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Study on Solving Drinking Water Problems of a Household in Coastal regions of Odisha, India

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ABSTRACT

Though water covers more than two-third (about 70%) of the earth's surface, still fresh water used for drinking purposes remains scarce (only about 2.5%). This is mainly due to presence of long coastlines & island nations. As a result most of the countries meet their water demands by desalination of sea water which is a very costly affair. In India, the state like Odisha has a long coastline. Till now Odisha has not developed a method from which water from sea can be used to provide drinking water to the people. The aim of this present work is to develop a portable device that can be used to meet the water requirement of a regular household. The device will first condense the water present in the atmosphere & then purify it so that it can be used for drinking. Such a device is called Atmospheric Water Generator. From this work, it was found that if the ambient temperature is 35 ºC or higher & if the relative humidity is greater than 50% then the device will function well & it will start condensing water. Thus in order to work the device in coastal areas of Odisha metrological datas are collected from internet for major coastal cities of Odisha and found that the relative humidity of coastal cities in Odisha remains above 50% throughout the year. Hence the developed device will work round the year without any problem.

Keywords**:** Atmospheric Water Generator, Desalination, Relative humidity, Dehumidifier unit

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1. INTRODUCTION

The decade 2005–2015 was declared the International Water Decade by the United Nations. The UN alerted policy makers about a 'global water crisis', noting in the 2006 Human Development Report that 2 million children die annually from diseases related to waterborne illnesses, and millions more women and children spend hours just collecting water, restricting their opportunities to do other things (UN 2006). Additionally, water-borne infectious diseases create more poverty and slow economic growth. The International Water Decade's goal, to be achieved by 2015, is to reduce by half the proportion of people who regularly obtain their drinking water from unhealthy sources or from faraway places. The goal also calls for better access to basic sanitation. Despite the consensus on the critical need for clean water to improve child and population health, simple provision of clean water through municipal or private piped systems has not yielded the expected immediate health improvements in most developing world communities. Recent systematic reviews and meta-analyses of interventions to improve water quality suggest that, although such interventions are generally effective in preventing diarrhoea, the substantial variation across water improvement trials points to still unknown factors that influence water quality and diarrhoea.

This suggests to us that detailed research is needed on household socio-demographic and sanitation factors influence water quality by structuring access to, and use of, different types of water source. Within a Water Safety Plan, quantitative microbial risk assessment (QMRA) can be used to assess the microbial safety of drinking water. QMRA has been suggested by various authors as the scientific basis for assessing risks of pathogen exposure (Teunis et al. 1997; Haas et al. 1999; Medema et al. 2003). The detailed evidence from behavioural studies of water use and quality indicates the roles played by variations in household storage of water and sanitary habits, such as hand washing, on microbiological contamination of household water supply (Clasen & Bastable 2003; Brick et al. 2004; Trevett et al. 2005).

There are certain areas in the coastal districts where both shallow and deep tubewells are not useful due to high salinity in groundwater. In many settlements in these areas, rainwater is preserved in natural or man-made ponds and collection of rainwater is the only source of drinking water (Kamruzzaman & Ahmed 2006). The water generator, made from air-conditioning and dehumidifier parts, replace or supplement the currently available water devices in the market to reach the more remote areas (Anbarasu and Pavithra, 2011). A senior design project was aimed at designing and creating a prototype of an atmospheric water generator (Niewenhuis et al. 2012).

They have tried to incorporate Liquid Desiccant method to extract humidity from air and convert it into drinking water. Kabeela et al. 2014, has done thermodynamic analysis for a Peltier device which is used to develop a device that uses the principle of latent heat to convert molecules of water vapour into water droplets called the Atmospheric Water Generator. It has a great application standing on such age of technology where we all are running behind renewable sources. Here, the goal is to obtain that specific temperature, called the dew point temperature, practically or experimentally to condense water from atmospheric humid air with the help of thermoelectric Peltier (TEC) couple. The aim of present work is to use the air in coastal areas to meet the needs of water for people by using a dehumidifier unit. Further the solar insolation is quite high in these areas round the year. This can be used to provide necessary power to the dehumidifier unit. Thus drinking water can be obtained from the atmosphere by harnessing solar energy. Such a device is called Atmospheric Water Generator.

2. DEHUMIDIFICATION TECHNIQUES

The first step of this technique is to analyse different methods of dehumidification to seek to harness this water from the atmosphere and utilize it for drinking. Three common psychometric methods of dehumidification stood out during preliminary research; a temperature drop below the dew point (refrigeration condensing), pressure condensing, or a combination of the two. In this present work, refrigeration condensing or dehumidification by refrigeration technique is applied.

2. 1. Dehumidification by refrigeration

This method circulates air over cooling coils connected in a refrigeration cycle to bring the water in the air below its dew point. The dew point of the water is dependent on the vapour pressure and humidity and tends to be a relatively low temperature compared to the ambient conditions. To reach the dew point the air running through the unit will have to be cooled a considerable amount. This approach is shown in Figure 1.The dehumidifier is one which removes moisture from the air by passing the air over refrigerated coils, there by cooling the air down to its dew point. This causes water vapour in the air to condense. This condensed water is captured by the refrigeration dehumidifier & directed into the storage unit. After a brief period of time, the water is expelled from the dehumidifier through a floor drain or through drainage pipe & the dried air released into the facilities environment.

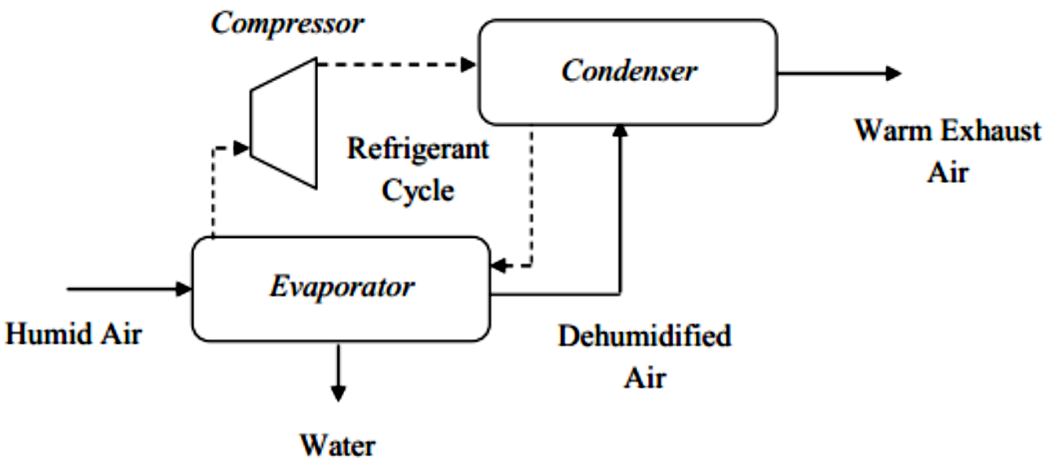

Figure 1. Dehumidification by refrigeration cycle

In this experiment refrigeration can be achieved by vapour compression refrigeration system. Vapour compression refrigeration system is a system which extracts water from humid ambient air by using Cooling Condensation Process to generate fresh drinking water. In a cooling condensation based atmospheric water generator, a compressor circulates refrigerant through a condenser and an evaporator coil which cools the air surrounding it, lowering the air's temperature to that of dew point and causing water to condense. A controlled-speed fan pushes filtered air over the coil. The resulting water is then passed into a holding tank with purification and filtration system to keep the water pure. Atmospheric water generating technology offers 99.9% pure drinking water 365 days a year. The atmospheric water generator is an environmentally safe source of sustainable water. The water generator, made from air-conditioning and dehumidifier parts, can generate enough amount of water to meet the drinking water requirements of a regular household. It also addresses the need for safe drinking water in remote areas and responds to the impending scarcity of potable water in certain areas due to the effects of global warming and natural disasters. The working principle of this system is shown in figure 2. In this figure vapour is generally considered as working fluid which evaporates & condenses without leaving the refrigerating plant. During evaporation it absorbs heat from the cold body that is used as latent heat for converting the working fluid from liquid to vapour at low pressure & temperature. This vapour at low temperature & pressure enters the compressor where it is compressed isentropically & it's temperature & pressure increased considerably to point such that it can be condensed with available condensing media. The vapour after leaving the compressor enters the condenser where it is condensed into high pressure liquid. Then it passes through the expansion valve where it is throttled down to to a lower pressure & temperature at constant enthalpy. Finally it passes on to evaporator where it extracts heat from the surrounding & vapourises to low pressure & temperature vapour.

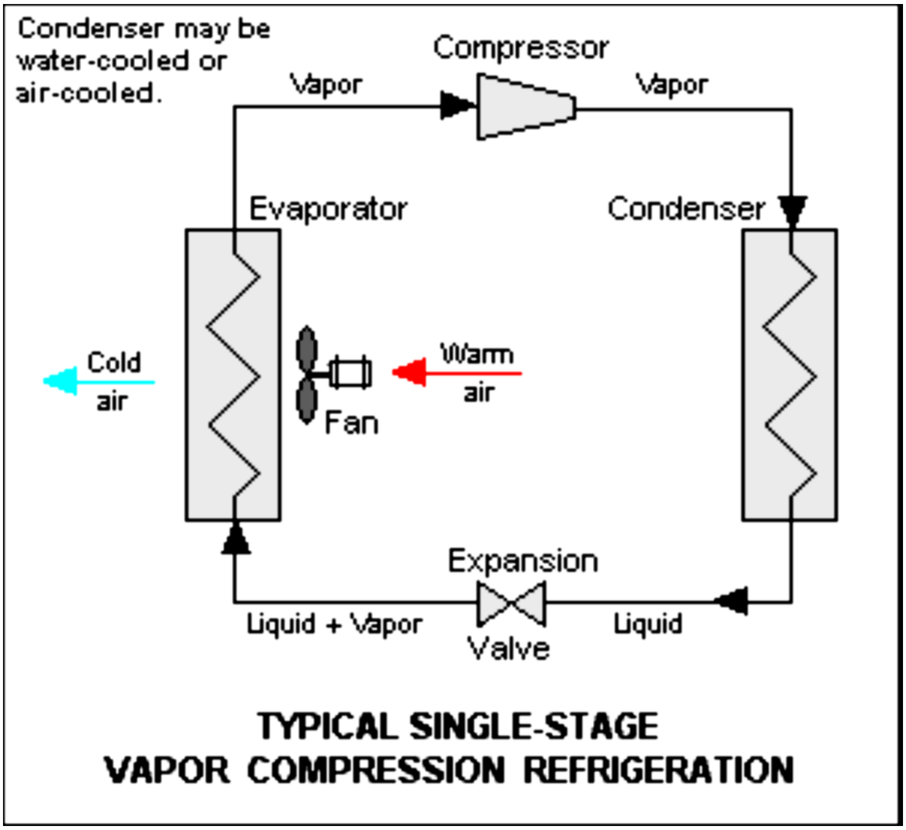

Figure 2. Vapour Compression Refrigeration cycle

Another method known as Peltier cooling which is exactly same as that of Vapour Compression Refrigeration method but here we use a Peltier device to achieve the required dew point temperature. Peltier device is compact, has less moving parts, is energy efficient and has a very long life span which requires very less maintenance.

3. FILTRATION UNIT

The water obtained from the device after condensation is not fit for drinking. It contains a lot of germs and harmful bacteria which may cause diseases. Also it contains a suspended particle which needs to be filtered out. This can be achieved by first passing the condensed water through activated carbon filter. Then it is subjected to ultraviolet light so as to kill the harmful microbes.

4. DEW POINT TEMPERATURE CALCULATION

A well-known approximation used to calculate the dew point, T_{dp}, given just the actual ("dry bulb") air temperature, *T* and relative humidity (in percent), *RH*, is the *Magnus formula*:

$$\gamma(T,RH) = ln(RH/100) + bT/c + T$$

$$T_{dp} = c\gamma(T,RH)/b - \gamma(T,RH)$$

where, b = 17.67 & c = 243.5 ºC and T is in ºC.

The above formulas is used to calculate the dew point temperature for different atmospheric conditions at which the device may be subjected to operate.

Table 1. Dew point temperature calculations at 30 ºC and different relative humidity conditions

Dry Bulb Temp. (in ºC)	Relative Humidity (%)	Required Dew point Temp. (in ºC)
30	45	16.78
30	50	18.46
30	55	20.00
30	60	21.40
30	65	22.71
30	70	23.94
30	75	25.09
30	80	26.18
30	85	27.20
30	90	28.18
30	95	29.11
30	100	30.00

Table 2. Dew point temperature calculations at 35 ºC and different relative humidity conditions.

Dry Bulb Temp. (in ºC)	Relative Humidity (%)	Required Dew point Temp. (in ºC)
35	45	21.37
35	50	23.09
35	55	24.67
35	60	26.12
35	65	27.48
35	70	28.74
35	75	29.93
35	80	31.05
35	85	32.11
35	90	33.12
35	95	34.08
35	100	35.00

Table 3. Dew point temperature calculations at 40 ºC and different relative humidity conditions.

Dry Bulb Temp. (in ºC)	Relative Humidity (%)	Required Dew point Temp. (in ºC)
40	45	25.94
40	50	27.72
40	55	29.34
40	60	30.84
40	65	32.24
40	70	33.54
40	75	34.78
40	80	35.93
40	85	37.02
40	90	38.06
40	95	39.05
40	100	40.00

Table 4. Dew point temperature calculations at 45 ºC and different relative humidity conditions

Dry Bulb Temp. (in ºC)	Relative Humidity (%)	Required Dew point Temp. (in ºC)
45	45	30.51
45	50	32.34
45	55	34.02
45	60	35.57
45	65	37.00
45	70	38.35
45	75	39.61
45	80	40.80
45	85	41.93
45	90	43.00
45	95	44.00
45	100	45.00

5. NUMERICAL ANALYSIS & RESULTS

Now a days, Finite Element Method (FEM) is one of the important numerical analysis method in the design or modeling of a physical phenomenon in various engineering disciplines. Its basis relies on the decomposition of the domain into a finite number of sub-domains (elements) for which the systematic approximate solution is constructed by applying the variational or weighted residual methods. In effect, FEM reduces the problem to that of a finite number of unknowns by dividing the domain into elements and by expressing the unknown field variable in terms of the assumed approximating functions within each element. These functions (also called interpolation functions) are defined in terms of the values of the field variables at specific points, referred to as nodes. Nodes are usually located along the element boundaries and they connect adjacent elements. The ability to discretize the irregular domains with finite elements makes the method a valuable and practical analysis tool for the solution of boundary, initial and eigen value problems arising in various engineering disciplines. The FEM is thus a numerical procedure that can be used to obtain solutions to a large class of engineering problems involving stress analysis, heat transfer, fluid flow etc. ANSYS is general-purpose finite-element modeling package for numerically solving a wide variety of mechanical problems that include static/dynamic, structural analysis (both linear and nonlinear), heat transfer, and fluid problems, as well as acoustic and electromagnetic problems. After the solution is converged the temperature and velocity profiles for various inlet and temperature conditions are plotted. The profiles are plotted for the mid plane and also for the total body.

The results are displayed below:

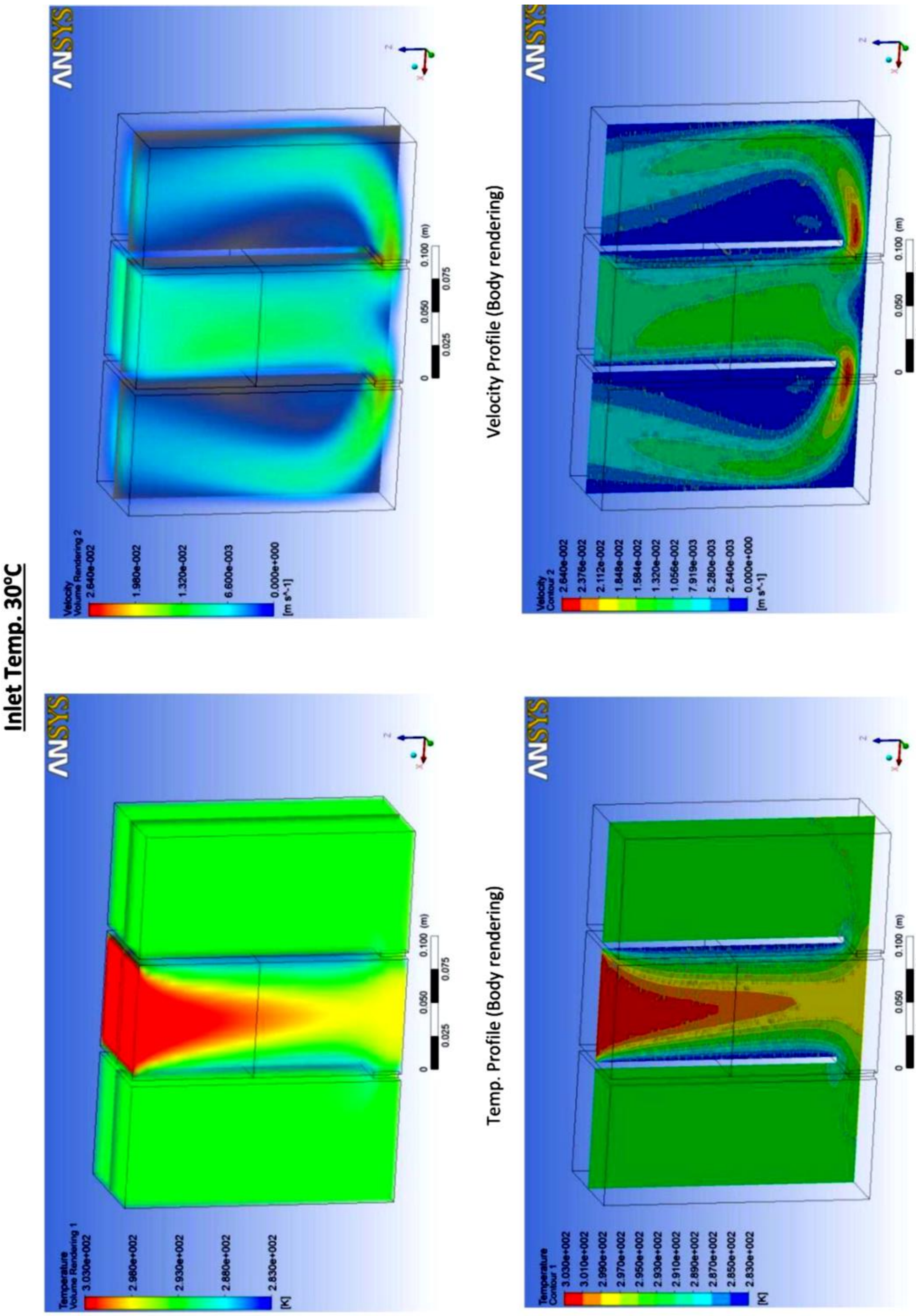

Figure 3. ANSYS results for inlet temperature 30 ºC

For inlet air temperature 30 ºC, Figure 3 shows that the temperature of air in the device drops down to that of 293 K or 20 ºC. Table 1 shows that for temperature 30 ºC the dew point temperature is greater than 20 ºC for relative humidity 60% or higher. Thus it is clear that if atmospheric temperature is 30 ºC and relative humidity is equal to 60% or higher the device will start condensing water.

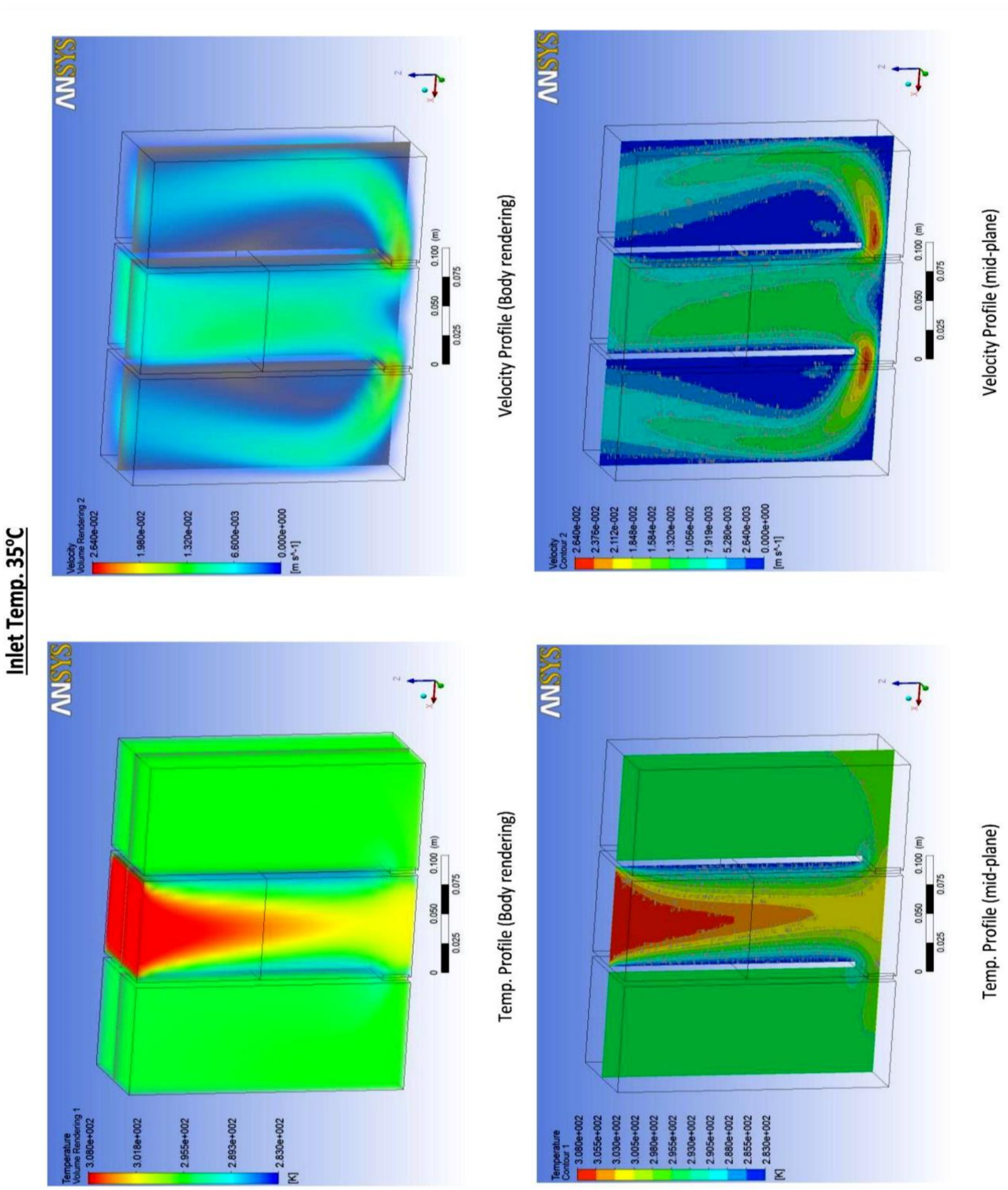

Figure 4. ANSYS results for inlet temperature 35 ºC

For inlet air temperature 35 ºC Figure 4 shows that the temperature of air in the device drops down to that of 295.5 K or 22.5 ºC. Table 2 shows that for temperature 35 ºC the dew point temperature is greater than 22.5^{0}C for relative humidity 50% or higher. Thus it is clear that if atmospheric temperature is 35 ºC and relative humidity is equal to or greater than 50% then the device will start condensing water.

Inlet Temperature 40 ºC

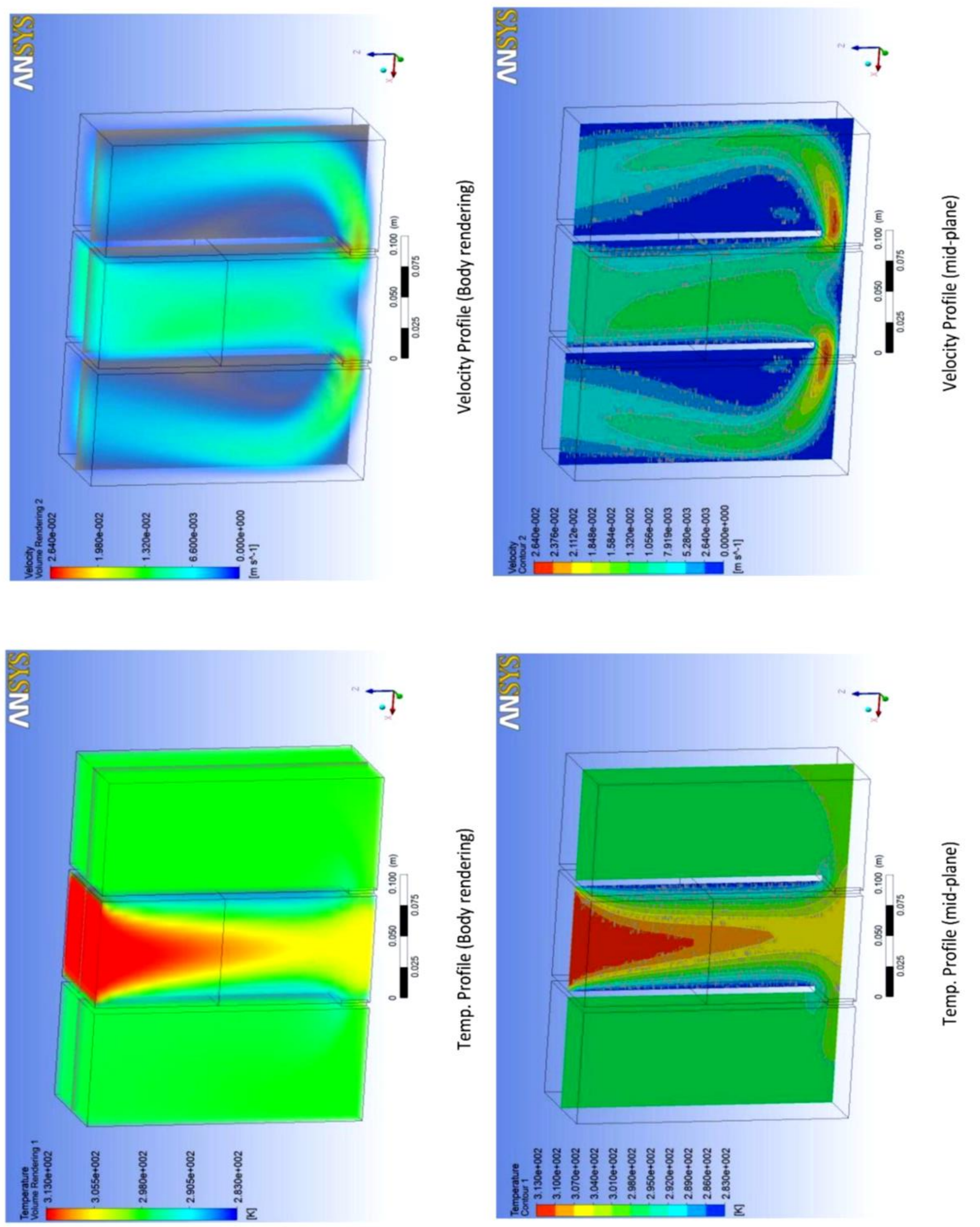

Figure 5. ANSYS results for inlet temperature 40 ºC

For inlet air temperature 40 ºC Figure 5 shows that the temperature of air in the device drops down to that of 298 K or 25 ºC. Table 3 shows that for temperature 40 ºC the dew point temperature is greater than 25 ºC for relative humidity 45% or higher. Thus it is clear that if atmospheric temperature is 40 ºC and relative humidity is equal to or greater than 45% then the device will start condensing water.

Inlet Temperature 45 ºC

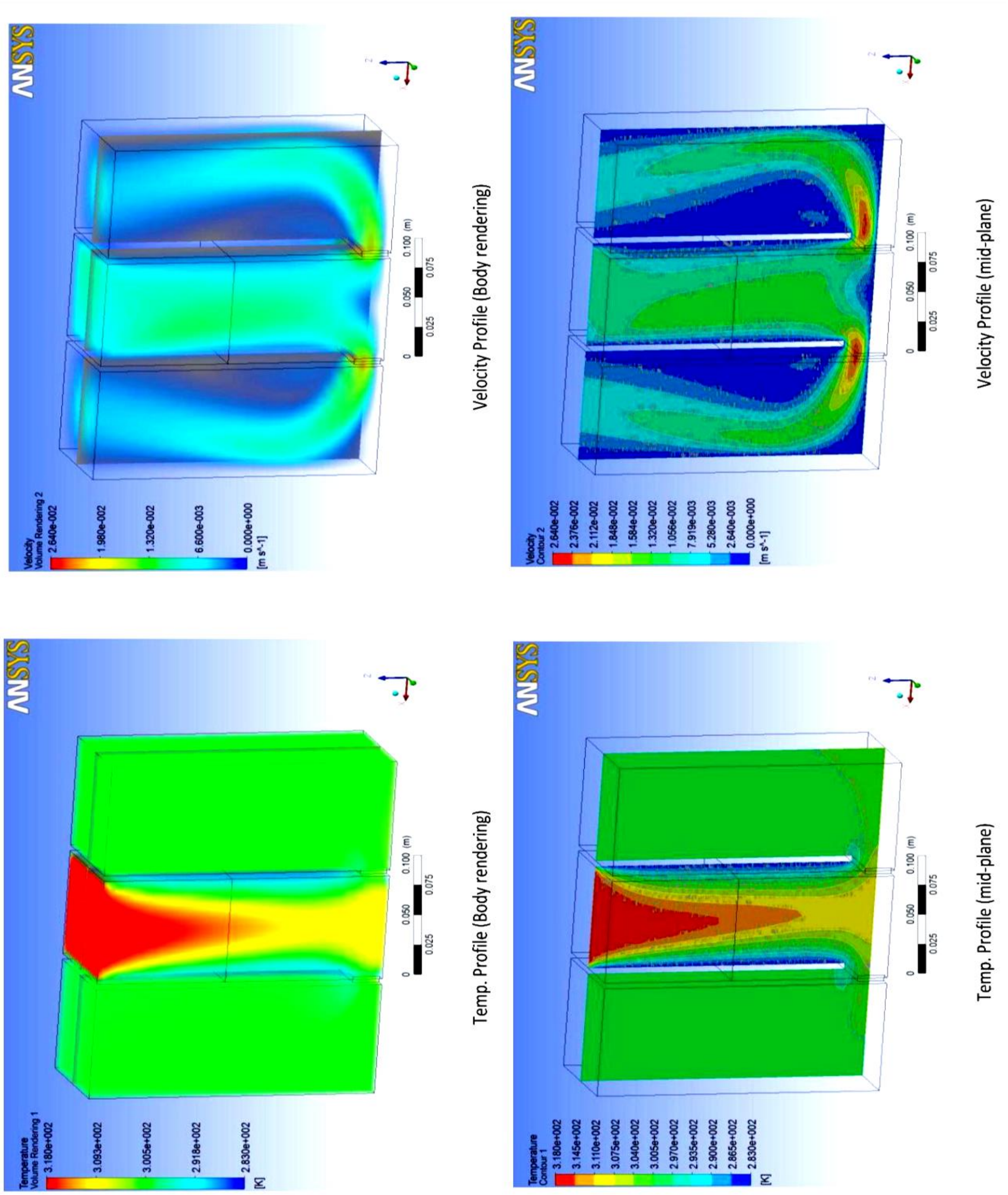

Figure 6. ANSYS results for inlet temperature 45 ºC

For inlet air temperature 45 ºC Figure 6 shows that the temperature of air in the device drops down to that of 300.5 K or 27.5 ºC. Table 4 shows that for temperature 45 ºC the dew point temperature is greater than 27.5 ºC for relative humidity 45% or higher. Thus it is clear that if atmospheric temperature is 45 ºC and relative humidity is greater than 45% then the device will start condensing water.

From all the above inferences we can finally conclude that if ambient temperature is 35 ºC or higher and if relative humidity is greater than 50% then the device will function well and it will start condensing water. Thus in order to find the work of the device in the coastal areas of Odisha, India metrological data's are collected from internet for major coastal cities of Odisha, India and the data's are presented below.

Table 5. Metrological data showing monthly average relative humidity (%) in Puri

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
2000	49.7	68.9	60.6	78	78.5	84.4	82.5	81.9	81.1	74.2	54.2	43.3	69.7
2001	51	63.1	78	75.8	83.8	82.7	84.8	83.1	83.1	82.1	73.2	50.5	74.4
2002	66.5	61.6	71.3	80.1	81.5	85.2	81.7	82.6	82.6	77.5	62.4	50.7	73.7
2003	57	78.4	73.7	80.1	83.2	85.4	86.8	86.1	84.1	85	63	58.2	76.7
2004	61.4	56.7	65.1	84.5	79.6	80.5	83.6	78.4	83.9	77.7	51.2	53.9	71.4
2005	59.6	63	68.8	72.5	78.2	79.4	83.7	80.1	81.1	83.6	57	53.8	72
2000-05	57.5	65.3	69.6	78.5	80.8	83	83.8	82.3	83.1	80	60.2	51.7	73
Mean Dif	-7.8	-8.6	-9	-6	-2.6	-3.3	-2.1	-4	-2	-5.8	-9	-8.4	-5.7
Max Dif	9	13.1	9.4	6	3	2.4	3	3.8	1	5	13	6.4	6.2

Table 6. Metrological data showing monthly average relative humidity (%) in Gopalpur

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
2000	59.2	73.2	68.4	81.1	77.6	81.7	79.7	81	80.4	70.7	56	46.8	71.3
2001	56.6	69.6	73.2	80.4	82	79.5	80.9	80.2	83.8	78.9	69.6	55	74.1
2002	69.6	68.2	71	79.6	80.8	82.6	78	78.4	77.5	77.6	62.5	56.1	73.5
2003	64	78.4	76.5	77.2	78	82.6	84.5	81.9	82.4	82.1	61.3	63.4	76
2004	67.1	62.9	71.2	84.8	83	80	82.3	75.1	82.2	77.9	61.4	57.2	73.8
2005	66.8	70.8	72.7	80.2	80.8	82.5	81.1	77.9	82.9	84.9	61	61.6	75.6
2000-05	63.9	70.5	72.2	80.5	81	81.5	81.1	79.1	81.5	78.7	62	56.7	74
Mean Dif	-7.3	-7.6	-3.8	-3.3	-3.4	-2	-3.1	-4	-4	-8	-6	-10	-5.2
Max Dif	5.7	7.9	4.3	4.3	2	1.1	3.4	2.8	2.3	6.2	7.6	6.7	4.7

From the above metrological data it is clear that the relative humidity of coastal cities in India remains above 50% throughout the year. Hence the developed device will work round the year without any problems.

6. CONCLUSION

After diligent study and research we found that Water Safety Plans have been developed for small-scale water supply systems .So, implementation of Water Safety Plans will support safe potable water supply in the water scarce coastal communities in Odisha, India. On running the device, initially condensation started and water droplets were formed on the cold surface of the Peltier device. But subsequently due to the deposition of these water droplets the thermal conductivity of the region decreased as water is not a good thermal conductor. Hence the condensation process slowed down subsequently. In order to increase the output in the future, a wiping mechanism may be incorporated in the device so as to increase the condensation rate.

Acknowledgements

Dr. Ramesh Chandra Mohapatra was born in Orissa, India in 1969. He graduated from Department of Mechanical Engineering of UCE, Burla, now VSSUT, Burla, Orissa, India. He received the degree of M. Tech in Thermal Engineering from Department of Mechanical Engineering of Indian Institute of Technology (IIT), Kharagpur, West Bengal, India and PhD in Mechanical Engineering from Utkal University, Vanivihar, Bhubaneswar, Orissa, India. He is presently working as Associate Professor & HOD of Mechanical Engineering Department in Government College of Engineering, Keonjhar, Orissa, India

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