Investigation of Water Condensation from Humid Air and The Feasibility Analysis of its Potable Characteristics

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Research Article

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Abstract

Freshwater scarcity will be one of the most challenging issues in the coming time. Atmospheric water harvesting could be a solution to such a problem in semi-arid and arid regions. This could help to fill the thirst as well as, improve irrigation. There are several methods available retrieve water vapour but research is needed for a cost-effective and efficient method with optimized parameters. This method utilizes the Peltier device for water condensation and in-depth experimental analysis has been done to investigate the optimal conditions for maximum water production from atmospheric moisture. The experimental setup was designed in such a way that during the condensation process, the online monitoring of water condensate was recorded for more than 10-12 hours each day using a digital electronic weighing balance with an accuracy of 0.01 gram. The produced water was tested for the physico-chemical parameters of condensed water, and the results were discussed with a comparison to the standard results. The rate of produced condensed water from humid air was achieved as 19 L/m^2-day. This study will help us to develop applications in the field of alternative water resources near the coastal areas for potability.

1. Introduction

Globally, it is well known that drinking water resources are decreasing both in quality and quantity-wise. In the last century, increasing world population became 7 billion from 2 billion people. It is estimated that this growth will not stop and it will become 9.3 billion approximately by 2050. Thus, the issues of limited natural resources and especially the crisis of water stocks arise. Indeed, the available drinking water reserves will be insufficient enough for the whole world. Therefore, it is necessary, as is the case in energy, for example, to find unconventional ways to produce water. The condensation of water vapour naturally present in the air could be a solution to this problem. The Atmospheric air contains different types of gases and the distribution of gases like nitrogen (78%), oxygen (21%), and carbon dioxide, argon, and other gases (1%). Moist air is a mixture of dry air and water vapour. The amount of water vapour present in the atmosphere from 0.4–1.5% of the weight of atmospheric air, which depends upon atmospheric temperature and pressure. The water vapour plays an important role in the natural condensation process (Talbot and Baird, 2002). The atmosphere contains more than 12.9×10^{12} m^3 of renewable water (Gökcek and Gökcek, 2016), which may utilized as one the alternate sources. In this study, the possibility of using Thermo-electric cooling (TEC) devices to retrieve water from the atmospheric air has been explored. India has approximately 7516.6 km to 5422.6 km of mainland coastline and 1197 km of Indian islands. Indian coastline touches nine states – Gujarat, Maharashtra, Karnataka, Goa, Kerala, Tamil Nadu, Odisha, Andhra Pradesh, West Bengal, and two territories – Puducherry and Daman and Diu. In the Indian coastal regions such as Gujarat, the relative humidity is higher and the availability of potable water is scarce. The water available in the humid air may be drawn using several methods (Sharan, 2007). Usually, these TEC devices are meant for cooling or heating, which may be used to create a surface below the dew point and can be regulated to condense the water vapour (Tiwari, 2011, Singh and Jerath, 2016). The technique developed in this study has been analyzed for its effectiveness and sustainability to produce water condensate. The water condensate produced in this process can be easily made useful for vegetation, plants, and animals, especially in arid and semi-arid environments. The physico-chemical parameters of dew generated from environmental humidity has been analyzed. The question of using dew water stored in the atmospheric air posed long ago, whether it can produce enough quantity for daily use. From the beginning of the 20th century, several experiments have been designed to produce clean water from humid air. The dew formation is the basic physical phenomenon for producing water condensate (Nikolayev et al., 1996). The physical parameters of dew water are similar to the distilled water, some chemical and physical parameters match with distilled water (Sharan et al., 2007). and can be converted to potable water easily.

The investigations found that the environment has different kinds of gases in different percentages (Torbjörn, 1996). The meteorological parameters like wind speed, wind direction, relative humidity, dew point temperature, etc. plays an important role to condense the dew water from water vapour (Beysens et al., 2005). The experimental setups have been designed and used to condense the dew water in the arid area where potable water is insufficient (Jacobs et al., 2008). The experimental setup interpolated in the area of Jerusalem in May 2003, to collect the dew water for 12 months. The condensed dew water from humidity was obtained is in order of 0.6 Lm^{-2}, which is a maximum possible quantity (Berkowicz et al., 2004). Marc Muselli's dew water collection device was inexpensive to collect the dew water which made use of an area of 10x3 m^2. The condensing rectangular surface area covered by foil made of TiO_2 and $BaSO_4$ microspheres are embedded in polythene with angle 60° from vertical. Huge dew harvesting systems have been fabricated on the ground at minimum cost. This device interpolated on the Mediterranean island (Corsica, France; Biševo, Croatia). These devices have been installed on some buildings mainly on the roof and some outdoor areas, which have more humidity. To collect the dew water by applying the thermally insulated condensing foil. The experimental maximum yield was 11.4l L/ day (Muselli et al., 2006; Medici et al., 2014). They experimentally found, that the effect of thermal discontinuities when water droplets grow on the cooling surface. It was reported that the temperature was different at edges, Centre, and corners. The effect of temperature difference on the mass diffusion and vapour concentration profile surrounding the drops have the direct effect of growing the dew drops. The collection of more water vapour gets faster growth on the surface, and less water vapour gets lower growth. The growth patterns direct compete to catch the water vapour which means, there is a linear water concentration profile towards the perpendicular direction to the substrate. The growth can be enhanced and reduced, which depends on the thermal homogeneity of the thermal profile. The mass diffusion controls the growth around the drops. The drops collection is more or less; it depends on the humidity near the boundary or middle of the surface (Gupta et al., 2019; Nilsson, 1996; Tiwari, 2011). An experiment investigated that condensation rate increase the influence of heat sinks orientation with 0°C to 90°C from vertical to horizontal. Finn's heat sink used for the heat rejection side of the peltier device and the cold side of the aluminium plate used for condensation. The condensation of water vapour from humid air by using the uncoated plate. The condensation rate increased by coating the surface of the aluminium plate with polytetrafluoroethylene (PTFE) up to 28 to 30%. The highest condensed water rate was 0.319 L/kWh (Hand and Peuker, 2019). The important innovation of an atmospheric water-extracting (AWE) device against the scarcity of fresh water. This AWE device worked on the vapour compression refrigeration cycle, and is used for different types of climatic conditions. The amount of condensation depends on psychometrics parameters. The setup was integrated with the climatic chamber in a laboratory to obtain the performance of AWE device. It works in seven different types of climates like humid and mild, humid and warm, dry and humid, humid and cold, dry and mild, mild and warm, mildly humid and warm. The condensate rate using this device is different in different climates and gain varies from 0.28 L/h to 1.78 L/h (Patel et al., 2020).

Historical events like the formation of spring and ponds from the dew water harvesting using large trees or stone make the fact evident that atmospheric moisture can be used as a source of fresh water. According to initial work, passive radiative condensers form a cool surface at the night. This method yields a maximum of 0.8 kg/day/m^2 of surface area, of dew water in arid and semi-arid climatic conditions. The process mainly depends on surface properties, weather conditions, and heat exchange. Further, advancements in active condensers and chillers resulted in the production of a large amount of potable water by using energy inputs. So, active condensers could be a novel alternative for producing potable water in areas having degraded water quality as well as quantity. These active condensers can help in extracting water from humid air. Several active condenser designs have been patented for producing 20 L/day of portable water by small devices and up to 200,000 L/day by larger devices. These water condenser devices have an efficiency rate of 650–850 Wh (electricity)/kg and the best efficiency of 250 Wh (electricity)/kg. Further, many studies also used solar energy, to reduce the consumption of non-renewable energy. One such method is the sorption-regeneration-condensation method. In this method, a large cooling surface is required. So, a modified version of it was proposed that could work at night only and regenerate itself during day time. Another method that could work for both day and night was dew water harvesting by sorption chillers, used with a heat sink. In this method, direct cooling results in a collection of dew water but proved to be an expensive and complex method. Till now no such method of atmospheric water production and collection is well established that could be used on a large scale for producing a large amount of portable water in regions of necessity (Island, 2007; Tu et al, 2018).

An experimental investigation of the water vapour condensation on a vertical aluminium plate (100x100x2.5) mm^3 has been proposed using the Peltier device. The setup was designed to control the condensation of water vapour in a regulated and unregulated environment. During the long duration of experimental investigation, which spreads from summers to winters the psychometrics variables like' ambient temperature, dew point temperature, relative humidity, wind velocity and atmospheric pressure were varied significantly. The psychometric variables were recorded using a multifunctional measurement device. A proportional integral derivative (PID) thermoelectric temperature controller was used as a power supply to Peltier device and precise temperature measurement for creating a homogenous low-temperature surface. The condensate nucleation was monitored and the surface was cleaned using an alcohol-based solvent.

In this study, a technique was evolved for both, rain and dew water collection from the atmosphere with the help of TEC devices at the location situated at Prayagraj, Uttar Pradesh, India. An experimental protocol was designed that condensed the dew water from the atmosphere. This experimental setup is very useful for the regions, such as coastal, arid, semi-arid, and mediterranean areas. The characterization of the condensing surface was performed at different temperatures in an atmospheric laboratory. Also, the phyco-chemical parameters of the produced dew water was tested, and its parameters have been discussed. The developed technology is fruitful for producing potable water in regions, where there is a scarcity of water in such type of areas. The setup was designed on a very small surface area (100 x100 mm^2). The water condensate from humid air was produced at this site with the rate of 19.0 L/m^2-day.

2. Material And Methods

2.1. Measurement Site

In Prayagraj the measurement site is situated in a close room, which is practically in contact with the open environment. The physical parameters like humidity, ambient temperature, wind velocity, pressure, and dew point are approximately the same but can be regulated slightly. This experimental setup was installed in Indian Institute of Information Technology (IIIT) Allahabad campus, at 25°27'N, 81°51'E at 98 m above the sea level. The mean annual rainfall is 800mm and the average annual temperature 25.7o C in this region. The annual variation coefficient is 63.

This place is situated at the interflow (Triveni Sangam) of the holy river Ganga, Yamuna, and Saraswati. The holy river Ganga and Yamuna are flowing continuously and are confluence at Prayagraj but the river Saraswati is not flowing here. This place is 650 km away from New Delhi capital of India. The Ganga and Yamuna are flowing around Prayagraj city.

2.2. Setup site

The experimental setup was installed in a closed room, where the water vapour condensation happens with the help of an aluminium plate (100 x100 mm2). The outer surface side is smooth by using the buffing process and another side was the plane. The plane side of the aluminium plate pasted with the cold side of the Peltier element (40 x 40 mm2). The hot side of the Peltier element pasted with an aluminium heat sink. The heat sink is attached with a small fan to dissipate the heat continuously. One small hole for the insertion of temperature sensor from the edge to the centre has been created. The sensor is embedded inside the plate up to the centre. This sensor measures the temperature of the plate’s surface. One more small fan put away from the setup. This fan is used to blow the wind around the setup. This fan is connected with the dc power supply. The speed of the outer fan is controlled by the power supply. The auto-tune PID thermoelectric temperature controller was connected to a Peltier element plate. The air is circulated with the help of the outer fan, and it circulates the humid air near the aluminium plate. It helps to remove the barrier of dry air from the condensing plate. An arrangement of water collecting container has been connected to the plate, which was directly kept on the electronic balance. The measurement of the condensed water has been taken with the help of the electronic weighing machine of model DS-852 G. The accuracy of the electronic weighing machine is 0.01 gram and it can weigh a maximum weight of 600 gram at one time. The PID thermoelectric temperature controller (model number LFI-3751), was working at different temperatures. The PID controller gives the power supplies to the Peltier element, temperature sensor, and fan simultaneously. The condensing outer surface of the aluminium plate was cleaned initially with acetone. When the temperature of the aluminium plate went down below the dew point, the nucleation starts and the drops of condensates appear on the flat surface. The humid air came in contact with the surface of the cold aluminium plate starts condensing.

3. Results And Discussion

3.1. Physical Variable Distribution

Figure 3 shows the psychometric variables like' relative humidity, ambient temperature, dew point temperature versus time. The maximum relative humidity was found in the months of July, August, and September. Dew point temperature was varied in days as well as every month of years and depends on the relative humidity and ambient temperature. The ambient temperature (T_a) was varied from time to time during the the day and its mean varies every month. The maximum temperature was found in March to June but relative humidity in these months was very low. The minimum temperature was found from November to January month, and in these months relative humidity was more but less than July to September. The months of July to September were very favourable to produce condensed water i.e. in this duration all psychometric variables were optimal to get maximum yield of condensed water.

3.2 Physical Variables Distribution during the Experiment

Figure 4 represented the psychometric variables, which were changing during the total time of the experiment. The experimental setup was placed in a room inside a building, which prevents a fast variation of psychometrics variable in proximity, but during the whole day, it varies slowly. A humidifier was used to control the relative humidity in the closed room. The relative humidity is very low in this region of North India, during the winter season; sometimes it goes below 30% during March-April. So, the humidifier was used to increase the relative humidity, and it was kept fixed with a slight variation of less than 5%. The relative humidity was almost fixed to 80% and a slight variation was observed during the experiment. The ambient temperature varies between 30–31°C and the dew point temperature was approximately in between 25–26°C during the experiment. The variation in flow velocity was recorded during the experiment from 0.20 to 0.34 m/s. The weight of condensed water was monitored continuously and data recorded every half an hour. Initially, it was observed that for the first 30 minutes, 1.4 grams of water condensed, and in the next half an hour it increases to 3.1 grams of water condensate. The maximum weight of condensed water was collected 4.3 grams in half an hour. After one hour of continuous condensation, it varies from 3.6 to 4.3 grams every half hour and after 12 hours of the total condensation, the approximate collection of condensed water was 95 grams.

Figure 4(a) represents the variation of the dew point temperature (T_d) and ambient temperature with time. Dew point temperature has a lower value as compared to ambient temperature during the experimental observation. Maximum water condensed on such points, where this difference is higher. Figure 4 (b) represents the relation between ambient temperature and relative humidity with experimental time. The important role of relative humidity and ambient temperature during the experiment was to increase the rate of condensation, a little humidity means more water can be condensed. The ambient temperature also affected the rate of water condensation. Figure 4(c) shows the variation of ambient temperature and flow velocity within the duration of condensation. The flow velocity also affected the condensation of water during the experiment. When the water vapour molecules came in contact with the surface of the cooled aluminium plate they change the phase from gas to liquid. The flow velocity should be minimum, so that it may only circulate the air molecules surrounding the experimental setup, and stop forming the batrrier of dry air around the cooling surface. Figure 4 (d) shows the relation between dew point temperature and rate of condensation with time. During the experiment, dew point temperature changes the rate of water condensation. A higher temperature difference between the dew point and the cooling surface tempareture increases the rate of condensation.

3.3. Flow Velocity and Condensed Water Weight

Figure 5 shows the condensed water and flow velocity concerning time. The role of wind velocity near the condensing plate is very important in the condensation process. The flow velocity increases the rate of water condensation with time and varies from 0.20 to 0.34 m/s. The flow velocity circulates the humid air surrounding the experimental active plate. When surrounding air comes in contact with the subcooling surface of aluminium vertical flat plate with the help of an outer fan, found the new water molecule to near the condensing plate to ready to phase changes from air to liquid. So condensing rate is increasing in this process continuously. The condensed water was found 2.8 gram in the first hour and increasing the condensed water in the next reading continuously. After two hours of starting the experiment, the maximum condensed water was found 8.6 grams per hour. The amount of condensed water varies during the experiment from 2.8 to 8.6 grams per hour as representing the plot.

3.4. Temperature characterization of condensing plates

The temperature distribution measurement has been performed on the surface of the aluminium plate with the thickness of 2.1 mm at different temperatures. To verify the thermal homogeneity of the active surface. The result shows that the temperature gradient on the surface of the aluminium plate was approximately 2°C. The active plate shows the temperature distribution from edge to centre, which varies from 0.5°C to a maximum difference of 2°C. The centre of the plate was at minimum temperature as compared to the edge. During the temperature distribution measurement the active surface temperature was kept more than the dew point temperature ($T_s \square T_d$).

The experiments have been performed for the different sizes and different thickness of plates at different temperatures as shown in Fig. 6. For the plate A in Fig. 6 the PID thermoelectric temperature controller was set at 23°C, the ambient temperature was 27°C, dew point temperature was 16.4°C and for plate B in Fig. 6, the PID controller was set at 21°C, the dew point temperature was 18°C, and the ambient temperature was 27°C. The temperature gradient was found maximum 2°C for both the plates. The air flowing over the plate surface bed affects the gas exchange at the liquid/gas interface, as it should be enhanced. Insufficient air molecule movement around the surface generally limits the gas exchange. The air movement affected the growth of condensation through energy and mass transfer. The latent heat exchanged through state change as liquid or gas, and the condensation of water vapour on the plate surface is directly improved through the air movement (Tiwari, 2011).

3.5. Observation of the condensation process

The rate of condensation depends on relative humidity, ambient temperature, dew point temperature, and wind velocity. After the stabilization time, the PID thermoelectric temperature controller is set at different temperatures below the dew point and the data has been collected. The PID thermoelectric temperature controller sets the active surface temperature with the help of a sensor inserted below the condensing surface at the different temperatures below the dew point to the increasing temperature difference. So, the maximum temperature set was equal to ambient temperature, where there is no condensation. The condensation process starts as we go below the dew point temperature. It has been observed that the temperature sensor was fixed just 0.5mm below the condensing surface, but there was a temperature gradient of 1–2°C observed from controller temperature, depending upon the ambient temperature. In open or uncontrolled environmental conditions, the rate of condensate produced was higher at the average ambient temperature 29.8°C, Dew point temperature 26.8°C, and relative humidity 84.1%, and then the PID thermoelectric temperature controller was set at 14°C. The experimental setup was working continuously for more than 18–20 hours and stores the water from humid air. An electronic balance was used to weigh the condensed water continuously. For that purpose, the whole experimental prototype unit was kept on the electronic balance, so that the surface profile of the condensing unit was not disturbed during the whole process.

The condensation phenomenon occurred on the different types of surfaces at different subcooling temperatures. The heat transfer coefficient of dropwise condensation is more than the film-wise condensation (Faghri and Zhang, 2006). Also, it was observed that the dropwise condensation and film-wise condensation coexisted on the surface simultaneously. The distribution of the dropwise region was a discrete region and the film-wise region forms a kind of rivulet. In this study, the dropwise condensation played the dominant role at the subcooling surface. The condensation of water vapour on the vertical aluminium plate of dimension (100 x 100 x 2.1) mm^3 is shown in Fig. 3. The PID thermoelectric temperature controller is set at 14°C and starts after 30 minutes considering stabilization time to give the output to the Peltier device. The experimental setup was working properly and drop grows on the surface of the plate after 30 minutes shown in Fig. 7(A). The setup was working continuously and in the next 30 minutes, the drops had increased the size shown in Fig. 7(B). The drops fall out after coalescence and leave a free space for growing the new drops. And then in the next 30 minutes or after 60 minutes, many drops grow to a maximum size and then fall. The nucleation of small drops happen on the new freed sub cooling surface and increases the size continuously. At the subcooling surface, the water molecules present in the humid air came to the contact of the surface of the aluminium plate by circulating the wind. Experimentally, it was found that the drops away from the film area also slide into the rivulets during the departure process. So, the water condensate was drained off from the condensing surface of aluminium plate notable in the form of rivulets, and barely big droplets form. Therefore, the rivulets were influenced by the subcooling temperature, but the dropwise region was more significant than the film wise region. When the subcooling temperature being constant for a long time, if the rivulets remained on the condensing surface of the plate then a steady-state was reached, this reduces the rate of condensation. The cleaning process of the condensing surface by acetone also affects the initial formation of the condensation type. It helps to reduce the oxidation effect could also, cause any change in the condensation form.

3.6 Physico-chemical parameters of water condensate

The whole condensation process occurs on the surface of the aluminium plate of dimension (100 x 100 x 2.1) mm^3. The psychometric variables like relative humidity, ambient temperature, dew point temperature, during the condensation experiment were recorded. The average values of the these papameters are like relative humidity (84.1%), ambient temperature (29.8°C), dew point (26.8°C), and flow velocity (0.25 m/s). The collected water condensate was clean and fresh and can be stored for a long time. The experimental setup was running from 8 am to 7 pm continuously and initially 1-litre water collected within first 10 days. The electronic weighing balance measured the amount of water collected from humid air. The physico-chemilal parameters of the collected condensed water were tested in the laboratory (see Table 1) and found that most of these parameters were very near to the distilled water. The tested parameters were compared with the standard drinking water report and also to the Indian drinking water draft (Draft Indian Standard, 2012). It was found that the physico-chemical parameters of the collected condensed water may have properties similar to the distilled water.

Table 1
The physico-chemical parameters of water condensate

Parameters	Unit	Requirement (Acceptable Limit)	Desirable limit	Maximum Permissible limit	Result of Condensed water	Distilled water	Test Protocol
1	2	3	4	5	6	7	8
			(IS 10500:2012) Second Revision				
Colour	Hazen	15 true colour unit *	5.0	15	< 5.0	ND $	2120 B, APHA 23rd 2017
Turbidity	NTU	5 Nephelometric Turbidity unit *	1.0	5.0	0.0	0.07 $	2310 B, APHA 23rd 2017
Chloride (Cl^-)	mg/L	250 mg/L !	250	1000	8.0	ND $	4500-Cl^-B, APHA23rd 2017
Electrical conductivity	µs/cm	50–500 µs/cm !	–	–	58.02	28 (µs/cm) %	2510 B, APHA 23rd 2017
Total Hardness (as $CaCo_3$)	mg/L	500mg/L as calcium carbonate *	200	600	0.0	0.3 mg/L @	2340 C, APHA 23rd 2017
Iron (Fe)	mg/L	0.4 mg/L *	0.3	No Relaxation	BDL	Less than 1 (mg/L) &	3500Fe-B, APHA 23rd 2017
Magnesium (Mg)	mg/L	10.5 mg/L *	30	No Relaxation	0.0	Less than 1 (mg/L) &	3500-B, APHA 23rd 2017
pH	--	6–8 *	6.5	8.5	7.5	6.5–7.5	4500-H^+B,APHA 23rd 2017
Sulphate($So^-{}_4$)	mg/L	500 mg/L *	200	400	8.19	Less than 2 (mg/L) &	4500-$So^{2-}{}_4$ APHA23rd 2017
Total Dissolved Solids	mg/L	1000 mg/L *	500	2000	101	11 mg/L &	2540D, APHA 23rd 2017
Alkalinity (as $CaCo_3$)	mg/L	200 mg/L #	200	600	20.0	0.52 $	2320B, APHA 23rd 2017
Nitrate($NO^-{}_3$)	mg/L	50 mg/L !	45	No Relaxation	1.12	.930 (mg/L) %	4500No_3^-B,APHA23rd 2017
Fluoride (F^-)	mg/L	1.5 mg/L !	1.0	1.5	0.22	0.002 @	4500F^-B, APHA 23rd 2017

Parameters	Unit	Requirement (Acceptable Limit)	Desirable limit	Maximum Permissible limit	Result of Condensed water	Distilled water	Test Protocol
Calcium (Ca)	mg/L	75 mg/L !	75	200	0.0	Less than 5 (mg/L) #	3500B, APHA 23rd 2017
* Solsoma, 2002, ! Lenntech, 2018, # Draft Indian Standard, 2012, $ Water Quality Report, 2017, @ Technical specifications, 2020, % Chemical properties, & EAS, 1999							

Table 1 shows the results of physico-chemical parameters of condensed water collected in the experiment, and the parameters were compared with indian standered water report 2012. The resultas of our sample are given at column 6. In the Table 1 certain parameters are given qualititatively and quantitavely as below detection limit (BDL), not detected (ND) and as per American Public Health Association (APHA) standerd. As per the table the physical parameter colour for drinking water limit vary from 5 to 15 Hazen (Draft Indian Standard, 2012) and acceptable limit of colour is 15 (Solsoma, 2002). The colour of the sample was less than 5, which is less than drinking water limit. The data was also comparerd with distilled water report (Report, 2017), as given in column 7, normally is it is ND. The turbidity parameter of sample result was 0.0 Nephelometric Turbidity Units (NTU) and acceptable limit of parameter is 5 NTU (Solsoma, 2002), which approaches to the distilled water limit given as 0.07 (Report, 2017). The Chloride (Cl^-) parameter of condensed water sample was 8.0 mg/L, which is very less than the acceptable limit 250 mg/L (Lenntech, 2018). The parameter electrical conductivity of water sample is 58.02 μs/cm and drinking water limit is 50–500 μs/cm (Lenntech, 2018). The parameter electrical conductivity of sample is lie around in limit of drinking water. The general parameter total hardness ($CaCo_3$) of testing sample is 0.0 mg/L close to distilled water limit, which is around 0.3 mg/L (Technical specifications, 2020) but range of drinking water is 200–600 mg/L and acceptable limit 500 mg/L. The general parameter Iron (Fe) of testing sample is below detection limit. The permissible limit of Iron in drinking water is 0.4 mg/L and distilled water limit of Iron is less than 1 mg/L. In the table, the parameter Magnesium (Mg) in the sample is 0.0 mg/L, while the acceptable limit for drinking water is 10.5 mg/L and in distilled water, it's limit is less than 1. The pH value of the sample is 7.5 and the pH value of drinking water required to be wihitn 6 to 8. While, the pH value range of distilled water is 6.5 to 7.5, so the pH value of the sample lie around in the range of drinking water and distilled water. The parameter Sulphate ($So^-{}_4$) of condensed the sample is 8.19 mg/L, while the acceptable limit of Sulphate ($So^-{}_4$) is 500 mg/L (Solsoma, 2002) and in the distilled water, it should be less than 2 mg/L, which is towards the testing sample (EAS, 1999). The chemical parameter total dissolved solids (TDS) of the tested sample is 101 mg/L and the range in the drinking water should be from 500 to 2000 mg/L. The admissible limit of drinking water is 1000 mg/L (Solsoma, 2002). The chemical paremetre TDS of distilled water is 11 mg/L (EAS, 1999). The parameter Alkalinity ($CaCo_3$) of the tested sample is 20 mg/L, which far away from both kind of waters i.e. the drinking water and the distilled water. The chemical parameter Nitrate ($NO^-{}_3$) of condensed sample is 1.12 mg/L, which very much less than the limit of drinking water, while it is close to the distilled water. Similarly, the case of Flouride (F^-) of the sample is 0.22 mg/L, which is close the distilled water limit 0.002 mg/L (Technical specifications, 2020). The important parameter Calcium (Ca) of sample water result is 0.0 mg/L, which similar vaue as distilled water. As per the data discussion given here, it is evident that the sample of water collected through the condensation process in this experiment have physico-chemical parameters very close to the distilled water. But there are some parameters, which are similar to the drinking water standards, which shows that the possibility of convenrting it to drinking purpose are also not denied.

4. Conclusions

The experimental setup was designed and installed in an environmetla laboratory, where the living environmental condition may be easily mimicked. The dropwise condensation phenomenon on the aluminium vertical plate was observed, it was found to be more beneficial than filmwise condensation because it may produce more water. The water condensate produced was clean and fresh and can be easily converted as potable. The physico-chemical parameters of the produced condensed water were analysed and found to be similar to the distilled water. The technology developed in this study is good enough to produce potable water. A further study in this direction may pave a way to develop some handy devices which can be used to produce potable water in the areas, where the relative humidity is higher and water availability is scarce, such as in coastal regions.

5. Declarations

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Data is available in Manuscript.

Authors' contributions:

Concept and design of the experimental setup and analysis of results, preparation of the manuscript is done by Dinesh kumar. Menuscipt review is done by Akhilesh Tiwari. Data analysis is done by Vidhu Agarwal. All the authors have read and approved the final manuscript.

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Figures

Figure 1

Atmospheric laboratory in the IIIT Allahabad Prayagraj.

Figure 2

The photograph of experimental setup with the PID Controller.

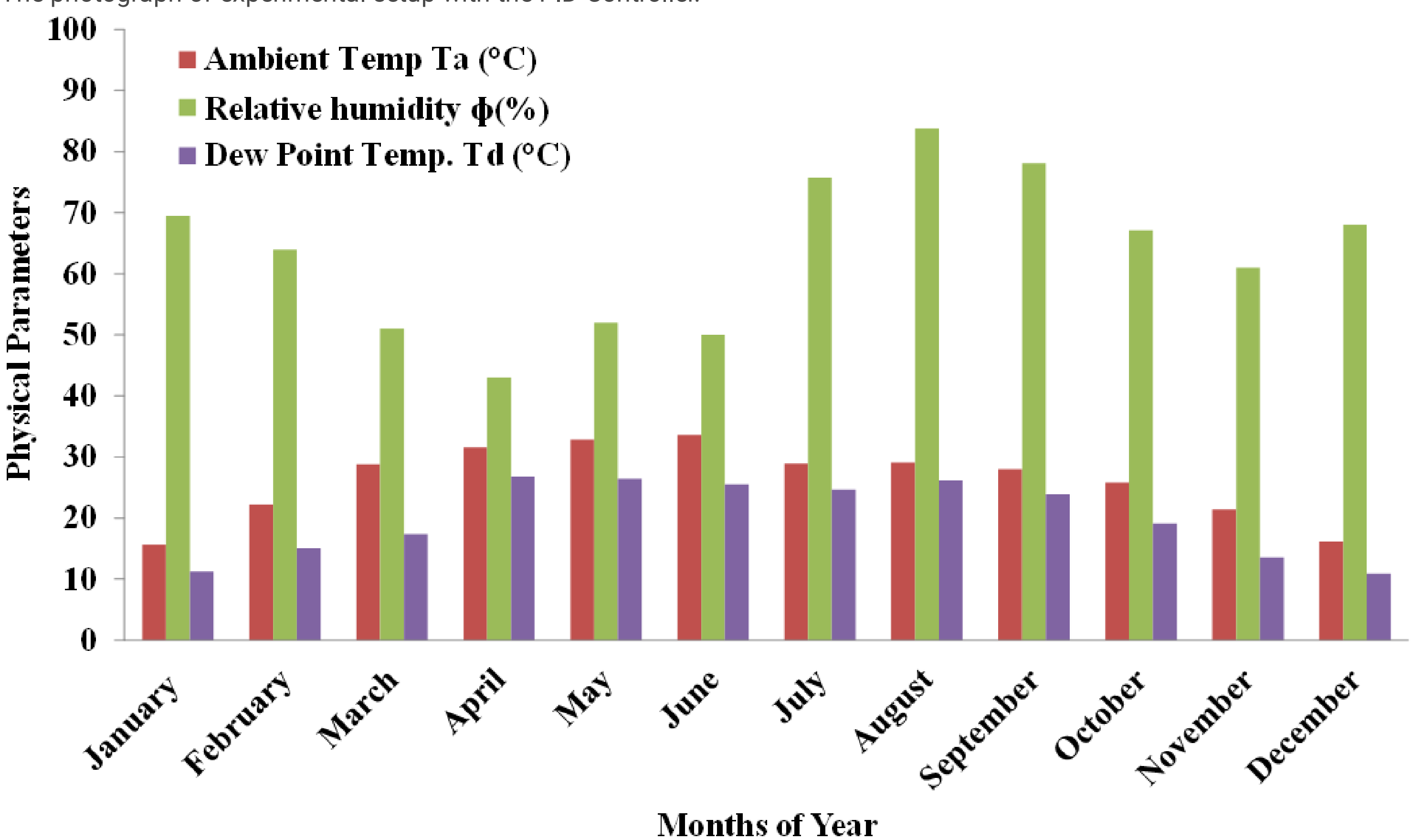


Figure 3

The psychometrics parameters recorded at the site from January to December yearly.

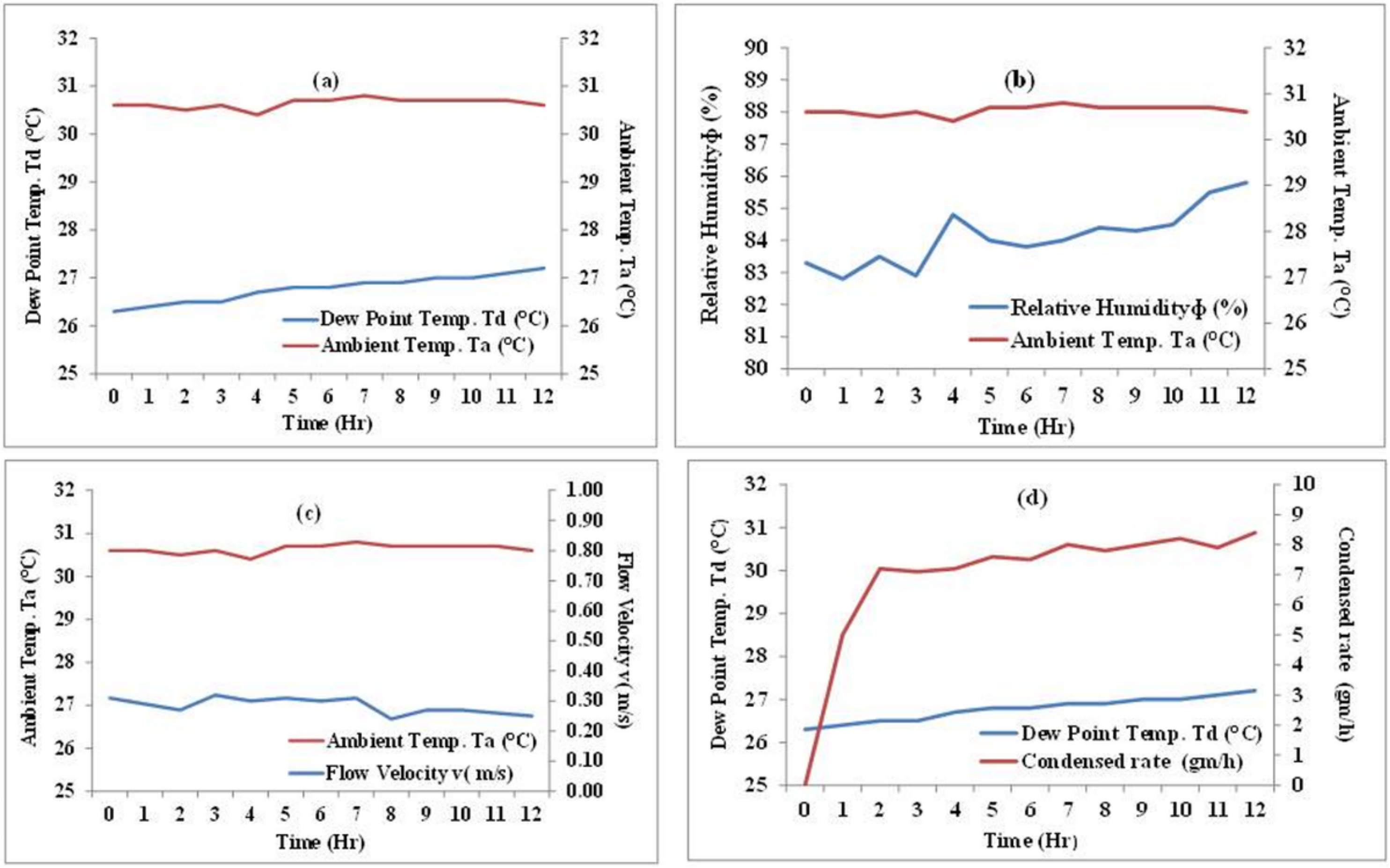


Figure 4

The psychometric variables distribution. (a) Dew point temperature and ambient temperature v/s time (b) Relative humidity and ambient temperature v/s time (c) Ambient temperature and flow velocity v/s time (d) Dew point temperature and condensed rate v/s time.

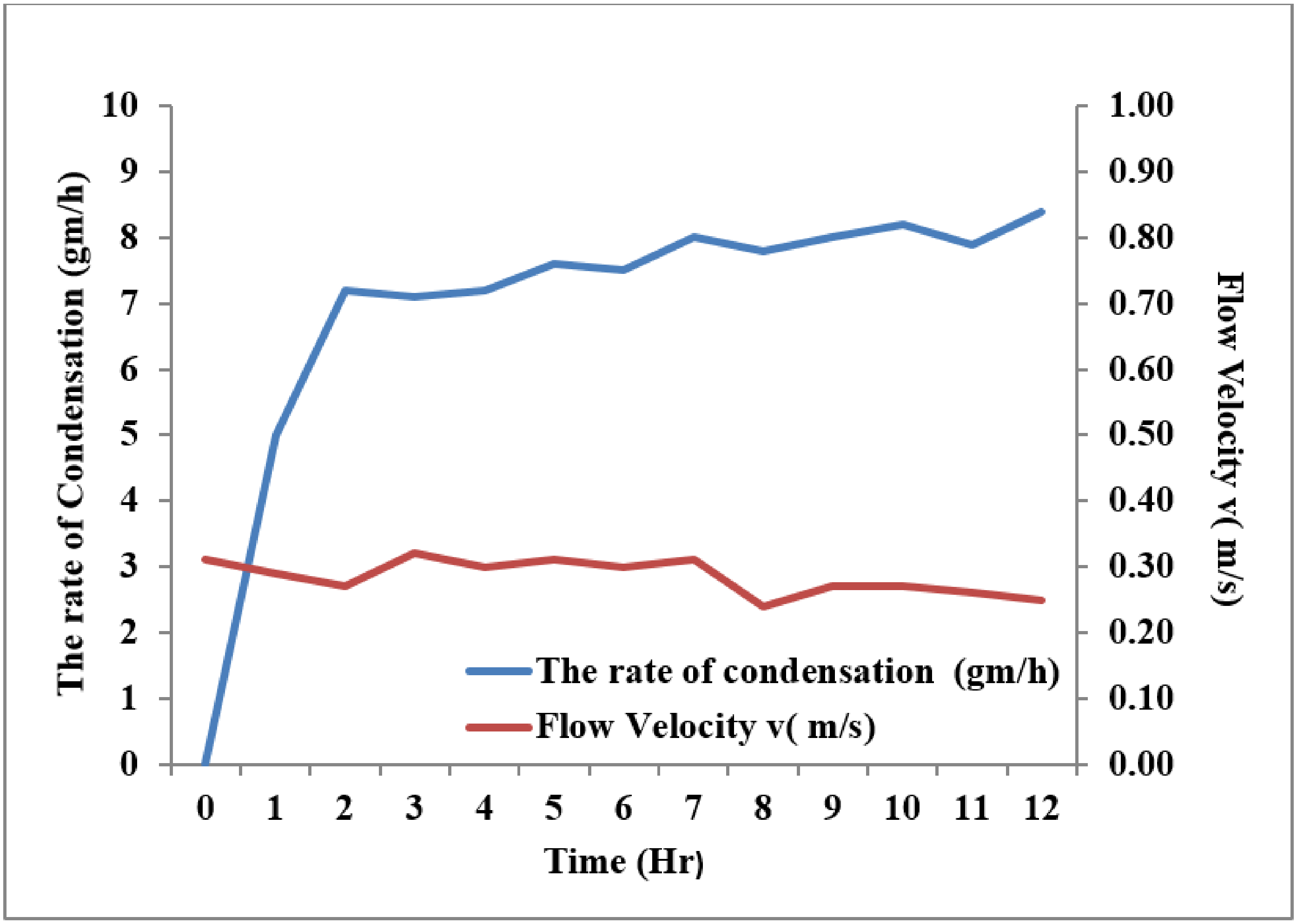


Figure 5

The rate of condensation and flow velocity distribution with respect to time.

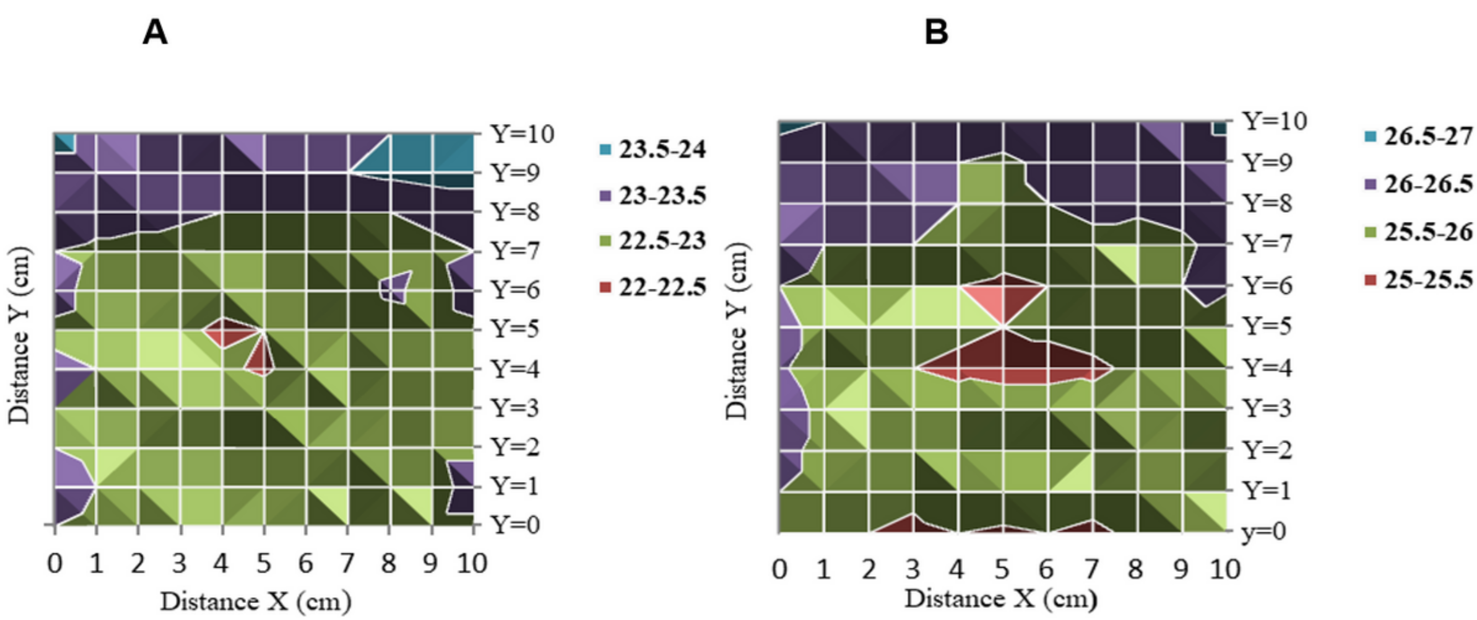
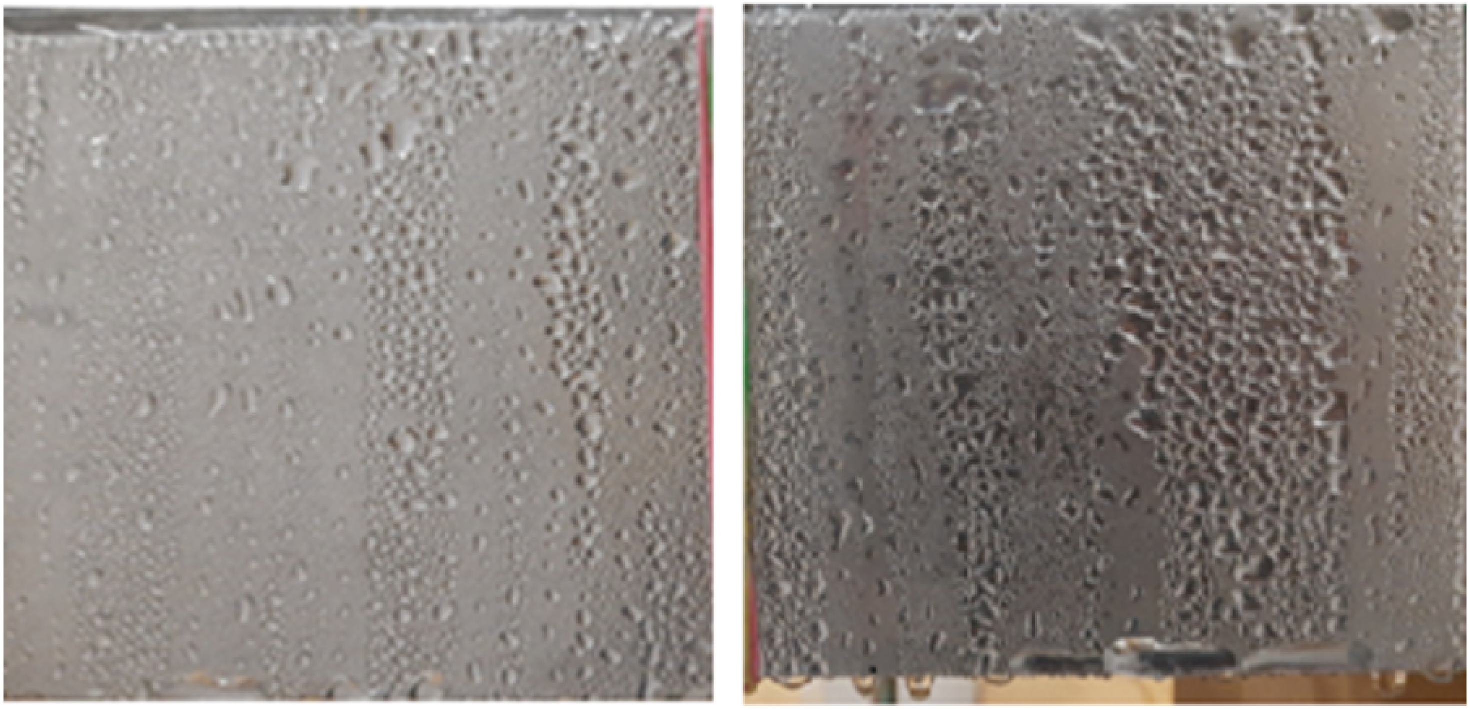


Figure 6

The temperature homogeneity graph on the surface of active aluminium plates.



A B

Figure 7

The surface profile of the condensation of water vapour at a different time on the subcooling surface of the plate (A) after 30 minutes (B) after 60 minutes

Supplementary Files

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- GraphicalAbstract.png