Desalinization of Brackish Water.

E.C. Ugwuoke, M.Eng. (In View)*; H.O. Orah, M.Eng; B.I. Onyia, M.Eng. (In View); I. Ofili, M.Eng.; and H.I. Edeh, Ph.D. (In View).

Projects Development Institute (PRODA), Enugu, Nigeria.

E-mail: emmychyugwuoke@yahoo.com*

ABSTRACT

There is limited access to drinking water that meets acceptable standard levels of biological, chemical, and physical constituents. Over 97% of water available on the Earth's surface is salty, and environmental pollution caused predominantly by anthropogenic activities is also contributing to the degradation of fresh water resources. The WHO reported that 78% and 96% of the rural and urban populations used clean drinking water in 2006 on a global scale, respectively. Four billion cases of diarrhea are reported annually, with 88% of them being ascribed to the use of unclean water, and insufficient sanitation and hygiene (WHO). This indicates the need for interventions that aim at providing clean water. In view of this, the millennium development goals incorporate a target to halve the percentage of the population without access to safe water by 2015 (UN). Indeed, this goal can be achieved through a multi-faceted approach which includes the development of appropriate technologies for water desalination.

This work centered on production of clean water from salt water by means of desalinization. The experiment was performed at National Centre for Energy Research and Development, University of Nigeria, Nsukka. The maximum volume of clean water produced was 4.3 litres. The atmospheric temperature of day during the experiment varied between 27°C -32°C. The maximum temperature of the salty water obtained at day 5 was 44°C. The solar Insolation at the Centre was 450W^2.

(*Keywords:* desalinization, salt water, drinking water, potable water, pond, hygiene)

INTRODUCTION

The shortage of drinking water is expected to be the biggest problem of the world in this century due to unsustainable consumption rates and population growth [1]. Pollution of fresh water resources (rivers, lakes and underground water) by industrial wastes has heightened the problem. Again, about one-third of that potential fresh water can only be used for human needs due to mixed factors [2]. The total amount of global water reserves is about 1.4 billion cubic kilometers. Oceans constitute about 97.5% of the total amount, and the remaining 2.5% fresh water is present in the atmosphere, polar ice, and ground water. This means that only about 0.014% is directly available to human beings and other organisms [3]. So, development of new clean water sources is imperative. Desalination of sea and/or brackish water is an important alternative, since the only inexhaustible source of water is the ocean.

Besides the problem of water shortage, process energy constitutes another problem area [1]. Desalination processes require significant amount of energy. It was estimated that the production of 1 million m^3/day requires 10 million tons of oil per year [4]. Due to high cost of conventional energy sources, which are also environmentally harmful, renewable energy sources (particularly solar energy) have gained more attraction since their use in desalination plants will save conventional energy for other applications, reduce environmental pollution and provide free, continuous, and low maintenance energy source.

The use of solar distillation has been practiced for a long time, and it gained more attraction after the First World War. Moreover, typical purification systems are easily damaged or compromised by disasters, natural or otherwise [5].

Solar desalination is suitable for remote, arid and semi-arid areas, where drinking water shortage is a major problem and solar radiation is high. The limitations of solar energy utilization for desalination are the high initial cost for renewable energy devices and intermittent nature of the sun. Due to these limitations the present capacity of solar desalination systems worldwide is about 0.01% of the existing large-scale conventional desalination plants [6]. So, efforts must be made to develop technologies, which will collect and use renewable energy more efficiently and cost effectively to provide clean drinking water besides developing technologies to store this energy to use it whenever it is unavailable.

The combination of solar energy with desalination processes can be classified into two main categories: 100% solar driven desalination plants or partial solar powered desalination plants. Solar plants could be designed to operate in a fully automatic fashion in the sense that when the sun rises, heat collection process is initiated automatically by a sensor measuring the solar radiation [1].

DESALINATION PROCESSES

Different types of water desalination processes have been developed. These can be classified into the following two categories [7]:

Phase Change or Thermal Processes

Grid electricity is not available in most rural areas of the country. Consequently, a sustainable source of energy is needed to produce clean water in such areas [8]. Thermal energy sources, such as fossil fuels, nuclear energy, or solar energy may be used to evaporate water, which is condensed to provide fresh water. The phase change desalination processes described here include multi-stage flash, multi-effect boiling, vapor compression, and freezing processes.

Multi-Stage Flash (MSF) Process

The process consists of many stages; in each stage the steam produced in the previous stage condenses and simultaneously preheats the feed water. Thus, the temperature difference between the hot source and seawater is fractionated into a number of stages. Therefore, the system approaches ideal total latent heat recovery. The operation of such a system requires pressure gradients in different stages; i.e. stages should be at successively lower pressures. Seawater, preheated in various stages, enters the solar collector, where it is heated to nearly saturation temperature at the maximum system pressure [1]. As the water enters the first stage through an orifice, its pressure is reduced, thus becomes superheated and flashes into steam. The steam produced passes through a demister to remove any suspended brine droplets, then to a heat exchanger where it condenses. This process is repeated through the various stages.

Multi-Effect Boiling (MEB) Process

The process consists of a number of elements, called effects. The steam from one effect passes through the next one, where it condenses and causes evaporation of a part of the seawater. This process requires that the heated effect be kept at a pressure lower than that of the effect from which the steam originated. In this system the feed water passes through heat exchangers for preheat, then instead of entering solar collector or heater, it enters the top of the first effect, where the heating steam raises its temperature to the saturation temperature for the effect pressure, and then another amount of steam from the solar collector is used to produce evaporation. The produced vapor is used in part to heat the incoming water and in part, to provide heat to the next effect. Also the sensible heat of condensation is used to preheat the feed water. This process usually operates on a once through system without much of circulation of the brine through the system, thus reducing pumping power and scale formation.

MATERIALS AND METHODS

Brackish Water

The salty brackish water used in the experiment was gotten from Afikpo in Abakiliki, Ebonyi State, Nigeria. The reason for the choice of Afikpo water was that the water contains lots of salt and other minerals. This has constituted a lot of problems for the inhabitants because of the lack of potable drinking water. A great deal of research has been done on a way to obtain a potable drinking water from the pond but due to the limitations of the developing economy and its location in a remote part of the country, effective results could not be achieved. Therefore solar desalinization was studied in this work to help the inhabitants distil potable drinking water from pond water and other water sources from the area.

Experimental Procedure

The 10 litres brackish water was poured into a container having a sieve on it to remove some materials that might block the solar still tap during discharge. The sieved water was then poured into a distillation basin. The set up was exposed to the sun to receive the solar radiation [9]. The essence of exposing it to sun is that the solar radiation provides the energy which will heat the absorber basin (painted black). The water in the basin will receive energy and increase in temperature. As the temperature of the water rises, vapor evaporates to the glass and condenses; it then trickles down from the sliding glass cover to the storage basin, where the pure water is collected.

Selection of the Solar Collector

The main object of the research is to develop an on-farm solar distillation system. The basic criterion of solar collector selection was to conduct different types of distillation experiments successfully without changing the basic design principle of different distillation systems. From a number of studies on industrial heat demand, several industrial sectors have been identified with favorable conditions for the application of solar energy.

Several experiments were carried out to utilize the solar energy in medium temperature range using vacuum tube collectors to increase the temperature in medium-high temperature range (Sharma et al) [10]. These vacuum tube collectors are efficient in low temperature range but not suitable for continuous processing in medium-high temperature range due to higher heat losses by increase in the amount of exposed area.

Decreasing the area from which the heat losses occur can increase energy delivery temperatures. With higher a concentration ratio, there is increase in temperature at which heat is delivered due to an increase in flux intensity and a decrease in the receiver area. For high temperature applications, different solar concentrators may be employed. A number of solar industrial process heat systems are installed and operated on experimental basis have reported the status of the development of medium temperature solar collectors for industrial applications. In this temperature range, solar thermal systems have a great scope of application (ESTIF,) [11]. Modern parabola trough concentrators and central receiver towers are operated by high-tech computer programmed tracking system and are used only in large-scale applications to justify the high investment costs and gross over design. In conventional paraboloid concentrators, not only frequent tracking about two axes is required but also receiver has to fix at the focal point as an integral part of the reflector. Moreover, focus lies in the path of incident beam radiations [12]. Despite of the high temperature output, such types of concentrators are not suitable for distillation and cooking purpose due to frequent changes of the focus position and inadequacy of handling approach at the receiver. This limitation, however, is solved by the Scheffler fixed focus concentrator which not only provides simple and precise automatic tracking but also a fixed focus away from the path of incident beam radiations.

For small scale applications in agriculture, post-harvest technology and food industry, this is a cheaper solution. Moreover, this type of concentrator can be completely fabricated in an ordinary workshop. In order to operate an on-farm distillery for the processing of different kinds of medicinal and aromatic plants, Scheffler concentrator was selected because of fixed focus and can be used for different types of distillation system and easy to fabricate.

RESULTS AND DISCUSION

Samples were from Afikpo ponds which saline and contains ions such as calcium, $Ca^{2-,}$ $SO_4^{2+,}$ Na^+, etc. The experiment was performed at National Centre for Energy Research and Development, University of Nigeria, Nsukka, Enugu State, Nigeria. The average solar insolation at the Centre is $450W/M^2$[13]. The results obtained show that distillate production depends but not on solar radiation. The increase in solar radiation gives rise to increase in distillate production [9].

From Table 1 maximum distillate production for the period of 10 days was 4.3 litres on day 7. The minimum production was 1.4 litres on day 1. The experiment performed by Alpesh Mehta et al.

yielded 1.5 liters using 14 liters of water but they also got 2.33 litres, theoretically [18]. The atmospheric temperature of the day was irregular during the experiment ranging from 27°C minimum in day 2 to 32 °C day 3.

The brackish water temperature on day 1 increased to maximum value by 3 pm. Also on day 5 the salty water temperature has its minimum value on day 5 by 10am which was 37°C.

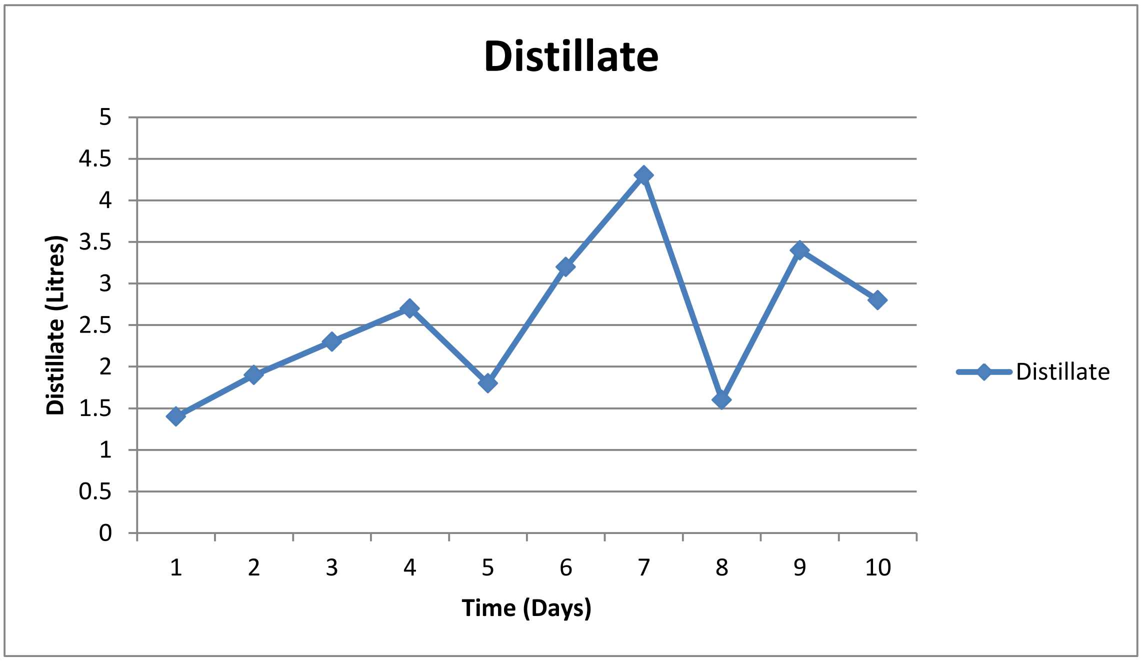

Figure 1: Distillate Production for a Period of 10 Days.

Table 1: Distillate Production for a Period of 10 Days.

Time (Days)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Distillate(Litres)	1.4	1.9	2.3	2.7	1.8	3.2	4.3	1.6	3.4	2.8

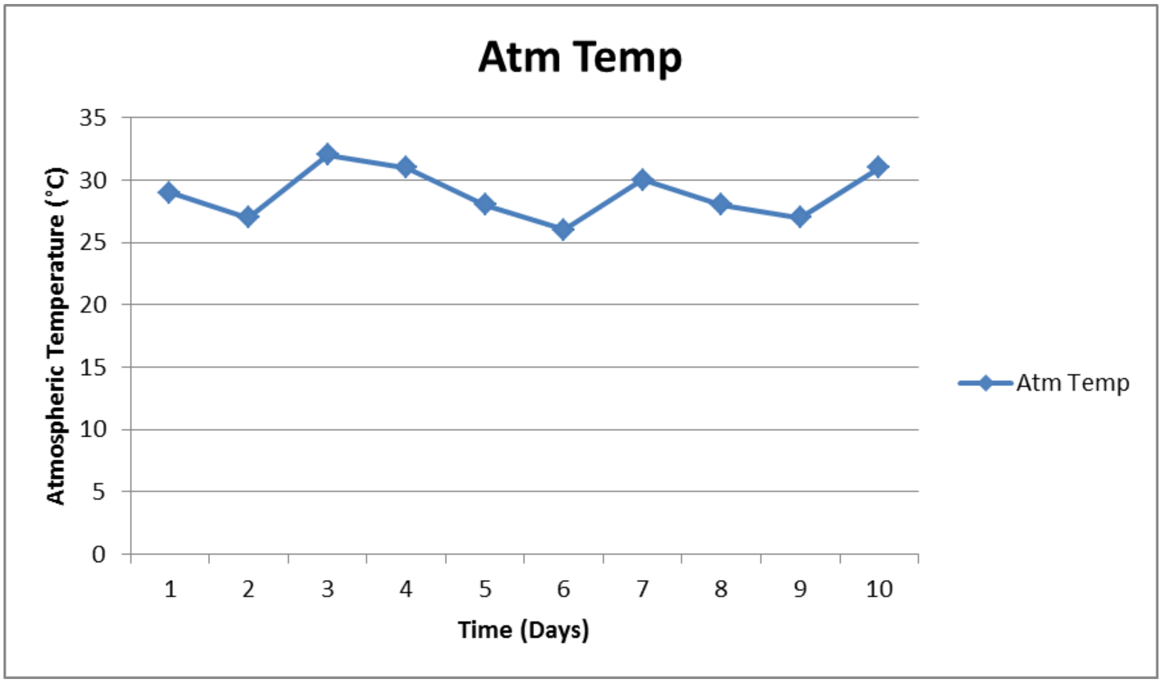

Figure 2: Atmospheric Temperature (°C) for a Period of 10 Days.

Table 2: Atmospheric Temperature (°C) for a Period of 10 Days.

Time (Days)	Temp. Of Brackish Water (°C)
1	29
2	27
3	32
4	31
5	28
6	26
7	30
8	28
9	27
10	31

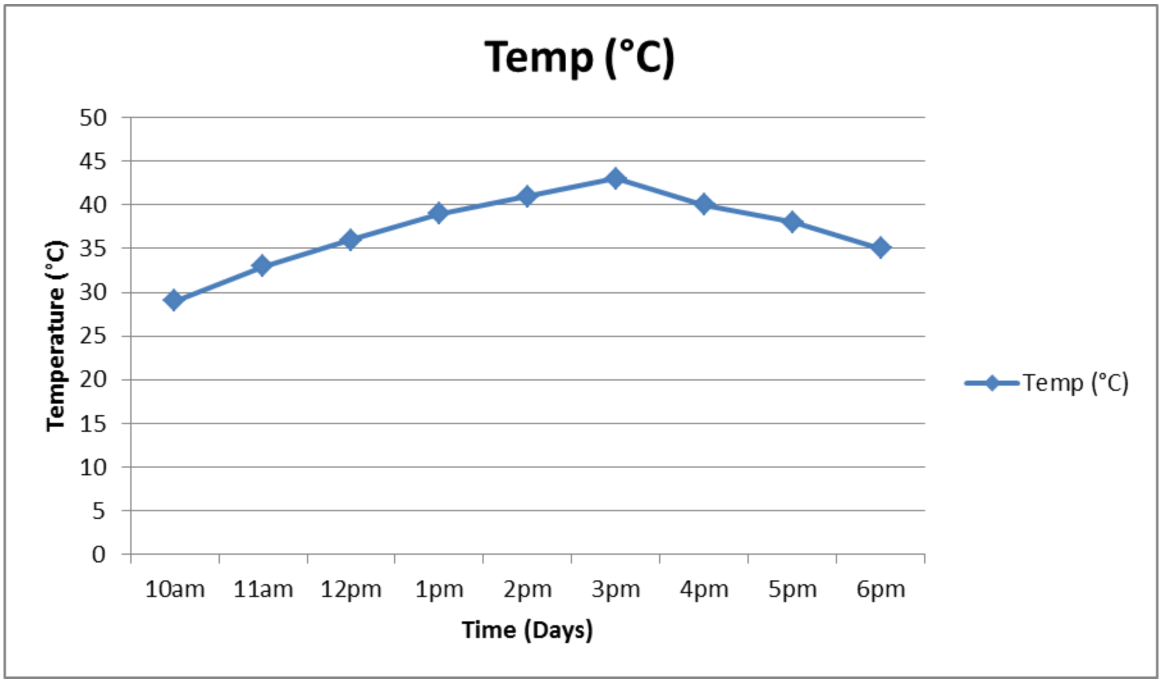

Figure 3: Brackish Water Temperature (°C) from 10 am to 6 pm in Day 1.

Table 2: Temperature of Brackish water (°C) from 10 am to 6 pm in Day 1.

Time (hr)	Temp. Of Brackish Water (°C)
10 am	29
11 am	33
12 pm	36
1 pm	39
2 pm	41
3 pm	43
4 pm	40
5 pm	38
6 pm	35

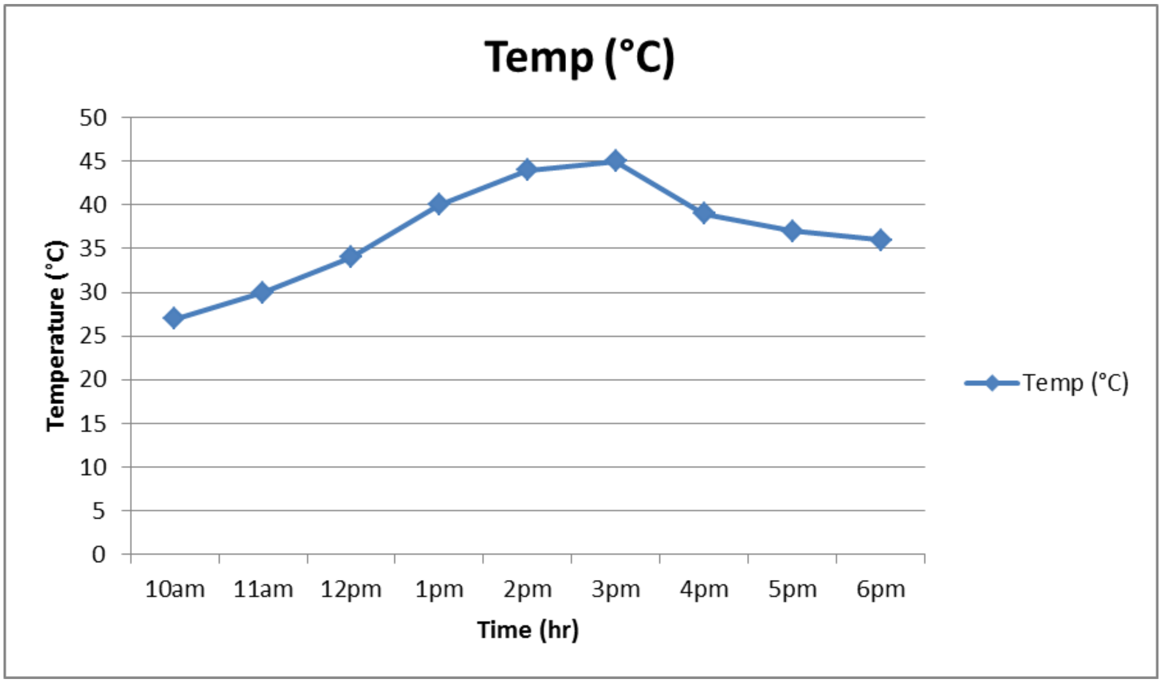

Table 3: Temperature of Brackish Water (°C) from 10 am to 6 pm in Day 5.

Table 3: Temperature of Brackish Water (°C) from 10 am to 6 pm in Day 5.

Time (hr)	Temp. Of Brackish Water (°C)
10am	27
11am	30
12pm	34
1pm	40
2pm	44
3pm	45
4pm	39
5pm	37
6pm	36

CONCLUSION

Solar distillation is a process where solar energy is used to produce fresh water from saline or brackish water for drinking, domestic and other purposes. There are several distillation methods developed for water desalination technology which differ in simplicity, cost and applications. In the last decades, much research has been conducted to minimize the cost of this process, and several methods have been developed. Among these methods, solar distillation appears as one of the best practical and the most economical, especially for mass production of fresh water from high saline water like seawater.

The work presented here studied the purification of salt water using this desalinization method. The maximum distillate obtained during the experiment was 4.3 litres. The atmospheric temperature of the day varied between 27°C - 32°C. The maximum temperature of the salty water on day 5 was 44°C recorded at 2pm.

REFERENCES

1. Saleh, A. and A. Al-Kharabsheh. 2003. "Theoretical and Experimental Analysis of Water Desalination System Using Low Grade Solar Heat". University of Florida.

2. Amitava, B. 2013. "Solar Stills for Desalination of Water in Rural Households". *International Journal of Environment and Sustainability.* ISSN 1927:9566 2(1):21-30. Nanotech Research Facility, PSG Institute of Advanced Studies, Coimbatore – 641004, India.

3. Bendfeld, J., C. Broker, K. Menne, E. Ortjohann, L. Temme, J. Vob, and P.C.M. Carvallo. 1998. "Design of a PV-Powered Reverse Osmosis Plant for Desalination of Brackish Water." *Proceedings of 2nd World Conference and Exhibition on Photovoltaic Solar Energy Conversion*: Vienna, Austria. 3075-3077.

4. Kalogirou, S. 1997, "Economic Analysis of a Solar Assisted Desalination System". *Renewable Energy*. 12(4):351-367.

5. Mehtal, A., A. Vyas et al. 2011. "Design of Solar Distillation System". *International Journal of Advanced Science and Technology*. 29, G.H. Patel College of Eng. & Technology: India.

6. Delyannis, E. and V. Belessiotis. 2001. "Solar Energy and Desalination". In: *Advances in Solar Energy: An Annual Review of Research and Development.* Goswami, D.Y. (ed.). 14. American Solar Energy Society: Boulder, CO. 287-330.

7. Kalogirou, S. 1997, "Survey of Solar Desalination Systems and System Selection." *Energy*. 22(1): 69-81.

8. Madhlopa, A. 2009. "Development of an Advanced Passive Solar Still with Separate Condenser". Energy Systems Research Unit, Department of Mechanical Engineering, University of Strathclyde: Glasgow, UK.

9. Ugwuoke, E.C. 2015. "Performance Evaluation of a Solar Water Distillation System". *The Pacific Journal of Science and Technology*. 16(2).

10. Sharma, S.D., T. Iwata, and H. Kitano. 2005. "Thermal Performance of a Solar Cooker Based on an Evacuated Tube Collector with a PCM Storage Unit". *Solar Energy*. 78:416-426.

11. ESTIF (European Solar Thermal Industry Federation). 2004. "A Study on Key Issues for Renewable Heat in Europe (K4RES-H)". *Solar Industrial Process Heat*–WP3 Task 3.5, Contract EIE/04/204\S07.38607.

12. Munir, A. 2010. "Design, Development and Modeling of a Solar Distillation System for the Processing of Medicinal and Aromatic Plants". Pakistan.

13. Ofili, I, and E.C. Ugwuoke. 2016. "Water Purification by Solar Distillation Process". The Pacific Journal of Science and Technology. 17(1).

ABOUT THE AUTHORS

E.C. Ugwuoke, is currently pursuing a Masters Degree program in Energy and Power Technology at the University of Nigeria, Nsukka and he also works with Projects Development Institute (PRODA), Enugu, Nigeria. His research interest is in renewable energy. He conducted research on solar water distillation system and biogas technology. Telephone: +2348039308009. E-mail: emmychyugwuoke@yahoo.com

H.O. Orah, is currently working with the Projects Development Institute (PRODA), Enugu, Nigeria as a Research Officer. Telephone: +2347081718990. E-mail: hariteks@yahoo.co.uk

B.I. Onyia, is a Principal Research Officer at Projects Development Institute (PRODA), Enugu, Nigeria. He is currently pursuing a Masters Degree at Enugu State University of Science and Technology. Telephone: +2348039317342.

I. Ofili, is an Assistant Chief Engineer at Projects Development Institute (PRODA), Enugu, Nigeria. Telephone: +2348033166479.

H.I. Edeh, is a Principal Research Officer at Projects Development Institute (PRODA), Enugu, Nigeria. He is currently pursuing a Doctorate Degree (Ph.D.) at Enugu State University of Science and Technology. Telephone: +2347031647607.

SUGGESTED CITATION

Ugwuoke, E.C., H.O. Orah, B.I. Onyia, I.Ofili, and H.I. Edeh. 2016. "Desalinization of Brackish Water". *Pacific Journal of Science and Technology*. 17(2):350-358.

[Pacific Journal of Science and Technology]