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Assessment of Atmospheric Water Harvesting Potential in Tagaytay City and Dasmariñas City, Cavite, Philippines

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ABSTRACT

This study aimed to assess the atmospheric water harvesting potential in two areas in Cavite: Dasmariñas City and Tagaytay City. A device was designed and assembled to collect atmospheric water data from the two locations during dry and wet seasons. The variation in the amount of atmospheric water collected was analyzed. Climatic parameters were also observed and its relationship to the amount of atmospheric water was established. Results showed that the difference between atmospheric water collection in Tagaytay City and Dasmariñas City, as well as between the wet and dry seasons, was present but not notably statistically significant. Collection at night, specifically during the time frame of 12:00 am to 6:00 am, produces more atmospheric water than collection during the day where the lowest quantity was obtained during the time frame of 12:00 pm to 6:00 pm. During the dry season, more atmospheric water was collected at the onset compared to a wet season where more atmospheric water was collected at the end. Additionally, relative humidity has a moderate and direct correlation to atmospheric water quantity while temperature and wind speed have a very weak and indirect correlation. The predictive model performs well and produces relatively accurate results. Moreover, the collected atmospheric water samples passed the physical drinking-water quality parameters such as turbidity, total dissolved solids, and color ranging from 0.10 to 0.40 NTU, 4 to 12 mg/L, and less than 2 CU, respectively. It also passed the chemical drinking-water quality parameters such as levels of cadmium and lead, and pH ranging from 0 to less than 0.00049 mg/L, 0 to less than 0.0038 mg/L, and 6.5 to 7.5, respectively. However, total coliforms were present in the samples, thus, an adequate treatment and cleaning process must be developed for the atmospheric water harvesting device.

Keywords: Atmospheric Water Harvesting, Atmospheric Water Quantity, Atmospheric Water Quality

INTRODUCTION

As the global population grows and climate change continues to alter weather patterns, the availability of fresh water is becoming an increasingly urgent issue. In many parts of the world, traditional sources of water are becoming scarce or unreliable, and alternative sources of water are needed. In the Philippines, the national water supply is totally extracted from conventional sources mainly the groundwater and surface waters which include rivers, lakes, and reservoirs (Asian Development Bank, 2013). However, due to high demand, water resources pollution, droughts and flooding, and lack of proper management plan, the water sources in the country are constantly subjected to a huge threat (Rubio & Lee, 2008). Approximately 9 million Filipinos still suffer from unsafe, underdeveloped, and unsustainable water sources and the inadequacy of water supply affects not only rural areas and low-income urban cities but foremost urban centers like Metro Manila (Palanca-Tan, 2020). According to the World Health Organization (2019), the effects of the El Niño phenomenon and climate change could worsen the problem because increasing temperatures may continue to dry – up the country's water resources. Furthermore, limited access to water supply can also lead to more serious health risks because people will be forced to tap into unsafe water sources. Finding a convenient and sustainable alternative source of fresh water is a way to solve this problem. One potential source of water is the atmosphere, there are 3.1 quadrillion gallons of water in the atmosphere at any given time and an active atmospheric water harvester can produce water from relative humidity as low as 30% (Inbar et al., 2020). The assessment of atmospheric water harvesting potential in specific locations can help identify the feasibility of using this underutilized resource. Atmospheric water harvesting potential is not well-researched in the country. Previous studies mainly focused directly on the design and fabrication of atmospheric water generators despite the fact that the climate trends and variability contribute more to the potential amount of water that can be harnessed from the atmosphere. There were prototype atmospheric water generator systems developed previously like Solar-Powered Atmospheric Water Generation and Purification

System (SAWGAPS) that proved to be functional but need to be further optimized (Cabacungan, et al., 2009). A portable atmospheric water sequestrator was also designed to harvest water from the atmosphere and investigated the effects of humidity ratio, volumetric air flow rate, and Peltier surface temperature on water generation (Borromeo, 2020). An atmospheric water generator based on Manolo Fortich, Bukidnon was also developed to investigate the longitudinal profile of the fins and intake fan component of the device. The study proved that relative humidity has a greater effect on atmospheric water generation than the length of fins and intake fan speed (Tan & Albiento, 2022). There should be a vast consideration of the climate profile and trends in the area selected for implementing atmospheric water harvesting technologies (Kgatla, Gidudu, & Nkhalambayausi Chirwa, 2022).

Cavite is a province located in the southern part of Luzon Island, and it is known for its rapidly growing population and expanding urbanization. The province is characterized by a tropical climate, with high levels of humidity (78.47%) which makes it a potentially suitable location for atmospheric water harvesting (Weather and Climate, 2017). According to Madrazo (2002, as cited in Valerio & Mallari, 2019), despite the rich freshwater resources in upland Cavite, the water availability will later be scarce for its households due to the threat posed by climate change, pollution, improper management, and rapid urbanization in the uplands most especially in Tagaytay City. It is projected that the province will later face challenges in securing freshwater resources for domestic, agricultural, industrial, and recreational purposes (Valerio & Philip, 2019). The increasing resident population and frequent visitation of tourists in urban areas in Cavite are the primary reasons for the water shortages felt in the area which compelled them to rely on neighboring municipalities to add up for their water supply (Punay, 2014). This study aimed to investigate the quantity and quality of the harvested atmospheric water at Tagaytay City and Dasmariñas City in the province of Cavite at different seasons and times of the day. Understanding atmospheric water harvesting potential is important to determine the availability and reliability of this water source. It aids in water

resource planning, including determining the feasibility of implementing atmospheric water harvesting technologies and estimating potential water supply that can be obtained during times of water stress or when traditional water sources are contaminated or unavailable. The results of this study may also serve as a basis for designing an efficient atmospheric water harvesting device. This study also supports the United Nations Sustainable Development Goals (SDGs), particularly SDG6: Clean Water and Sanitation, SDG11: Sustainable Cities and Communities, and SDG13: Climate Action.

METHODOLOGY

Study Area

Figure 1 shows the locations where the atmospheric water was collected and assessed. Zambal, Tagaytay City, and Sampaloc I, Dasmariñas City is located within the inland areas in the province of Cavite and experiences the Type I climate of the Philippines. Tagaytay City is located at a higher elevation at 630 masl compared to Dasmariñas City at 150 masl. Higher elevations often have cooler climates and higher relative humidity which influences the capacity of air to hold moisture. Tagaytay City has a hilly and mountainous terrain with a 10% to 25% slope while Dasmariñas City has a relatively flat landscape with 0% to 18% slope which can affect wind patterns and atmospheric moisture content.

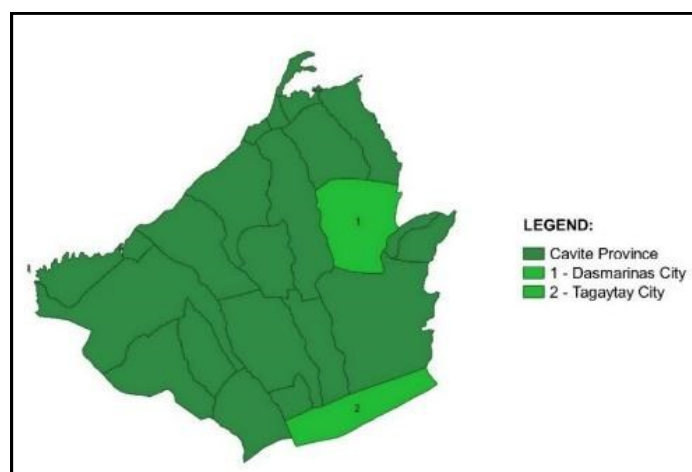


Figure 1. Map of Cavite province highlighting the study areas.

Moreover, Zambal, Tagaytay City is relatively far from industrial zones and urban centers and has more vegetative cover compared to Sampaloc I, Dasmariñas City which is closer to industrial zones and urban centers with less vegetative cover due to urbanization. This influences air pollution and anthropogenic influences which could contaminate the collected atmospheric water. The variations in the study areas help capture a broader understanding of atmospheric water have potential under various factors.

Atmospheric Water Harvesting Device

Figure 2 shows the atmospheric water harvesting device used in this study. One unit of atmospheric water harvesting device was used for each station. Each device was placed in an open space with an even surface. It is composed of a 12 L/day dehumidifier that serves as the main atmospheric water harvester with a compressor power of 185 W. It produces water at a minimum temperature of 5oC and a minimum relative humidity of 30%. The dehumidifier was supported by a stable portable structure that was made of 20-mm blue polyvinyl chloride (PVC) pipes and fittings. Caster wheels were installed under the four corners of the frames. The overall dimension of the setup is 530 mm in length, 550 mm in width, and 1,775 mm in height. It is powered by an electrical source and equipped with sensors and data loggers placed in front of the dehumidifier to measure the temperature, relative humidity, and wind speed. Moreover, the device was designed specifically for research purposes only and does not consist of water-filtration systems or water-treatment technologies.

To ensure the cleanliness of the atmospheric water harvesting device, the air filter, drainage hose, and water container were regularly cleaned every after a 6-hour time of collection to prevent the buildup of dust, mold, or bacteria that can contaminate the collected atmospheric water. These components were washed using a mild detergent and then rinsed and dried thoroughly to remove any residues. Proper ventilation in the sampling stations where the device was placed was ensured to help prevent the accumulation of pollutants and microorganisms in the air.



Figure 2. Atmospheric water harvesting device.

Data Collection

The atmospheric water quantity for both sampling stations was collected daily. Each machine was operated for 12 hours per day, divided into 2 time ranges, for a total of six hours per time range. On the first day, the machine was operational from 6:00 am to 12:00 pm followed by 6:00 pm to 12:00 am. The next day, the machine was operational from 12:00 am to 6:00 am followed by 12:00 pm to 6:00 pm. Furthermore, water samples were taken on an hourly basis and discarded after weighing. The atmospheric water harvesting device operated for 30 days per month for 4 months, from April 2022 (end of dry season), May 2022 (start of wet season), October 2022 (end of wet season), and November 2022 (start of dry season), in accordance with the Type I climate of the Philippines.

For climatic parameters, temperature, relative humidity, and wind speed were taken into consideration in the study. Ambient temperature and

relative humidity were automatically measured in degrees Celsius (°C) and in percentage (%), respectively, using DHT22 sensors installed in an Arduino UNO microcontroller. Reading from these parameters was taken every 10 minutes and stored in a Secure Digital (SD) card. On the other hand, wind speed was manually measured in meters per second (m/s) using a handheld digital anemometer. Reading from this parameter was taken every 20 minutes and manually recorded in an Excel sheet. The sensors were placed in front of the dehumidifier to obtain an accurate measurement.

For the atmospheric water quality, atmospheric water samples were collected and stored into a 1L PET bottle designated for physical and chemical water quality parameter testing and to a 100 mL glass bottle designated for microbiological water quality parameter testing which was provided by the water testing laboratory. The sampling was taken every 15th and 30th day of each month.

Data Analysis

The difference in location, season, and time of collection were considered in the assessment of the quantity of the atmospheric water harvesting potential. Two factors, location and time range, were used for the treatments to investigate the possible difference in atmospheric water quantity during the dry and wet seasons. A 2x4 factorial under Randomized Complete Block Design (RCBD) was used for the experiment and the blocking factors were the onset and end of each season assuming that the amount of atmospheric water harvested during these periods may represent possible variation. On the other hand, two factors, location and season, were used as treatments in determining the overall atmospheric water quantity. A 2x2 factorial under Randomized Complete Block Design (RCBD) was used for the experiment and the blocking factors were the onset and end of season. The onset and end of each season also served as replications of the treatment combinations. Two-way ANOVA was used to compare the atmospheric water quantity in terms of location and time range during the dry and wet seasons, while location and season for the overall atmospheric water quantity. For comparison of means, Tukey's Honest Significant Difference

(HSD) test was used. The treatment combinations used in this study were as follows:

Treatment Combinations under Dry Season at Different Locations and Time Ranges

D1 - Tagaytay, 12mn– 6am
D2 - Tagaytay, 6am – 12nn
D3 - Tagaytay, 12nn – 6pm
D4 - Tagaytay, 6pm – 12mn
D5 - Dasmariñas, 12mn – 6am
D6 - Dasmariñas, 6am – 12nn
D7 - Dasmariñas, 12nn – 6pm
D8 - Dasmariñas, 6pm – 12mn

Treatment Combinations Under Wet Season at Different Locations and Time Ranges

W1 - Tagaytay, 12mn– 6am
W2 - Tagaytay, 6am – 12nn
W3 - Tagaytay, 12nn – 6pm
W4 - Tagaytay, 6pm – 12mn
W5 - Dasmariñas, 12mn – 6am
W6 - Dasmariñas, 6am – 12nn
W7 - Dasmariñas, 12nn – 6pm
W8 - Dasmariñas, 6pm – 12mn

Treatment Combinations of Overall Amount of Atmospheric Water Harvested under Wet and Dry Seasons at Two Different Locations

O1 - Tagaytay (dry season)
O2 - Tagaytay (wet season)
O3 - Dasmariñas (dry season)
O4 - Dasmariñas (wet season)

On the other hand, regression analysis was used to analyze the relation of each climatic parameter such as temperature, relative humidity, and wind speed to the atmospheric water quantity. Seventy-five percent (75%) of the total raw data count was used to test the strength of the relationship and establish the simple regression model between the climatic parameters and the amount of atmospheric water. The remaining 25% was used for validation. Three statistical measures of accuracy were used for the predictive model evaluation such as the Nash-Sutcliffe efficiency (NSE), Percent bias (PBIAS), and RMSE-observations standard deviation ratio

(RSR).

The formula for getting the values of NSE, PBIAS, and RSR are shown in **Equations 1, 2, and 3**, respectively.

$$NSE = 1 - \left[\frac{\sum_{i=1}^n (Y_i^{actual} - Y_i^{predicted})^2}{\sum_{i=1}^n (Y_i^{actual} - Y^{mean})^2} \right] \quad \text{Equation 1}$$

$$PBIAS = \frac{\sum_{i=1}^n (Y_i^{actual} - Y_i^{predicted})}{\sum_{i=1}^n (Y_i^{actual})} \quad \text{Equation 2}$$

$$RSR = \frac{\sqrt{\sum_{i=1}^n (Y_i^{actual} - Y_i^{predicted})^2}}{\sqrt{\sum_{i=1}^n (Y_i^{actual} - Y^{mean})^2}} \quad \text{Equation 3}$$

Where:

Y_i^{actual} = ith actual observation for the constituent being evaluated;

$Y_i^{predicted}$ = ith predicted value for the constituent;

Y^{mean} = mean of actual data for the constituent being evaluated;

n = total number of the observations

RESULTS AND DISCUSSIONS

Atmospheric Water Quantity During Dry Season

The amount of water collected at different time ranges during the dry season observation in liters was shown in **Table 1**. Based on the two-way ANOVA there were significant differences between the start and end of season, time of collection, and treatment combination. The biggest amount of water collected is at D1, with 2.61 L, while the lowest is at D7, with 2.15 L. This is because Tagaytay City,

Table 1. Amount of atmospheric water collected per time range during the dry season.

TREATMENT	ATMOSPHERIC WATER QUANTITY (L)		
	R1	R2	MEAN
D1	2.65	2.58	2.61 ^a
D2	2.43	2.32	2.38 ^{abc}
D3	2.27	2.10	2.19 ^{bc}
D4	2.55	2.47	2.51 ^{ab}
D5	2.57	2.54	2.55 ^a
D6	2.43	2.19	2.31 ^{abc}
D7	2.35	1.96	2.15 ^c
D8	2.53	2.28	2.41 ^{abc}
MEAN	2.47	2.31	

*means with the same letter are not significantly different

situated at a higher elevation, generally experiences cooler temperatures compared to Dasmariñas City. Additionally, the amount of water collected at the onset of the season with an average value of 2.47 L is always higher than the water collected at end of the season with an average value of 2.31 L. At the start of the dry season, residual moisture from the preceding wet season was still present in the atmosphere. As the dry season progresses, the temperature increases lead to a decrease in atmospheric water content (Bureau of Meteorology, 2018). With less moisture available, the amount of atmospheric water collected diminishes over time. On the other hand, the effect of locations and interaction between factors does not have a significant effect based on the results. This may be attributed to the general similarity of weather patterns and atmospheric conditions in Tagaytay City and Dasmariñas City which falls on the same climate type, situated in the same province with comparable temperature ranges and humidity levels.

Furthermore, in both locations, the amount of water collected during the night (D1, D4, D5, D8) is greater than the amount collected during the day (D2, D3, D6, D7). Temperatures often drop at night,

resulting in a decrease in the air's ability to hold moisture. As the temperature drops, the relative humidity rises, resulting in a larger concentration of water in the atmosphere. Moreover, the atmosphere is more stable at night due to the cooling of the Earth's surface, which restricts vertical air movement and can lead to the accumulation of moisture near the surface, resulting in increased atmospheric content (Genthon, et al., 2017). The approximate total atmospheric water harvesting potential in Tagaytay City and Dasmariñas City was 9.69 L/day and 9.78 L/day during the dry season. Based on the Water Supply and Sanitation Master Plan (NEDA, 2021), the per capita consumption of water for domestic use (Level III) is at least 100 L/day/person. The harvested atmospheric water covers only about 9.69% and 9.78% of the daily consumption of an individual in Tagaytay and Dasmariñas City, respectively. The harvesting of atmospheric water has been limited to the capacity of the device used in this study. A larger capacity with a complete system may increase the amount of atmospheric water that can be harvested.

Atmospheric Water Quantity During Wet Season

The amount of water collected at different time ranges during the wet season observation in liters was shown in **Table 2**. The Two-way ANOVA showed a significant difference between the onset and end of the season, time of collection, and treatment combinations at a 1% level of confidence, and a significant difference in location at a 5% level of confidence. The highest amount of water was obtained at W1 (2.71 L), while the least amount of water was collected at W7 (2.30 L). It's also worth noting that the amount of water collected at the onset of the wet season is less than the amount collected at the end of the season. The previous dry season lowered moisture levels, resulting in a drier atmospheric condition. Rainfall replenishes moisture and increases relative humidity as the wet season progresses, increasing the atmospheric water content. At the end of the wet season, moisture availability is higher, resulting in greater atmospheric water accumulation (Bureau of Meteorology, 2018). Similar to the dry season, the amount of water collected in the wet season during the night is greater than during the day.

Table 2. Amount of atmospheric water collected per time range during the wet season.

TREAT MENT	ATMOSPHERIC WATER QUANTITY (L)		
	R1	R2	MEAN
W1	2.68	2.74	2.71 ^a
W2	2.41	2.56	2.48 ^{bc}
W3	2.13	2.33	2.23 ^d
W4	2.56	2.69	2.62 ^{ab}
W5	2.66	2.72	2.69 ^a
W6	2.26	2.39	2.32 ^{cd}
W7	2.09	2.30	2.20 ^d
W8	2.52	2.67	2.59 ^{ab}
MEAN	2.41	2.55	

*means with the same letter are not significantly different

Furthermore, more atmospheric water was collected in Tagaytay City than in Dasmariñas City. The approximate total atmospheric water harvesting potential in Tagaytay City and Dasmariñas City were 10.04 L/day and 9.80 L/day during the wet season. The harvested atmospheric water during this season covers only about 10.04% and 9.80% of the daily consumption of an individual in Tagaytay City and Dasmariñas City, respectively assuming Level III domestic connection.

Overall Atmospheric Water Quantity

As shown in **Table 3**, in terms of location, O1 and O2 obtained more atmospheric water than O3 and O4. This means that Tagaytay City may collect more atmospheric water than Dasmariñas City. Furthermore, in terms of season, O2 and O4 got more atmospheric water than O1 and O3. This suggests that there was more atmospheric water available for collection during the wet season than during the dry season. However, the result of the two-way ANOVA conducted revealed that there is no significant difference in the replications, locations, seasons, interaction of factors, and treatment combinations. This was because the sampling stations experienced a similar type of

Table 3. The total amount of atmospheric water collected per season.

TREAT MENT	ATMOSPHERIC WATER QUANTITY (L)		
	R1	R2	MEAN
O1	149.87	142.77	146.32 ^a
O2	145.74	156.05	150.90 ^a
O3	148.22	134.52	141.37 ^a
O4	144.86	152.35	148.61 ^a

*means with the same letter are not significantly different

climate. Additionally, the collection methods, experimental setup, and sampling periods are standardized, identical, and consistent for both location and season. This indicates that the location and season at which atmospheric water was collected did not lead to a significant increase or decrease in the quantity of atmospheric water collected, hence, harvesting of atmospheric water can be done in any season and in any of the locations without causing significant variation in its quantity. Based on the Water Supply and Sanitation Master Plan (NEDA, 2021), the per capita consumption of water for domestic use (Level III) is approximately 100 – 150 lpcd.

Relationship of Climatic Parameters and Atmospheric Water Quantity

Figure 3 to **Figure 5** shows the relationship of climatic parameters such as temperature, relative humidity, and wind speed to the atmospheric water quantity. It can be observed that relative humidity ($R^2 = 0.5035$) has a stronger relationship with the atmospheric water quantity compared to the temperature ($R^2 = 0.2773$) and wind speed ($R^2 = 0.1004$). This indicates that relative humidity could better explain variability in the amount of atmospheric water compared to the two climatic parameters. It can also be seen that atmospheric water quantity has an increasing trend with relative humidity while a decreasing trend with temperature and wind speed. The reason behind this is that as the relative humidity increases, the air becomes closer to its saturation point which means it contains high water vapor. On the other hand, as temperature

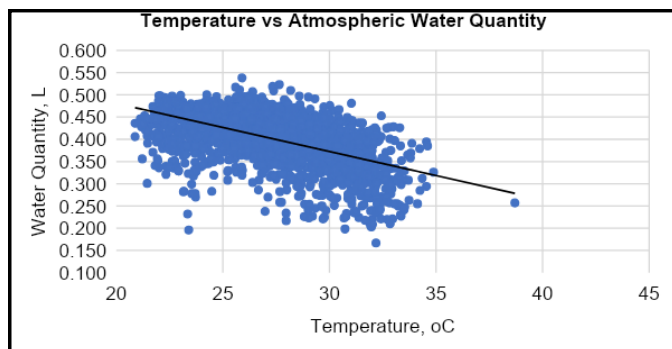


Figure 3. Temperature vs atmospheric water quantity.

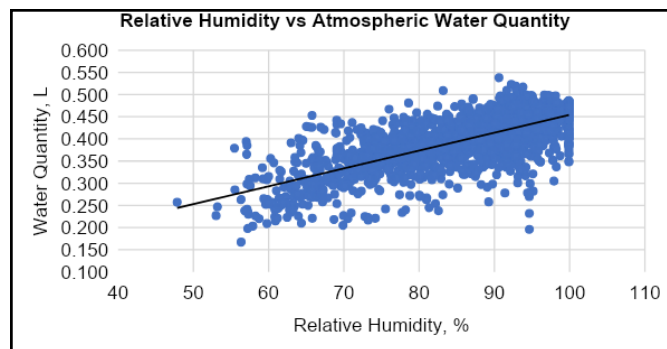


Figure 4. Relative humidity vs atmospheric water quantity.

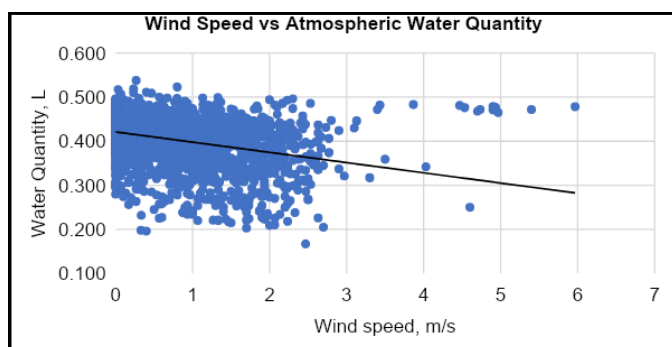


Figure 5. Wind speed vs atmospheric water quantity.

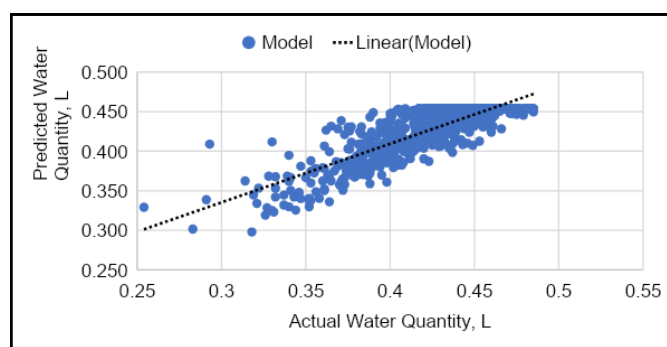


Figure 6. The predictive model of atmospheric water quantity based on relative humidity.

increases the capacity of air to hold water vapor decreases, leading to a decrease in atmospheric water quantity. Finally, as wind speed increases it easily displaces air masses and disturbs the vertical movement of air which is crucial for lifting and condensing moisture (Huang, 2016).

The plot between the predicted amount of atmospheric water quantity based on the simple regression model of relative humidity and the actual amount of atmospheric water is shown in **Figure 6**. An R^2 value of 0.7183 suggests a strong accuracy in predicting atmospheric water based on the relative humidity. This further proved that based on the two locations in Cavite, high relative humidity levels are often associated with increased atmospheric water quantity due to saturation of air leading to condensation (NASA, 2020).

Table 4 shows the results of the three measures of accuracy of the model and its indication according to Calkins (2005). The Nash-Sutcliffe Coefficient (NSE) of the model was computed to be 0.71 which

was considered a good fit between the actual data and predicted results. The computed percent bias (PBIAS) was -0.008, which is about the PBIAS optimal value of zero. The negative sign indicated that the model tends to marginally overestimate the results. Lastly, the RMSE-Standard Deviation Ratio (RSR) value was computed to be 0.54, which indicated a better model prediction performance.

Physical Property of Atmospheric Water

The results of the physical analysis of the collected atmospheric water samples are shown in **Table 5**. Based on the Philippine National Standards for Drinking Water (PNSDW) the accepted values for turbidity, total dissolved solids, and apparent color are 5.00 NTU, 600 mg/L, and 10 CU, respectively. Results showed that all of the physical parameters of the collected atmospheric water that has been evaluated were within the accepted values. This indicated that the harvested atmospheric water is relatively free of suspended particles, harmful microorganisms that can cause waterborne diseases,

Table 4. Results of the measures of accuracy for the predictive model.

MEASURE OF ACCURACY	VALUE	RANGE OF VALUES (Moriasi, 2007)	REMARKS
Nash-Sutcliffe Coefficient (E)	0.71	E = 0, Perfect Fit E > 0.75, Very Good Fit 0.64 < E < 0.75, Good Fit 0.5 < E < 0.64, Satisfactory Fit E < 0.5, Unsatisfactory	Good Fit
Percent Bias (PBIAS)	-0.008	PBIAS = 0, Optimal Value Positive Value = model underestimation bias Negative Value = model overestimation bias	Near-optimal value and indicates model overestimation bias
RMSE-Standard Deviation Ratio (RSR)	0.54	RSR = 0, Perfect Model Simulation Values may range from 0 to a large positive value.	Low RSR means low RMSE which indicates better prediction performance and accuracy

Table 5. Physical Properties of the Harvested Atmospheric Water.

DATE OF COLLECTION	TURBIDITY (NTU)		TOTAL DISSOLVED SOLIDS (mg/L)		APPARENT COLOR (CU)	
	Tagaytay	Dasmariñas	Tagaytay	Dasmariñas	Tagaytay	Dasmariñas
April 15	0.15	0.25	6.00	11.00	<2.00	<2.00
April 30	0.10	0.25	6.00	12.00	<2.00	<2.00
May 15	0.30	0.30	6.00	11.00	<2.00	<2.00
May 30	0.15	0.15	6.00	11.00	<2.00	<2.00
October 15	0.20	0.20	4.00	12.00	<2.00	<2.00
October 30	0.20	0.20	5.00	11.00	<2.00	<2.00
November 15	0.20	0.20	5.00	10.00	<2.00	<2.00
November 30	0.40	0.20	5.00	9.00	<2.00	<2.00

and dissolved substances, such as salts, minerals, and metals, that can negatively affect the taste and quality of water. The samples also have no discoloration that could be caused by contaminants, such as organic matter or minerals (Wilson, 2019).

Chemical Property of Atmospheric Water

The results of the chemical analysis of the collected atmospheric water samples are shown in Table 6. The Philippine National Standards for Drinking Water (PNSDW) established the accepted values for the level of cadmium, lead, and pH as 0.003 mg/L, 0.01 mg/L, and 6.5 – 8.5, respectively. All of the chemical parameters of the harvested atmospheric water were within the said safe values. Cadmium

and lead are toxic heavy metals that can cause serious health effects if consumed in high amounts over prolonged periods and may be more harmful to children (Bouida, et al., 2022). Results also showed that the samples were not too acidic nor too alkaline making it safe for human consumption and other uses.

Microbiological Property of Atmospheric Water

Table 7 shows the results of the total coliform test of the atmospheric water samples. 5 out of 8 atmospheric water samples in Dasmariñas City and 4 out of 8 atmospheric water samples in Tagaytay City failed the test as they exceeded the PNSDW limit for total coliform which is <1.1 MPN. Total

Table 6. Chemical Properties of the Harvested Atmospheric Water.

DATE OF COLLECTION	CADMIUM (mg/L)		LEAD (mg/L)		pH	
	Tagaytay	Dasmariñas	Tagaytay	Dasmariñas	Tagaytay	Dasmariñas
April 15	0.00000	0.00000	0.00000	0.00000	7.30	7.50
April 30	0.00000	0.00000	0.00000	0.00000	7.00	7.00
May 15	0.00000	0.00000	0.00000	0.00000	7.20	7.40
May 30	0.00000	0.00000	0.00000	0.00000	6.60	7.30
October 15	<0.00049	<0.00049	<0.0038	<0.0038	6.50	6.90
October 30	<0.00049	<0.00049	<0.0038	<0.0038	7.40	6.80
November 15	<0.00049	<0.00049	<0.0038	<0.0038	7.40	7.00
November 30	<0.00049	<0.00049	<0.0038	<0.0038	6.70	6.60

Table 7. Total coliform of the collected atmospheric water samples.

DATE OF COLLECTION	TOTAL COLIFORM (MPN)	
	Tagaytay	Dasmariñas
April 15	<1.10	>8.00
April 30	<1.10	>8.00
May 15	>8.00	>8.00
May 30	>8.00	>8.00
October 15	>8.00	>8.00
October 30	<1.10	<1.10
November 15	<1.10	<1.10
November 30	>8.00	<1.10

coliform bacteria are generally not considered harmful, but their presence indicates a potential health risk. The result indicates that microorganisms were present in some of the atmospheric water samples. This can be attributed to the lack of a treatment process within the atmospheric water harvesting device and the inability to clean the internal components beyond the detachable air filter such as condensation coils. Atmospheric water harvesting devices and components both active and passive may be contaminated with algal and bacterial growth and bird droppings (Jarimi, Powell, & Riffat, 2020). In the study conducted by Cabacungan et al. (2009), the fabricated solar-powered atmospheric water generation with a purification system yielded water with no detected

fecal coliform and within the accepted value of total coliform set by the PNSDW. This suggests that the purification system and implementation of regular cleaning and maintenance of the unit are essential if we consider the harvested atmospheric water for human consumption. Regular testing and monitoring of water quality must also be done to guarantee that the water supply remains safe and that any issues can be identified and addressed promptly to prevent the spread of harmful bacteria and other pathogens in the water supply to protect public health.

CONCLUSION

The researchers effectively assessed the atmospheric water harvesting potential in terms of its quantity and quality in Dasmariñas City and Tagaytay City in Cavite in two tropical seasons (dry and wet). With the results obtained in the study, it can be concluded that higher amounts of atmospheric water can be collected in Tagaytay City and the wet season. The time of collection at night gains more atmospheric water than during the day, specifically, at 12:00 am to 6:00 am, followed by 6:00 pm to 12:00 am, then at 6:00 am to 12:00 pm, and at least at 12:00 pm to 6:00 pm. During the dry season, more atmospheric water can be collected at the onset of the season while more atmospheric water can be collected at the end of the season during the wet season. Moreover, there is a significant difference in the amount of atmospheric water collected during the wet and dry seasons. Nevertheless, when considering the total atmospheric water collected

across both seasons, no significant difference was observed.

In terms of its relation to climatic parameters, atmospheric water quantity is greatly influenced by relative humidity which has a moderate correlation and has increasing trend indicating that as relative humidity increases the atmospheric water quantity also increases compared to temperature and wind speed which both have a very weak correlation and a decreasing trend indicating that as temperature and wind speed increases, atmospheric water quantity decreases. The predictive model based on relative humidity performed well and can be used for accurate prediction of atmospheric water quantity.

On the other hand, the atmospheric water quality passed the acceptable limits established by the Philippine National Standards for Drinking Water in terms of physical and chemical parameters. However, total coliforms were present in the atmospheric water which suggests that the atmospheric water harvesting device lacks cleanliness and adequate treatment process, hence, implementation of adequate treatment and disinfection processes is necessary. Based on the results, the design of the device must be improved and optimized in terms of its current design and operation to increase its capacity to harvest atmospheric water in areas with the same climatic conditions as Tagaytay City and Dasmariñas City in the province of Cavite.

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