Implementation of a Pilot Plant for Distilling Water Using Solar Energy[1]

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Abstract -. The Project for implementing a pilot plant for distilling water using solar energy has been carried out under the guidelines of the Contract N° 180-FINCyT-FIDECOM-PIMEN-2014 in a partnership between the Universidad de Piura, Empresa de Transportes Periche S.R.L. and FINCyT. Solar potential of the north area of Peru guarantees the supply of thermal and photovoltaic energy necessary for the operation of the distiller panels and the pumping system. Also, the use of information tools in designing and simulating the pilot plant processes help in their optimization. The production of the pilot plant is 300 liters per day operating 8 hours, and the quality of the water obtained metes the parameters established for the water for human consumption according the DS N°031-2010-SA from the Peruvian Ministry of Health. The importance of the implementation of this pilot plant lies in its sustainability and the guarantee of a continuous water supply in rural areas.

Key words — distillation, water, solar energy. Pilot plant, renewable energy

I. Introduction

THis document describes the implementation of a pilot plant for distilling water, using exclusively solar energy. The pilot plant has been developed in the partnership of the Universidad de Piura with the company Transportes, Distribuciones y Servicios Periche S.R.L. and FINCyT under the guidelines of the Contract N° 180 – FINCyT – FIDECOM – PIMEN – 2014.

The relevance of using a water distillation system base don solar energy is justified in the regularity and the solar potential of the area, that according to the publications from SENAMHI-MEM [1] amounts to 6.5 kWh/m^2, the availability of untreated water and the need of the population in having water for domestic use. The use of renewable energy as a supply for the pilot plant provides sustainability and friendly basis with the environment.

In the pilot plant Project we have utilized cloth-type distilling solar panels for distilling untreated water, and photovoltaic panels for the electric supply of the pumping system.

The volume of distilled water obtained amounts to 300 liters, and the quality of the distilled water metes the parameters established for human consumption water, according to the DS N° 031-2010-SA from the Peruvian Ministry of Health. This guarantees the safety of the distilled water, and prevents the factors of health risks.

II. Materials and Methods

A. Location of the Project

The Project site, owned by the company Transportes, Distribuciones y Servicios Periche S.R.L., is located at 5°32’40.03” South latitude and 80°49’7.27” west latitude. At the north access of the city of Sechura, approximately 600 meters from the bridge entering into the city, in the district of Sechura from the Department of Piura, Perú.

The land is located in a agriculture area, and it has an untreated water pond of approximately 1,828.2 m^2 of surface area.

B. Features of the untreated water

Pumping tests at a constant flow of the pond indicated that it is possible to operate with an optimal flow of 16.63 l/s, with a 3” diameter pump, for a 6 hours daily pumping.

Hydrodynamic parameters, transmissibility 6.09x10^{-2} m^2/s, permeability 115.49x10^{-4} m/s, storage coefficient 0.12, set a high estimated transmissibility, permeability of material of thick sands and a storage as free aquifers.

To evaluate untreated spring water, we requested an analysis of water quality to the Health Engineering Lab from the Universidad de Piura. The results obtained indicate that the untreated water require a previous treatment in order to be considered appropriate for human consumption (see Table I).

This paper is a result of the Project “Implementación de planta piloto de destilación de agua usando energia solar” (Implementation of a pilot plant for distilling water using solar energy), requested by Transportes, Distribuciones y Servicios Periche S.R.L. and financed by the Fondo para la Innovación, Ciencia y Tecnología (FINCyT) (Fund for Innovation Science and Technology) and Fondo de Investigación y Desarrollo para la Competitividad (FIDECOM) (Fund for Research and Development for Competitiveness) in Peru.

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TABLE I
POND WATER ANALYSIS

Parameter	Amount	Result
pH	7.97	Meets
Conductivity	3080 µS/cm	Does not Meet
True color	19.3 mg (Pt-Co)/L	Does not Meet
Chlorides	638.6 mg Cl^-/L	Does not Meet
Total Hardness	644 mg $CaCO_3$/L	Does not Meet
Odor	Acceptable	Meets
Nitrates	< 0.1 mg NO_3-/L	Meets
Flavor	ND	Does not Meet
Total dissolved solids	1896 mg/L	Does not Meet
Sulfates	208.1 mg SO_4^{2-}/L	Meets
Turbidity	2.4 NTU	Meets
Total coliforms	130 NMP/100 mL	Does not Meet
Thermostable coliforms	33 NMP/100 mL	Does not Meet
E. coli	33 NMP/100 mL	Does not Meet
Heterotrophic bacteria	1500 UFC/mL	Does not Meet

The result is determined based on the Water Quality Regulation for Human Consumption DS N° 031-2010-SA From the general Secretariat of Environmental Health from the Ministry of Health. Lima – Perú, 2011.

C. Description of the pilot plant

The pilot plant for water distillation has a raw water storage tank that comes from the raw water pond, a photovoltaic pumping shed, a raised tank, a piping system, supporting structure, water distilling panel and a storage tank of distilled or processed water. The plant was designed to process 300 liters per day, working from 8 to 10 hours according to solar availability.

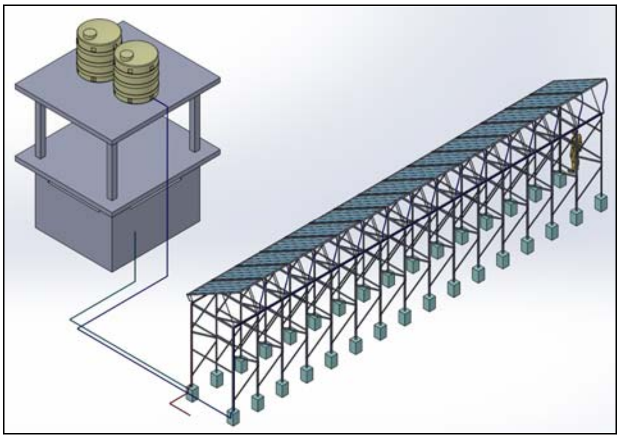

Figure 1.- Pilot plant diagram

Water distilling panels used are panel-type distillers, from the brand Fcubed Solar Water Processors, model CAROCELL™ 3000. Its dimensions are 1110 x 2880 mm with an effective area of 3 m^2.

The process in the pilot plant begins by capturing raw water from the pond. Then, using photovoltaic pumps, we bring the raw water to the raised tank. Then, by gravity, raw water is sent to the intake of the distilling panels, where the distilled water is separated from waste water. The distilled water flows by gravity towards the storage tank located in the pumping station, and waste water is sent again to the raw water pond.

Water distilling process begins by entering water on the top part of the panel. Then, the water flows into a panel installed inside. The panel allows the water flow to be slow, so that solar radiation heats the water by radiation and convection. This heating generates the evaporation of the water, which rises and hits against a clear screen where it condenses due to thermal crash with the external temperature. Condensed water flows through the clear screen and it is collected at the lower part of the panel and sent to a storage tank. On the other hand, the water that is not condensed also is collected at the lower part and sent to the raw water pond.

Figure 2.- Distilling panels installed

D. Pilot plant design

The design of the water distilling pilot plant has been developed considering the following components: assessment of solar energy available, direction of the distilling panels, mechanic and hydraulic design and testing protocol of the pilot plant.

The assessment of solar energy available has been calculated based on the information from the meteorological station installed in the area of Bayovar, and the result was proven as it in the Atlas Solar Peruano (Peruvian Solar Atlas) [1].

In order to define the number of water distilling panels, we installed a distilling panel as a testing, and we determined its distilling water performance, which amounts to 20 liters on average per day. The performance is not even throughout the day, having greater water production at midday, when solar radiation is maximum. According to these results, we sized the pilot plant with fifteen distilling panels.

In order to set the orientation of the solar distilling panels, it is necessary to determine the solar trajectory throughout the day and the year. For this purpose, we used the tools available in the web SunEarthTools.com. These tools have been developed by the Italian government, and are free of access.

Based on the solar information obtained with this information tools, we performed shadow simulation throughout the day in the dates June 21st and December 21st of December, which correspond to the limit days of extreme run of the solar trajectory.

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With regards to the photovoltaic pumping system, we considered a solar pump with a maximum flow of 12 m^3 with dynamic altitude of 15 m, which generates a daily energy demand equal to 7,800 Whp which will be addressed by 4 photovoltaic panels of 195 Wp, and a charging control system with sensors in the tank and in the raised tank.

For the mechanical and hydraulic design, we have worked with the software Solidworks y EPANET, where we simulated supporting structures to calculate mechanical forces, and the piping of the system to determine hydraulic pressure falls respectively.

In the simulation of the supporting structures, we have considered live loads, wind loads, dead loads and anti seismic loads. Factorization of loads has been performed using the AISC-LRFD methodology, analyzing the most critical scenarios of the load combinations, according to the technical regulation ANSI MH16.1:2012.

The live load considered is zero. The dead load was set by the weight of the structure plus the weight of the panels and the water volume that flows during the process. The wind load was set considering the wind speed at 10 m of high equal to 80 km/h, and the seismic load was set according as indicated in the Peruvian regulation E.030 for an area classified with seismic grade 3.

Structural profiles considered in the design of the supporting structure are of ASTM A36 angular steel, and PL 2x1/8” sheet.

In the simulation of the water flow in the piping of the system, we applied the Darcy-Weisbach equation in permanent regime, with a roughness coefficient of 0.0015 mm due to working with PVC piping, and losses of 0.012 m per each line.

Testing protocol from the pilot plant is based on the analysis of water quality and the production of water processed. Quality of water processed was analyzed by the Health Engineering Lab from the Universidad de Piura, and the production of the water processed was determined based on the measuring of the intake and exit flows performed at the field.

For the analysis of water quality, at the Health Lab from the UDEP, methods and references from 2012 indicated in Table II were used.

TABLE II
METHODS AND REFERENCES

Parameter	Quantity	Title
pH	SMEWW-APHA-AWWA-WEF Part 4500-H+ A, B 22nd Ed.	pH Value. Electrometric Method
Conductivity	SMEWW-APHA-AWWA-WEF Part 2510 A, B 22nd Ed.	Conductivity, Laboratory Method
True color	SMEWW-APHA-AWWA-WEF Part 2120 C 22nd Ed	Color. Spectrophotometric-Single-Wavelenght Method (Proposed)
Chlorides	SMEWW APHA-AWWA-WEF PArt 4500-Cl^- B, 22nd Ed.	Chloride. Argetometric Method
Total hardness	SMEWW-APHA-AWWA-WEF Part 2340 C, 22nd Ed	EDTA Titrimetric Method
Odor	SMEWW-APHA-AWWA-WEF Part 2115 B, 22nd Ed	Threshold Odor Test
Nitrates	ISO 7890-3	Spectrometric method using sulfosalicylic acid 1988
Total dissolved solids	SMEWW-APHA-AWWA-WEF Part 2540 A, C 22nd Ed.	Total Dissolved Solids Dried at 180 °C
Sulfates	SMEWW-APHA-AWWA-WEF Part 4500-SO_4^{2-} E., 22nd Ed	Turbidimetric Method
Turbidity	SMEWW APHA-AWWA-WEF. 22nd Ed 2130 B	Nephelometric Method
Total coliforms	SWEWW APHA-AWWA-WEF Part 9221 B, 22nd Ed.	Multiple Tube Fermentation Technique For Members of the Coliform Group, Standard Total Coliform Fermentation Technique
Thermostable coliforms	SMEWW APHA-AWWA-WEF Part 9221 E (1, 2) 22nd Ed	Multiple Tube Fermentation Technique For Members of Coliform Group, Fecal Coliform Procedure. Thermotolerant Coliform Test (EC Medium)
E. coli	SMEWW APHA-AWWA-WEF Part 9221 F1, 22nd Ed	Multiple Tube Fermentation Technique For Members of Coliform Group, Escherichia coli procedure using Fluorogenic Sustrate Escherichia coli Test (EC-MUG Medium)
Bacterías heterotróficas	SMEWW APHA-AWWA-WEF Part 9215 B, 22nd Ed	Heterotrophic plate count Pour Plate Method

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TABLE III
ANALISIS OF OF WATER FROM PROCESS

Parameter	Quantity	Result
pH	8.22	Meets
Conductivity	854 µS/cm	Meets
True color	5 mg (Pt-Co)/L	Meets
Chlorides	177.8 mg Cl^-/L	Meets
Total hardness	140 mg $CaCO_3$/L	Meets
Odor	Aceptable	Meets
Nitrates	< 0.1 mg NO_3-/L	Meets
Flavor	ND	Meets
Total dissolved solids	495 mg/L	Meets
Sulfates	57.7 mg SO_4^{2-}/L	Meets
Turbidity	2.4 NTU	Meets
Total coliforms	< 1.8 NMP/100 mL	Meets
Thermostable coliforms	< 1.8 NMP/100 mL	Meets
E. coli	< 1.8 NMP/100 mL	Meets
Heterotrophic bacteria	17 UFC/mL	Meets

The result is determined based on the Regulation of Water Quality for Human Consumption DS N° 031-2010-SA from the General Secretariat of the Environmental Health from the Health Ministry. Lima – Perú, 2011.

III. RESULTS

After implementing the pilot plant for distilling water, we performed volume testing, measuring intake and exit volumes of water. The volume of distilled water amounts to 300 liters per day.

On the other hand, with regards to water quality, results of analysis performed by the Health Lab indicate that the water is valid for human consumption. See table III.

IV. DISCUSSION AND CONCLUSIONS

From the results showed in the previous section, we can conclude that the pilot plant, which has 15 distilling panels, can distill 300 liters daily, and water quality distilled is appropriate for human consumption, according to the DS N° 031-2010-SA.

Supply of solar energy, both thermal as well as photovoltaic, guarantees the sustainability of the pilot plant. Also, the environmental and social impact is favorable, because the environment does not get contaminated, and water is generated for human consumption, helping in the care of the population of the area.

The positive impact from the Project and the feasibility of the replication of it in areas with similar environmental conditions, either urban or rural, open a line of investigation of high interest for the development of similar projects in population, that currently do not have basic health systems. This would help lowering infant mortality and gastrointestinal diseases.

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