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ANALYSIS OF WATER TEMPERATURE INFLUENCED BY ARDUINO-CONTROLLED ON SOLAR DESALINATOR OF LOW COST

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Abstract. *The solar desalinator is a low cost installation and operation equipment that can contribute to tackling the problem of water shortages in the world. Because to the importance of this equipment, the present work has the objective to quantify the relation of the temperature of the water with the production of the equipment. For this, a compact desalinator with glass cover in square pyramidal form and a heating system controlled by a logic programmer was built. As a result, it was verified the efficiency of the logic controller as an auxiliary tool to perform experimental work and the relationship between temperature and production of the desalinator was verified and quantified. This has justified the use of auxiliary equipment for water heating.*

Keywords: *Solar desalinator, Temperature of water influence, Logical Programmer, Solar Energy, Compact Desalinator*

1. INTRODUCTION

According to Schiermeier (2014), up to a fifth of the world's population can suffer serious shortages in water supply if the world's temperature is raised to 2 ° C. This real concern about the availability of drinking water to the world justifies the need for studies aimed at the purification of water unfit for consumption.

The purification of water, whether from the sea or polluted, is the solution to the prevention of global scarcity. There are several techniques for this purpose, one of which is the desalinator. Due to the abundance of solar energy, the desalinator that uses this energy is considered a green equipment.

In fact, one of the most promising energy alternatives for the world is the use of abundant and clean solar energy (Vidal, 2002). It is an environmentally friendly energy source with unmatched potential with any other energy system (Ramos, 2011). Because Brazil is a tropical country, solar energy availability is equivalent to 1.13 X 1010 GWh in most of the year (Aldabó, 2002). In order to have an idea of this potential, the annual amount of solar energy that the earth receives corresponds to 10,000 times the world energy consumption in this period (Cresesb, 2004).

The application of solar energy in desalination of water is a technique that allows the obtaining of drinking water in an ecologically correct way and with minimum production cost. This technique is so efficient and easy to apply that Shiva Gorijan (2015) states that the problems of water scarcity in Iran can be solved by applying this desalination technique.

The solar desalinator consists basically of a reservoir of water (water to be treated) and a cover that allows the entrance of the solar radiation and prevents its exit (provoking the greenhouse effect) and allows the condensation and collection of the treated fluid (Lima, 2012).

The level of solar radiation, ambient temperature, wind speed, relative humidity, the presence of clouds and dust are natural parameters that directly influence the production of the solar desalinator (Abujazar, 2016). The ambient temperature is directly related to the desalinator productivity, with the temperature variation from 20ºC to 40ºC, there is an increase of approximately 14% in the production of a simple solar desalinator (Al-Hinai, 2002). Lima (2012) verified the increase of the productivity of a solar desalinizador as a function of the preheating of the fluid.

The evaluation of the influence of water temperature on the desalinator production is a study that allows a better understanding of the equipment and becomes the first step to verify the efficiency of the application of techniques that increase the temperature of the fluid to increase water production .

In this context, the objective of this paper is to present the manufacturing process of a compact solar desalinator of simple and easily constructed materials with four-sided pyramidal coverage and to verify the influence of temperature on its production. It also aims to show the performance of logical programmers in aid of practical studies.

1.1 Solar energy

The main source of energy on planet earth is the sun. In the form of radiation, this energy can be both a source of heat and light. Solar radiation is a short-wave electromagnetic energy, only one part of it hits the earth, another is absorbed by the atmosphere. The intensity of the radiation varies with the time of year and with latitude (Frota, 2001).

The amount of daily solar radiation that the planet receives has such a high potential that it can supply the world's energy needs ten thousand times in that period. Brazil, despite the different types of existing climates, has an annual average of uniform solar radiation, with high averages. The values of solar radiation incident in any region of the country vary from 4.2 to 6.7 kWh / m² (Pereira, 2006). Thus solar energy availability is equivalent to 1.13 X 1010 GWh in most of the year (Aldabó, 2002).

Due to the high availability of energy and the cost to use it, solar energy is being increasingly demanded (Jefferson, 2015) and, therefore, technologies for its use are being developed at all times.

The use of this source to obtain desalinated water is a method that has several advantages such as low initial investment, operation and maintenance costs.

1.2 Solar dessalinator

The solar desalinator consists of a black vessel filled with brackish or saline water up to a certain depth and covered by a slanted glass to facilitate the transmission of solar radiation and the condensation of the water vapor generated. The solar radiation that enters the equipment heats the black container which in turn heats the water causing its evaporation. Because of the pressure difference and temperature difference with the exterior, the water vapor rises and is condensed along the inclined glass lid and is collected by a suitable container in the lower part (Sharon, 2015).

The productivity of the desalinator can be increased by the association of other devices to cause water heating, such as the association of a parabolic concentrator (Lima, 2012), collectors (Omara, 2013), concentrator mirrors (Al-Garni, 2014), among others.

Cooper (1973) found that the type of insulation of the tank walls, the thickness of the water slide and the inclination of the glass cover impacted the performance of the equipment. Deronzier (2015) developed a multi-effect solar distiller with several coupled solar collectors and 12 stages of evaporation, which resulted in high production, reaching up to 35 liters per square meter day (L / m².day). Chendo (1991) found that by filling the black vessel with rocks, the distiller increased production and allowed desalination for up to 4 hours after sunset.

1.3 Logical programming aided by Arduino

Free hardware platforms have become very important in teaching and engineering development in recent years. Among them is the arduino, characterized by its versatility, popularity and low price. The logic controller has a plethora of applications, including temperature control, which can be done simply and quickly (Candelas, 2002).

The low cost, the ease and the amount of information open makes the device to be applied in both education and industry. The device is nothing more than a free platform for programming.

The use of arduino for the production of scholarly works is something growing around the world. The present work used this platform to obtain the temperature control in narrow bands and to allow the greater reliability of the results.

2. METHODOLOGY

Aiming at the best understanding of this article, the methodology was divided into three main topics: 2.1 Construction of the solar desalinator, 2.2 Construction of the temperature control system and 2.3 Data collection and treatment.

2.1 Construction of the solar desalinator

All materials needed for the construction of the desalinator were purchased at the commercial center of the city of mossoró-rn. A cad design (computer assitent design) was used to guide the construction and later the equipment was built.

2.1.1 Materials used

All the materials used for the construction of the desalinator are shown in Fig. (1). They were purchased simply and with low cost in the commercial center of Mossoró-RN.

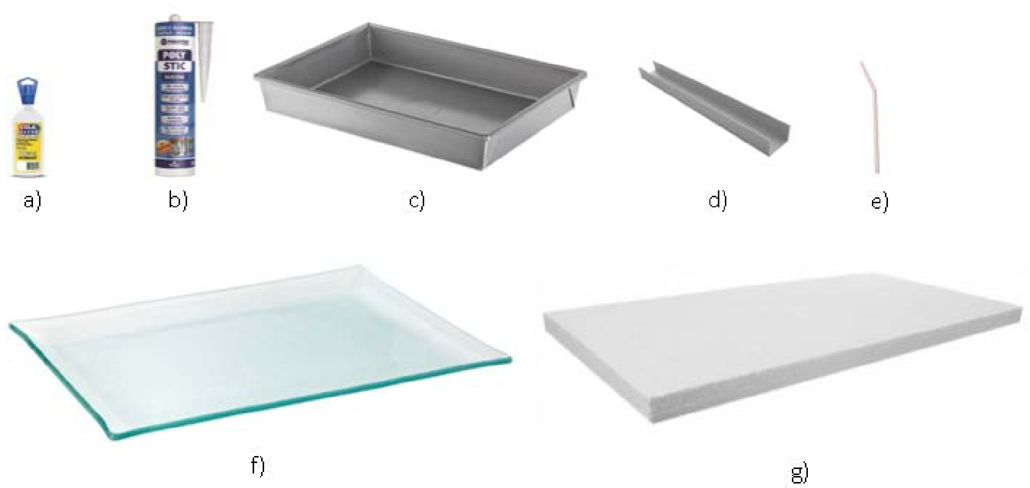

Figure 1: Materials used for the construction of the furnace - a) polystyrene glue; b) Industrial silicon; c) cake form; d) U-shaped aluminum lamella; e) straw; (f) 3 mm glass sheet; g) 40 mm styrofoam sheet.

The desalinator was constructed from a cake form to serve as a reservoir, lamella for the uptake of water, the glass to form the cover and the styrofoam to serve as thermal insulation.

2.1.2 Construction of the desalinator

Using the CAD tool it was possible to design and visualize the desalinator, Fig. (2).

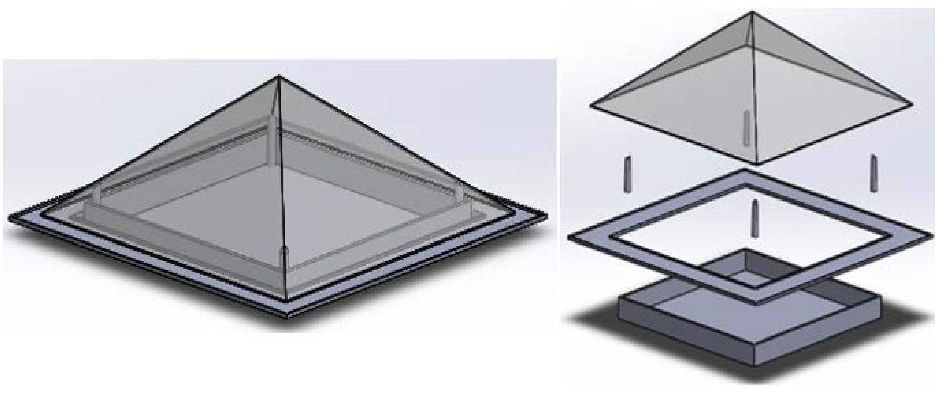

Figure 2. Desalinator design

From the design shown in Fig. (2) it was possible to obtain all the necessary dimensions for the final design. Figure 3 shows all the dimensions in millimeters that were used.

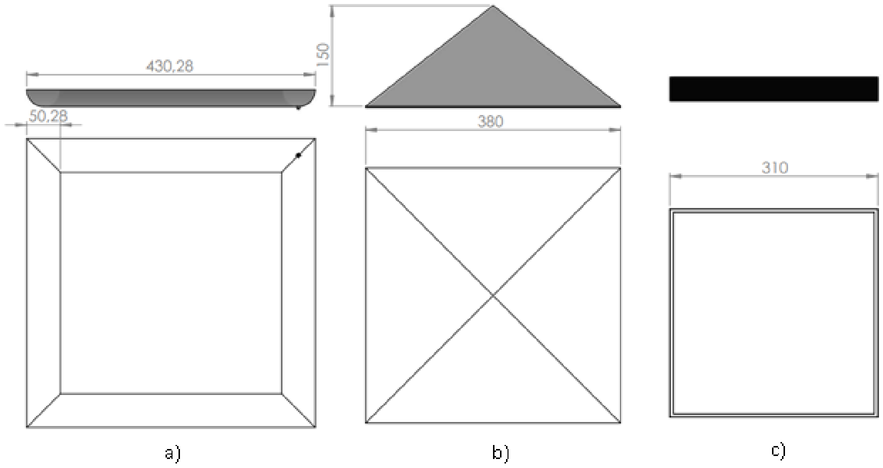

Figure 3. Dimensions of the desalinator - a) gutter; b) glass cover; c) the cake form.

The angle of the glass cover was approximately 52 degrees to the horizontal axis. The inner width of the gutter was 2 mm less than the width of the cake shape for interference fit. With the design defined, the construction phase (physical) of the equipment was started.

From the materials shown in Fig. (1), the following steps were possible: The glass was cut into 4 triangles which were glued with silicone to obtain a 4-sided pyramidal geometry. Then the lambril was cut and joined with the aid of the silicone and painted white to form a square chute for the capture of the desalinated water. The nozzle for draining the fluid was created from a straw.

The cake form was painted black and had its connections sealed with silicone. Finally, the thermal insulation of the desalinator was made with the Styrofoam and Styrofoam glue, so that the insulation thickness was 40 mm. Figure 4 shows the desalinator ready.

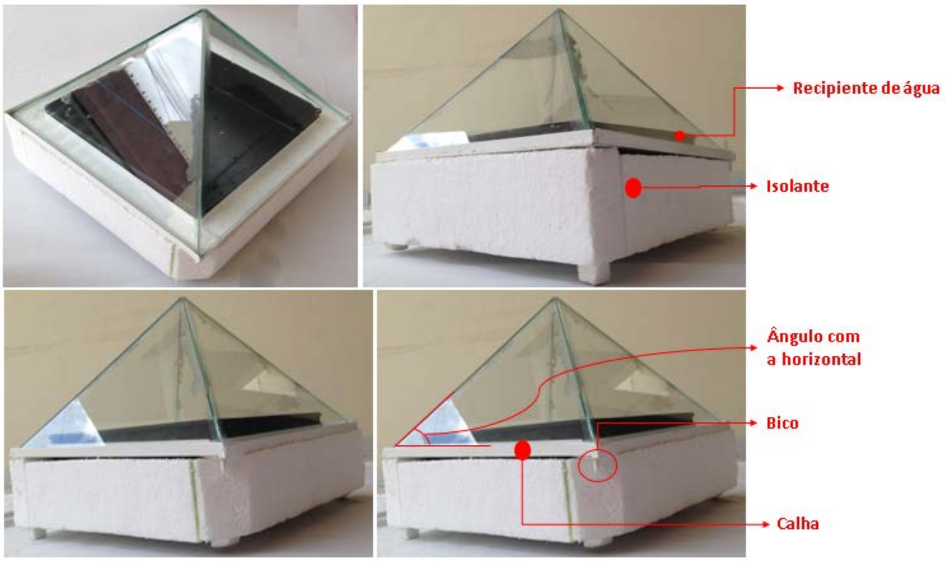

Figure 4. Desalinator finalized.

2.2 Construction of the temperature control system

The temperature control system was made from the Arduino, the materials used and the programming done are shown below.

2.2.1 Materials used

For the control of temperature were used: an Arduino Uno, a resistance for heating, a temperature sensor, a relay of 5 V, epoxy glue, in addition cables, insulation tape and a computer to carry out the programming. The materials are shown in Fig. (5).

The temperature sensor needed a modification to submerge in the water. An electrical insulation was placed using epoxy adhesive and insulation tape. The relay required a connection with electrical resistance and electrical insulation.

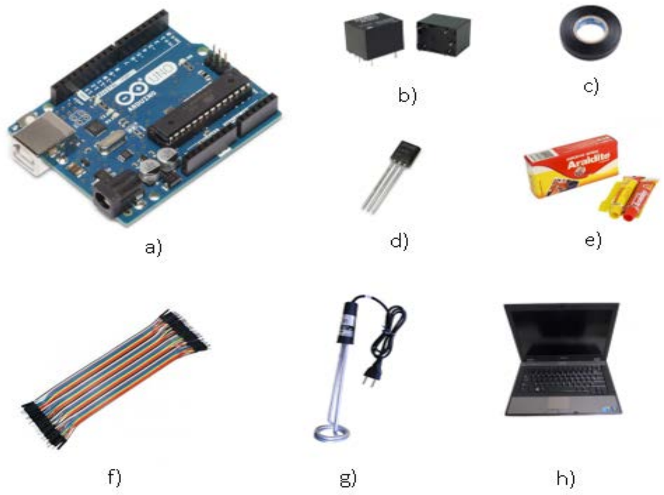

Figure 5. Materias used for the temperature control – a) Arduino; b) 5V relay; c) tape insulation; d) temperature sensor LM35; e) epoxy glue; f) cables and connectors; g)electrica resistence; h) computer.

As a result, the temperature sensor, the electric resistance and the relay were in accordance with Fig. (6).

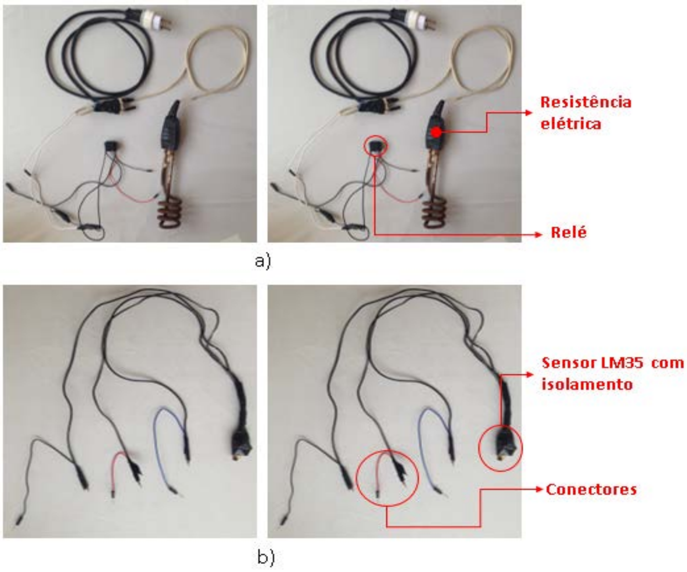

Figure 6. Electrical adaptations - a) electrical resistance and relay; b) LM35 temperature sensor e electrical connectors

After gathering all the necessary materials, the programming for the temperature control was made.

2.2.2 Programming

All programming has been developed in Arduino software. It was programmed so that every three seconds a new temperature reading was made and shown on the display. Figure 7 shows the programming used.

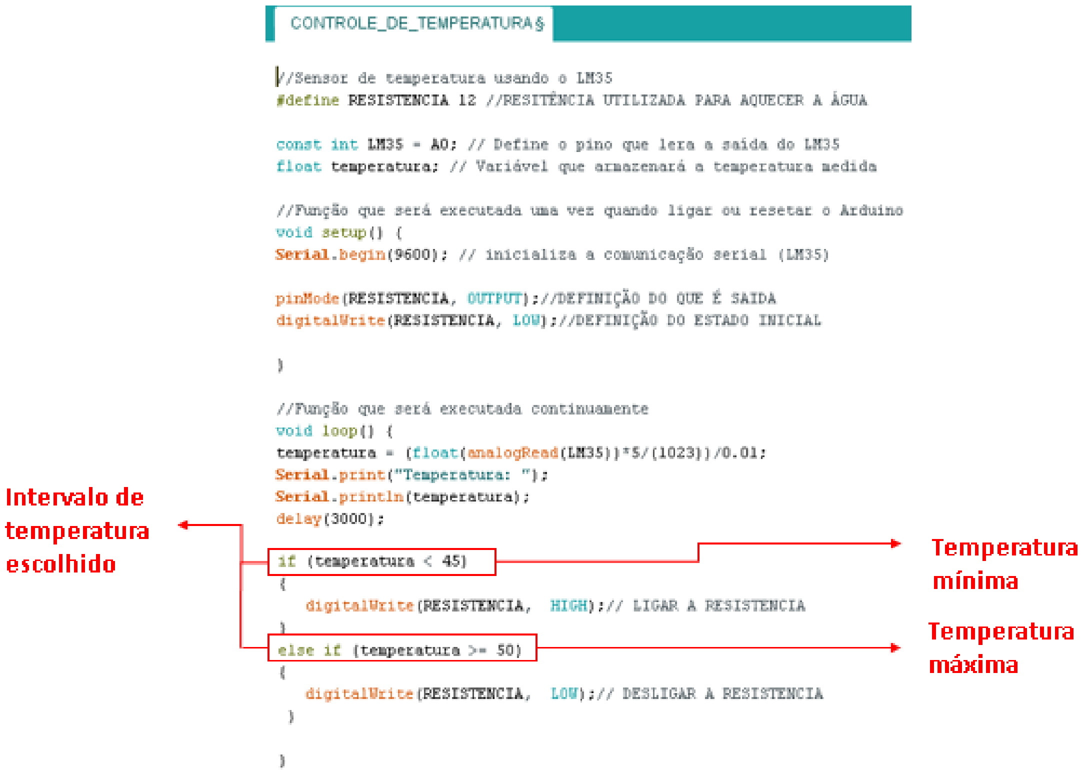

Figure 7. Programming for temperature control

The case shown in Fig. (7) is the temperature control of the water so that it is between 45 and 50 ° C, operating as follows: when the programming is started the temperature sensor checks the water temperature, if it is less than 45 ° C, the relay is activated and the electrical resistance (which is immersed in the water) is switched on. After three seconds the sensor re-read the temperature, if it is above 50 ° C, the resistance is switched off.

When it was necessary to analyze a new temperature range, the minimum and maximum temperature values were edited.

2.3 Collection and processing of data

The temperature control system and the solar desalinator were coupled, the result is shown in Fig. (8). The electric resistance was placed inside the vessel with water and the temperature ranges were chosen.

The condensed water was collected through the nozzle by a graduated beaker. The temperature ranges analyzed were: 45-50, 50-55, 55-60, 60-65, 65-70, 70-75, 75-80, 80-85, 85-90 and 90-95 ° C.

For each temperature range, 3 analyzes per day were performed over a period of 2 days, for example: for the temperature range between 45-50 ºC, three analyzes per day were performed, one in the period from 9:00 am to 11: 00 hours, another from 12:00 to 14:00 hours and the last from 15:00 to 17:00 hours, for two days.

Data collection took place over a period of 20 days. It is important to note that on rainy or cloudy days, the samples were canceled to avoid the influence of lower temperature and higher humidity in the desalinator production (Durkaieswaran, 2015 and Kumar, 2015).

As the data collected for the same conditions were close, a simple mean was used to represent the results of each temperature range.

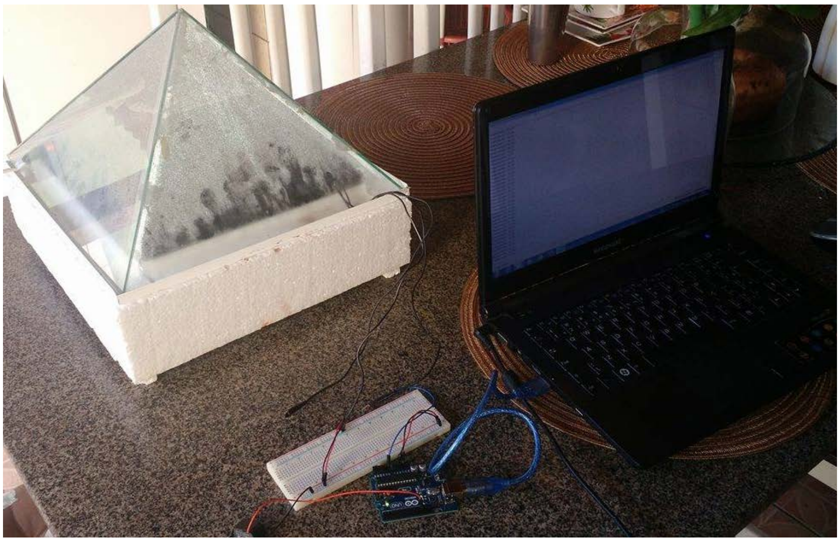

Figure 8. Desalinator in conjuction with the temperature control system.

3. RESULTS E DISCUSSIONS

From the data collected and treated, the graph contained in Fig. (9) was constructed. It is possible to verify a direct relationship between the temperature and the production of the solar desalinator. The area where the water to be treated occupies is 90000 mm².

For the temperature range of 45-50 ° C, a production of 17 ml per hour of desalinator operation was verified. Doubling this temperature range, the production of the desalinator increased more than sixfold, reaching production of 110 ml per hour.

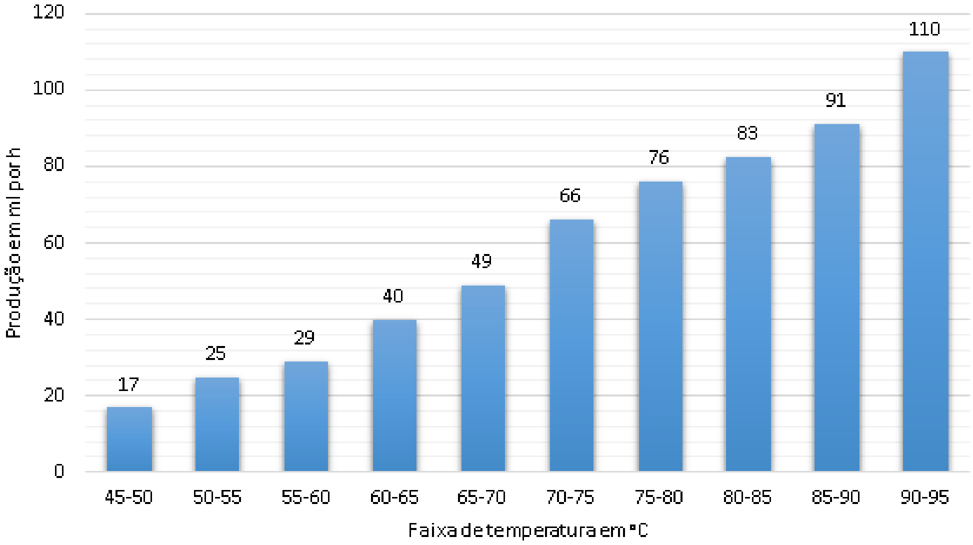

Figure 9. Influence of the water temperature on solar desalinator production, production in ml per hour.

From this graph it is possible to build another, this time relating the temperature to the production in liters per hour per square meter, as shown in Fig. (10).

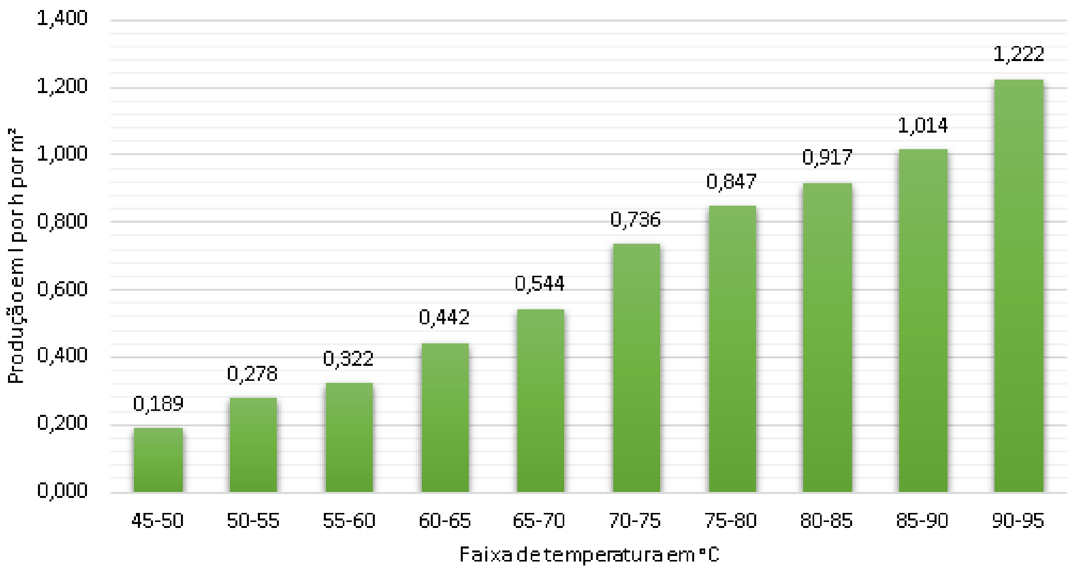

Figure 10. Influence of the water temperature on the production of solar desalinator, production in liters per hour per square meter.

For a temperature between 90 and 95 ° C in an area of one square meter it is possible to produce more than one liter of desalinated water per hour.

Using the average between each temperature range it becomes possible to obtain the graph of Fig. (11). It shows the production of the equipment in a continuous dotted line and the second degree polynomial that generates the trend line in dotted lines.

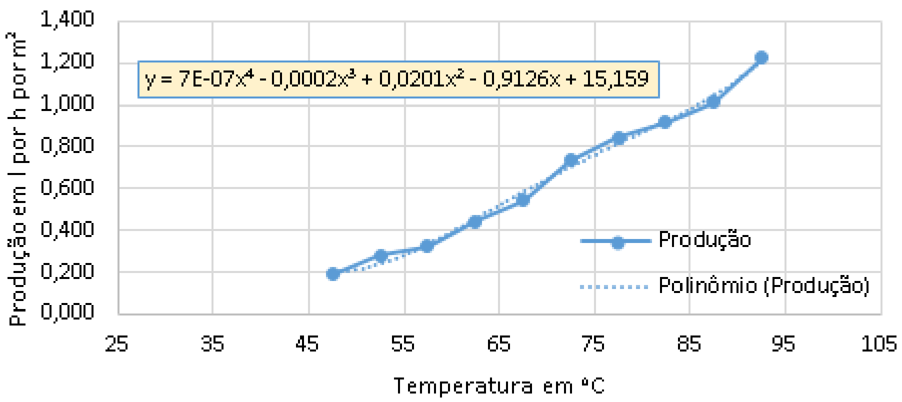

Figure 11. Production as function of the temperature and the trend line polynomial.

From the graph of Fig. (11), Eq. (1) is generated to predict the production according to the water temperature in the desalinator vessel.

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$$P = 0{,}0000007t^4 - 0{,}0002t^3 + 0{,}0201t^2 - 0{,}9126t + 15{,}159 \tag{1}$$

Where P is the production in liters per hour per square meter and t is the temperature in degrees Celsius. Therefore, it is verified that the higher the temperature of the fluid, the greater the solar desalinator production (Kumar et al., 2015).

According to the results obtained, it is noted that the use of other equipment associated with the solar desalinator is totally justified, such as:

- The solar collector with absorber surface in PVC liner sheets developed by Reis (2009) was able to heat the water to a temperature above 52 ºC; or,

- The alternative low cost solar heater proposed by Costa (2007) that was able to heat the water up to 55 ºC;

- Vacuum tube solar heater that Xie (2016) studied through a conceptual and experimental analysis. These reached a temperature of up to 85 ° C in the water.

In fact, the higher the temperature reached by the auxiliary heating system, the better the desalinator production.

4. CONCLUSIONS

From the results obtained:

- It is possible to build a solar desalinator with materials found in any commercial center of any city;

- Arduino is a tool that enables the automation of systems and with this allows to obtain results more faithful to reality;

- The relationship between temperature and production of a compact solar desalinator has been proven and quantified;

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