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MESH MATERIAL FEASIBILITY TESTS FOR MAXIMUM WATER COLLECTION BY USING WHITE PE PLASTIC SHEET, BLACK POLYOLEFIN MESHES AND HDPE GREEN MESH

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ABSTRACT

Multiple linear regression analysis prove that meteorological effects and material properties of mesh can affect the volume of water collected. To compare the feasibility of material tests for maximum water collection, One-way ANOVA analysis were used to obtain comparison data. This study aimed to find an alternative way to reduce water scarcity issues in highland area. The sources of surface water and sources of groundwater are almost none. The material (mesh) that used onto the atmospheric water harvester implements an important role in maximizing water collection volume. A potable sturdy frame to hold the mesh material tests were developed and the water collected will be directly flow into a water container and the volume of water collected will be recorded.

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This study aimed to select the most applicable mesh material that can be add up on to atmospheric water harvester to maximize volume of water collection.

Keywords: atmospheric water; material tests; meshes; maximum water collection.

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1. INTRODUCTION

Atmospheric water are consists of three different states which are fog, water precipitation (dew) and rainfall. In this study, fog is one part of the important hydrology cycle of coastal, high-altitude and forested regions that commonly overlooked by the world community [2] while dew is known as water precipitation that formed on the plants surfaces that plays crucial roles as water supply in desert area [4]. As for rain, it is water droplets that condense through water vapors condensation process at the atmosphere after the water vapor evaporates from Earth surfaces. As it accumulates until it reach optimum weight before it is precipitate into rainfall [7].

Recent research study shows atmospheric water harvesting can be an alternative source that can reduce water scarcity issue among people in semi-arid, highland, coastal and tropical regions [2]. It presents atmospheric water harvester as viable alternatives to existing water supply systems. Water scarcity issues become more serious when the populations increase over the years. This matter ultimately contributes to the occurrence of water scarcity [3].

Traditionally, fog harvesting uses a simple method where the use of mesh that framed on a sturdy frames and expose to the air. When the fog passes through the mesh, water vapor deposited and becomes dew which will accumulate and run down to water collector or drainage container [6]. Throughout the fog water harvesting studies, there are new models for fog water collection, an impaction model and an efficiency model that had been developed to describe the process that occur on a [5]. Fog water harvesting implies a passive, low cost and maintenance system to supply fresh drinking water for communities that lived in foggy area. It is also useful when the water sources are scarce [2].

In Malaysia, tropical climate did not affected badly by the water scarcity issue compare to arid climate. However, for highland area, clean water supply is limited because there is less availability of surface water. Therefore, supplying water for people in tropical regions has gained high importance in the recent days. The methods of collecting water by harvesting from atmospheric or air humidity could be very beneficial. In [10] pointed out the importance of alternative water supplies such as atmospheric water harvesting in food security. To continue the research on atmospheric water harvesting, research on mesh material's feasibility on maximizing volume of water collection was carried out.

2. METHODOLOGY

The experiment was conducted at vacant area nearby Environmental Research Laboratory of Universiti Malaysia Kelantan, Jeli Campus. The experiment was carried out for 60 days continuously and the monitoring data will be taken between 7.30 am to 7.45 am. Water precipitation on the material test panels (white PE plastic sheet, Black Polyolefin Mesh and HDPE Green Mesh) volume of water collected will be recorded in the morning. The meteorological data can be obtained from the Malaysia Meteorological Department's website.

2.1. Preparation of Sturdy Frame for Material Tests

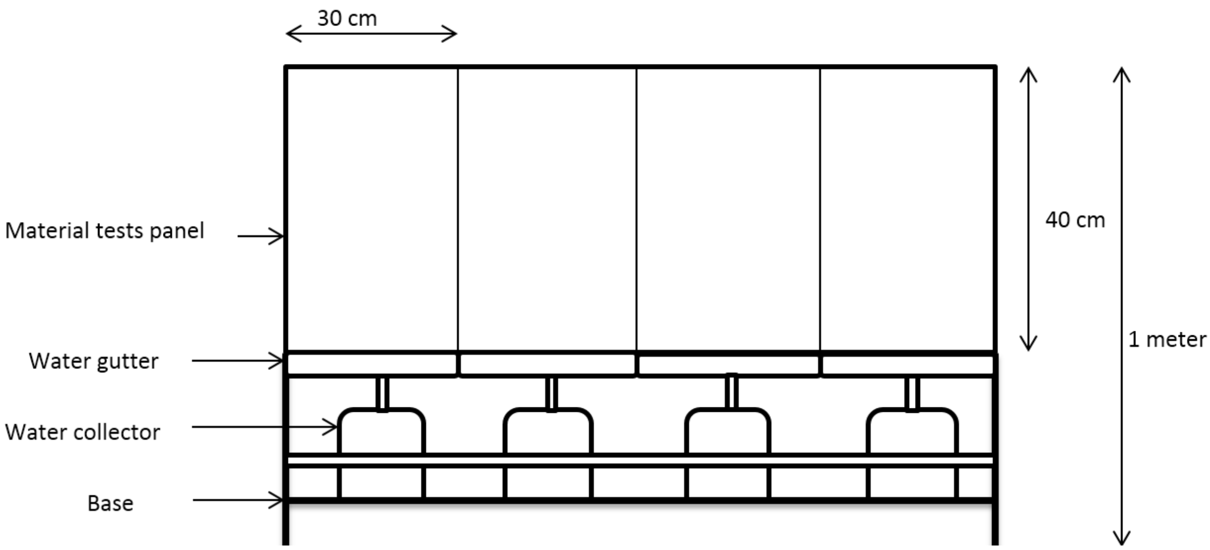

Fig.1. Material tested sturdy frame

1 meter height of sturdy frame with 2 meter width was developed by using stainless steel. Four panel segments for material tests were divided with 1 feet width each. The segments were setup about 0.5 meters above the ground. Each segment was connected with water gutter that will collect deposited water droplets which flows into the water container. Material test was attached to the panel segments by using cable ties.

2.2. Characterization of Material Test

Material tests should have textural surfaces and chemical features on their surfaces to harvest the fog. The material tests should have the surface wettability characteristics (hydrophobicity and hydrophilicity) [9] length scale (width and length of the mesh) and weave density on the fog-harvesting capability of woven meshes. For an ideal fog-collecting surface, liquid droplets converted toward the mesh and deposited on the surface will be drained quickly by gravity into the collecting gutter without the loss by re-entrainment to the airflow, thus refreshing the base mesh surface for the capture of new fog droplets [8].

Therefore, hydrophilicity of mesh surfaces is important as it attracts fog droplets to deposit on the mesh surfaces. Meanwhile, hydrophobicity of a surfaces will helps in providing water deposited flow into the water collector easily. The mesh weave patterns surfaces cannot be too sparse or too close because the water deposited will easily loss through the air because of the wind. Thus, the mesh density also plays an important role to withstand the wind blow or storms [1].

2.3. Statistical Analysis

All analysis results were subjected to statistical analysis to determine mean and standard deviation using the latest statistical software (SPSS software). To relate the primary data collection with secondary data collection, multiple linear linear regression analysis will be used to correlate the interrelationship between type of mesh materials and meteorological data. Meamwhile, to compare the feasibility of mesh material tested, analysis of variance (ANOVA) will be used.

3. RESULTS AND DISCUSSION

3.1. Descriptive Analysis on Volume of Water Collected (cm^3) in 60 days

Table 1. Volume of water collected for each material test

Mesh Material Tests	Volume of Water Collected in 60 days
White PE Plastic sheet	33.3
Black Polyolefin Mesh (2mm)	34.6
Black Polyolefin Mesh (1mm)	49.7
HDPE Green Mesh	43.3

Based on Table 1, the highest volume of water collected in 60 days is (Black Polyolefin Mesh 1mm width range = 49.7 cm^3). Black Polyolefin Mesh with weave width 1mm is feasible in capturing rain water, drizzle and fog than the other mesh. The lowest volume of water collected in 60 days is (PE White Sheet plastic = 33.3 cm^3). White PE Plastic Sheet is not durable with high wind blow because it is basically use for agricultural purposes. White PE Plastic Sheet usually use on the ground to cover the Earth to prevent weed growth. Therefore, less water droplets can be deposited onto the plastic surfaces. To apply the White PE Plastic Sheet, artificial slit was made to prevent the plastic torn because of wind pressure. For Black Polyolefin Mesh with width 2mm weave, the water collected for 60 days are 34.6 cm^3 because the mesh were torn from the panel segments for several times because of the wind blow and for HDPE Green Mesh, the volume of water collected are 43.3 cm^3.

Table 2. Volume of water collected in 60 days

Date of Month (February)	Volume of Water Collected (cm³)			
	White PE Plastic sheet	Black Polyolefin Mesh (2mm)	Black Polyolefin Mesh (1mm)	HDPE Green Mesh
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A

9	N/A	N/A	N/A	N/A
10	38.6	38.6	38.6	38.6
11	110	110	110	110
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	154	N/A	154	295
17	N/A	N/A	N/A	N/A
18	N/A	N/A	N/A	N/A
19	N/A	N/A	N/A	N/A
20	N/A	N/A	N/A	N/A
21	N/A	N/A	N/A	N/A
22	N/A	N/A	N/A	N/A
23	120	120	160	165
24	N/A	N/A	N/A	N/A
25	130	38.6	110	110
26	N/A	N/A	N/A	N/A
27	N/A	N/A	N/A	N/A
28	N/A	N/A	N/A	N/A
29	230	110	154	340
30	230	110	154	340
31	N/A	N/A	N/A	N/A
32	N/A	N/A	N/A	N/A
33	N/A	N/A	N/A	N/A
34	N/A	N/A	N/A	N/A
35	N/A	N/A	N/A	N/A
36	N/A	N/A	N/A	N/A
37	N/A	N/A	N/A	N/A

38	N/A	N/A	N/A	N/A
39	N/A	N/A	N/A	N/A
40	N/A	N/A	N/A	N/A
41	N/A	N/A	N/A	N/A
42	N/A	N/A	N/A	N/A
43	N/A	N/A	N/A	N/A
44	N/A	N/A	N/A	N/A
45	N/A	N/A	N/A	N/A
46	N/A	N/A	N/A	N/A
47	N/A	N/A	N/A	N/A
48	370	480	700	800
49	N/A	N/A	N/A	N/A
50	N/A	N/A	N/A	N/A
51	N/A	N/A	N/A	N/A
52	N/A	N/A	N/A	N/A
53	N/A	N/A	N/A	N/A
54	55	0	0	38.6
55	N/A	N/A	N/A	N/A
56	55	N/A	N/A	38.6
57	250	N/A	N/A	420
58	N/A	N/A	N/A	N/A
59	580	920	760	980
60	N/A	N/A	N/A	N/A

*N/A-null data record

Based on Table 2, most of the days in 60 days experimental have no record for volume of water collected unless for several days which are on day 10th, 11th, 16th, 23rd, 29th, 30th, 48th, 54th, 56th, 57th and 59th where the weather is rainy. For null data record is that the water collected is less than 0.1 cm^3 or there absence of water in water container due to the hot weather. Figure 2-5 show the volume of water collected for each mesh materials respectively to show the differences between the volumes of water collected between 4 mesh materials.

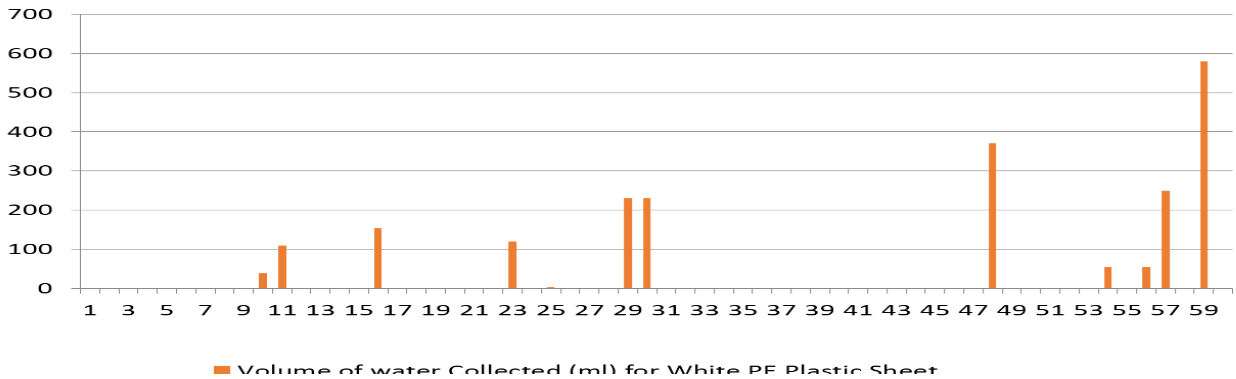

Fig.2. Volume of water collected in 60 days for white PE plastic sheet

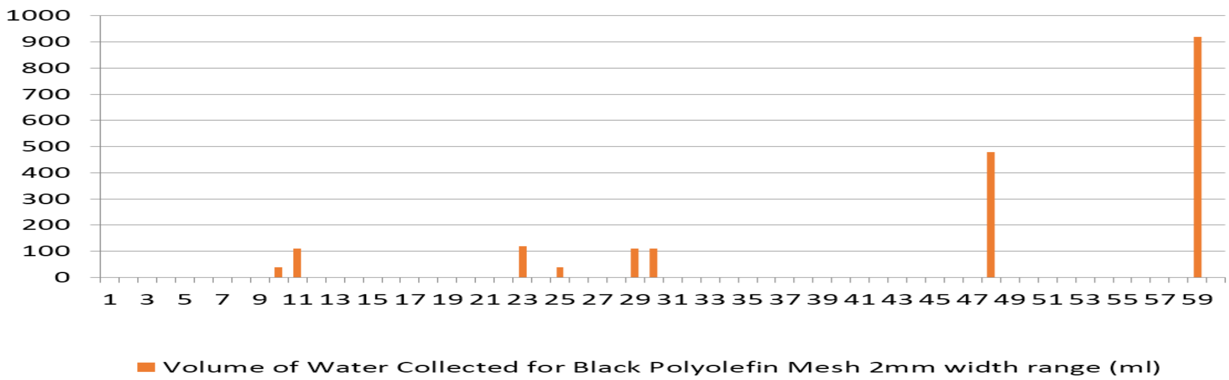

Fig.3. Volume of water collected in 60 days for black Polyolefin mesh (2mm width range)

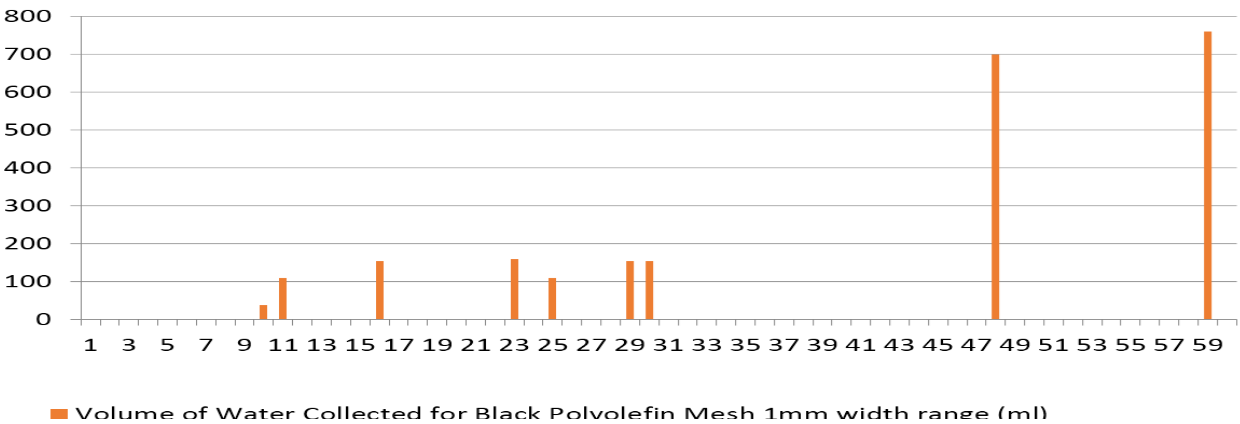

Fig.4. Volume of water collected for black Polyolefin mesh 1mm width range (ml)

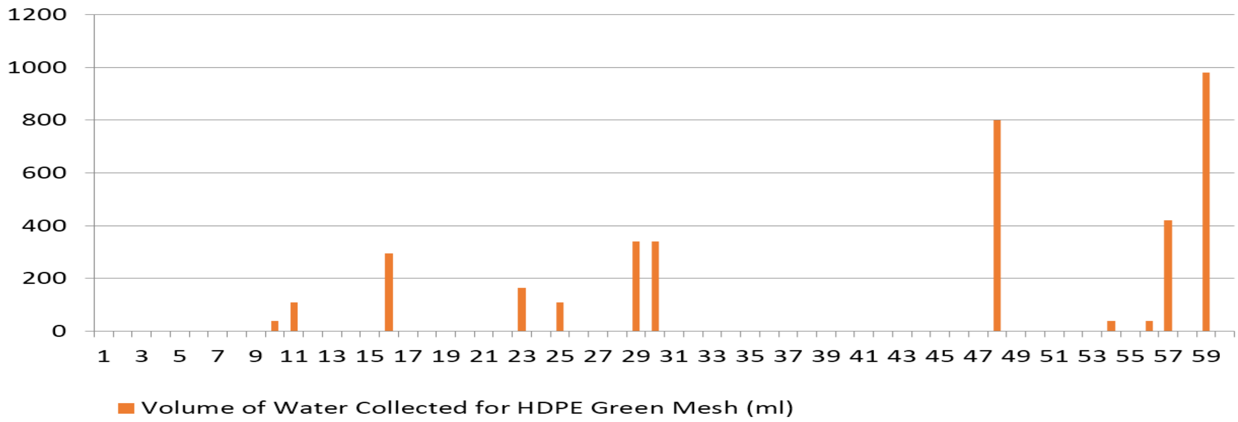

Fig.5. Volume of water collected for HDPE green mesh (ml)

3.2. One-Way ANOVA Analysis

Before doing an analysis of variance for feasibility comparison of mesh's material according to its volume of water collected. A descriptive statistical (Table 3) was made by using SPSS software to simplify the task completing the one way ANOVA.

Table 3. Descriptive statistics for volume of water collected by mesh materials in 60 days

Types of Mesh	No of Days	N	Mean Water Collected (ml)	Std. Dev.	Std. Error	95% Confidence Internal Mean		Min	Max
						LB*	UP**		
White PE Plastic Sheet	60	60	36.56	102.44	13.23	10.09	63.02	0.00	580.00
Black Polyolefin Mesh 2mm			32.12	134.58	17.37	-2.65	66.88	0.00	920.00
Black Polyolefin Mesh 1mm			39.01	136.46	17.62	3.76	74.26	0.00	760.00
HDPE Green Mesh			61.26	180.66	23.32	14.59	107.93	0.00	980.00

*upper boundary

**lower boundary

After creating a descriptive statistical data in Table 3, the analysis was further carry out in Table 4 for one way ANOVA analysis. By using data information in Table 3, ANOVA analysis data was made.

Table 4. ANOVA analysis

No			Sum of Squares (SS)	df	Mean Square (μ^2)	F	Sig.
1	White PE Plastic Sheet	Between Groups	619158.944	59	10494.219	.	.
		Within Groups	0.000	0	.		
		Total	619158.944	59			
2	Black Polyolefin Mesh 2mm	Between Groups	1068578.256	59	18111.496	.	.
		Within Groups	0.000	0	.		
		Total	1068578.256	59			
3	Black Polyolefin Mesh 1mm	Between Groups	1098731.154	59	18622.562	.	.
		Within Groups	0.000	0	.		
		Total	1098731.154	59			
4	HDPE Green Mesh	Between Groups	1925728.119	59	32639.460	.	.
		Within Groups	0.000	0	.		
		Total	1925728.119	59			

$\mu 1$ = mean square for white PE plastic sheet

$\mu 2$ = mean square for black polyolefin mesh with 2mm width range

$\mu 3$ = mean square for black polyolefin mesh with 1mm width range

$\mu 4$ = mean square for HDPE green mesh

H_0: $\mu 1 = \mu 2 = \mu 3 = \mu 4$

H_1: $\mu 1 \neq \mu 2 \neq \mu 3 \neq \mu 4$

Mean square (μ^2) is used to test the variability of the test on mesh's material feasibility. According to Table 4, the mean square is different for each mesh's material which means H_0 is not accepted while H_1 is accepted. Moreover, the F value is less than 0.0001 which means the terms of feasibility of the material is significant.

3.3. Multiple Linear Regression Analysis

The analysis continues with multiple linear regression analysis to find the interrelationship between meteorological effects such as relative humidity, rainfall amount and duration and dry bulb temperature. It is important to relate the meteorological effect with the feasibility of materials to prove the applicability of mesh to capture atmospheric water.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.528	4	2.132	0.542	0.706[b]
	Residual	216.518	55	3.937		
	Total	225.046	59			

a. Dependent Variable: RH (%)

b. Predictors: (Constant), HDPE_Green_Mesh, Black_Polyolefin_Mesh_2mm, Black_Polyolefin_Mesh_1mm, white_PE_plastic_sheet

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.653	4	0.913	0.069	0.991[b]
	Residual	727.197	55	13.222		
	Total	730.850	59			

a. Dependent Variable: Rainfall_Duration (min)

b. Predictors: (Constant), HDPE_Green_Mesh, Black_Polyolefin_Mesh_2mm, Black_Polyolefin_Mesh_1mm, white_PE_plastic_sheet

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.033	4	0.008	0.028	0.998[b]
	Residual	16.104	55	0.293		
	Total	16.137	59			

a. Dependent Variable: Rainfall_Amount (mm)

b. Predictors: (Constant), HDPE_Green_Mesh, Black_Polyolefin_Mesh_2mm, Black_Polyolefin_Mesh_1mm, white_PE_plastic_sheet

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.647	4	0.412	0.580	0.678[b]
	Residual	39.053	55	0.710		
	Total	40.700	59			

a. Dependent Variable: Dry_Bulb_Temp

b. Predictors: (Constant), HDPE_Green_Mesh, Black_Polyolefin_Mesh_2mm, Black_Polyolefin_Mesh_1mm, white_PE_plastic_sheet

4. CONCLUSION

In a conclusion, the most feasible mesh material for fog harvesting is Black Polyolefin Mesh with 1mm width range for weave design where the material can withstand strong wind and has similar properties as wettability surfaces. The hydrophilicity of the mesh materials allowed fog droplets to precipitate onto its surfaces and flow into the water gutter. The width range between the strips of the mesh which is 1mm decreases the disappearance of water droplets brought by the wind. Thus, it proves that the impaction of fog particle and surface area of the mesh allows practical fog harvesting.

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