1674}{273.15 + T} \tag{2}$$

where AH: Absolute humidity. T: Air temperature, and RH: Relative humidity. Relative humidity differs from absolute humidity in that the relative humidity RH, by definition, is the ratio of the current content of a unit of air volume of water to the air content of water at the saturation at the same temperature and air pressure. By definition, absolute humidity AH is the weight of water vapor present in an air volume of one unit (Dahman *et al.* 2017). The relationship between T, dew point T_d and RH was calculated using Equation (3) (Ngaina *et al.* 2014; Davis *et al.* 2016):

$$T_d = T_a - (RH + 100)/5 \tag{3}$$

where T_d: dew point temperature. T_a: ambient air temperature. RH: relative humidity. The upper dew point value indicates an increase in the air content of the transported water droplets. The estimated air content of the water WH is the amount of water that can accumulate in liters in 24 hours. The requirement for calculating this content is that the relative humidity (RH) is above 69%, then it was calculated by Equation (4) (Dahman *et al.* 2017):

$$WH = 24 \times AH \times U_Z \times E_{eq} \times 3.6 \tag{4}$$

Table 1 | Wind speed range and frequency of directions at the sites

Frequency								
D8 NW	**D7 W**	**D6 SW**	**D5 S**	**D4 SE**	**D3 E**	**D2 NE**	**D1 N**	**Site**
28.8%	32.9%	7.6%	9.3%	3.7%	4.7%	4%	9%	St_1
21.3%	19.4%	12.9%	13.4%	7.2%	6.8%	8%	11%	St_2
2–6			St_1			Wind speed range (min ave. – max ave.)		
3–8 m/s			St_2					

Table 2 | Monthly mean parameters for site **St$_1$**

Annual average	**Sep 2020**	**Aug 2020**	**Jul 2020**	**Jun 2020**	**May 2020**	**Apr 2020**	**Mar 2020**	**Feb 2020**	**Jan 2020**	**Dec 2019**	**Nov 2019**	**Oct 2019**	**Sep 2019**	**St$_1$**
26.4	30.7	36.1	33.3	28.5	27.9	22.3	18.8	15.9	14.7	15.3	23.2	27.5	32.6	Air temperature °C (daytime)
16.6	22.8	24.2	22.7	22.4	18.6	15.2	12.4	8.1	8.3	10.1	16.2	19.3	22.4	Air temperature °C (night-time)
21.6	25.4	26.8	26.1	23.5	21.2	18.7	15.6	13.3	11.5	13.8	19.4	22.7	26.3	Ground surface temperature °C (daytime)
10.3	16.9	21.1	20.6	15.6	13.5	11.9	10.7	7.2	5.8	6.8	9.9	13.4	16.5	Ground-surface temperature °C (night-time)
19.2	14.8	9.5	9.6	14.4	18.1	20.7	22.3	26.2	28.1	26.8	23.3	19.2	15.7	Dew point temperature °C
61	58	53	51	50	58	63	65	66	69	68	66	63	61	Relative humidity %
0.03	0.01	–	–	0.01	0.01	0.02	0.04	0.05	0.08	0.07	0.06	0.04	0.02	Absolute humidity (kg/m^3)
4	5	5	6	5	5	3	3	3	3	2	2	2	5	Wind speed (m/s)
6	2	–	–	1	2	7	11	13	15	12	10	5	3	Number of rainy days
0.19	0.07	–	–	0.06	0.15	0.23	0.35	0.45	0.42	0.38	0.27	0.18	0.09	Air content of water L/24 hour

Table 3 | Monthly mean parameters for site **St$_2$**

Annual Average	**Sep 2020**	**Aug 2020**	**Jul 2020**	**Jun 2020**	**May 2020**	**Apr 2020**	**Mar 2020**	**Feb 2020**	**Jan 2020**	**Dec 2019**	**Nov 2019**	**Oct 2019**	**Sep 2019**	**St$_1$**
28.4	34.6	38.4	36.2	32.1	30.3	24.9	21.6	17.8	16.4	18.3	26.7	30.4	34.5	Air temperature °C (daytime)
14.5	19.2	22.1	20.9	18.8	15.3	11.7	10.4	6.9	7.3	8.5	14.2	17.8	19.6	Air temperature °C (night-time)
27.4	32.8	41.2	35.7	30.2	24.5	19.2	14.4	12.5	13.4	18.8	23.1	27.2	33.6	Ground surface temperature °C (daytime)
12.4	17.9	20.1	20.7	15.3	12.6	10.4	8.9	6.7	5.3	6.2	8.5	12.1	16.2	Ground surface temperature °C (night-time)
18.1	12.7	5.7	5.7	13.1	17.6	21.2	23.1	25.5	27.5	26.4	22.7	18.4	14	Dew point temperature °C
52	53	39	41	42	51	58	60	61	64	63	56	53	51	Relative humidity %
0.8	0.6	0.2	0.2	0.4	0.6	0.8	1.2	1.5	1.6	1.7	1.5	1.1	0.7	Absolute humidity (kg/m^3)
5	4	7	8	6	4	4	4	3	3	3	3	4	5	Wind speed (m/s)
3	–	–	–	1	1	2	7	8	10	8	4	2	1	Number of rainy days
0.14	0.05	–	–	0.04	0.12	0.11	0.18	0.29	0.38	0.36	0.22	0.14	0.06	Air content of water L/24 hour

where WH: estimation of the amount of water likely to be collected in liters. AH: absolute humidity. U_Z: wind velocity at the height at which the device positioned. E_{eq}: effectiveness of the device, often estimated 30% at SC 35%.

It should be noted that most of the field studies and previous climate modeling studies tended to consider all non-rainfall water inputs, especially the fog and dew, as one category. Although both are derived from different climatic phenomena,

Table 4 | Average non-rainfall amounts collected during the study period estimated in liter/m^2/day for the flat model (A), estimated in liter/day for the cylindrical model (B), using coated double polypropylene mesh with SC 35%

	St$_1$		**St$_2$**	
	Model (B)	**Model (A)**	**Model (B)**	**Model (A)**
Sep. 2019	0.2	0.1	0.1	*0.1*
Oct. 2019	0.2	0.1	0.1	*0.1*
Nov. 2019	0.5	0.3	0.2	*0.1*
Dec. 2019	0.8	0.5	0.4	*0.3*
Jan. 2020	0.9	0.5	0.4	*0.3*
Feb. 2020	0.8	0.6	0.4	*0.3*
Mar. 2020	0.5	0.4	0.3	*0.2*
Apr. 2020	0.3	0.2	0.2	*0.1*
May. 2020	0.2	0.2	0.2	*0.1*
Jun. 2020	0.2	0.1	0.1	–
Jul. 2020	0.1	–	–	–
Aug. 2020	0.1	–	–	–
Sep. 2020	0.1	0.1	0.1	–
Annual. average	0.4	0.2	0.2	*0.1*

due to technical limitations that impede the identification of non- rainfall sources that exist in the atmosphere (Kaseke *et al.* 2017).

RESULTS AND DISCUSSION

Climatological analysis

Table 1 shows the top wind speeds average of 8 m/s, It is a 'gentle breeze' according to the Beaufort wind scale. A minimum wind speed average of 2 m/s, is classified as 'light air'. Wind speeds between 2 and 5 m/s, as mentioned previously, are favorable for fog water collection. These results also suggested that the study area may be suitable for the generation of electrical or mechanical energy on a small scale, with several small turbines connected together to generate enough electric power.

Tables 2 and 3 show the temperature behavior throughout the year, with a highest temperature averages from July to September. Relative humidity behaves differently to temperature, decreasing from July to September and increasing from December to March. The minimum average humidity is 50% and the maximum average is 69%, which is appropriate for dew water collection. No significant relationship between temperature and relative humidity was found as the maximum amount of water vapor that air can contain depends on the temperature, although the amount of water is not guaranteed to be the same for each temperature point. Here it was observed that relative humidity does not follow the temperature pattern or vice versa, since each is independent of the other.

Water yield

The results of the field experiments (Table 4) showed differences between the theoretical data and projections (Tables 1–3) and the quantities of water actually collected. These differences varied between significant and slight differences due to wind direction and mesh collection mechanism. This mechanism was based on collision of water droplets, 10–40 μm, suspended in the air, with the mesh filaments. Therefore, the winds carrying these droplets, in terms of speed and direction towards the mesh, play a significant role in the collection process. When the wind was not perpendicular to the mesh surface, the amount of water decreased as the collision surface decreased, and the amount decreased with the change of the wind direction from perpendicular to the mesh surface level. A solution to the problem of wind direction was the cylindrical design of the model (B). Ideal wind speed value for the combination process was 2–5 m/s. Wind speeds often exceeded this value during wet events 'troughs', which have favorable climatic conditions for water collection.

During humid climatic conditions, which are usually associated with rain, the process of determining the yield of the collected water, whether it is rainy or not-rainy, becomes not possible. The amount of non-rainwater has been roughly estimated, Table 4, by calculating the average quantities of water collected on days that did not include rainfalls of each month. In order to assess water production for non-rainwater, values were compared with the total values of water collected during the months of December, January, and February (Table 5).

The effect of the wind factor is clearly shown by the difference in the annual mean amount of non- rainfall water collected by flat and cylindrical models using the same mesh. The difference in the amount of non-rainwater collected between the two models is 100% (Table 4). Moreover, the slight difference between the small amounts of collected rainfall water between the two models did not exceed 25% (Table 5), indicating a mechanical collection capacity nearly equivalent. The difference in amounts of non-rainfall water due to meteorological factors were mainly due to wind.

Influence of shading coefficient and mesh type

Double mesh made from polypropylene (PP), SC 35% per layer, gave better results than the other types of mesh used. While, polypropylene double mesh with SC 35% per layer, which was coated with silicone and a silica coatings layer, showed 40% better results in collecting non-rainfall water yield than all other types. This was consistent with numerous previous studies which recommended the use of double meshes with SC 35% (Eissa 2013; Davis *et al.* 2016; Dahman *et al.* 2017). Double mesh with large SC 50%, 60%, had the lowest water yield. The reason may be the smallness of the mesh openings, at this high ratio of SC, which clog with water droplets, preventing more air carrying moisture and water droplets from passing through it. This is the main purpose of the hydrophobic coating, resulting in higher mobility of the water droplets on the mesh filaments, which makes them move downward due to their weight without staying for long periods in the openings. This can be checked by comparing the collection yield of coated meshes with that of uncoated meshes, as shown in Table 6.

The metallic mesh of SC 40%, which is close to the recommended ratio (35%), mesh yield, for example, was less than the polyethylene (PE) mesh with SC 60%. The same was found for coated metallic mesh. This could be due to a number of potential reasons. Amongst them is the weight of the metal mesh that does not allow horizontal movement of the mesh at low wind speeds compared with the flat model. This means fewer areas of collision between the air transport water droplets and the mesh surface. Moreover, the temperature of the mesh metal decreased in very cold weather, which transformed it into a surface on which the droplets freeze instead of flowing towards the collector stream. Furthermore, the coating on the metal mesh exhibited relatively low stability in difficult climatic conditions in general, in hot conditions in particular, and corroded more rapidly than on other types of mesh.

Water yield quality

The quality of the water collected by this method depends on the quality of the surrounding air, the water transported through the air and the surface of the mesh. To check if this water, rainfall and non-rainfall, is safe to drink, chemical analyses were carried out on it. Analyses included pH, electrical conductivity (EC), total dissolved solids (TDS), chemical oxygen demand (COD), total organic carbon (TOC), nitrates (NO_3), nitrites (NO_2), and sulfates (SO_4), in addition to lead, chrome, cadmium and iron. The results were within acceptable limits of the specifications of the Syrian drinking water standards (8 September

Table 5 | Average total amount of water collected over three months, estimated in liter/m^2/day for the flat model (A), estimated in liter/day for the cylindrical model (B), using the coated double polypropylene mesh with a SC of 35%

		St_1		**St_2**	
		Model (B)	**Model (A)**	**Model (B)**	**Model (A)**
Non-rainfall	Dec. 2019	0.8	0.5	0.4	*0.3*
	Jan. 2020	0.9	0.5	0.4	*0.3*
	Feb. 2020	0.8	0.6	0.4	*0.3*
Ave.		0.8	0.5	0.4	*0.3*
Rainfall	Dec. 2019	2.7	2.2	1.0	*0.8*
	Jan. 2020	3.0	2.6	1.2	*0.9*
	Feb. 2020	2.9	2.3	0.9	*0.7*
Ave.		2.8	2.4	1.0	*0.8*

Table 6 | The productivity of the mesh types used in the study for rainfall waters during January and April 2020 according to the cylindrical model (B), estimated in liter/day

	St_1		St_2	
Mesh type	**Coated**	**Uncoated**	**Coated**	**Uncoated**
Jan. 2020				
(PP) – SC 35% - Single	0.6	0.4	0.3	*0.1*
(PP) – SC 35% - Double	0.9	0.6	0.4	*0.3*
(PP) – SC 50% - Single	0.8	0.5	0.3	*0.1*
(PP) – SC 50% - Double	0.6	0.4	0.2	–
(PE) – SC 60% - Single	0.6	0.3	0.2	*0.1*
(PE) – SC 60% - Double	0.4	0.2	0.1	–
Metal – SC 40% - Single	0.2	0.1	0.1	–
Apr. 2020				
(PP) – SC 35% - Single	0.1	–	0.1	–
(PP) – SC 35% - Double	0.3	0.2	0.2	*0.1*
(PP) – SC 50% - Single	0.2	0.1	0.2	*0.1*
(PP) – SC 50% - Double	0.2	0.1	0.1	–
(PE) – SC 60% - Single	0.1	0.1	0.1	*0.1*
(PE) – SC 60% - Double	0.1	0.1	0.1	–
Metal – SC 40% - Single	0.1	–	0.1	*0.1*

Table 7 | Values of selected water quality parameters collected at the sites over the study period

			St_1		St_2	
	Syrian standard specifications	**World Health Organization (who)**	**Ave.**	**Max.**	**Ave.**	**Max.**
pH	9–6.5	8–6.5	7.4	7.8	7.3	8.2
$EC\ \mu S/cm$	1,500	400	195	366	321	711
TDS mg/L	900	600	237	389	420	542
NO_3 *mg/L*	50	45	12	27	13	39
NO_2 *mg/L*	0.2	0.3	0.08	1.4	0.06	1.4
SO_4^{-2} *mg/L*	250	250	98	154	76	115
Pb mg/L	0.01	0.01	0.004	0.008	–	–
Cr mg/L	0.05	0.05	–	–	–	–
Cd mg/L	0.003	0.003	–	–	–	–
Fe mg/L	0.3	0.3	0.15	2.3	0.14	2.1
COD mg/L	2	2	0.6	1.1	0.4	0.8
TOC mg/L	3	4	1.2	2.2	0.6	0.9

2020; Maarouf *et al.* 2019), and World Health Organization for Safe Drinking Water standards (8 September 2020; Udhayakumar *et al.* 2016). TDS and EC showed high values, but remained within the permissible limits of the World Health Organization specifications (Table 7).

TDS and EC high values at $\mathbf{St_2}$ could be attributed to dust episodes and southern winds from the desert, which carries dust and micro-particle suspensions, which suspended in the air. The concentrations of Pb, Cr and Cd were below the detection limits, except for Pb at $\mathbf{St_1}$. Probably the reason is the $\mathbf{St_1}$ site located east of Homs, Hama Road, and what strengthens this hypothesis is the high values of total organic carbon (TOC) at the same site compared to other sites.

CONCLUSIONS AND RECOMMENDATIONS

The semi-arid region had the best results in terms of the amount of non-rainfall water collected, followed by the very arid region. This is in broad agreement with climate data and theoretical projections. In addition, this water obtained met the standards of the Syrian Standards Organization and the drinking water quality standards of the WHO.

A more comprehensive investigation on fog and dew water harvesting is needed for a longer period of time until the results indicate that collecting water from humidity and fog can be another promising additional source of clean freshwater. This is true especially in areas that suffer from difficulties in supplying safe and freshwater, including coastal areas where even mountain villages suffer from the interruption of drinking water for many days.

Therefore, we recommend further research in this area and increase the capacity of collection devices by increasing the area of the meshes. It is necessary to work on increasing the effectiveness of the mesh by improving the mesh material used and carefully examining the climatic conditions adapted to the functioning of each. Research and the development of new and alternative ways of collecting atmospheric water is required because it is a relatively clean, constantly renewable and inexhaustible source.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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