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Use of Water from Air Conditioning Equipment for Non-Drinking Purposes: A Case Study at the Federal Institute of Pernambuco - *Campus* Afogados da Ingazeira

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Palavras-chave— ***Escassez de água; Inferência Estatística; Reuso de Água condensada.***

Abstract— *Due to population growth and economic development, freshwater consumption is increasing. Several regions of Brazil and the world face one of the biggest water crises, being necessary to create alternatives to avoid the waste of water. In this sense, the use of water from air conditioners is presented as a possible solution to reduce future environmental impacts. The present study aimed to study the feasibility of using non-potable water from air conditioning devices at the Federal Institute of Pernambuco (IFPE) - Campus Afogados da Ingazeira. For this, experimental research was used as a methodology, with an in loco view. Initially, a survey of the parameters that characterize air conditioners was carried out, such as: number of air conditioners per power; operating temperature; and number of hours of operation. Through a carbon dioxide meter model JD-112, the independent variables were collected: power (BTU); internal and external temperature in degrees Celsius (°C); relative indoor and outdoor air humidity in percentage (%); and internal and external carbon dioxide (CO2) in particles per million (p.p.m.). At the same time that this device was making the measurement, a bucket with a storage capacity of 20 liters was placed in the air conditioning drain, thus collecting its dependent variable, the flow in liters per hour. After registering the variables, a statistical inference was carried out with a multiple linear regression model using the least squares method, using the SISREG software (2019), in which a general regression equation was created, which can be estimated through the independent variables the hourly flow rate of condensed water. As a result, the average monthly flow of condensed water was estimated, which generated 38.599 liters, providing an average monthly savings with the cost of treated water at COMPESA of R$ 311,44. With this, the present study clearly demonstrates the great potential of using water from air conditioners, which cannot only be taken into account the economic factor, but associated with the environmental benefit brought by it, which is the basis of its elaboration.*

Resumo— *Devido ao crescimento populacional e desenvolvimento econômico, o consumo de água doce vem aumentando. Diversas regiões do Brasil e do mundo enfrentam uma das maiores crises hídricas, sendo necessário criar alternativas para evitar o desperdício de água. Nesse sentido, o aproveitamento de água dos aparelhos condicionadores de ar, apresenta-se como uma possível solução para diminuir futuros impactos ambientais. O presente estudo teve como objetivo estudar a viabilidade do aproveitamento de água não potável proveniente dos aparelhos de condicionamento de ar no Instituto Federal de Pernambuco (IFPE) – Campus*

Afogados da Ingazeira. Para isso, utilizou-se como metodologia uma pesquisa experimental, com vista in loco. Inicialmente foi realizado o levantamento dos parâmetros que caracterizam os aparelhos condicionadores de ar, como: quantidade de condicionadores de ar por potência; temperatura de funcionamento; e quantidade de horas de funcionamento. Através de um medidor de dióxido de carbono de modelo JD-112 foi coletado as variáveis independentes: potência (BTU); temperatura interna e externa em graus celsius (°C); umidade relativa do ar interna e externa em porcentagem (%); e o dióxido de carbono (CO2) interno e externo em partículas por milhão (p.p.m.). Ao mesmo tempo que este aparelho fazia a medição, um balde com capacidade de armazenamento de 20 litros foi colocado no dreno do ar condicionado, colhendo assim sua variável dependente, a vazão em litros por hora. Após esse registro das variáveis, foi realizado uma inferência estatística com modelo de regressão linear múltipla pelo método dos mínimos quadrados, através do software SISREG (2019), em que foi criado uma equação geral de regressão, ao qual se consegue através das variáveis independentes estimar a vazão horária da água condensada. Como resultado foi estimado a vazão média mensal de água condensada, a qual sua geração foi de 38.599 litros, proporcionando uma economia média mensal com o custo de água tratada da COMPESA de R$ 311,44. Com isso, o presente estudo demonstra de forma evidente o grande potencial de aproveitamento de água proveniente dos aparelhos condicionadores de ar, a qual não se pode levar apenas em consideração o fator econômico, mas associá-lo ao benefício ambiental trazido por este, que é o fundamento de sua elaboração.

I. INTRODUCTION

"The growing human population is putting incredible pressure on natural resources. Drinking water, in particular, is an essential resource that is becoming increasingly scarce every year" (ABNIS et al., 2020, p. 94). According to the National Water Agency - ANA (2018), it is estimated that 97.5% of the water in the world is salty, leaving only 2.5% of fresh water, with the majority (69%) being difficult to access because it is concentrated in glaciers, 30% is groundwater (stored in aquifers) and 1% is found in rivers.

According to Furtado Filho e Silva (2020), 12% of the planet's drinking water reserves are located in Brazil, but they are unevenly distributed, generating situations of abundance for some regions of the country, such as the North region, and situations close to scarcity, as in the Northeastern semiarid region. The scenario becomes even worse when comparing the population density in inhabitants per square kilometer (inhab/km²) with the concentration of water resources in the North and Northeast regions of Brazil. According to Guevara et al. (2019), the North region has 4.12 inhab/km² and concentrates 68.5% of all available water resources in Brazil, while the Northeastern region, on the other hand, has a density of 34.15 inhab/km², concentrating only 3.3% of all water resources in the country.

With the problem of water scarcity and high temperatures, especially in the regions closest to the equator, the IFPE - Campus Afogados da Ingazeira, located in the Sertão de Pajeú, has a semi-arid climate with high temperatures resulting from low air humidity, in addition to long dry periods, with scarce and poorly distributed rains. Specifically in the city where the property under study is located, this shortage is felt and has its effects on the rationing of drinking water. Currently existing with two days with uninterrupted water and five days without water.

Thus, the Federal Institute of Pernambuco (IFPE) – Campus Afogados da Ingazeira, as a public education institution and user of a large number of air conditioning devices, becomes a potential site for the implementation of building systems for the use of water from the same. This work has as general objective to identify the potential of production of condensed water of the air conditioners of the IFPE - Campus Afogados da Ingazeira. The specific objectives are: To survey parameters that characterize the air conditioners and the environment in which it is inserted, in the IFPE – Campus Afogados da Ingazeira; To measure through scientific methodology, using the statistical inference tool, through linear regression model, the hourly, daily and monthly production, according to the power of the air conditioners; And to assess monetary losses due to non-reuse of condensed water from air conditioners.

II. THEORETICAL FOUNDATIONS

2.1 WATER RESOURCES

According to the United Nations World Report on the Development of Water Resources (UNESCO, 2021), freshwater consumption has increased sixfold in the last century and has continued to advance at a rate of 1% per year, as a result of population growth, development economy and changes in consumption patterns. The growing urbanization started the process of environmental degradation, requiring more discussions about sustainability and the environment.

The State of Pernambuco has 75% of its semi-arid territory, covering an area of 86,341 km², comprising the mesoregions of Sertão do São Francisco, Sertão Pernambuco and Agreste, where 3.9 million inhabitants reside. Most of the state is recurrently affected by severe drought problems (SÁ, 2019, p. 14).

2.1.1 Overview of Water Use in Brazil

According to the study published by ANA (2021), by 2040 a 42% increase in water withdrawals is expected, from 1,947 m³/s to 2,770 m³/s, an increase of 26 trillion liters per year extracted from springs. Also, according to ANA (2021) the use of water resources for irrigation is responsible for 50% of water withdrawals, urban supply (25%), industry (9%) and animal use (8%).

2.1.2 Water scarcity and Water Stress in Brazil

According to the concept of the United Nations (UN), Water Security deals with the availability of water in sufficient quantity and quality to meet human needs, the practice of economic activities and the conservation of aquatic ecosystems, accompanied by a level of acceptable level of risk related to droughts and floods (ANA; 2021).

According to ANA (2021), comparing the number of people affected by drought with the number of people affected by floods, show that from 2017 to 2020, approximately 89 million people were affected by droughts and droughts in Brazil, about 15 times more than due to floods that reach approximately 6 million people.

2.1.3 Water Reuse

Reuse water, according to article 2, III of the Resolution of the National Water Resources Council, CNRH nº 54/2005, is any wastewater that meets the standards required for its use in the intended modalities. It can be recovered and used for various purposes.

State Law No. 16,584 of 2019, in its article 1, Sole Paragraph, aims to promote measures necessary for conservation, reduction of waste and the use of alternative sources for the capture and use of water in buildings, as well as the awareness of users about its importance for life (PERNAMBUCO, 2019).

2.1.4 Use of water from air conditioners

Air conditioners promote the generation of water resulting from condensation, which most of the time is wasted to the ground or to the sewer. Taking into account the large-scale use of air conditioners in public institutions, the waste is even greater. Notwithstanding this, the water can be collected and used for cleaning the institution, gardening and/or flushing the bathroom.

2.2 CLIMATIZATION SYSTEM

2.2.1 Basic Refrigeration Cycle

Compressor, evaporator, condenser, expansion valve, and refrigerant are basically the elements that make up the basic refrigeration cycle, they work together to transfer thermal energy from one environment to another.

2.2.2 Operation of Air Conditioning Devices

In the evaporator there is a sensor (thermostat) that when the desired temperature is reached it sends a command signal to the compressor, so that it is turned off. “The thermostat measures the temperature of the air that returns to the device. Upon realizing that the ambient air is at the requested temperature, the thermostat turns off the compressor, maintaining only the ventilation of the air conditioner” (CALDAS; CAMBOIM; 2017; p.175). If there is any change in temperature, the compressor is turned on again until the desired temperature is reached. The compressor is responsible for circulating the refrigerant gas inside the system, which has four more components: condenser; expansion valve; evaporator; and coolant fluid. When the system is running, it produces dripping water.

2.2.3 Generation of Water from Air Conditioning Devices

The evaporator absorbs the warm air from the environment, while the coil that is in the evaporator circulates the cold refrigerant gas, as both are in the evaporator, there is an exchange of heat between the hot absorbed air and the cold refrigerant gas that is circulating in the coil, exchanging so the warm air from the environment for cold air, this process of heat exchange, hot for cold, generates condensed water, which will be sent to the drain. For Furtado Filho e Silva (2020, p. 54), the condensation process is what generates the water, this process transforms water vapor into liquid water and happens when the steam comes into contact with the cold surface of the coil, changing from gas to liquid.

2.2.4 Drainage system

The drainage system is responsible for expelling the water generated by the air conditioning device, taking the water to the external environment through ducts that must be correctly installed, otherwise the system may malfunction and, instead of ejecting the condensed water to the external environment, it can cause the water to drip inside the environment, causing serious problems to the device.

2.3 STATISTICAL INFERENCE

"In statistics, the collection of all the elements of interest is called a population. The selection of some elements from this population is called a sample" (MANN 2015, p. 31). Also, according to MANN (2015), an important part of statistics deals with decision-making, inferences, predictions and predictions about populations, based on results obtained from samples. For example, one can quantify the volume of condensed water in a public building. To do this, a part of the air condensers in operation in this public building is selected, the volume of water emitted by such devices is found and a decision is made based on this information. These means of decision making are known as inferential statistics.

2.3.1 Linear Regression Model

The application of linear regression is based on the so-called "linear regression models". "A regression model corresponds to a mathematical equation, which describes the relationship between two or more variables. The dependent variable is the one that is being explained, while the independent variable is the one that is used to explain the variation in the dependent variable" (MANN, 2015, p. 786). That is, linear regression models can be classified according to the number of independent variables they have, according to Fundão (2018) when there is only one independent variable in the model, it is called "Simple Linear Regression Model" and if has more than one independent variable is called "Multiple Linear Regression Model".

According to Silva (2018), to validate a regression model, it is necessary to observe some assumptions, such as normality of errors, linearity of the relationship between the response variable and the explanatory variables, homoscedasticity of errors, and absence of multicollinearity. As for NBR 14.653-2 of 2011 in its Annex A, item A.2, in addition to these assumptions, it is also necessary to observe the verification of autocorrelation, independence and inexistence of atypical points, in order to obtain unbiased, efficient and consistent evaluations (BRAZIL, 2011).

III. MATERIAL AND METHODS

The methodology of the dissertation by Souza A. (2020) was taken as a basis, whose study is a quantitative, exploratory and descriptive research, with an on-site view, making it possible to identify the potential for hourly production of condensed water from air conditioners of air from the IFPE – Campus Afogados da Ingazeira, through scientific methodology using linear regression.

3.1 PRESENTATION OF THE BUILDING SUBJECT TO THE STUDY

This study was developed at the Federal Institute of Education, Science and Technology of Pernambuco (IFPE) – Campus Afogados da Ingazeira, located at Rua Edson Barbosa de Araújo, S/N, Manoela Valadares neighborhood. The building under study has 7,148.00 m² of built area, with the entire ground floor area, currently consists of the guardhouse, 8 blocks, being divided into administrative and teaching blocks, and a paved parking.

This entire structure of rooms at the IFPE – Campus Afogados da Ingazeira is air-conditioned, and air conditioning devices of different powers are used. The Campus is open from 7:00 am to 10:00 pm, with classes in the morning, afternoon and evening, in addition to the functioning of the administrative sectors, morning and afternoon.

3.2 RESEARCH INSTRUMENT

The measuring instrument called Carbon Dioxide Detector model JD-112, also known as "aerometer" was used to carry out the data collection and fill in the worksheets for quantification of the independent variables.

In addition to the research instrument mentioned above, two buckets with a capacity of 20 l (liters) of water were also used, a beaker graduated in 1000 ml (milliliters) to assist in the measurement, and a stopwatch to check the time on different days.

3.3 SURVEY OF AIR CONDITIONING EQUIPMENT PARAMETERS

Initially, some parameters were raised, such as:

- Number of air conditioners in operation;
- Equipment power – BTU (British Thermal Units);
- Devices operating time;
- Temperature in the device usually used in the sectors of the IFPE – Campus Afogados da Ingazeira.

These parameters were used with the objective of directing a significant sample to reproduce the population of installed equipment.

3.4 MANUAL COLLECTION MODEL

To quantify the volume of condensed water expelled by an air conditioner, it was necessary to capture this water, where a 20-liter bucket was taken and connected directly to the drain of an air conditioner.

3.5 MEASUREMENT OF THE DEPENDENT VARIABLE (VOLUME OF CONDENSED WATER) AND INDEPENDENT VARIABLES

With the operation of the manual water collection model, it was possible to perform the hourly measurement (dependent variable) of the water generated by the air conditioners under study. The measurement of independent variables (internal temperature, external temperature, RH (%) internal, RH (%) external, internal CO_2 and external CO_2), was performed using a carbon dioxide detector, which was placed in the center of the rooms, on top of a desk, at a height of 1.10 m from the floor.

Data were collected from 28 different environments with different cooling capacities, in March and April 2022, with 3 hourly measurements of the dependent and independent variables per air conditioner, from 8:00 am to 9:00 am, from 11:30 am to 12:30 pm, and from 5:00 pm to 6:00 pm, these times were chosen to capture all variations in temperature and flow of people in the environments.

3.6 STATISTICAL INFERENCE TO OBTAIN THE LINEAR REGRESSION EQUATION

From the methodology of "Statistical Inference" of NBR 14.653-2 of 2011, it was possible to create a linear regression model, using the SISREG software version 2019 to help in the calculations. It is worth mentioning that this study was carried out between the months of March and April 2022, which according to the Pernambuco Water and Climate Agency - APAC (2022), these months mentioned above correspond respectively to the autumn and summer seasons.

3.7 VALIDATION OF THE REGRESSION MODEL

By identifying the independent variables, it was possible to show that they interfere in the result of the dependent variable. This data collection aims to obtain a representative sample to explain the behavior of the equipment. After this step, data processing was carried out, making it possible to observe the influence of variables on the hourly volume of condensed water.

With the help of the SISREG software (2019), the validation of the regression model was carried out, in which it was necessary to analyze some assumptions: analysis of the coefficient of determination; correlation coefficient analysis; analysis of variance; null hypothesis testing of the regressors; randomness of residues; normality of waste; signal coherence – linearity; and multicollinearity test.

3.8 MODEL CONSTRUCTION

To quantify the dependent variable (condensed water flow) it was necessary to build a regression model, with all the assumptions analyzed, strictly following the step-by-step procedure shown in the previous topic. Through the SISREG software (2019), a mathematical model of homogenization was generated through scientific research methodology.

3.9 CALCULATION OF THE MONTHLY VOLUME OF CONDENSED WATER

To determine the volume of condensed water expelled by each air conditioner, an equation with a regression model was performed using the SISREG software (2019), using the independent variables and the dependent variable, for each power of the air conditioner, considering the number of hours in operation and the number of appliances in the Campus building, the hourly, daily and monthly volume of condensed water is obtained.

3.10 SAVINGS WITH CONDENSED WATER REUSE

Through the results of the regression models obtained for the refrigeration capacities surveyed, the hourly flow of condensed water from the air conditioners of the IFPE - Campus Afogados da Ingazeira was calculated, considering the current values of the cubic meter of water charged by COMPESA (*Companhia Pernambucana de Saneamento*/ Sanitation Company of Pernambuco), savings were obtained in March and April 2022, with the reuse of condensed water from the air conditioners of the present study.

IV. RESULTS

Initially, the parameters of the air conditioners were identified, as shown in Table 1.

Table 1: Parameters of the Air Conditioners.

Power of appliances in BTUs.	Number of air conditioners.	Operating Time in hours (h).	Operating temperature in degrees Celsius (°C).
12.000	5	10	23
18.000	5	10	23
24.000	51	10	23
36.000	16	10	23
48.000	7	10	23

Source: The author (2022).

From this survey it was possible to carry out measurements of the dependent (flow in liters per hour) and independent variables (internal temperature, external temperature, RH (%) internal, RH (%) external, internal CO2 and external CO2) of the air conditioners existing in the Campus Afogados da Ingazeira.

In order to have a non-biased and quite significant regression model, an analysis was carried out on the assumptions that determined the equation. The SISREG software (2019) was responsible for performing such analyses, in the case of the analysis of the coefficient of determination, it was 95.08%, that is, the model adopted explains approximately 95% of the formation of the value of the condensed water flow, and only 5% can be attributed to the coefficient of indeterminacy, that is, 5% of the adopted model cannot be explained, due to other variables, inaccuracies, information vices, as well as random disturbances.

The correlation coefficient of the variables was 0.9750, being characterized with an extremely strong correlation between the independent variables, power (BTU), internal CO2 level (p.p.m.), external temperature (ºC) and relative humidity of the external air (URext %), and the dependent variable (Hourly condensed water flow), according to Table 2.

Table 2: Correlations between independent variables – general model.

Variable	Linear Form	Power	Internal CO2	External Temperature	External relative humidity	Flow
Power	ln(x)		7	17	58	95
Internal CO2	ln(x)	-72		0	8	16
External Temperature	x	9	-8		49	17
External relative humidity (%)	ln(x)	-21	15	-49		57
Flow (l/h)	ln(y)	96	-72	4	-5	

Source: Data from Sisreg Software Version 1.6.7 (2019).

It was observed that the independent variables do not present strong isolated correlations between them, which is necessary to have no changes in the regression model, thus allowing a better adherence to the established regression model, not causing changes in the model used to compose the equation of the regression.

When the null hypothesis test of non-representation of the model to explain the phenomenon was carried out, it was rejected at the level of significance, equal to 1%, considering that the F statistic, with a result of 3,707.54 is higher than the point critical distribution F of Snedecor equal to 3.32 referring to 4 degrees of freedom in the numerator and greater than 120 degrees of freedom in the denominator, at the 99% confidence level. Complying with the Significance Tests criterion described in Brazilian Standard 14.653-2/2011.

When performing the null hypothesis test for the absence of regression, it was observed that the non-importance of the independent variables in the formation of the value of the hourly volume of condensed water for the general model did not apply, that is, this assumption was rejected, with a significance level of 1% as shown in Table 3, that is, it is 99% certain that the variables: power (BTU), internal CO2 level (p.p.m.), external temperature (ºC), and relative humidity of the external air (URext%) , has importance in the value of the hourly volume of condensed water.

Table 3: Verification of the hypothesis test of the regressors (student's T test) – general model.

Equation				
Returnees	Equation	T-Observed	Significance	Non-Linear Growth
Power	ln(x)	81,89	0,01	9,66%
Internal CO2	ln(x)	-4,5	0,01	-1,19%
External Temperature	x	4,69	0,01	1,68%
External relative humidity (%)	ln(x)	19,14	0,01	4,26%
Flow (l/h)	ln(y)			

Source: Data from Sisreg Software Version 1.6.7 (2019).

In the analysis of the randomness of the model residuals, Figure 1, the data were presented randomly, which leads to the belief that there was no violation of the basic assumptions, homoscedasticity, independence and non-autocorrelation. That is, the samples did not show any defined pattern, stating that the regression model is not biased, it is consistent and efficient.

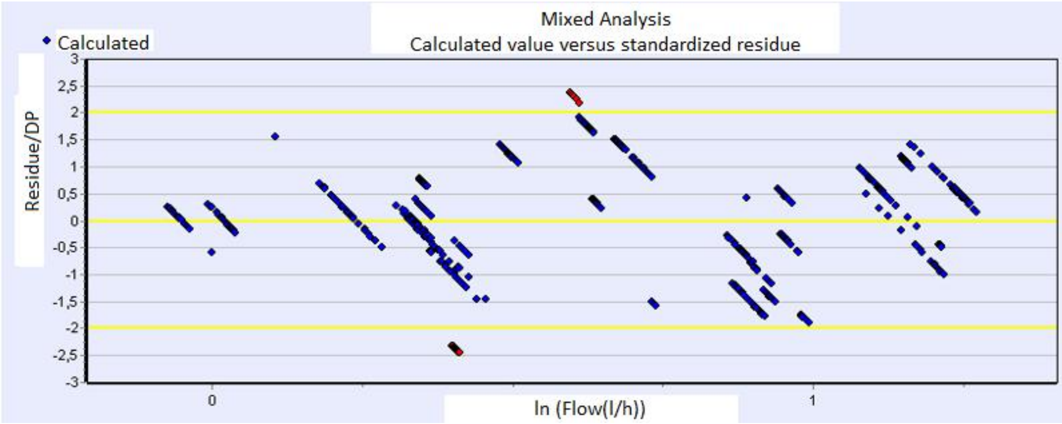

Fig.1: Residuals versus adjusted values – general model.

Source: Data from Sisreg Software Version 1.6.7 (2019).

In the residual normality test, Figure 2, it was found that 67% of the standardized residuals are in the range (-1.00+1.00), 89% are in the range (-1.64, +1.64) and 95% in the range (-1.96, +1.96), thus showing signs in favor of the normal distribution for the random errors of the model. NBR 14,652-3 of 2011 requires intervals of 68%, 90% and 95%. That is, the data are distributed within the admissible intervals of the normal distribution curve, of the aforementioned standard.

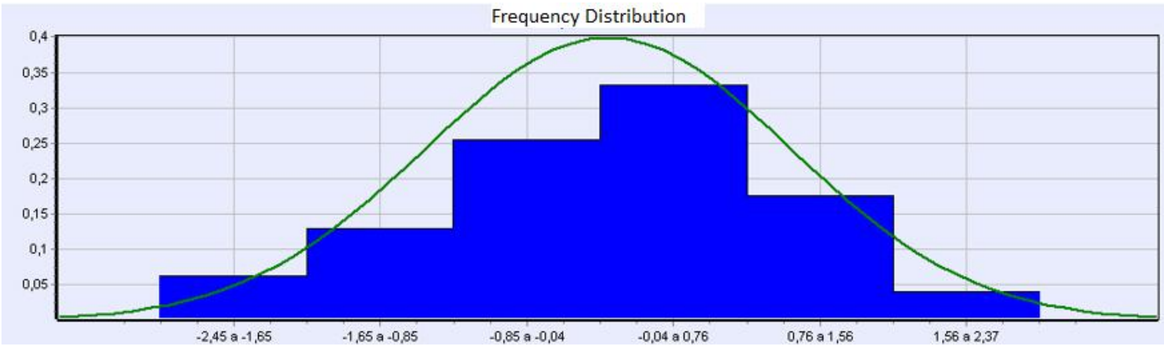

Fig.2: Frequency distribution of standardized residues – general model

Source: Data from Sisreg Software Version 1.6.7 (2019).

Signal coherence - linearity of the variables power (BTU), internal CO2 level (p.p.m.), external temperature (ºC) and relative humidity of external air (URext%), were respected in the regression model, statistically proving that the hypotheses related to these variables are true.

Figure 3 shows that the power of the equipment had a positive growth, that is, the greater the power of the air conditioning, the greater the flow of condensed water of the object being evaluated. On the other hand, internal carbon dioxide (internal CO2) showed a negative growth, that is, the lower the CO2 index, the greater the flow of condensed water from the object being evaluated.

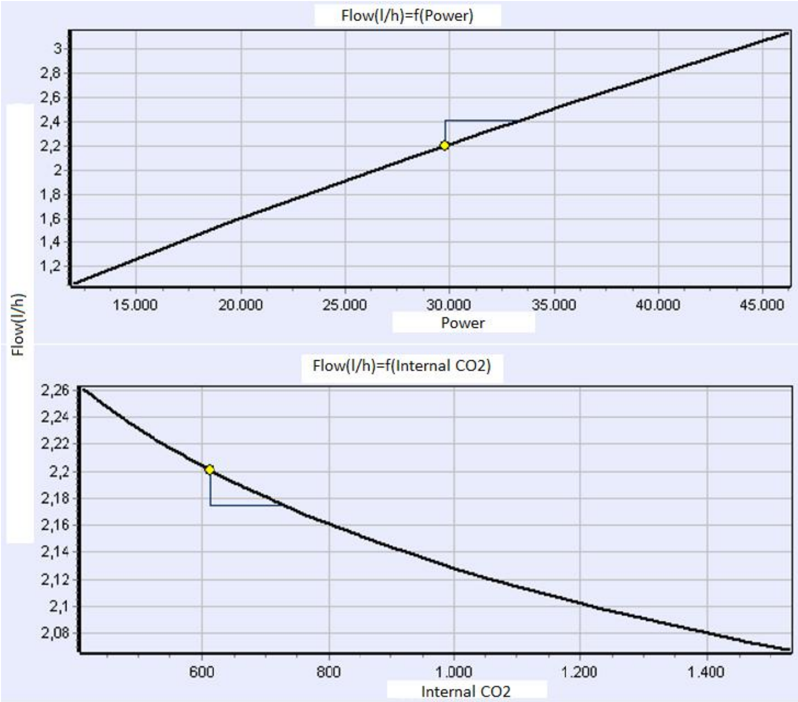

Fig.3: Internal CO2 power and coherence graph – Linearity – General model.

Source: Data from Sisreg Software Version 1.6.7 (2019).

Figure 4, showed that the external temperature positive growth, that is, the higher the external temperature, the greater the flow of condensed water from the object being evaluated. On the other hand, the percentage of external relative humidity (URext%), showed a positive growth, that is, the higher the URext%, the greater the flow of condensed water from the object being evaluated.

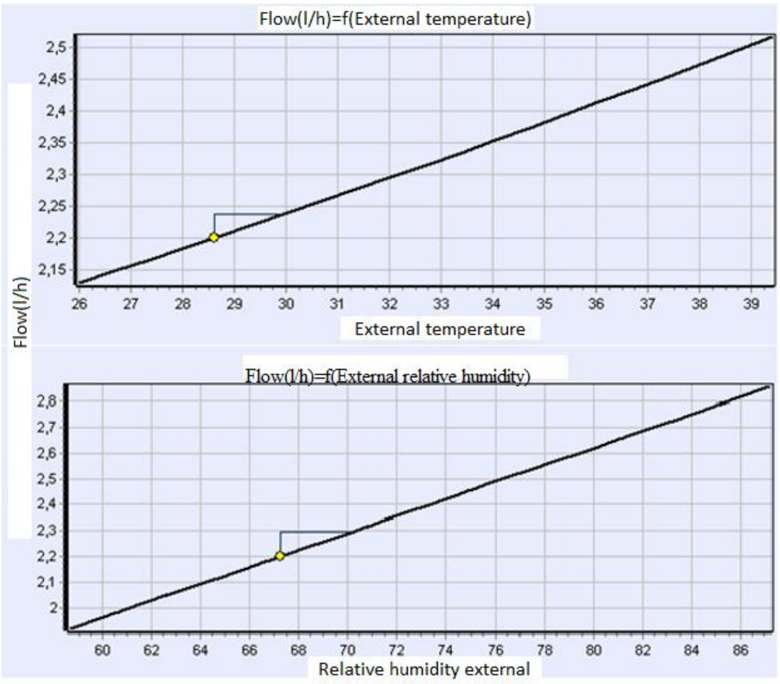

Fig.4: External temperature coherence and external relative humidity percentage coherence graph – Linearity – General model.

Source: Data from Sisreg Software Version 1.6.7 (2019).

A test for the existence of multicollinearity was performed between the independent variables considered: power (BTU); internal CO2 level (p.p.m.); external temperature (ºC); and relative humidity of the outside air (URext%). When performing the analysis of correlations with influence, no result was found that indicated the presence of the phenomenon that could restrict the use of the model.

After performing the analysis of the assumptions, a general equation model was created, using the SISREG software (2019), a mathematical model of homogenization was generated, using the Least Squares Method for unbiased estimates of the parameters, given by Equation 1.

Equation 1: Model equation to quantify the condensed water flow for any refrigeration capacity (between 12,000 to 48,000 BTU).

$$\mathbf{Flow\ (l/h)} = \mathbf{0{,}0000084995711 x\ Power^{0{,}80700615}\ x\ InternalCO_2{}^{-0{,}067939186}\ x\ e^{(0{,}01240481 * External\ temperature)}\ x\ Outdoor\ Relative\ Humidity\%^{1{,}0056452}} \quad \text{(Eq. 1)}$$

Where:

- Flow (l/h) – This is a dependent variable (explained) that corresponds to the hourly flow per equipment cooling capacity;
- Power (BTU) - This is an independent quantitative variable that corresponds to the cooling capacity of the air conditioner object of study;
- Internal CO2 (p.p.m.) – This is an independent quantitative variable that corresponds to the level of carbon dioxide in the external environment close to the device under study;
- External temperature (ºC) - This is an independent quantitative variable that corresponds to the external temperature where the device under study is located;
- Outdoor relative humidity - URext (%). – This is an independent quantitative variable that corresponds to the percentage of the humidity of the outside air of the environment where the device under study is located.

The estimated flows were obtained through Equation 1, in which the average of the independent variables between the months of March and April 2022, power (BTU), CO2 level (408.46 p.p.m.), external temperature (28.63 °C), external air relative humidity - URext% (67.28%), entered them in the equation, thus obtaining the estimated flows, which are presented in Table 4, which shows the hourly flow of condensed water, by capacity of refrigeration.

Table 4: Hourly flow of the other evaporating units for the 80% confidence interval.

Power (Btu)	Unit Hourly Flow (l/h)		
	Minimum	Estimated	Maximum
12000	1,07	1,09	1,11
18000	1,49	1,51	1,53
24000	1,89	1,9	1,92
36000	2,62	2,64	2,66
48000	3,31	3,33	3,35

Source: The author (2022).

Considering the hourly flow rates for each refrigeration capacity presented in Table 4, and the composition of the Refrigeration equipment components of the Campus Afogados da Ingazeira presented in Table 1 of this work, we have the following results for the hourly, daily and monthly volume of the building under study, which are duly presented in Table 5.

Table 5: Unit and total hourly volume of the HVAC system of the building under study.

	Total Hourly Volume (l/h)	Total Daily Volume (l/h)	Total Monthly Volume (l/h)
Minimum	174,28	1.742,80	38.341,60
Estimated	175,45	1.754,50	38.599,00
Maximum	177,13	1.771,30	38.968,60

Source: The author (2022).

With the implementation of a capture system for the reuse of condensed water by the air conditioning equipment components of the climatization system of the Campus under study, considering the estimated volume of this water collected monthly. Knowing that COMPESA has a current tariff structure for public buildings, in which consumption of 10m³ must be charged R$71.81 and above 10m³ must be charged R$10.89 per m³, there is an average monthly consumption between the years 2018 and 2022, in the months of March and April of treated water of 134,100 liters. With these data, it was possible to calculate the monthly savings between the months mentioned above, if a catchment system were implemented, there would be savings with the reduction of the cost of reusing this water of R$ 311.44 monthly, as shown in the Table 6.

Table 6: Annual cost reduction with the water tariff.

COMPESA		Air Conditioners	
Average Monthly Consumption (liters)	Average Monthly Cost (R$)	Average Monthly Volume Generated (liters)	**Average Monthly Savings (R$)**
134.100	R$ 1.180,41	38.599	**R$ 311,44**

Source: The author (2019).

A comparison was made between the average monthly cost of treated water at COMPESA in March and April between 2018 and 2022, in relation to the use of condensed water produced by air conditioners between March and April 2022. 2022, in which a reduction in the cost of treated water of approximately 27% can be observed.

Following the same line, a comparison was made between the average monthly consumption of treated water at COMPESA, in relation to the generated volume of condensed water, respecting the same chronology mentioned above, in which a reduction in the consumption of treated water of approximately 29 %.

Other authors have carried out several studies on the use of water in air conditioners, with the volume of condensed water being quantified, as shown in the following studies.

A study was carried out on the condensed water in four air conditioners of 24,000 BTU's (British Thermal Units - British Thermal Unit) at the Federal Institute of Mato Grosso - Campus Bela Vista, in the city of Cuiabá - MT, Lima et al. (2020, p.44) pointed out that, "quantitatively, the measured flow varied as a function of the relative humidity of the air and, for the devices studied, it was, on average, 2.5 liters/hour and 5 liters/hour, for air humidity of 10% and 60% respectively". Also, according to Lima et al. (2020, p.43), "the reuse of drainage water from air conditioners may not be of great importance in terms of volume, but it is of paramount importance for consolidating the ecological awareness of users" (2020, p.43).

In one of the units of Centro Universitário Uninassau, located in the city of Teresina -PI, the feasibility of reusing water from air conditioners for non-potable purposes was analyzed, Furtado Filho e Silva (2020, p.50), showed that 77 air conditioning units installed in the Uninassau building emitted a significant volume of 6.67 liters/hour. Still from the perspective of Furtado Filho e Silva (2020, p. 53), the reused water from air conditioners is inappropriate for consumption, but can be used for different purposes, such as, for example, energy generation, refrigeration equipment, and vehicle washing.

V. CONCLUSION

The current water crisis is not an issue that only affects the city of Afogados da Ingazeira, in the hinterland of Pernambuco, the locus of this study. It is a scenario that intensifies every day and affects billions of people across the planet. It is therefore necessary to seek as many alternatives as possible to mitigate this reality: the technique presented here aims to be another ally in this fight.

Currently, all the condensed water produced by the Federal Institute of Pernambuco – Campus Afogados da Ingazeira, is not used for non-potable activities. This study demonstrates the economic viability of this use.

A quantitative analysis of the hourly, daily and monthly flow was carried out, in which, using a multiple linear regression by the least squares' method, a general model equation was obtained that estimates the hourly flow (dependent variable) based on the independent variables: power (BTU), internal CO_2 level (p.p.m.), external temperature (ºC) and relative humidity of the external air (URext%). It was observed that the model satisfactorily met the objectives defined for the study.

The present study clearly demonstrates the great potential for using/using water from air conditioners, due to its considerable flow and the existing demand for water for non-potable use. From an economic point of view, the estimated production of 38,599 liters per month would result in an average monthly savings of R$ 311.44, between the months of March and April.

Furthermore, the environmental benefit must certainly be considered. The use of sustainable techniques is in line with the vision of the rational use of public resources and the establishment of a collective socio-environmental awareness fostered by the Ministry of Education (MEC), of which the Federal Institutes participate.

Finally, it is not expected to exhaust all possible reflections in this field in the work presented here. It is recommended, in future researches, that in addition to the studies of flow estimation of ambient refrigeration systems, the results obtained in the research be compared with the mathematical models found in the literature.

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