Proceedings of the
International Conference on Mechanical Engineeringand Renewable Energy 2015
(ICMERE2015) 26 – 29 November, 2015, Chittagong, Bangladesh

ICMERE2015-PI-264

SOLAR DESALINATION IN BANGLADESH: PROGRESS, PROSPECT AND CHALLENGES

Abu Shoaib Saleh[1,*]

[1]Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
[1,*]abushoaibsaleh@gmail.com

Abstract*-The paper is an attempt to analyze the potentials and challenges of the application of solar energy in desalination as an appropriate technology to produce fresh water in coastal areas of Bangladesh. There exists a deficiency of supply to meet the needs of a huge and rapidly increasing population which has turned the shortage of pure water in country into a harsh reality. Solar distillation offers a simple and attractive solution which suits the small scale units located in areas with abundant sunlight. Traditional desalination techniques, namely, vapor compression, multi stage flash, ion exchange etc. are expensive for small scale production and triggers pollution as they use conventional energy sources. Solar systems only need the installation and maintenance cost to start and continue operation. Being a cost efficient form of energy, systems of any capacity ensuring high solar performance can be designed. The paper consists of an overall review and technical assessments of some passive and active solar distillation developments in Bangladesh and has also recommended some research areas in this field leading to high efficiency.*

Keywords: Desalination, Solar energy, Bangladesh, and Water insufficiency.

1. INTRODUCTION

Water is one of the most necessary element of life. It is used in a large scale for domestic, agricultural, industrial uses round the globe every single day. The earth has three-fourth of its surface lying under water. Unfortunately 97.5% of the available fresh water is salty which restricts their use to a great extent, but only 2.5% remain as freshwater in icebergs, lakes, rivers etc. sources and however only 0.014% of the earth's water reserve is directly available for mankind and other organisms [1]. Owing to this fact, many countries face deficiency of supply and storage of water. Bangladesh is blessed with vast storage of fresh water both on the ground and under the ground. In recent days, pollution has made a large amount of fresh water useless and the arsenic pollution of ground water has added more to the fresh water deficiency. Bangladesh includes Sundarbans, the biggest mangrove forest on the earth in its southern part. It also has an expanded coastline. Majority of lands of Bangladesh does not lie much above the sea level. Its coastal areas are mostly flat, outstretched to the sea shore. Supply of pure and fresh water in these areas is a major problem.

Desalination of sea water in such areas can be an affordable source of fresh water for the inhabitants. Process of desalination requires considerable amount of energy. Use of fossil fuels for desalination makes it expensive and also harmful to the environment. Thus a low cost and environment friendly solution has been sought for long. Bangladesh receives intense sunlight throughout the year. It can be used as an energy source to desalinate sea water. Solar energy in Bangladesh is not much used. Solar energy can be used to power the Reverse Osmosis (RO) process which requires only 3-5.5 kWh energy per cubic meters of water [2]. Government of Bangladesh has stepped towards renewable energy recently and solar PV cells are being used in some projects of PDB for rural electrification. In near future solar energy may also be used in solar water heating, solar cooling, food processing etc. However, this paper focuses on the developments in desalination process in Bangladesh and the possibilities of solar energy in the field as an affordable solution of energy.

2. BACKGROUND OF SOLAR DESALINATION

Desalination is a water treatment process that segregates dissolved salts and minerals from saline water to produce fresh water that has low rate of Total Dissolved Solids (TDS) and is suitable for drinking. Till 2013 more than 16 thousand industrial scale desalination plants have been operated, and they have produced about 78.4 million cubic meters of fresh water every day [3]. Desalination techniques using solar energy was first described by the Greeks long ago and was also known to the Arab alchemists [4]. Solar powered desalination plants are incompetent with fuel powered plants in large scale. They have greater efficiency in small scale. However as oil deposit reaches exhaustion, small scale household solar powered plants may be adopted for sustainable solution to water demand. The common sea water desalination techniques are based on two methods,

evaporation and membrane separation. Evaporation requires large amount of energy. Due to low energy consumption and production cost, membrane separation is getting more attention recently. Solar insolation at different locations of the country varies from 3.9 kWh/m^2 to 6.3 kWh/m^2[5]. It is enough to drive the RO process for desalination.

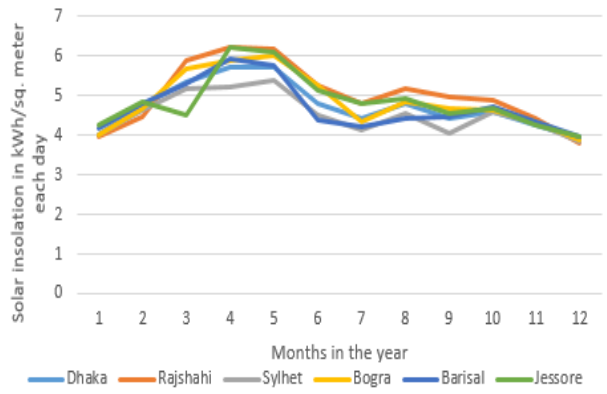

Fig.1: Solar insolation at different cities of Bangladesh [5]

The Reverse Osmosis (RO) technology using membrane separation method is so far the most energy efficient process of water desalination [6]. Other membrane method processes are Electro Dialysis (ED), Nano Filtration (NF), and Membrane Distillation (MD) etc.

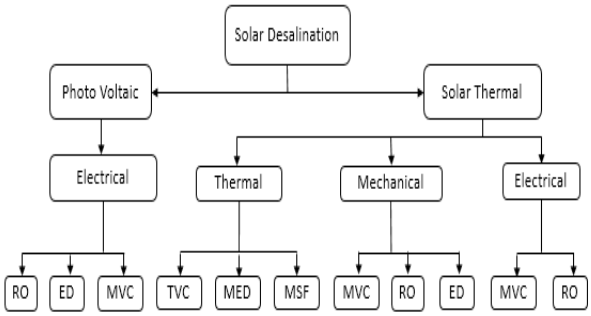

Fig.2: Solar desalination techniques at a glance

Bangladesh has an enormous and fast growing population. Demand of fresh water is ever increasing with population. Ground water is used as a major source in the country. But arsenic pollution has decreased its reliability. Waste and pollutants has contaminated most of the fresh water sources, like rivers, canals, lakes. The problem is more acute in coastal areas. Salinity in water and soil is increasing in Bangladesh gradually, imposing a serious threat upon the flora and fauna of the coastal areas, especially in Sundarbans. Continuous increment in salinity in the water and soil of Sundarbans is acting as a slow poison to the ecosystem of the natural wonder. It also threatens the livelihood of the inhabitants. After recent calamities like Sidr, Aila, Mohashen and consequent tidal surges, it has received a further boost. As a result, the population of coastal districts like Khulna, Satkhira, Pirojpur, Barguna and Patuakhali are at stake. Millions of people are struggling with salinity in these regions.

3. SOLAR POWERED DESALINATION TECHNOLOGIES

Solar energy for sea water desalination can be utilized in two ways. One way is to collect the required amount of thermal energy to drive the phase change process directly from the sun through solar collectors and distillate sea water with that, known as direct collection system. Another way is the indirect collection system where electricity is produced from solar energy that is required to drive the membrane process such as RO or ED. Every process requires a pre chemical treatment of sea water to prevent corrosion, foaming, scaling, fouling and biological growth and also a post chemical treatment after the process to enhance purity level[7]. Recently more sophisticated methods like Multi Stage Flash (MSF) and Multiple Effect Distillation (MED) are being implemented.

3.1Multi Stage Flash (MSF) Distillation

60% of the total water desalination in the world is carried out in MSF Distillation process[8]. The MSF process is carried out in a pressure vessel divided in many sections. Each section has lower temperature and pressure than its previous one. Sea water is pumped through pipes passing each section and then finally entering the brine heater. In the brine heater, extra heat is added which may be extracted by directly burning fossil fuel, using solar energy or even using the waste heat of a power plant. Sea water is heated in the brine heater up to a temperature between 70^{0}C and 100^{0}C and at this stage it is called 'brine'. Brine enters the pressure vessel and passes the sections one after another. When it enters each section, operating at lower temperature and pressure than the previous, immediately part of it turns into partial vapor. The partial vapor is condensed as fresh water with the help of sea water, moving in pipes, passing through each section and thus the pre heating is also done. The distilled water is then collected and stored in tanks. MSF distillation plants requires 23-27 kWh of energy per cubic meters of water distilled[9].

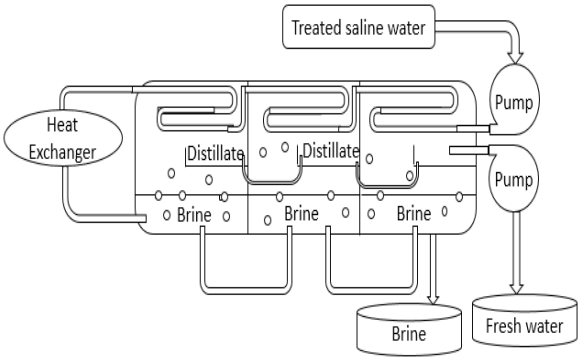

Fig.3: Multi Stage Flash (MSF) Distillation

3.2 Multiple Effect Distillation (MED)

Similar to the MSF distillation process, MED process too is carried out in a pressure vessel divided in many sections. The pressure and temperature of each section is maintained lower than its previous one. In case of MED, the vapor is circulated through the pipes passing each section of pressure vessel and sea water is sprayed from the top of the vessel. Sprayed saline water flows by gravity and comes in contact with the pipes. Therefore the steam inside gets condensed and is then collected as distilled fresh water. However part of saline water turns into partial vapor being in contact with the pipes carrying steam. The vapor is passed to the next section of the vessel through pipes and it functions as the previous section. The concentrated brine deposits in the lower part of the vessel and is collected from there. Distilled water from the pipes are kept in storage tanks for supply. Notable advantage of this process is that it can operate at very low temperature, around 60^0C-70^0C, and also at a very low concentration of saline water. Thus scaling effect owing to increase in salinity at low temperature is small[10].

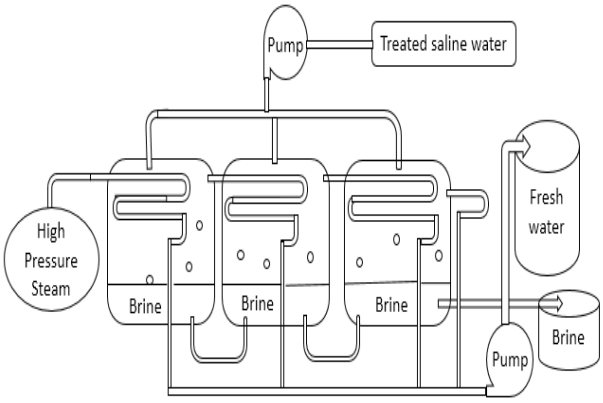

Fig.4: Multiple Effect Distillation (MED)

3.3 Reverse Osmosis (RO)

Reverse Osmosis (RO) is an effective way of water purification. RO separates dissolved particles, ions and even bacteria from water using a semipermeable membrane. Water is driven through the membrane by a pump creating higher pressure than the osmotic pressure of the system. The membrane allows only water to pass through. Pollutants are retained in the high pressure zone. Sea water has an osmotic pressure of around 27 bars, so 40-82 bars of pressure is exerted to overcome it[11]. Membranes are made from industrial polymers for this process. RO method needs careful pretreatment of water before entering the process which increases its cost. Also after the process it is treated by chlorination or UV rays. The membrane needs to be changed at regularly and maintenance cost is high. Though it is still a costly process, with the increasing fuel price, RO is being considered a dependable process in future and more research is being carried out to improve it.

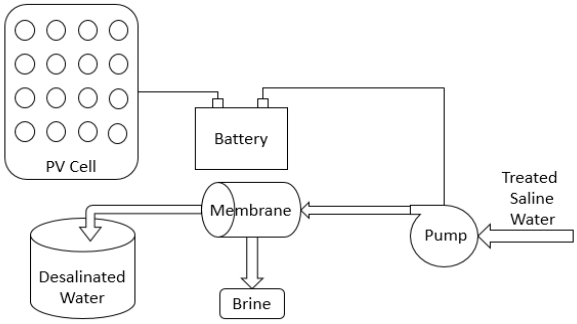

Fig.5: Reverse Osmosis (RO)

3.4 Electro Dialysis (ED)

Electro dialysis (ED) is a process where dissolved ions are transferred from one solution to the other through ion exchange membrane under the influence of an applied electric field. The electricity it needs can be generated from sun light using solar photo voltaic cell. Unlike the RO process, the dissolved ions move through the membrane in this system. ED can be used to purify water containing high salinity. But this is not as efficient as the RO process. As the salinity decreases, the ion concentration decreases and process becomes difficult to be carried out. Expense rises as the required salinity level decreases. Also it cannot remove non charged impurity or dissolved ions with high molecular weight. So the water requires intense chemical pretreatment.

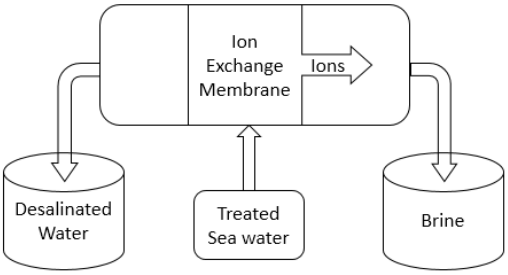

Fig.6: Electro dialysis (ED)

4. ECONOMIC AND ENVIRONMENTAL ANALYSIS

Despite being a land of rivers and having plenty of ground water storage, it is an irony that these sources are not available in the coastal zone. The rivers, canals and other sources on ground and the underground water both are saline in these areas and cannot be used in most cases. Coastline of Bangladesh is nearly 734 km long and influences the nearby coastal areas and island with a community of around 50 million people[12]. It is almost one-third of the total population of Bangladesh and thereby indicates the gravity of fresh water supply shortage in the country. Bangladesh is also regularly struck by natural disasters. The country faced three big cyclones consecutively, Sidr in December 2007, Aila in May 2009 and Mohashen in June 2013. Each of these caused mass flooding of the coastal area and therefore raised the salinity of ground and water even more. Agricultural production in these areas has come to a

standstill because of this and life is at stake for want of fresh water. Solar desalination of saline water can ensure fresh water for millions of inhabitants in these areas and bring great relief.

There are various ways of desalination. Solar powered desalination is very suitable for Bangladesh as it gets ample sun light and the process is very cost effective. Faruq et al. showed that a solar desalination plant can be built with an investment of only Tk. 1200 ($15) which can provide fresh water for 10 years with an estimated production cost of Tk. 0.33 per liter only[13]. They also showed that production is greater in summer due to better exposure to sun and it triggers between 1pm to 4pm[13]. Socio-economic condition of the country is not much improved and so low cost technology is very important. Major problem of this technology is that the process is solely dependent on solar energy. If small units are installed on large scale for each family or one for a few, people will be able to take care of the plants on their own and store water in drums and tanks for their use. This will solve the issue and also save from maintenance cost, since small plants are easy to be taken care of, people would be able to do so for their own good. Desalination is the only acceptable solution in the coastal areas where salinity in ground and water is high. Due to salinity even rain water cannot be stored in canals for future use. However only 1% of total desalination is done by renewable energy[4]. Fuel based desalination plants are very expensive and difficult to afford in a developing country like Bangladesh. Solar desalination is surely an affordable solution in this case.

Desalination using fuels emits CO_2 in the environment increasing carbon emission. It is an important source of potable water supply in gulf countries like Saudi Arabia, UAE, and Israel etc. The gulf region mostly consists of oases extended to the sea. Ground water storage is also inadequate and hence sea is the only source of water in the area. Lattemann et al. mentioned that around 65% of total desalination is operated in gulf areas [14]. Inhabitants of the region will also be the biggest consumers of this technology in future because of their geological position. Fuel powered desalination plants burn an equivalent of 203 million tons of fuel every year [4]. The gigantic figure gives an idea of the immense pollution and carbon emission it causes. Carbon emission is one of the biggest problem today and measures are being taken to decrease it to zero.

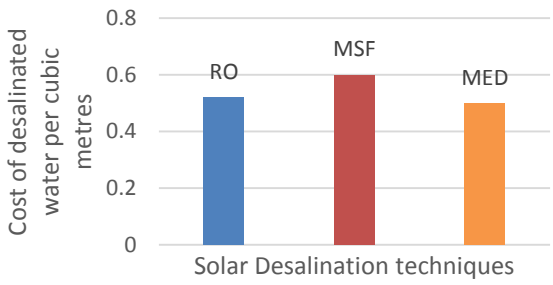

Fig.8: Cost of thermal and RO desalination processes [14]

Fuel cannot be burnt in large scale for the sake of Sundarbans and it is also the owner of the wonderful sea beach of Cox's Bazar in its coastal areas. Smokes and fumes from burnt fuels will destroy the ecosystem of the natural wonder Sundarbans. It will also degrade the environment of Cox's Bazar area and harm the turnover from tourism. Solar desalination in this case is a feasible solution. It causes zero carbon emission and therefore does not harm the environment at all providing fresh water.

5. RECOMMENDATION

Modern world needs adequate fresh water and energy to move on. Bangladesh is a developing country with a GDP of above 6%. It has to ensure fresh water for all its citizens on its journey to development. With about one-third of its population being influenced directly by coastline and sea, solar desalination can be a pragmatic solution.

(1) Solar powered RO plants can be installed in small scale for one or few families to meet their needs. RO plants are efficient and people will be able to maintain the plant on their own. They will also be able to store water in peak production hours of afternoon in drums for the night.

(2) RO plants need the membrane to be changed at regular intervals. So membrane stocks should be made available for the household owners of RO plants in the respective areas assigning dealers.

(3) The government can seek the help of international donors to raise fund for the initiative. The local government of the areas and NGOs can be affiliated in this program who will be able to reach the inhabitants within a short time.

(4) The government can also involve researchers and engineers from home and abroad to go through researches and modeling in search of more efficient solutions or increasing the efficiency of the existing technology. Large investments to fund the researchers and engineers in this case will surely yield fruitful results.

(5) Local universities can also collaborate with the related industries and other universities not only within the country but also internationally.

(6) Government can use its foreign relation with other countries in this regard. Such steps will enhance efficiency, reveal new technologies for fresh water production and supply which will prepare Bangladesh for the challenges lying ahead.

Despite the benefits, solar desalination is not free from drawbacks. It comes with some problems which are still to be solved.

(1) Solar desalination processes are not fully dependable, especially in a tropical country like Bangladesh. Bangladesh gets a huge amount of rainfall. During rainfall intensity of sunlight reduces considerably. Moreover, 80% of the annual rainfall of Bangladesh occurs during May to July. During this time capacity of solar desalination plants will be greatly reduced. So an alternative source of water is a must.

(2) Bangladesh is often struck by tidal surges and cyclones which will destroy the installed solar

desalination plants and cause huge loss. To avoid this, small plants should be designed to offer mobility at least to some extent. In that case, desalination plant or some part of it may be carried to safety before the calamity strikes.

7. REFERENCES

[1] http://www.wrsc.org/attachimage/total-water-resources. (Accessed June 2015)

[2] "Energy requirements of desalination processes," Encyclopedia of Desalination and Water Resources (DESWARE), 2013.

[3] http://www.globalwaterintel.com/desalination-industry-enjoys-growth-spurt-scarcity-starts-bite. (Accessed June 2015)

[4] S. A. Kalogirou, "Solar energy engineering: Processes and systems," *Progress in Energy and Combustion Science*, 2009.

[5] M. A. H. Mondal, "Technical and Socio-economic Aspects of Selected Village Based Solar Home Systems in Bangladesh," International Institute of Management, University of Flensburg, 2005.

[6] R. Einav, Harussi and Perry, "The footprint of Desalination Process on the Environment," *Desalination*, vol. 152, pp. 141-154, 2002.

[7] S. A. Kalogirou, "Seawater desalination using renewable energy sources," *Progress in Energy and Combustion Science*, vol. 31(3), pp. 242-81, 2005.

[8] "Introduction of Nuclear Desalination," IAEA, 2000.

[9] IAGS, "The Connection: Water and Energy Security," 2008.

[10] M. Al-Sahali and H. Ettouney, "Developments in thermal desalination processes: Design, energy, and costing aspects," *Desalination*, Vols. 214(1-3), pp. 227-40, 2007.

[11] U. Lachish, "Optimizing the Efficiency of Reverse Osmosis Seawater Desalination," 2002.

[12] http://feppcar.org/122/coastal-zone-management-in-bangladesh/. (Accessed June 2015)

[13] S. M. A. A. Faruq, M. S. Akter, M. A. Amin and M. Z. Islam, "Desalination of Water using Conventional Basin Type Solar Still," *Global Journal of Researches in Engineering Civil And Structural Engineering*, vol. 13(3), pp. 35-42, 2013.

[14] S. Lattemann, M. D. Kennedy, J. C. Schippers and G. Amy, "Global desalination situation," *Sustainability science and engineering*, pp. 7-39, 2010.