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EXPERIMENTAL RESULTS OF MULTI-EFFECT HUMIDIFICATION (MEH)-DEHUMIDIFICATION SOLAR DISTILLATION

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Abstract. *Desalination is widely adopted in the world to meet fresh water and process water demands. Nearly 10,000 tons of oil is required every year to produce 1,000 m³/day of desalinated water. Desalination industry can be made sustainable if they are integrated with renewable energy and if proper brine disposal. Renewable energy based desalination units are highly suitable for arid, semi-arid and remote regions where no other mode of power supply is possible. Most of them require thermal and/or electrical input that can be provided by solar energy and hence much focus has been given to solar based systems. In Brazil one of the big obstacles to develop the solar energy industry is the lack of solar resource knowledge and measurement. The objective of this paper is present experimental results of a Multi-Effect Humidification (MEH) - dehumidification solar distillation unit installed in Natal. This MEH system has two cycles of water. The closed cycle is fulfilled with distilled water that will be heated in the solar thermal array and will heat the water of the open cycle through a heat exchanger. The open cycle is fulfilled with the raw water that needs to be processed. This water is heated and evaporates. In another stage, the steam condensates and it consists basically by water molecules (H_2O). The brine is discharged from the evaporator. Seawater testing results are presented and all parameters measured are considerably satisfactory for drinking water.*

Keywords: *Desalination, solar energy, multi-effect humidification.*

1. INTRODUCTION

Fresh water demands are increasing day by day because of industrialization, motorization and increased life standards of mankind. Naturally available fresh water reserves are not capable of meeting the fresh water demands because of their less availability. This situation can be tackled only if mankind finds some other ways to produce fresh water. Luckily, desalination technology developed long back resembling natural hydrological cycle has the capacity to tackle this problem but it consumes more energy and also has some negative impacts on environment (H. Sharon, K.S. Reddy, 2015).

Since 2012, there has been a gradual and intense decrease in rainfall in some regions of Brazil. This weather phenomenon has undermined significantly the supply of water for public supply, especially in the Brazilian semiarid region and in the metropolitan areas (São Paulo and Rio de Janeiro). Other sectors that depend on water storage, such as irrigation and hydropower (main energy matrix of the country) are also being affected by the lack of rain and the lower volume of water in the reservoirs (ANA, 2014). This dry season is considered the most severe in the last 100 years.

Rio Grande do Norte is one of the States in the semiarid region of Brazil and, as mention before, is facing this terrible dry season nowadays. Drilling water wells in this region does not solve the problem, because the water collected is mostly brine. This region is located over a crystalline rock.

The objective of this paper is to present some experimental results of a desalination unit installed in Natal, Rio Grande do Norte, Brazil and try to give some alternative solution to the drinking water problem. This equipment is part of a Cooperation Agreement between two Research Institutes: Centre for Gas and Renewable Energy Technologies (CTGAS-ER) - Brazil and Agroscience - Germany.

2. DISTILLATION SYSTEM DESCRIPTION

The desalination unit uses the process called humidification–dehumidification desalination. The main idea behind this process is to heat brine and produce some steam. This steam contains only H_2O molecules. Later, the steam condensates in a different chamber and is collected outside of the system. The amount of not-evaporated brine increases its concentration of salts and is discharged from the system. In this particular system, the energy used to heat the brine is solar thermal. Figure 1 presents a photograph of the installed system.

Figure 1. MEH system with solar energy

The Figure 2 shows the main components of the equipment and the two different cycles: closed and opened.

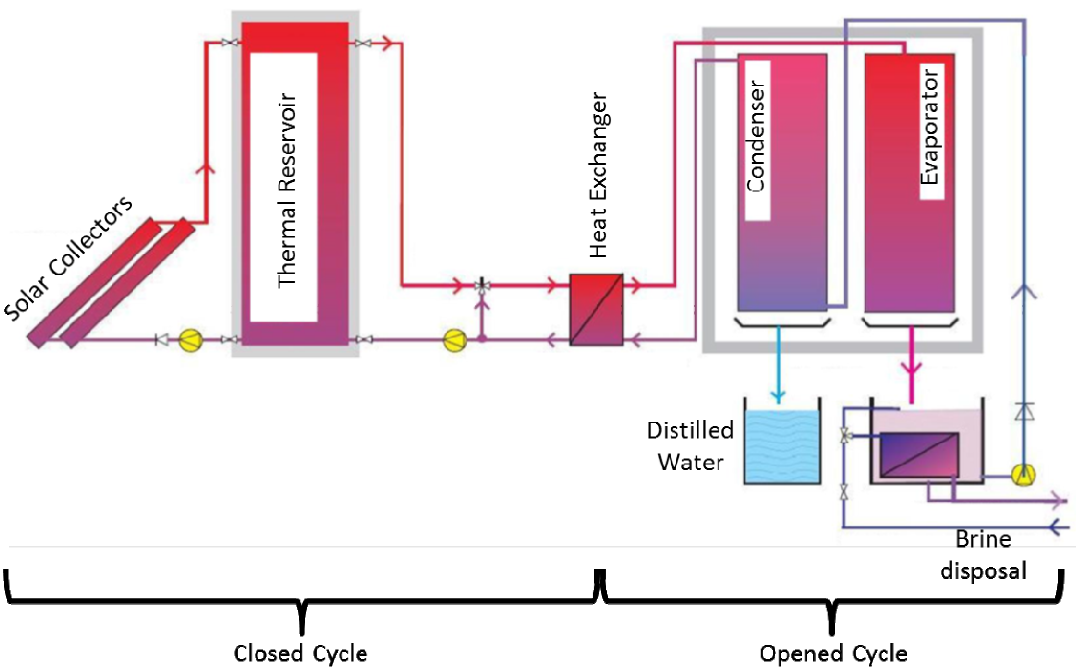

Figure 2. MEH system components

The solar collectors, thermal reservoir, distilled water and the heat exchanger are the components of closed cycle. The distilled water is heated by a solar thermal array of 12 collectors, divided in three lines of four panels in series. The hot water goes to the thermal reservoir and when it reaches the range of 75ºC to 85ºC in the top of the thermal reservoir, the equipment starts to work.

In the opened cycle, the tank is fulfilled with the raw water (brine, sea water). The brine is heated in the heat exchanger and goes to the evaporator. Water desalination is made by multiple evaporation of salty water and consecutive condensation of the generated humidity. The energy is recovered by sophisticated arrangement of condensation-evaporation unit and it requires process energy on a low level.

The product of this process is distilled water, stored in a different tank, and the brine disposal for others purposes. The multi-effect humidification is presented in details in the Figure 3. Distilled water is not considered drinkable, because the human body demands some essentials minerals. In order to add those minerals, the produced water passes through a re-mineralization filter.

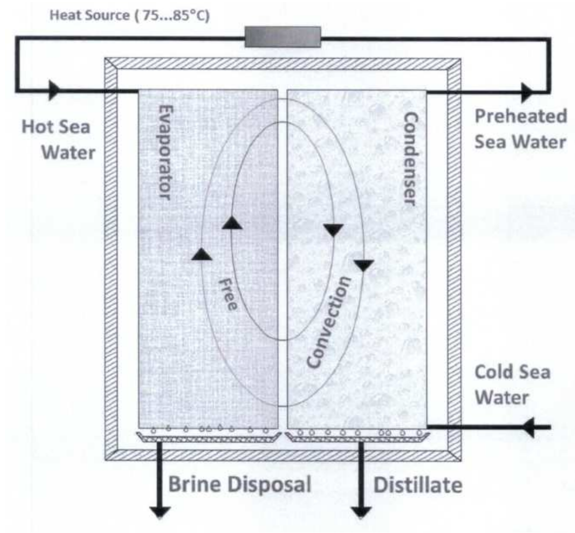

Figure 3. Functional scheme of the MEH principle

(a) (b) (c) (d)

Figure 4. System components: (a) raw water tank, (b) desalination unit, (c) distilled water and (d) re-mireralization filter and drinkable water tank.

3. EXPERIMENTAL RESULTS

In order to test the system in the most severe sample of water, 500 liters of seawater was filled in the raw water tank to be processed. This test was made between September 25th and 30th of 2014 and Figure 5 presents the Total (beam and diffuse) solar radiation average per hour on a horizontal surface, (INPE,2015).

In terms of water produced, 30% of the water was distilled and 70% was discharged as brine. Table 1 presents the water quality before and after the process. The rate production of water was 100 l/day. Different testes were made with the equipment and in some days it have achieved the production of 150 ~ 200 l/day.

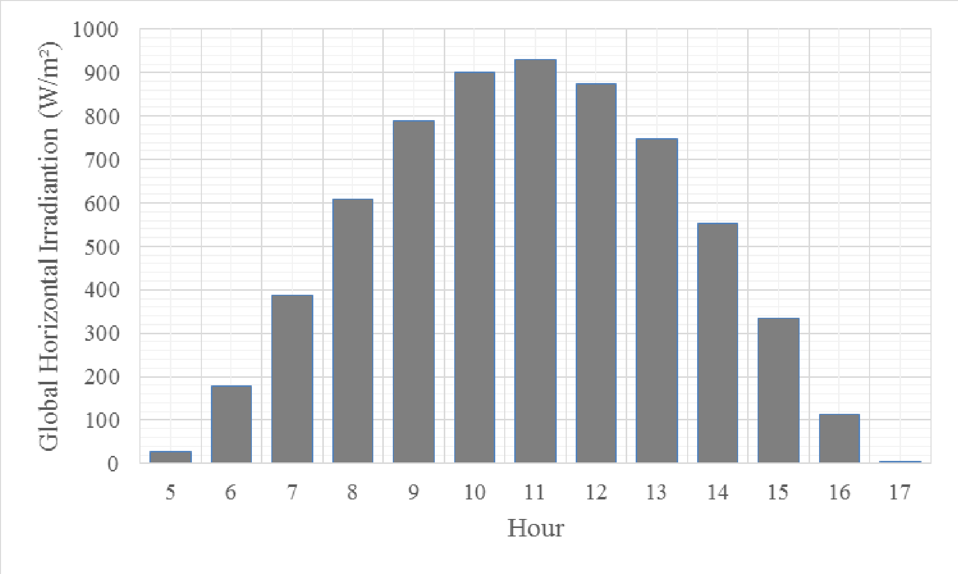

Figure 5. Global Horizontal Irradiance.

Table1. Water quality before and after the process.

Water Test Results			
Parameter	**Raw Water** (mg/l)	**Distilate** (mg/l)	**Brazilian Standard Limits for Drinking Water*** (mg/l)
pH	7.99	10.6	-
Chloride	22,425.80	41.75	250
Sodium	5,543.833	6.321	200
Nitrate	4.58	< 2.00	10
$CaCO_3$	2,563.57	39.67	500
Nitrite	< 0.10	< 0.10	1
Fluoride	0.458	< 0.10	1.5
Sulfate	3,575.20	< 10.0	250
Aluminium	2.998	< 0.01	0.2
Arsenic	< 0.0005	< 0.0005	0.01
Barium	< 0.001	< 0.001	0.7
Cadmium	< 0.0005	< 0.0005	0.005
Copper	< 0.005	< 0.005	2
Chromium	< 0.0005	< 0.0005	0.05
Iron	< 0.2	< 0.2	0.3
Manganese	< 0.0005	< 0.0005	0.1
Mercury	<0.0002	<0.0002	0.001
Nickel	< 0.001	< 0.001	0.07

4. CONCLUSIONS

The equipment is considered a good alternative to minimize the problem of drinking water in the Brazilian semiarid region where water from wells is salty and the solar resource is high. Photovoltaics modules can be used to make this equipment totally isolated from the grid. It's very remarkable the concentration decrease of Chloride, Sodium, $CaCO_3$ and Sulfate in the process.

The water production rate depends basically on amount of irradiance in the solar collectors.

Future research activities are intended to quantify all equipment components to be sure about the national content rate and try to work with a local manufacturer to develop national equipment.

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