Theoretical and Experimental Analysis of Atmospheric Water Harvesting Device

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ABSTRACT

A semi-open atmospheric water harvesting device using atmospheric water vapor processing technology was designed and built. The processor is a device which extract water molecules from the atmosphere, ultimately causing a phase change from vapor to liquid. This is done by concentrating air, containing water vapor through a solid desiccant. Then heating the desiccant to remove the air and allow it to condense and then collect the condensate.

The research focuses on the development of a relationship for the amount of silica gel to the amount of water produced to determine the sufficient amount required for the specific application. This relationship was found to be $M_w = 1.0776 M_s - 0.4752$, with a solar panel efficiency of 10.7%.

The recorded values collected were then used to calculate the amount of water produced and were compared to the actual amount of water collected.

The study concentrates on the extracting potable water from air especially with respect to the remote/rural arid places with deficit of natural fresh water and electricity supply. Solar energy as a power supply were focused on with discussing their strengths and limitations.

Keywords: Atmospheric Water Harvesting device, Desiccant, Silica gel, Solar panel, Solar Energy, Condensate, air.

1. INTRODUCTION

The basis for this project is that water is essential for the healthy functioning of the human body. Having access to safe and sufficient water and sanitation are now recognized as a basic human right. Freshwater scarcity and stress are increasing in tropical regions as a result of expanding populations, tourism, climate change and pollution, states the United Nations Environment Program.

Despite widespread water pollution and shortages of drinking water, there is an abundance of water around us, from the air that we breathe to the water in the sea. Water harvesting and treatment technologies that are solar or wind powered is the most environmentally friendly way to extract pure quality water from the air or sea at a low cost. Therefore, by designing a solar powered device capable of removing water vapor from the air and safely capturing it for the use of safe, clean drinking water.

This provides a new approach to solving the problem of water scarcity in tropical regions.

2. LITERATURE REVIEW

2.1 Importance of Extracting Water from Atmospheric Air

Shortage of drinking water is chronic, severe, and widespread in the regions of Northern Africa, Middle East, and Central and Southern Asia. The problem of providing arid areas with fresh water can be solved by the following methods [1]:

(i)   Transportation of water from other locations
(ii) Desalination of saline water (ground and underground)
(iii) Extraction of water from atmospheric air.

Transportation of water through these regions is usually very expensive, and desalination depends on the presence of saline water resources, which are usually rare in arid regions.

Water is available in abundance on the earth; however, there is a shortage of potable water in many countries in the world. In many countries, non-renewable energy from oil and natural gas is used to desalinate water from sea water in multi-effect evaporators. It is also common in some places to use electric power to run reverse osmosis units for water desalination. In the first method, a large quantity of heat is required to vaporize the water, while the second method requires electric power to generate high pressure to force the water component of seawater through a membrane. Both methods consume large amounts of energy and require high skill operation.

Nevertheless, these two methods, until recently, were considered as the most practical way of desalinating seawater because the Gulf countries, known for their shortage in drinking water, are also known for the availability of oil as a cheap source of energy. Due to the fossil fuel-based energy consumption in both methods, CO_2 emission will always be an issue of environmental concern. Also there are many places where energy is too expensive to run such desalination processes [1].

Sometimes fresh water is required at locations far from the energy grid-lines, requiring a local source of energy. Hence, even countries with rich resources of energy, such as the Gulf countries, have shown a strong interest in the desalination processes that often utilize renewable energy sources.

2.2 Why use atmospheric air?

The Atmospheric air is considered a huge and renewable source of fresh water. The atmosphere contains about 12,900 km^3 of fresh water, whereas liquid water resources of inhabited lands is about 12,500 km^3 [2].

Air, composed primarily of nitrogen (78%) and oxygen (21%) contains varying amounts of water in vapor form, depending on its temperature and pressure. The amount of water in the atmosphere is calculated from its partial pressure, p within the air mass. At a given temperature and pressure, the partial pressure cannot exceed a certain level without condensation occurring; this is the saturation pressure, p_S. The relative humidity R.H. is then defined as the ratio of partial pressures at the same pressure. The p_S rises in conjunction with the increase in air temperature (or pressure) and the water mass capacity of 1 m^3 of air also rises. For air at a given temperature and RH, the psychometric diagram, representing the mass fraction of water in the air at different temperatures and R.H. allows the air's water saturation point to be ascertained. This is "dew temperature",the temperature at which water vapors condenses.

For instance, the dew temperature of air at 20ºC and 80% relative humidity is 18ºC. The dew temperature falls to 10ºC if the R.H is only 25%.

On most substrates, condensation occurs in the form of droplets, representing partial wetting of the substrate by liquid water. As they expand, the droplets touch and merge, their growth becoming self-similar over time. The astonishing result is that with this growth, a substantial proportion of the medium remains dry (ideally 45%).

2.3 Adsorption-desorption on desiccants

Silica gel is a form of colloidal silica [3] which consist of porous grains with high surface area that are able to adsorb and retain substantial quantities of water. The adsorption capacity of this adsorbent can be over 0.40 $g_{H2O}/g_{silicagel}$ [4]. Silica gel adsorbs water because of the silanol groups on its surface [5]; [6]. Some of these groups are polarized and they are the active sites for hydrogen bonding. Apart from its high surface area, silica gel has many other advantages such as ability to regenerate after use by releasing the adsorbed water. Desorption of water occurs when grains are exposed to thermal energy or subjected under vacuum conditions [5]. Moreover, it is mechanically, physically and

The following are performance parameter affecting the silica gel desiccant:

(i)   Ambient (outdoor) air moisture.
(ii)   Outdoor air temperature. Inlet temperature may have diurnal and seasonal variation which must be accounted for in the system design and water output specifications.
(iii)   Natural wind velocity through desiccant or fan assisted to 2–3 m/s. Focus is on maximizing

thermally stable, non-toxic and non-corrosive [7]. Its surface can be easily modified [8]; [9]. Silica gel is a material of a significant importance in process engineering. For example, it can be used for water vapor removal from ventilation air in buildings, in thermal energy storage systems or in heat pumps, air-conditioning and refrigeration systems [10]; [11]; [12]; [13]; [14]; [15]. In all these applications, an adsorber is the main component of the system. Designing an efficient adsorption system for thermal applications requires in-depth studies about the mass and heat transfer phenomena in an adsorber. Although silica gel is widely used, the state-of-the-art in the field of moisture transfer within its pores is not sufficient yet [13].

Beysens and Milimouk [2] describes the following method of water harvesting that will have significant importance in this study. This type of atmospheric water collector uses desiccants (silica aerogels, zeolites, etc.), which adsorb atmospheric water at ambient temperature. For regeneration, the desiccant needs to be heated to 150-300°C. The water vapor is then recovered by means of condensation at normal temperature. Here too, for the early equipment now on the market, a considerable energy supply, at least equal to the latent heat of evaporation is necessary to recover the adsorbed water. However, there are prototypes in which daylight provides this energy via the use of a solar
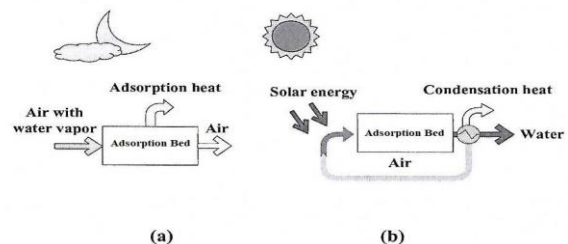

FIGURE 1: Principle of the solar-driven adsorption air-to-water cycle

collector with a heating element attached. In this case, the method is as follows: air is ventilated at night over a bed of desiccants that adsorb the water vapor. During the day, the premises are closed, the greenhouse effect increases the temperature and, as in solar desalination pools, the water vapor is partially desorbed, condenses on a cold part and is collected. The only energy required is for the ancillary equipment (ventilators, etc.).

moisture removal rate, therefore bias is fortuitously towards smaller and less equipment expensive.
(iv)   Desiccant should be as dry as possible when re-exposed to the process air stream.
(v)   Outdoor air moisture content at the site would usually be relatively high so moisture of air entering reactivation would be higher, therefore a relatively high reactivation temperature may be required.
(vi)   Air velocity through desiccant: set air stream at minimum required to transport heat to desiccant, to

optimize energy consumption of subsequent condensation process.

3. MATERIALS AND METHODS

The materials used for atmospheric water harvesting device consists of a rectangular frame, with metal sheet sidings as shown in Figure 2. There are 3 small solar powered fan erected at the front and both sides of the device to induce air flow into the device during the adsorption phase. The inlet to the device is at the bottom, this help the air to pass through the membrane. This feature would help in the adsorption of water vapor. After the adsorption process occurs, air was exhausted out via the three fans and stop. The heating element placed at the bottom of the device heated up the desiccant material to release the water vapor from the desiccant as shown in Figure 3.

The hot saturated air then rises to the top of the device where it condensed into droplets. Since the device is tilted at an angle, the droplets runs down and was collected in a reservoir. Solar panels were placed on both sides at the top of the device to power the fans and the heating element with the aid of two 12V batteries and a power inverter. There was also be a manual angle controller, to adjust the inclination angle of the whole device to maximize the amount of solar energy collected.

Figure 2: Atmospheric Water Harvesting Device-plan view

Figure 3: Atmospheric Water Harvesting Device-front view

3.1 Experimental Procedure

The following are the procedure used in the experimentation of the water harvesting device:

(i)   Ensure that the device is able to get proper exposure to the sunlight.
(ii)   Adjust the slope of the device to 10º.
(iii)   Allow the PV solar panels to charge up the two 12V batteries to full charge for approximately 5 hours.
(iv)   Ensure that the batteries are fully charged by checking the display on the solar controller.

(v)   Measure ambient temperature and relative humidity using the thermocouple and hygrometer respectively.
(vi)   Open the back panel of the device and place the tray of silica gel weighing 0.5kg on the heater.
(vii)   Close the back panel ensuring that it properly sealed.
(viii) Switch on the fans using the switch and observe the color change of the silica gel and record the time.
(ix)   Perform two measurements/repetitions for the following steps:
-       Measure and record the inlet dry bulb temperature and R.H using the thermocouple and hygrometer respectively.
-       Measure and record the outlet dry bulb temperature and R.H using the thermocouple and hygrometer respectively at 15 minute intervals. That is the R.H at the exhaust of each fan until the silica is saturated. (Turns from orange to white).
(x)   Switch off the fans and turn on the D.C. to A.C. inverter to power on the heater.
(xi)   Record the temperature and R.H during the heating of the silica gel using a thermocouple and hygrometer. Also note the time required for evaporation to begin.
(xii)   Turn off the heater when all moisture is released and leave to cool off and collect the water produced.
(xiii) Measure the mass and volume of water collected.
(xiv)   Repeat steps (vi) to (xiii) for 1kg, 1.5kg and 2 kg of tray of silica gel respectively.

3.2 Required Apparatus for testing:

The following are the equipment needed for testing the device:

➢ Hygrometer – to measure dry bulb temperature and relative humidity.
➢ Scale – to weight the amount of water collected.
➢ Thermocouple- to measure the temperature changes of the silica gel during heating in desorption phase.
➢ Measuring cylinder- to measure the volume of water collected.
➢ Stopwatch – to record time.

3.3 Experimentation

The composite desiccant material is placed on the tray as shown in Figure 2. For the adsorption process, the fans induced airflow into the system. The adsorption process starts because of the vapor pressure difference between the surface of composite desiccant material and atmospheric air. The composite desiccant material (adsorbent) has lower vapor pressure than that of the atmospheric air. This process continued until the equilibrium conditions was reached, i.e. when the vapor pressure on the adsorbent surface is the same as that of atmospheric air, attained. The silica gel changed color from orange to white to indicate that it is saturated as shown in Figure 4.

At the end of this process, the fans stop and the device was exposed to the sun rays for the regeneration process. As the

temperature of the composite desiccant material rises due to the heating element, the vapor pressure difference between the surface of composite desiccant material and the air of the inner space of the box increases. Therefore, adsorbed moisture is transferred to the air of the inner space and increases the vapor pressure. As the solar intensity increases and thus heating element temperature, mass transfer of vapor from material to the air of inner space increases and reaches to saturation condition. The water vapor condenses on the inner side of the glass and after coalition forms the small drops as shown in Figure 5. The small drops slide along the surface of the glass and get collected in the reservoir. The maximum regeneration temperature depends upon the available heat.

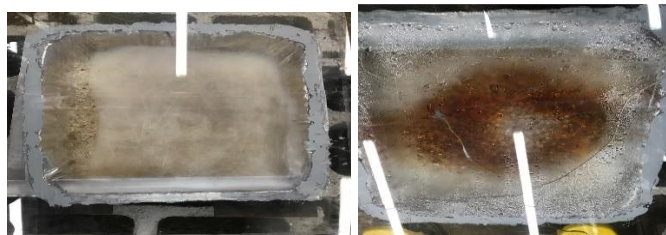**Figure 4: Color change of the indicating silica gel after the Adsorption Process.**

Figure 5: Condensate on the glass during the Desorption Process.

The schematic of the electrical connection of the atmospheric water harvesting device is shown in Figure 6.
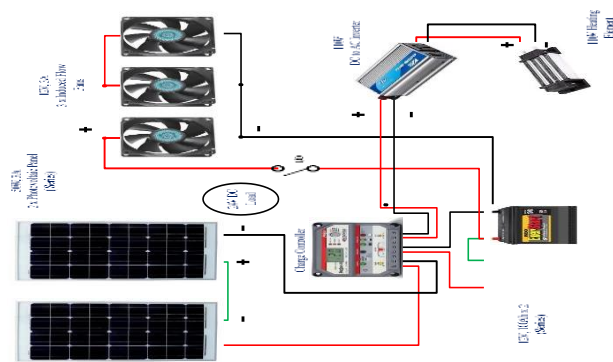

Figure 6: Electrical Schematic Diagram for the Device

4. RESULTS AND DISCUSSION

Nine sets of tests were performed in this study: due to space limitations only the results of selected tests are used here to evaluate the validity of the theoretical models. Tables 1, 2, 3, 4 and 5 summarizes the pertinent parameters of the tests. The results of the ambient and adsorbent bed relative humidity for 0.5, 1, 1.5 and 2 kg Silica gels samples are shown in Tables 1, 2, 3, and 4 respectively while Results of measurements of mass of the adsorbed water collected using varying amounts of silica gel are presented in Tables 5.

Eight sets of tests were presented to show the results for two types of silica gel phase, adsorption and desorption cases and also the ambient and the adsorbent bed air conditions.

The process of adsorption involves separation of a substance from one phase accompanied by its accumulation or concentration at the surface of another. The adsorbing phase is the adsorbent, and the material concentrated or adsorbed at the surface of that phase is the adsorbate. In this study the adsorbate is the water vapor from the atmosphere while the adsorbent is the silica gel. Adsorption is an exothermic process so it results in heat rejection. Therefore, in order to maintain the process, the adsorbent bed was cooled by three fans (A, B, and C) to remove the rejected heat and also to act as air simulator into the bed.

Desiccants acting as water vapor concentrators extract water vapor from air by establishing a vapor pressure gradient causing flow of water molecules toward the desiccant surface. Desiccants that do not change chemically or physically when water vapor is added are called adsorbents. In contrast, absorbents undergo chemical or physical changes when they absorb water. Usually, adsorbents are solids while absorbents are liquids. Water vapor molecules are attracted to the desiccant surface electrical field and condense inside capillaries.

The mass of fresh water extraction from atmosphere depends significantly on sorbent amount, solar collector heat, and mass transfer capacity in bed; and the more silica gel used the efficient the device would be. Two solar-driven fresh water devices are fabricated on the sorption cycle to extract fresh water from the atmosphere.

The open cycle concept machine is designed and produces 0.036 kg of water with 0.4 m^2 solar collector area, using 0.5 kg silica gel for initial experiment.

Comparison of relative humidity at saturation with time for samples 0.5kg, 1kg, 1.5kg, 2kg silica gels were shown in Figure 7. The general trends of the curves for the experimental results for the samples are similar and the higher the relative humidity, the more water is adsorbed and in a quicker time. 2kg, 1.5kg and 0.5kg silica gels has the highest relative humidity and adsorb the highest amount of water vapor from air between 15 minutes to 90 minutes of the experimentation while 1kg silica gel adsorb least water vapor from air. Between 90 minutes to 120 minutes' silica gel weigh 1.5kg adsorb more water vapor than other samples. Figures 8 and 9 show the results for desorption tests on silica gel.

The higher the desorption temperature, the more water released. For regeneration, the desiccants (0.5, 1, 1.5 and 2kg silica gels)

were heated to about 130ºC as shown in Figure 9. The water vapor was then recovered by means of condensation at normal temperature. A considerable amount of energy at least equal to the latent heat of evaporation was supplied to recover the adsorbed water. A solar collector with a heating element attached was used to supplied the energy required. In this case, the method is as follows: air is ventilated at night over a bed of desiccants that adsorb the water vapor. During the day, the premises are closed and energy is supplied through a heating element attached to a solar collector, the water vapor is partially desorbed, condenses on a cold part and is collected. The only energy required in this experimentation is from the ancillary equipment. The amount of water produced with different mass of silica gel is shown in Figure 10.

Comparison between calculated and actual mass of water collected in 2hrs/kg of Silica Gel is shown in Figure 11.

There was a strong correlation between the calculated mass of water collected per hour and the amount of silica gel used. This correlation can be used to determine the required amount of silica gel for a specific amount of water needed to be collected.

Table 1: Ambient and Adsorbent Bed Relative Humidity for 0.5 kg Silica Gel (Adsorption Phase)

Time, t/mins.	0	15	30	45	60	75	90	105	120	Average
Ambient Relative Humidity (%)										
Inlet	49.6	50.2	53.4	53.4	52.8	53.0	54.7	52.1	52.4	42.4
Relative Humidity at Saturation [inside the device] (%)										
Fan A	50.8	39.3	41.6	42.7	43.1	44.3	46.0	47.2	47.9	45.1
Fan B	51.2	40.2	41.9	43.9	45.7	46.5	47.2	49.7	54.0	46.7
Fan C	52.2	43.8	42.1	44.8	46.3	47.5	48.6	49.2	52.3	47.1
Average	51.4	41.1	41.9	43.8	45.0	46.1	47.3	48.7	51.4	46.3

Table 2: Ambient and Adsorbent Bed Relative Humidity for 1.0 kg Silica Gel (Adsorption Phase)

Time, t/mins	0	15	30	45	60	75	90	105	120	Average
Ambient Relative Humidity (%)										
Inlet	36.9	38.4	40.2	40.3	40.6	45.3	44.5	40.3	41.8	40.9
Relative Humidity at Saturation (%) [Adsorption phase inside the device]										
Fan A	43.8	25.0	28.4	28.5	29.3	31.6	32.4	36.5	42.1	33.0
Fan B	42.6	25.3	29.0	29.3	29.7	31.9	33.1	36.8	39.0	33.2
Fan C	40.2	28.3	28.1	29.2	30.1	32.2	32.8	36.8	40.4	33.1
Average	42.2	26.2	28.5	29.0	29.7	31.9	32.7	36.7	40.5	33.1

Table 3: Ambient and Adsorbent Bed Relative Humidity. for 1.5 kg Silica Gel (Adsorption Phase)

Time, t/mins.	0	15	30	45	60	75	90	105	120	Average
Ambient Relative Humidity (%)										
Inlet	53.1	50.6	50.3	49.8	50.6	52.1	48.	48.3	47.6	50.1
Relative Humidity at Saturation [inside the device] (%)										
Fan A	50.3	41.6	42.1	43.3	44.6	45.2	46.8	49.7	53.3	46.0
Fan B	50.7	38.7	41.5	42.5	43.9	44.6	46.1	49.9	52.5	45.6
Fan C	46.3	41.2	42.8	43.6	44.9	46.6	48.1	55.5	59.1	47.9
Average	49.1	40.5	42.1	43.1	44.5	45.5	47.0	51.7	55.0	46.5

Table 4: Ambient and Adsorbent Bed Relative Humidity for 2.0 kg Silica Gel (Adsorption Phase)

Time, t/mins.	0	15	30	45	60	75	90	105	120	Average
Ambient Relative Humidity (%)										
Inlet	56.1	50.6	53.2	55.0	58.1	56.5	57.1	56.1	55.9	55.4
Relative Humidity at Saturation [inside the device] (%)										
Fan A	55.1	40.5	41.2	42.8	44.1	45.3	46.8	49.9	50.1	46.2
Fan B	55.5	41.4	42.2	43.6	45.5	46.8	47.7	49.6	49.8	46.9
Fan C	55.6	40.9	42.3	43.0	45.8	46.8	48.2	50.3	50.1	47.0
Average	55.4	40.9	42.2	43.1	45.1	46.3	47.6	50.0	50.0	46.7

Table 5: Actual (Experimental) mass of water collected using varying amounts of silica gel

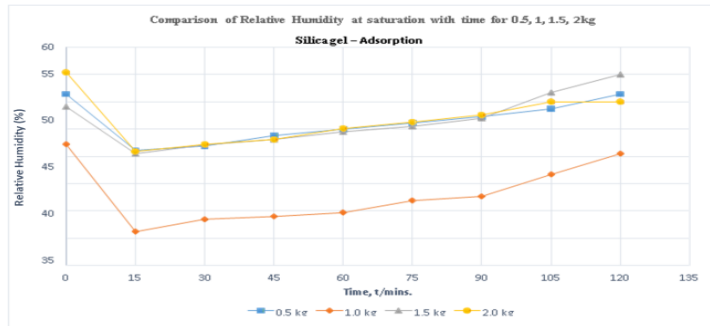| Mass of Silica gel, ms/kg	Actual mass of water collected/ kg (Experimental)
0.5	0.036
1.0	0.061
1.5	0.128
2.0	0.211

Figure 7: Comparison of Relative Humidity at saturation with time for 0.5, 1, 1.5, 2kg desiccants
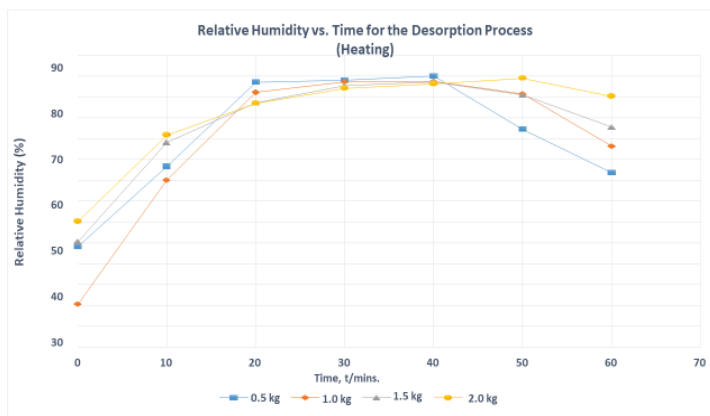

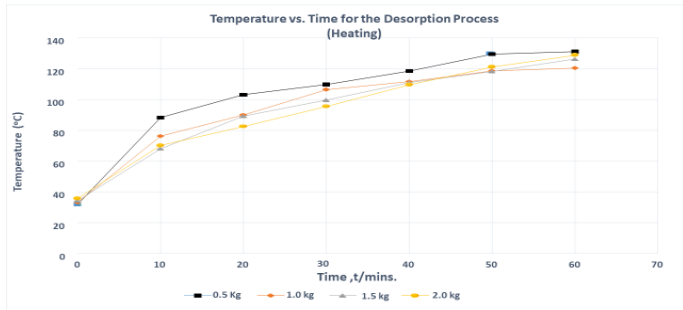**Figure 8: Relative humidity per time for the Desorption phase (heating of desiccants samples)**

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Figure 9: Temperature per time for the Desorption phase (heating of desiccants samples)

4.1 Sample calculation to determine the amount of water absorbed by 1 kg of silica gel.

Inlet conditions: Volume flow rate, $V_a = 0.37$ m³/s
Taking ambient temperature: 32.1ºC (305.1K)
Average Relative Humidity: 40.9% = 0.409 See Table 2
Outlet conditions: Temperature: 34.9ºC
Average Relative Humidity: 33.1% = 0.331 See Table 2

Determination of the saturation pressure, P_{g1} at the inlet:

P_{g1} = P at T = 32.1ºC
Interpolating from saturated water and steam to determine the inlet saturation pressure, P_{g1} corresponding to ambient temperature, 32.1ºC.

$P_{g1} = 0.04789 \ bar$

Relative Humidity, $\varphi = P_s/P_g$

Where, $P_s = partial \ pressure \ of \ vapour \ in \ the \ air$

$P_g = saturated \ pressure \ corresponding \ to \ the \ temp. \ of \ the \ vpour$

Partial pressure of the vapour in the air, $P_{s1} = \varphi_1 P_{g1}$

$$= 0.409 \times 0.04789$$

$P_{s1} = 0.01959 \ bar$

(i)   Calculating concentration/ moisture content of water vapor in the air:
Specific Humidity, $\omega = m_s/m_a = 0.622 \times P_s/P\text{-}P_s$

where: subscript **s** denotes the vapor and **a** denotes the dry air.

the total pressure, P is the barometric pressure.

Taking barometric pressure, P = 1.01326 bar.

$\therefore \omega_1 = 0.01226$

(ii)   Determination of the Dew Point Temperature corresponding to partial vapor pressure, P_{s1}:

Interpolating from saturated water and steam to determine the Dew Point Temperature, T_d corresponding to ambient temperature, 32.1ºC.
Dew point Temperature, $T_d = 17.2°C$
The water vapour content of air is often quoted as dew point. This is the temperature to which the air must be cooled before dew condenses from it.

(iii)   Calculation of the mass flow rate of air:

Form the equation, $P = P_a + P_s$
where: P_a is the partial pressure of the dry air, and P_s, the partial pressure of the vapor in the air.
$P_a = P - P_s = 1.01326 - 0.01959 = 0.99367 \ bar$
Using the following equation:

$P_a V_a = \dot{m}_a R_a T$
The gas constant of air, $R_a = 0.287$ kJ/kg-K
$\dot{m}_a = P_a V_a / R_a T = 0.4199$ kg/s
The mass flow rate is assumed constant throughout the process.

(iv)   Determination of the saturation pressure, P_{g2} at the outlet:
Interpolating from saturated water and steam to determine the outlet saturation pressure, P_{g2} corresponding to outlet temperature of 34.9ºC.
$P_{g2} = 0.05758 \ bar$
Relative Humidity $= \varphi_2 = 0.331$
Partial pressure of the vapour in the air,
$P_{s2} = \varphi_2 P_{g2} = 0.331 \times 0.05758$
$P_{s2} = 0.01906 \ bar$

(v)   Calculating concentration/ moisture content of water vapor in the air:
$\therefore m_{s2} = \omega_2 \times \dot{m}_a = 0.01192 \dot{m}_a$
Mass of water absorbed per hour by the silica gel $= \dot{m}_{s1} - \dot{m}_{s2}$
$= (0.01226 - 0.01192) \times \dot{m}_a$
$= 3.4 \times 10^{-4} \times 0.4199 \times 3600$
$= 0.605 \ kg/hr$
Assuming the mass of water absorbed is equal to the mass released after heating; Mass of water collected = 0.605 kg/hr.
Therefore, after exposing the device for 120 minutes = 2 hrs. (Table 6).
The amount of water collected using 1 kg of silica gel is
2 × 0.605 = 1.21 kg of water.
Therefore, a correlation can be estimated between the mass of water collected per hour and the mass of silica gel used. The following relationship is made:
$Mw = 1.0776 Ms - 0.4752$ (which is of the form $Y = mX + C$)
where: Y = Mass of water collected per hour, Mw /kg/hr
m = gradient = 1.0776 kg/hr.
X = Mass of Silica gel, Ms /kg
C = y-intercept = -0.4752 kg
Using this relationship, one can determine the required amount of silica gel needed to produce a certain amount of water as shown in Figure 10. Taking into consideration, cost of the silica gel and the amount of heat energy needed to release the water vapor from the silica.

Table 6: Comparison of Calculated and Actual values of water collected using varying amounts of silica gel

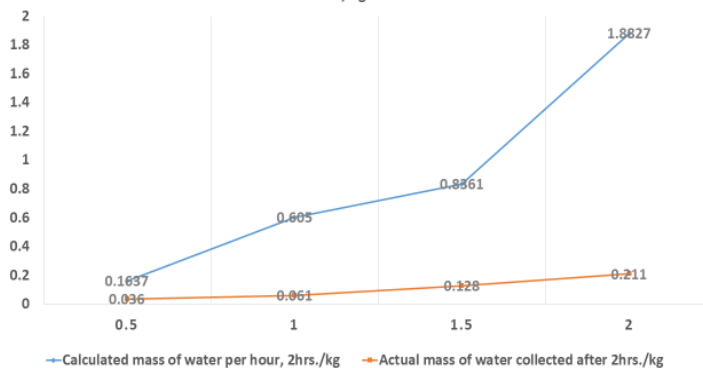|	Calculated		Actual	
Mass of Silica gel, ms/kg	Mass of water per hour, Mw/kghr^{-1}	Mass of water collected after 2hrs/kg	Mass of water collected after 2hrs/kg	Effectiveness (%)
0.5	0.1637	0.3274	0.036	11.0
1.0	0.605	1.21	0.061	5.0
1.5	0.8361	1.6722	0.128	7.7
2.0	1.8827	3.7654	0.211	5.6

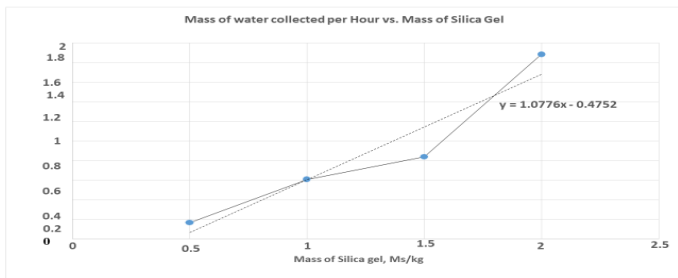**Figure 10: Amount of water produced with different mass of silica gel**

Figure 11: Comparison between calculated and actual mass of water collected in 2hrs/kg of Silica Gel

5. CONCLUSION

A semi-open adsorption air-to-water device was designed and analyzed for fresh water production from the atmosphere. The system was analyzed and tested under different conditions. Result show that the device has a low performance in the adsorption and desorption process due to some experimental errors. The conclusion are as follows:

The device that was designed, constructed and tested will be suitable as a demonstration apparatus to show the possibility for extracting water from the atmosphere. The novelty in this design is that the inclination angle can be varied from 0-10º and can work with different amounts of silica gel.

The calculated results differed from the actual results which was due to some errors in the experiment. These were; uneven heating during the desorption phase, water vapor escaping since the device was semi-open, some of the condensate at the top glass dripped back into the tray rather than running off etc.

The higher the desorption temperature, the more water released proving that the temperature did not exceed 120ºC, otherwise the silica gel will burn and become useless.

The higher the relative humidity, the more water is adsorbed and in a quicker time.

There was a strong correlation between the calculated mass of water collected per hour and the amount of silica gel used. This correlation can be used to determine the required amount of silica gel for a specific amount of water needed to be collected.

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