CHEMICAL ENGINEERING TRANSACTIONS

VOL. 100, 2023

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Sauro Pierucci, Flavio Manenti

ISBN 979-12-81206-03-8; **ISSN** 2283-9216

DOI: 10.3303/CET23100006

Generation of Water with Peltier Cells from the Humidity of the Air

Claudia Liliana Felles Isidro[a], Domingo Manuel La Rosa Trinidad[b], Máximo Cisneros Tejeira[a], Fiorella Vanessa Güere Salazar[c], Zanhy Leonor Valencia-Reyes[c*], Elmer Benites-Alfaro[c,d], Alex Segundino Armas Blancas[c]

[a]José Faustino Sánchez Carrión National University, AV Mercedes Indacochea s/n Ciudad Universitaria, Huacho 15136, Lima, Peru
[b]Pontifical Catholic University of Peru, AV Universitaria 1801, San Miguel 15088 Lima, Peru
[c]National University of San Marcos, Ciudad Universitaria, Lima 15081, Peru
[d]César Vallejo University, AV Alfredo Mendiola 6232 Los Olivos Lima 15314, Peru
zvalenciar@unmsm.edu.pe

The world today faces a global problem that has been talked about for several years. It is about climate change, an issue of great importance because it affects society, the ecosystem and because not the economy of a country. In this context, Peru is no exception, currently the country is facing difficult and different problems as a consequence of global warming, the change in seasonal periods that are increasingly longer has generated periods of drought, where the soil is arid generating food shortages, causing rationing measures and the non-existence of water, these conditions become the greatest affectation of the towns far from the city, with little infrastructure. According to the World Health Organization, water scarcity affects 4 out of 10 people on the entire planet, thousands die each year from diseases caused by the consumption of non-potable water, given that 18% of the population does not have access to a sanitation network. According to the United Nations, populations that are below 1,700 m^3 of water/inhabitant/year are experiencing a situation of water scarcity. In Peru, between 7 and 8 million people still do not have drinking water. Being Huacho the most vulnerable city, groundwater constitutes its main source of water, the extraction is done mainly through tube wells, making it necessary to search for new alternative surface sources. Peltier cells from the condensation of air humidity in the city of Huacho, Peru. In this sense, the methodology consisted of designing and building equipment at the laboratory level to obtain water from the environment with the support of a program developed in Arduino Mega, which is a microcontroller board based on the ATmega1280. This prototype used in electronic circuits under the thermos-electric concept, worked at 3 amperes of current, with an average ambient temperature of 16.32 °C, average relative humidity of 81.97 % and average dew point of 13.22 °C, meteorological characteristics that the city of Huacho for the month of October 2021. It is concluded that through the Peltier cells it was possible to obtain a total volume of monthly water 7148.90 mL, with humidity and temperature being the fundamental parameters to control; in such a way that this system is an alternative in obtaining water resources so scarce and essential for life, a method of relatively low cost to take advantage of water vapor from the environment.

1. Introduction

The growth of the world population has perceived the demand for water, with approximately 80 percent of the Latin America population concentrated in urban areas (Azabache Liza et al., 2022). Among the main causes of water scarcity and deteriorates, we can mention the indiscriminate use in the industry, bad agricultural practices, accelerated urbanization, scarcity due to drought, deficient waste disposal that affects the availability of water resources, which It has led to waste and unsustainable contamination of the environment and water resources. Environmental problems have been causing prolonged periods of drought, causing water shortages because of global warming. In addition to the irrational use of water, they have led to the conditions of the liquid element becoming a big problem, therefore, to contribute to a solution to the problem, a prototype capable of obtaining

Paper Received: 27 February 2023; Revised: 25 April 2023; Accepted: 12 May 2023
Please cite this article as: Felles Isidro C.L., La Rosa Trinidad D.M., Cisneros Tejeira M., Guere Salazar F.V., Valencia Reyes Z.L., Benites-Alfaro E., Segundino Armas Blancas A., 2023, Generation of Water with Peltier Cells from the Humidity of the Air, Chemical Engineering Transactions, 100, 31-36 DOI:10.3303/CET23100006

water has been designed and elaborated, using for this Peltier cells, considering thermoelectric principles and atmospheric parameters humidity and temperature. The atmospheric water generator is a device that can convert atmospheric moisture directly into usable and even drinkable water. It is such a device that uses the principle of latent heat to convert water vapor molecules into water droplets. It has great application in this age of technology where we are all running after renewable sources (Nitheesh et al., 2019). The use of Peltier cells to make compact and precise temperature control devices has been constantly expanding in recent years (Mannella et al., 2014). The Peltier cell-based water generator system is proposed as an easy-to-implement alternative to heat pumps and air treatment units currently used on the market, in terms of cost, ease of installation and maintenance. The system can be independent if it is equipped with a photovoltaic panel and a wind microturbine, capable of being used in places where there is no electricity. The system, with different configurations, was modeled in the African city of Kigali, in Rwanda (Congedo et al., 2021). Currently, the dry seasons are longer because of global warming, which has generated scarcity and rationing of water, these conditions become the main problem in locations far from urban areas and with little infrastructure. In this way, in Mexico, a prototype was developed in which a Peltier cell arrangement is implemented to obtain the greatest amount of water possible under environmental factors, such as humidity and temperature, as well as an analysis of efficiency, cost and feasibility with a system commercial water generator with similar capacity (Chávez et al., 2020). To complement the present investigation, it is important to be able to evaluate an economic analysis of costs related to size for the cooling process using Peltier cells (Shi et al., 2023).

2. Methodology

The purpose of the research is to propose an alternative solution to the scarcity of fresh water, taking advantage of environmental conditions such as air humidity, for which a water generator prototype has been designed that can be used to capture suspended drops of water in the air through the principles of condensation from prototypes built through Peltier cell arrangement and the correct functioning of the prototype, considering the temperature and humidity.

2.1 Population and Sample

The population was constituted by the air humidity of the research area in approximately 22 m^2, located in the city of Huacho. The sample consisted of nine shots per day, which were collected in a container. To which the following hours were considered: Hour 3:00 a.m. to 7:20 a.m., with 20-minute intervals of data collection during the month of October 2021, with a total of 288.

2.2 Techniques

It was implemented based on sensors and tests of experimental prototypes, temperature sensors and a relative humidity sensor were used, the first to measure said variable on the cold side and the hot side of the Peltier cell. The microcontroller brand was Arduino mega from the Open-Source project.

3. Results and Discussion

Start-up of the prototype and design proposal

3.1 Data acquisition

To carry out the data acquisition, an Arduino Mega data acquisition card connected to the computer by means of a USB cable has been used; To do this, two sensors have been inserted into the voltage outputs to measure two thermodynamic variables: temperature and relative humidity.

3.2 Control operations with Arduino Mega

With respect to the data acquired, with these control operations have been carried out with the support of the Arduino Mega software, among them is the design of a proportional regulator, as well as the processing of card entry data. Subsequently, the data already processed has been directed to the output channels of the card that have been used to carry out the control over the Peltier effect cell.

3.3 Amplifier stage

An amplifier circuit was configured to adapt the output voltage and current from the data acquisition card to the Peltier cell, without losing control over that data.

3.4 Controlled condensation and drip module

A module has been created using a Peltier cell and a heatsink with forced air ventilation, so that, when electric current circulates over it, the atmospheric vapor of the circulating air condenses, producing water dripping.

3.5 Prototype design proposal:

According to (Acosta & Reina, 2019), very favorable results were obtained in the generation of water with Peltier cells compared to other prototypes. The prototype designed and built consisted of the following parts as shown in Figure 1.
Peltier cells that are joined by a copper plate and a temperature sensor.
Peltier cells system through the orders of the Arduino.
The sensor, which measures the ambient temperature and relative humidity (DHT22).
The collector system controller consists of an Arduino mega that has been programmed to activate the actuator when the temperature of the LM35 indicates a temperature greater than minus five degrees and maintain it for five minutes after that time it deactivates, and the system begins to collect frost of water.

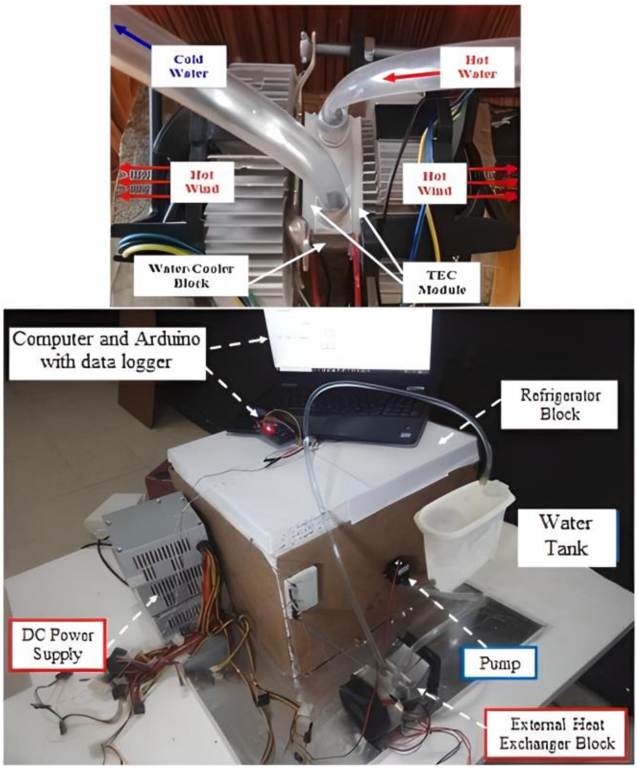

Figure 1. Prototype design for obtaining water with peltier cells

The physical parameters at the laboratory level considered for the collection of water with the designed and built prototype are shown in Table 1.

Table 1: Physical parameters at laboratory level

physical parameters	Average
average relative humidity	81.97
average room temperature	16.32
average Dew Point	13.22
number of Peltier cells	4
number of samples	31
approximate time (min)	twenty
October 2021	from 1 to 31

Water was collected for a month with measurements per hour with the prototype designed and built. The results obtained by the prototype were from 7:00 am to 7:00 am with a maximum volume of 801.70 mL; and with less volume between 6:00 am - 6:20 am and from 6:30 am to 6:50 am with volumes of 790.80 mL. In total, 7,148.90 mL were collected per month.

Peltier cells were used, the results showed that, under the most favorable weather conditions in march, with 3 and 7 Peltier cells, it is possible to condense around 1800–2900 g/h, respectively, under tropical climate conditions (Congedo et al., 2021). In the present investigation, 0.01g/h was obtained with a Peltier cell, keeping in mind that the Huacho area has very dry hot weather conditions.

3.4 Descriptive analysis of the results.

Table 2 shows the results of the descriptive analyzes of the environmental parameters (Humidity, dew point, temperature) and water volume. Regarding the humidity parameter, its average is 82.05% dispersed in 1.49%; the sample dispersion is 2.00% of the value of the sample mean; and the median is observed with a value of 82.00. Comparing the mean with the median, a positive asymmetry is evident (arithmetic mean > Median) corroborated with the value of asymmetry that is greater than 0 (0.35 > 0). The highest concentration of data is observed below the median, so there is a greater amount of data below the median (82.00).

Table 2: Descriptive analysis of environmental parameters and water volume

Parameter	Humidity (%)	Dew Point (°C)	Temperature (°C)	Volume (mL)
Half	82.05	13.24	16.33	25.67
Medium	82.00	12.91	16	26.40
Deviation Standard	1.49	0.54	0.47	3.96
Maximum Value	86	14.26	17	33.70
Minimum Value	79	12.34	6	16.60
Variability coefficient	0.02	0.04	0.03	0.15
kurtosis	3.74	1.97	1.55	3.19
Asymmetry	0.35	0.35	0.74	-0.39

In Figure 2a and 2b, extreme values are observed, with the maximum humidity value being 86% and the minimum being 79%. When analyzing the average class size in the box-and-whisker plot (figure 2 b), positive skewness was identified (skewness = 0.35); In addition, in the box and mustache plot, no outliers are observed at each end, the coefficient of variation is less than 20% (2.00%), the data does not show a normal distribution. The highest percentage of data (figure 2a) is found at 82% humidity.

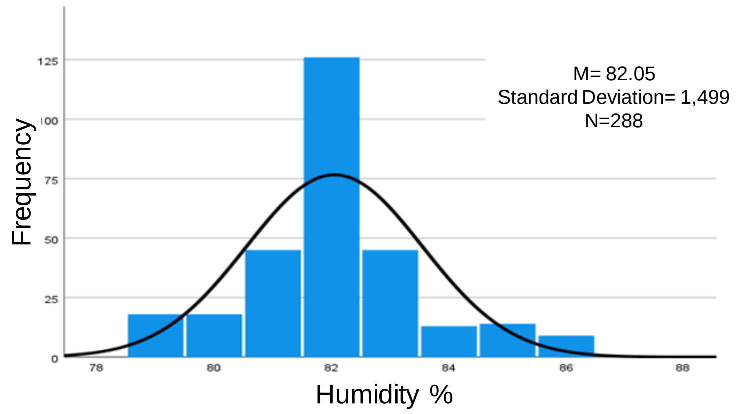

Figure 2 a) Bar graph

Regarding the relationship between humidity (%), volume of water (mL) and temperature (°C), a special effects diagram was made (figure 3), according to the horizontal line parallel to the x axis that falls on the volume 26 mL, the means with respect to humidity levels 82%, 83%; 85% and 86% report high effects of water volumes at temperatures close to 17 °C.

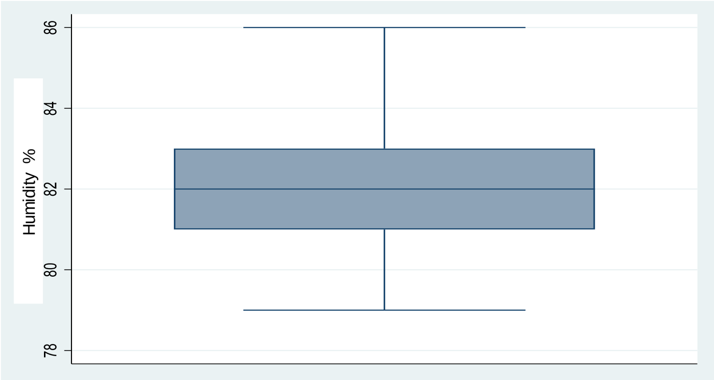

Figure 2 b) Humidity box plot

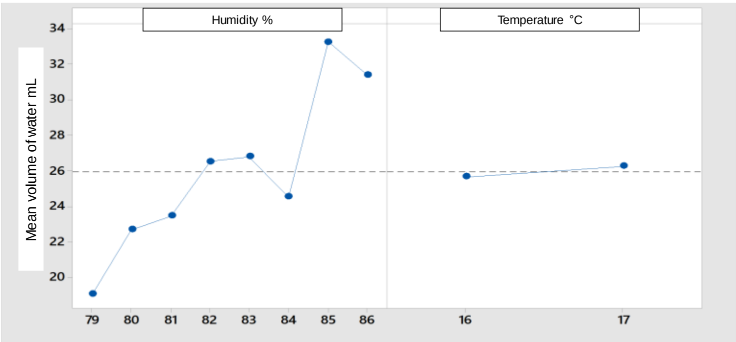

Figure 3. Diagram of main effects

Comparative analysis

An analysis of a commercial water production system was conducted to compare the system in terms of efficiency, cost, and feasibility. To analyze the relationship between the two systems, their operation was considered with the same parameters and the resizing of the prototype. Table 3 shows the result.

Table 3: Hydropanel Performance vs. Peltier Cells

Performance variables	Hydropanel	Peltier cells
Construction costs	US$ 5600	US$2350
Water production	1,000mL	1,000mL
Efficiency check	---	Ok
Duration of the System (years)	8	15
Power Supply	Photovoltaic	Photovoltaic Autonomous
Control Environment Variables	----	OK
Power/water generated	3.8 W/mL	1.4W/mL
Cost lt/day	US $ 2.00	US $ 0.90

4. Conclusion

It was demonstrated through the prototype designed and built under the physical parameters of the environment such as: average ambient temperature 16.32 °C and average relative humidity 81.97% and average dew point 13.22 °C of the city of Huacho, for the month of October of the year 2021, managed to collect 7 148.9 mL of water from the environment. This is because the Peltier cells can reduce their temperature on the cold side to the point of equaling or being below the dew point, causing the change from the gaseous state of the water to the liquid state and therefore generating dripping water and Peltier cell array was implemented to obtain as much water as possible under environmental factors.

A prototype system was developed to produce water from ambient humidity. For this, the methods of using Peltier Cells to condense water vapor in the environment were investigated and implemented, to implement it a set of tests was carried out. Then the structure was chosen, with Peltier cells the maximum amount of water was obtained and it was determined in which climatic conditions it would be applied.

Acknowledgments

To all the researchers for their contribution and dedication in this investigation

References

Acosta, J., & Reina, W. (2019). *Sistema de Supervisión y Control del Prototipo Generador de Agua a partir de Celdas de Peltier* [Universidad Distrital Francisco José de Caldas]. https://repository.udistrital.edu.co/bitstream/handle/11349/15593/AcostaRodríguezJairoAntonio2019.pdf?sequence=1&isAllowed=y

Azabache Liza, Y., Santillan Gutierrez, K., Rodriguez Espinoza, R., Guerrero Escobedo, A., Mendiola Cespedes, A., Olano Arevalo, R., & Vela Vasquez, T. (2022). Removal of Color and Turbidity in Runoff Water Using Coconut (Cocos nucifera) Endocarp Activated Carbon. *CHEMICAL ENGINEERING TRANSACTIONS*, *93*, 355–360. https://doi.org/doi.org/10.3303/CET2293060

Chávez, J., Espejel-Blanco, D., Hernández-Aguirre, F., & Rascón-Barceló, L. (2020). Validación y análisis de eficiencia en la producción de agua mediante la implementación de celdas Peltier. *Revista Del Desarrollo Urbano y Sustentable*, *6*(19), 22–30. https://doi.org/10.35429/JUSD.2020.19.6.22.30

Congedo, P., Baglivo, C., & Negro, G. (2021). A New Device Hypothesis for Water Extraction from Air and Basic Air Condition System in Developing Countries. *Energies*, *14*(15), 1–18. https://doi.org/10.3390/en14154507

Mannella, G., La Carrubba, V., & Brucato, V. (2014). Peltier cells as temperature control elements: Experimental characterization and modeling. *Applied Thermal Engineering*, *63*(1), 234–245. https://doi.org/10.1016/j.applthermaleng.2013.10.069

Nitheesh, K., Saravanan, S., & Ahamed, Ashik, A. (2019). Atmospheric Water Generation with the Concept of Peltier Effect. *International Journal of Engineering Research & Technology (IJERT)*, 1–4. https://www.ijert.org/research/atmospheric-water-generation-with-the-concept-of-peltier-effect-IJERTCONV7IS11106.pdf

Shi, L., Abed, A., Fayed, M., Abdulghani, Z., Anqi, A., Amine Khadimallah, M., Moria, H., & Wae-hayee, M. (2023). Economic cost analysis of air-cooling process using different numbers of Peltier modules; Experimental case study. *Thermal Engineering*, *41*. https://doi.org/10.1016/j.csite.2022.102627