Effect of absorber rock on the performance of solar still

Bachelor of Science thesis

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A thesis submitted to the Department of Mechanical Engineering, Military Institute of Science and Technology, Dhaka, in January, 2018 in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering

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STUDENT DECLARATION

This is to certify that the thesis entitled, on "**Effect of absorber rock on the performance of solar still"** is an outcome of the investigation carried out by the author under the supervision of Dr. A.K.M Sadrul Islam, Former Professor & Head, Department of Mechanical Engineering, BUET. This thesis or any part of it has not been submitted to elsewhere for the award of any other degree or diploma or other similar title or prize.

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SUPERVISOR CERTIFICATION

This is to certify that **Marina Islam Sifat**, Student no: 201318016; **Farhan Ishrak** , Student no: 201318058; **Iqtear Uddin Mohammad Biplob**, Student no: 201318065; have completed their undergraduate thesis report on "**Effect of absorber rock on the performance of solar still**" under my supervision. To the best of my knowledge, the report is their original work and was not submitted elsewhere for other purpose.

I wish their ever success in life.

APPROVED BY

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January, 2018

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ABSTRACT

Pure and fresh water is being scarce day by day. In spite of being a riverine country the people of Bangladesh are not provided with sufficient amount of pure drinking water. A large number of people including children and infants face severe water borne diseases and many of them die. Solar still is a cheap, useful, non-toxic, clean and easy to made renewable technology which can be used to provide pure water. The potential of solar still is high in Bangladesh due to the climate conditions. Effectiveness of a solar still can be analyzed from different point of views considering different parameters. Over the time various modifications have been made and investigations have been done to find the factors that enhance the performance of solar still. However, in our experiments initiatives were taken to study the performance of a simple passive solar still having black colored rocks as absorber medium. The objective of this paper was to find the effect of black colored rock absorber medium on the performance of solar still during the presence of day light and also during the period when the sun light disappeared. It has been observed that using such absorber medium results in yield of pure water even after sun-set.

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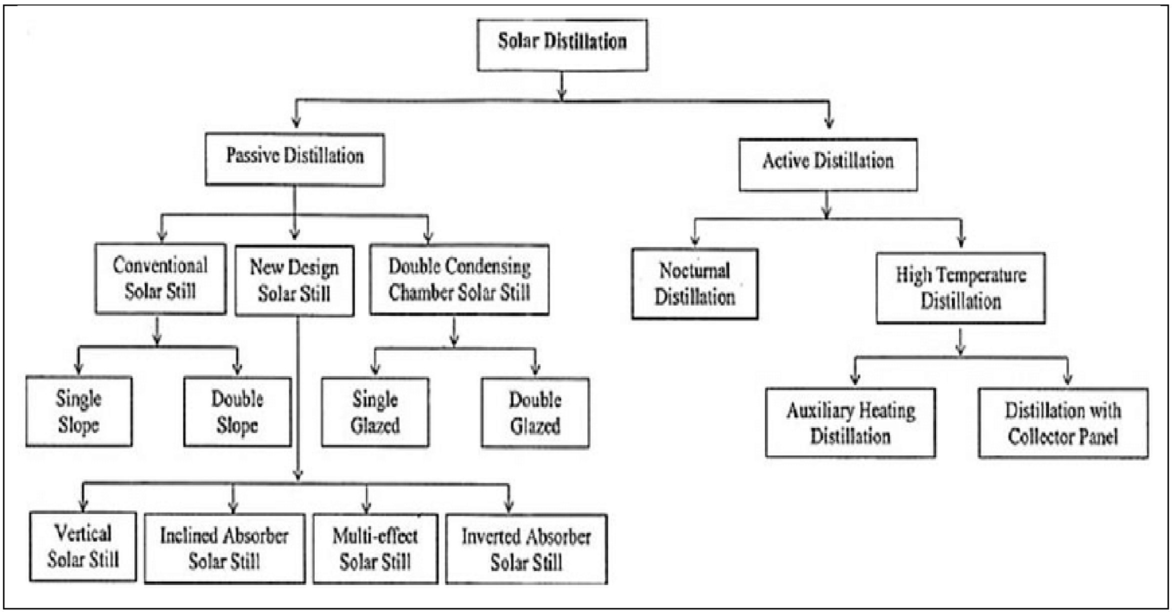
Chapter 1
Introduction

The increase in demand for pure drinking water is increasing day by day. The global warming are creating a worldwide imbalance between supply and demand of fresh water.On the other hand though the ocean makes up 70 percent of the earth's surface and accounts for 96 percent of the water on the planet. The problem is, this water can't be consumed. It's oversaturated with salt. Desalination is the process of turning salty ocean water into drinking water.Solar distillation represents a most attractive and simple technique among other distillation processes and is especially suited to small-scale units at locations where solar energy is considerable.

The Middle East has been a leader in desalination so far. Saudi Arabia, United Arab Emirates, Kuwait, and Israel rely heavily on desalination as a source for clean water. Israel gets 40 percent of domestic water from desalination. These countries also have hardly any groundwater or fresh water sources so desalination is a case of innovation by necessity. These countries make up the one percent of the world currently relying on desalination to meet water needs. But the UN predicts that by 2025, 14 percent of the world will rely on desalination to meet water needs.

The increasing salinity of the soil in Bangladesh's coastal villages has not just made safe drinking water hard to come by.So in Bangladesh perspective sollar still can be very bery effcetive.

A **solar still** distills water, using the heat of the Sun to evaporate, cool then collect the water. it seemed necessary to search for solar stills that are easy to construct and that could provide us with the necessary daily amount of drinking water .there are many types of solar still is available.And it can be classified as follow:



1.1 Active Solar Stills: In an active solar still, an extra thermal energy is fed to the water in the basin to create a faster rate of evaporation. A broad classification of the solar stills is depicted above. Further the active solar stills are classified as:

1. High temperature distillation solar stills: - hot water is fed into the basin from a solar collector panel.

2.Pre-heated water application solar stills: - hot water is fed into the basin at a constant flow rate.

3. Natural production solar stills- hot water is feed into the basin once in a day.

1.2 Passive solar still: In a passive still the distillation takes place purely by direct sun light. The single slope and double slope solar stills are the conventional low temperature solar stills, operating at a temperature below 60°C. Of the above two, single slope solar still is more versatile and efficient than double slope solar still.

1.3 Features of passive solar system:

1. Instead of using PV panels passive collectors usually rely on south facing surfaces or window to absorb sun-light.

2. Design of passive solar collectors is based on laws of thermodynamics .There may be a variety of designs.

The success of passive solar still depends on a number of points such as

a. It's orientation

b. The thermal properties of it's wall

c. Design of the still

d. The effect of absorber medium

e. Weather effect

In this study only the effect of black colored absorber medium on the effect of a simple passive solar still was analyzed.

1.4 <u>some common types of solar still</u> **are** shown below:

1.

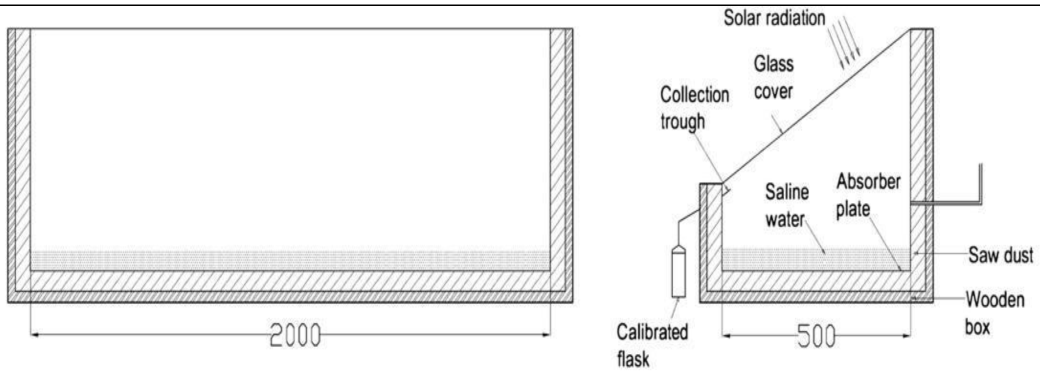


Figure 5, Conventional solar still
source-Z.M. Omara solar still research

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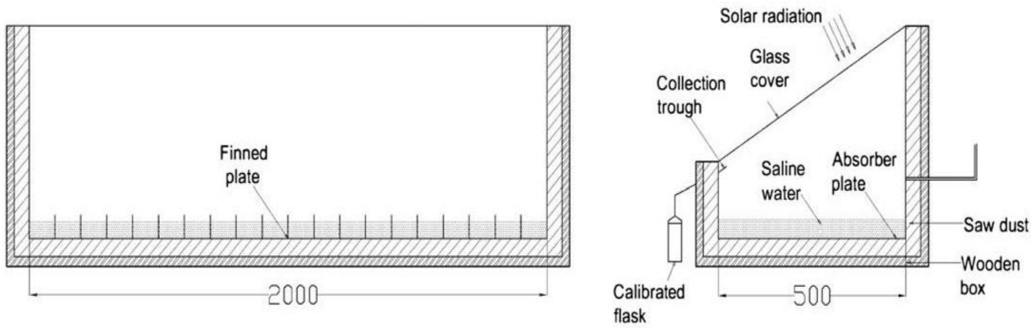

Figure 6,Finned solar still
source-Z.M. Omara solar still research

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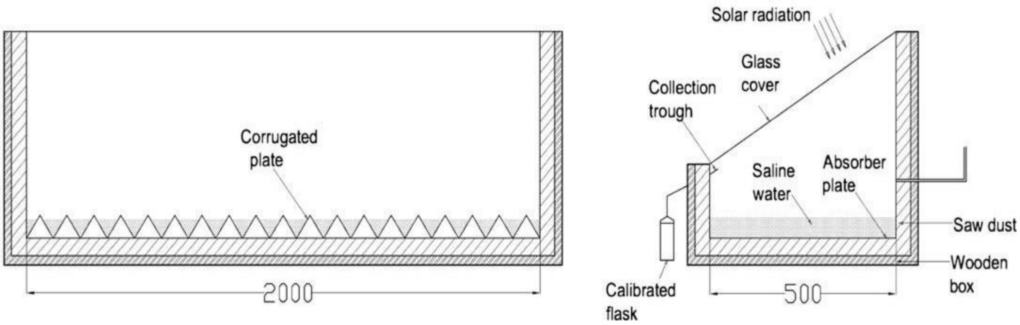

Figure 7, Corrugated solar still
source-Z.M. Omara solar still research

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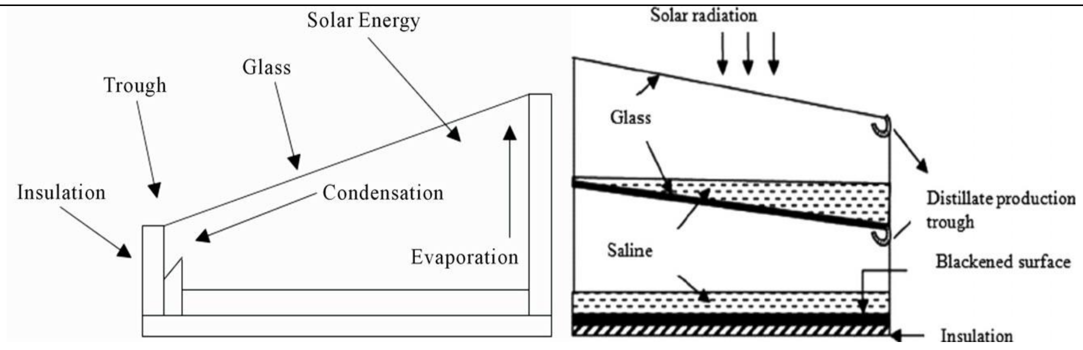

Figure 8, a. Single basin (single slope)
b. Double basin (single slope)
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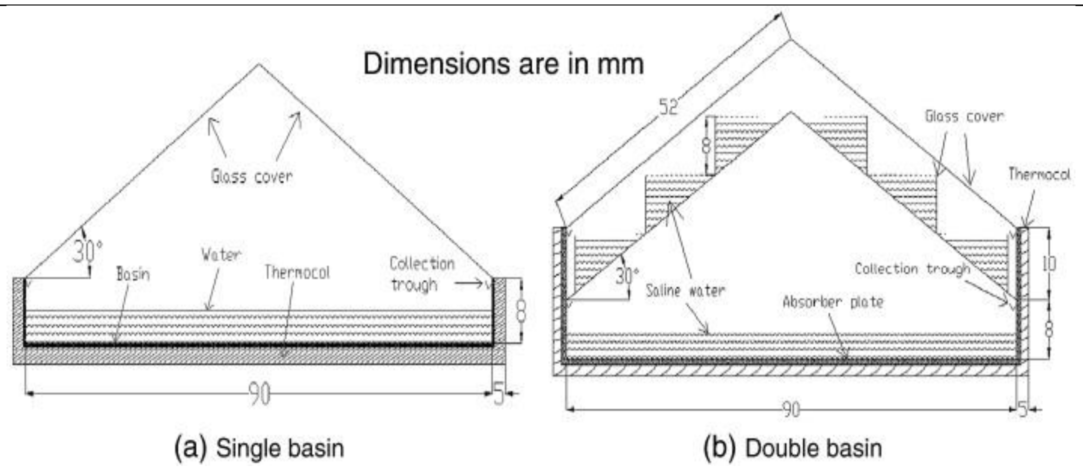

Figure 9, Double slope
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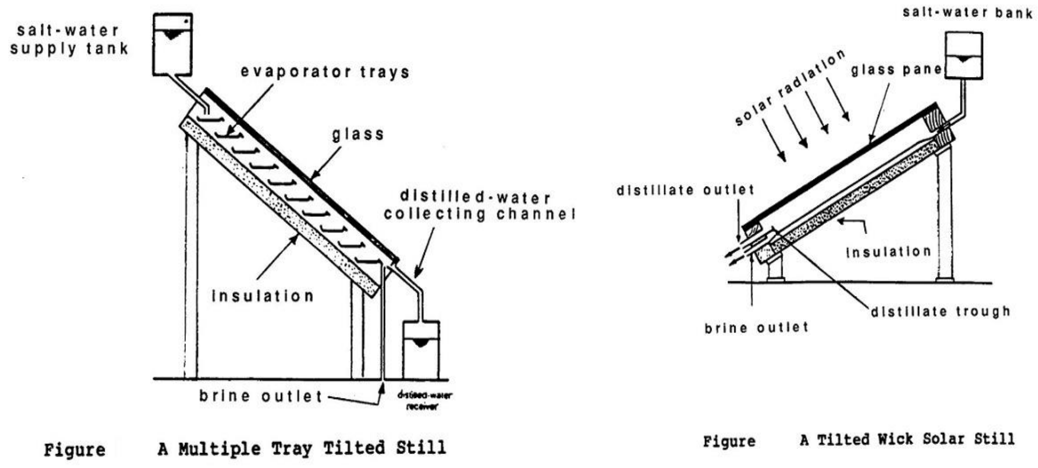

Figure 10, Tray tilted still
Source: Jim Leckie, Gill Masters, Harry Wh and Lily Young, More Other Home Garbage (San Francisco, Californi Sierra Club Books,1981),p.304.
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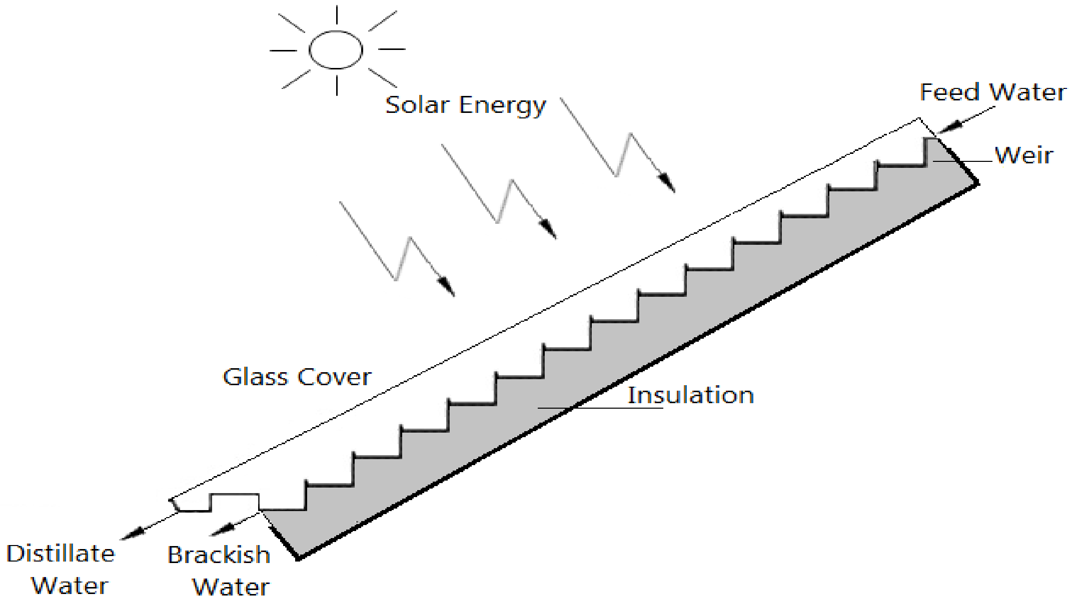

Figure 11,Multiple stepped cascade solar still (improve design)
Source: Solar-Powered Desalination, Emrah Deniz
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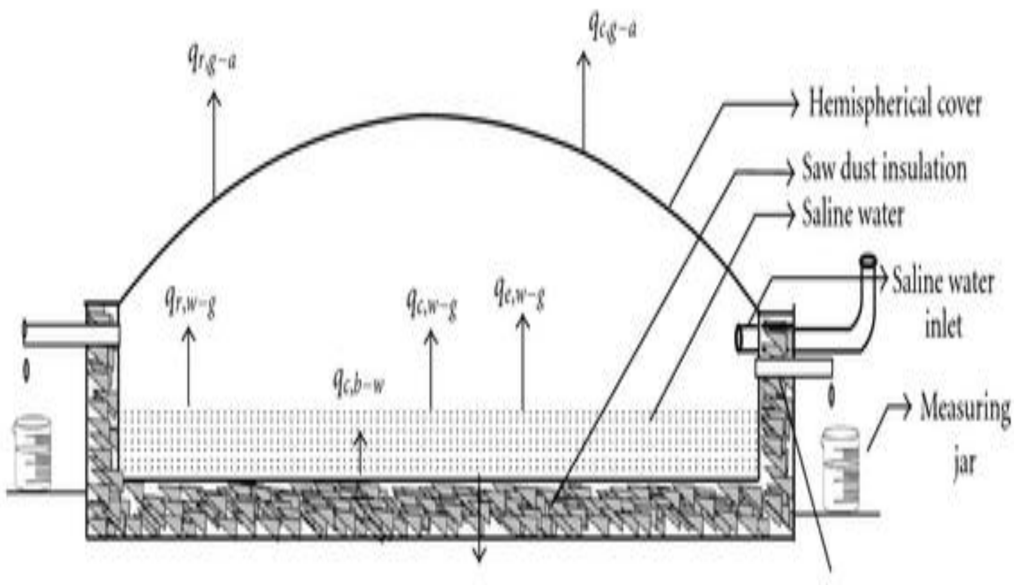

Figure 8, Schematic view of hemispherical solar still.
Source: Desalination,Volume 286, 1 February 2012, Pages 342-348
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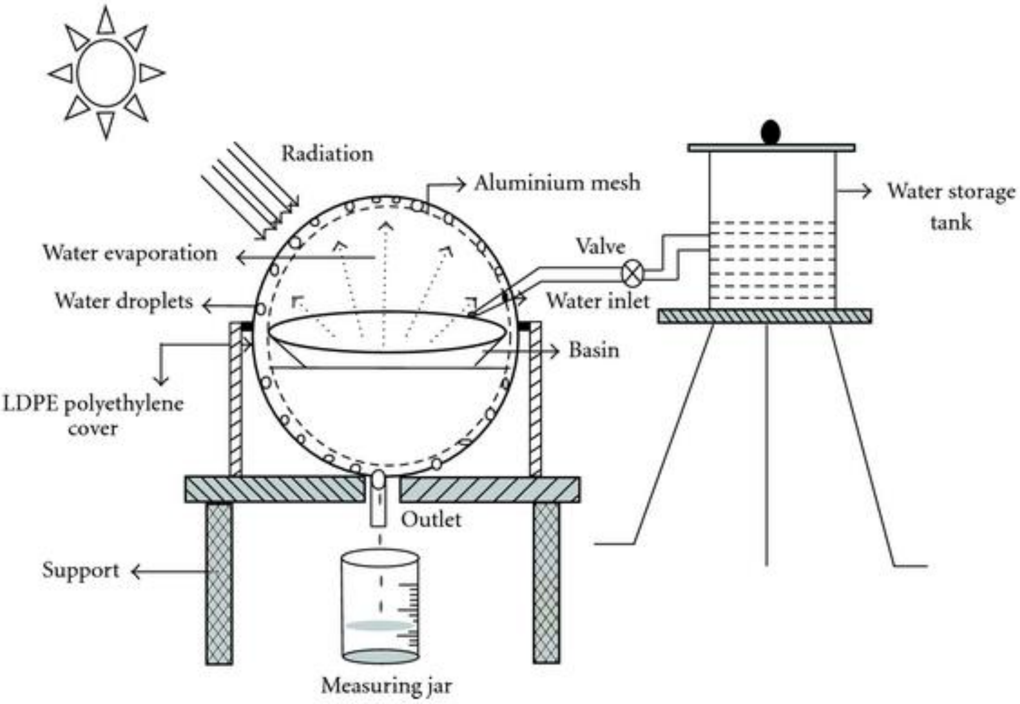

Figure 9, Spherical solar still
Source: https://www.hindawi.com/archive/2012/569381/fig2/

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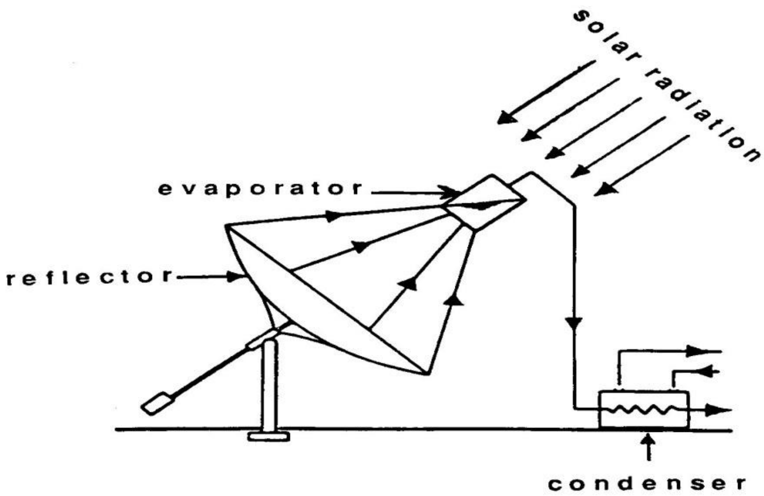

Figure 10. A Concentrating Collector Still

Source: Jim Leckie, Gil Masters, Harry Whitehouse, and Lily Young, More Other Homes and Garbage, (San Francisco, California: Sierra Club Books, 1981), p. 305.

1.5 Distribution of the Earth's Water: The distribution of water on the Earth’s surface is extremely uneven. Only 3% of water on the surface is fresh; the remaining 97% resides in the ocean. Of freshwater, 69% resides in glaciers, 30% underground, and less than 1% is located in lakes, rivers and swamps. Looked at another way, only one percent of the water on the Earth’s surface is usable by humans, and 99% of the usable quantity is situated underground. So, it is a huge challenge to meet the demand of fresh water worldwide.

1.6 Water Impurities:

1.Suspended particles.

2.Dissolved inorganic salt.

3.Dissolved organic compound.

4.Micro-organism

5.Pyrogens

1.7 Common methods to purify water: Water purification is the process of removing undesirable chemicals, biological contaminants, suspended solids and gases from water. The goal is to produce water fit for a specific purpose. Most water is disinfected for human consumption (drinking water), but water purification may also be designed for a variety of other purposes, including fulfilling the requirements of medical, pharmacological, chemical and industrial applications. The methods used include physical processes such as filtration, sedimentation, and distillation; biological processes such as slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light.[17]

Popular methods for purifying water, especially for local private supplies are listed below. In some countries some of these methods are also used for large scale municipal supplies. Particularly important are distillation (desalination of seawater) and reverse osmosis.

1.7.1 Boiling: Bringing water to its boiling point at 100 °C (212 °F), is the oldest and most effective way since it eliminates most microbes causing intestine related diseases, but it cannot remove chemical toxins or impurities. For human health, complete sterilization of water is not required, since the heat resistant microbes are not intestine affecting The traditional advice of boiling water for ten minutes is mainly for additional safety, since microbes start getting eliminated at temperatures greater than 60 °C (140 °F). Though the boiling point decreases with increasing altitude, it is not enough to affect the disinfecting process. In areas where the water is "hard" (that is, containing significant dissolved calcium salts), boiling decomposes the bicarbonate ions, resulting in partial precipitation as calcium carbonate. This is the "fur" that builds up on kettle elements, etc., in hard water areas. With the exception of calcium, boiling does not remove solutes of higher boiling point than water and in fact increases their concentration (due to some water being lost as vapor). Boiling does not leave a residual disinfectant in the water. Therefore, water that is boiled and then stored for any length of time may acquire new pathogens.

1.7.2 Granular Activated Carbon adsorption: a form of activated carbon with a high surface area, adsorbs many compounds including many toxic compounds. Water passing through activated carbon is commonly used in municipal regions with organic contamination, taste or odors. Many household water filters and fish tanks use activated carbon filters to further purify the water. Household filters for drinking water sometimes contain silver as metallic silver nanoparticle. If water is held in the carbon block for longer periods, microorganisms can grow inside which results in fouling and contamination. Silver nanoparticles are excellent anti-bacterial material and they can decompose toxic halo-organic compounds such as pesticides into non-toxic organic products.

1.7.3 Distillation: involves boiling the water to produce water vapor. The vapor contacts a cool surface where it condenses as a liquid. Because the solutes are not normally vaporized, they remain in the boiling solution. Even distillation does not completely purify water, because of contaminants with similar boiling points and droplets of unvaporized liquid carried with the steam. However, 99.9% pure water can be obtained by distillation.

1.7.4 Reverse osmosis: Mechanical pressure is applied to an impure solution to force pure water through a semi-permeable membrane. Reverse osmosis is theoretically the most thorough method of large scale water purification available, although perfect semi-permeable membranes are difficult to create. Unless membranes are well maintained algae and other life forms, in course of time colonize the membranes.[18]

1.7.5 Direct contact membrane distillation (DCMD):Applicable to desalination. Heated seawater is passed along the surface of a hydrophobic polymer membrane. Evaporated water passes from the hot side through pores in the membrane into a stream of cold pure water on the other side. The difference in vapor pressure between the hot and cold side helps to push water molecules through

1.7.6 Desalination: is a process by which saline water (generally sea water) is converted to fresh water. The most common desalination processes are distillation and reverse osmosis. Desalination is currently expensive compared to most alternative sources of water, and only a very small fraction of total human use is satisfied by desalination. It is only economically practical for high-valued uses (such as household and industrial uses) in arid areas.

1.7.7 Electrolytic water treatment : An apparatus and method for electrolytically treating water which includes one or more reactors. Each reactor has a liquid containing vessel and one or more pairs of electrodes. The electrodes are suitable for a continuous anodic or cathodic operation for treating water. A power source for each reactor provides voltage and current to the electrodes. A controller maintains the voltage and current provided to the electrodes.[19]

1.8 Salinity:

As Bangladesh belongs to one of the seaside countries, the adverse impact of saltwater intrusion is significant here. Salinity is spreading not only soil but also in ground water significantly. The Southwest (SW) region of Bangladesh is facing salinity intrusion both environmentally and anthropogenically. In that circumstance, the dominating livelihood agriculture is affected severely including soil and ground water degradation, health problems and long term effect on ecosystem. Study from the Soil Resource Development Institute (SRDI) found that, from 2000 to 2009, saline water intrusion increased up to 15 km north of the coast and in the dry season reached up to 160 km inland, entering into other interior coastal districts as well due to low flow from upstream rivers. In line with that, this article explored local people's experience with salinity intrusion in interior coast of SW region.[23]

1.8.1 Soil salinity in Bangladesh:

Salinity mainly affects land and water in the coastal areas. With the consequence of climate change, it gradually extends towards inland water and soil. This scenario of gradual salinity intrusion in the coastal area of Bangladesh is very threatening to the primary production system, coastal biodiversity and human health. The total amount of salinity affected land in Bangladesh was 83.3 million hectares in 1973, which had been increased up to 102 million hectares in 2000 and the amount has raised to 105.6 million hectares in 2009 and continuing to increase (Soil Resources Development Institute (SRDI), 2010) . In the last 35 years, salinity had been increased around 26 percent in this country. Salinity intrusion is spreading into the non-coastal areas as well. Recently, International Rice Research Institute (IRRI)'s Seed Study, funded by USAID, has identified 12 districts of Bangladesh as salinity affected area through GIS mapping[24]

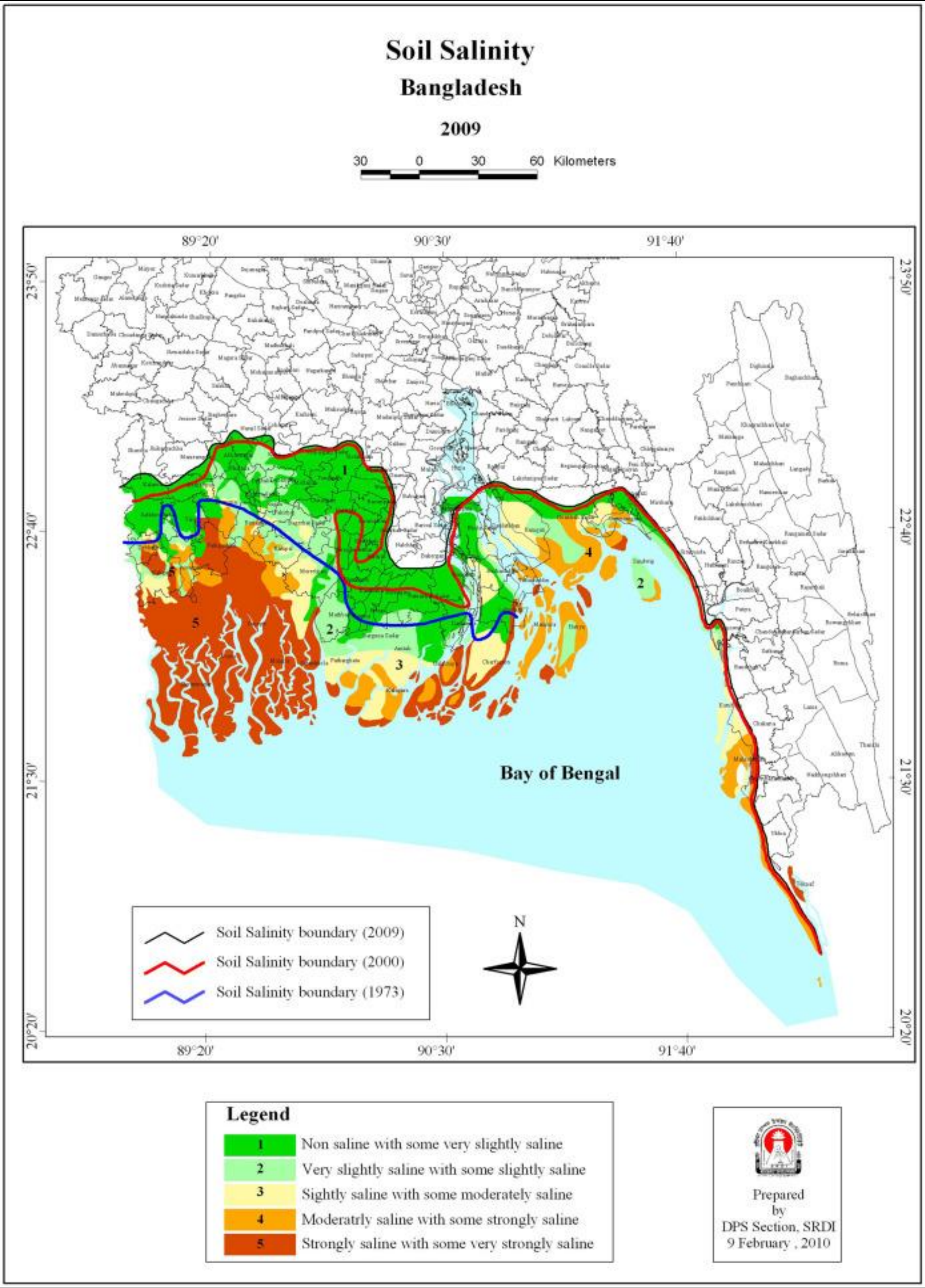

Figure 11, Soil salinity in Bangladesh

1.8.2 <u>Ground water salinity</u> : The discovery of arsenic in drinking water was deemed "the largest mass poisoning of a population in history" threatening the lives of millions. Now Bangladesh is facing another environmental and health threat that is a result of rising salinity levels in drinking water supplies (Khan et al, 2008). A major cause of increased salinity levels is saline intrusion into groundwater both in exposed and interior coastal areas. Saline intrusion into aquifers is a slow process that is influenced by a range of bio-physical and anthropogenic factors. Figure shows the current extent of saline intrusion into coastal aquifers in south-western Bangladesh. This map was prepared by the Bangladesh Agricultural Development Corporation (BADC) using data from 100 salinity observation wells. During 2009-2011. SWIBANGLA research project.[25]

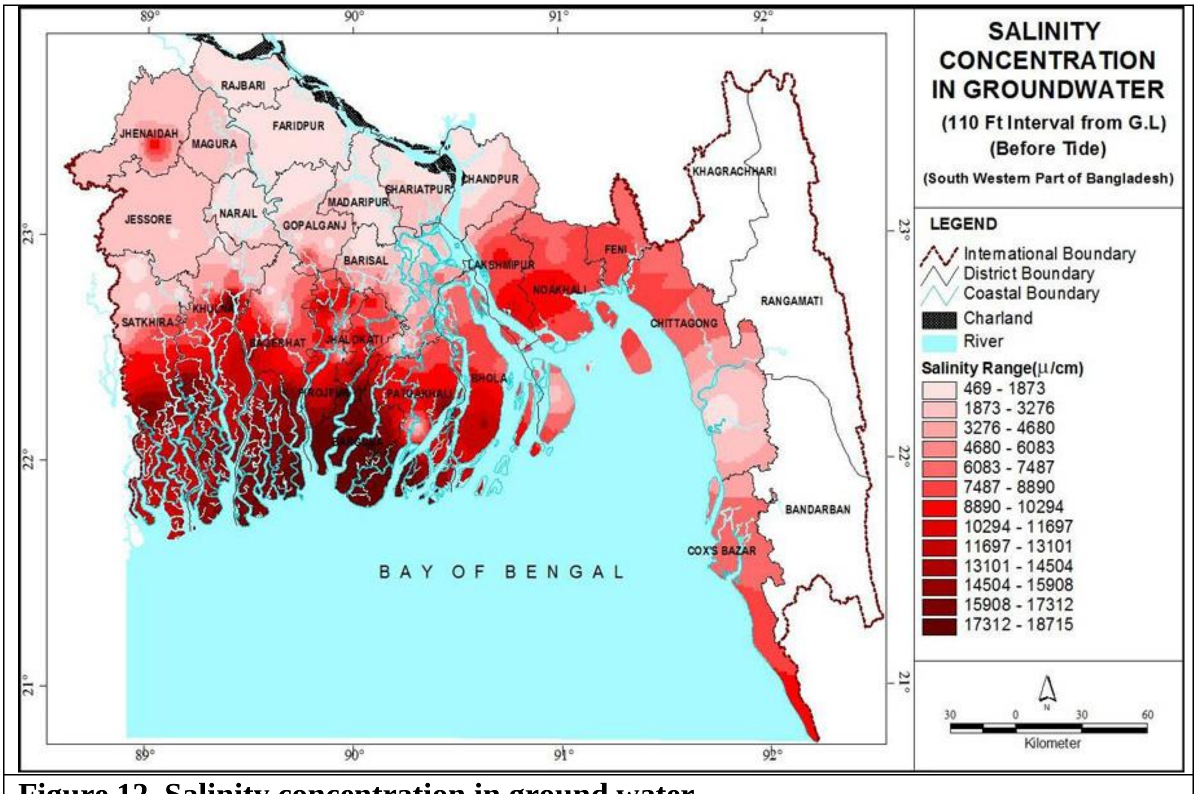

Figure 12, Salinity concentration in ground water
Source: Bangladesh Agricultural Development Corporation (BADC) ,(2009-2011)

1.8.3 River satinity: Studies conducted by the World Bank, Institute of Water Modelling and World Fish–Bangladesh between 2012 and 2016 have quantified the effects of increasing salinity in river waters in coastal Bangladesh, including the areas in and around the Sundarbans (the world's largest mangrove forest that straddles the coast of Bangladesh and India[26] The increase in salinity is likely to hit the poor hardest. At present, 2.5 million poor (including 1.4 million extreme poor) in this part of Bangladesh are already suffering from shortage of drinking water and scarcity of water for irrigation for dry-season agriculture. The studies indicate that even in the best future case, the livelihoods of 2.9 million poor and 1.7 million extremely poor would be adversely affected by increasing salinity of river water. In the worst future case for salinity incursion considered, there will be adverse impacts on 5.2 million poor and 3.2 million extremely poor people.

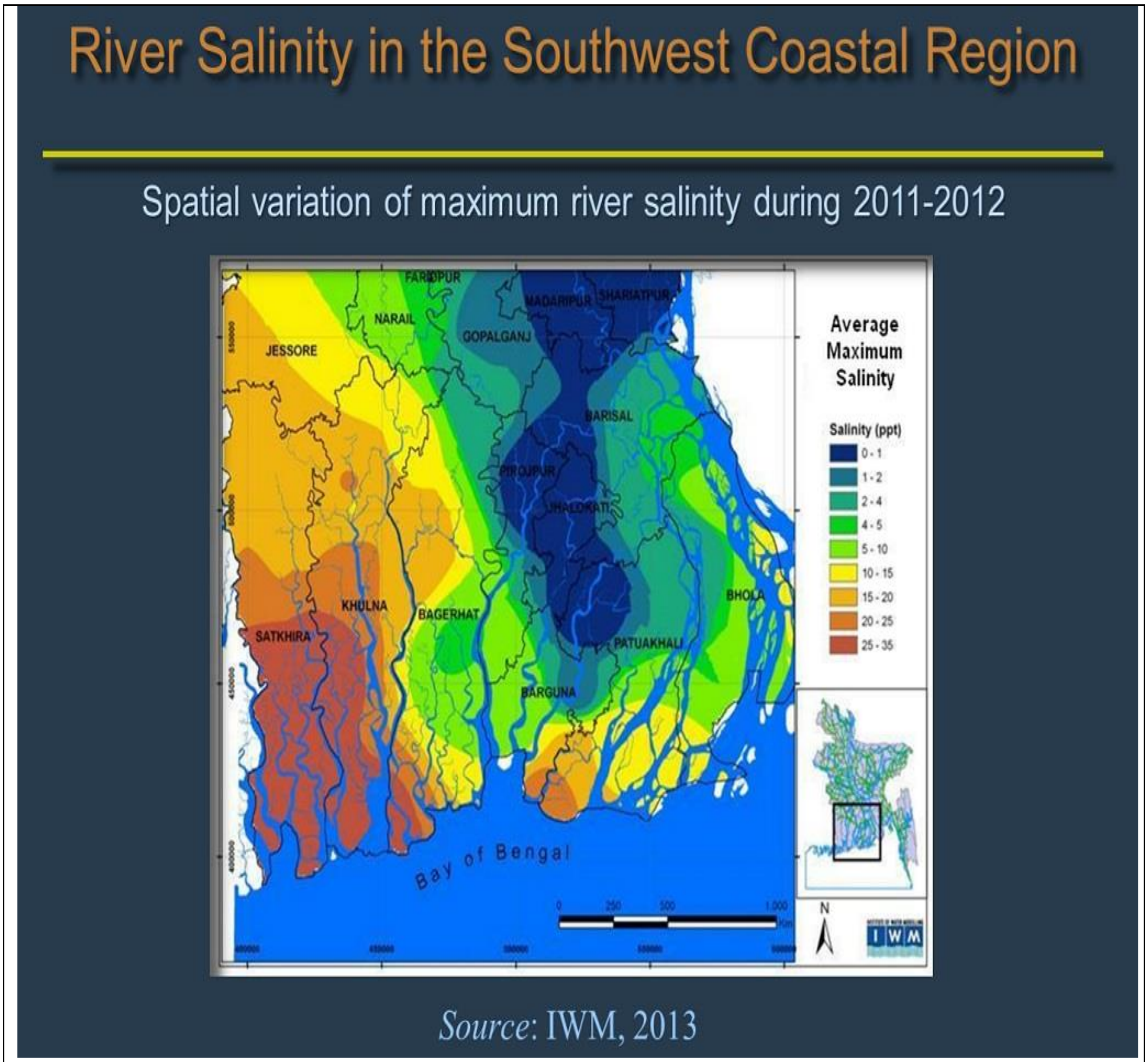

Figure 12, River salinity in the southwest coastal region

1.9 Impact of taking saline water:

There is strong evidence of the link between excessive salt consumption and several chronic diseases (WHO, 2006). Interventions to reduce population-wide salt intake have been shown repeatedly to be highly cost-effective, hence the urgency to implement strategies/policies/programmes tackling the reduction of dietary salt intake. A technical report produced by WHO and the FAO recommended ingestion of less than 5 g sodium chloride (or 2 g sodium) per day as a population intake permissible limit, while ensuring that the salt is iodized (WHO, 2003). This expert consultation stressed that dietary intake of sodium from all sources influences blood pressure levels in the population and should be limited so as to reduce the risk of coronary heart disease and stroke. Results from a recent study in Bangladesh (Khan et al, 2011) [27] included the following: i) Average per capita estimated sodium intakes from drinking water ranged from 5 to 16 g/day in the dry season, compared with 0.6–1.2 g/day in the rainy season; ii) Women who drank shallow tube-well water were more likely to have urine sodium > 100 mmol/day than women who drank rainwater; and iii) The annual prevalence of hypertension in pregnancy was higher in the dry season than in the rainy season.[28]

1.10 Solar irradiation in Bangladesh

Geographical location of Bangladesh is considered to be an ideal place for solar energy utilization . Annual solar radiation available is over 1900 kWh/m2. Average solar irradiations varies from 4 to 6.5 kWh/m2. However, significant variation in data of solar energy is evident, as there is no ground data current energy which is 3000 times higher than the electricity generated as of year 20 06 in the country .[22] Average monthly solar irradiation in six divisional districts is presented in Fig. It is found that 94% of the land area in Bangladesh have such radiation which is sufficient for appropriate utilization based on available technology .Maximum radiation begins from March to April, and minimum–December to January . The highest solar radiation is found at Rajshahi district showing an immense potential of solar energy utilization .

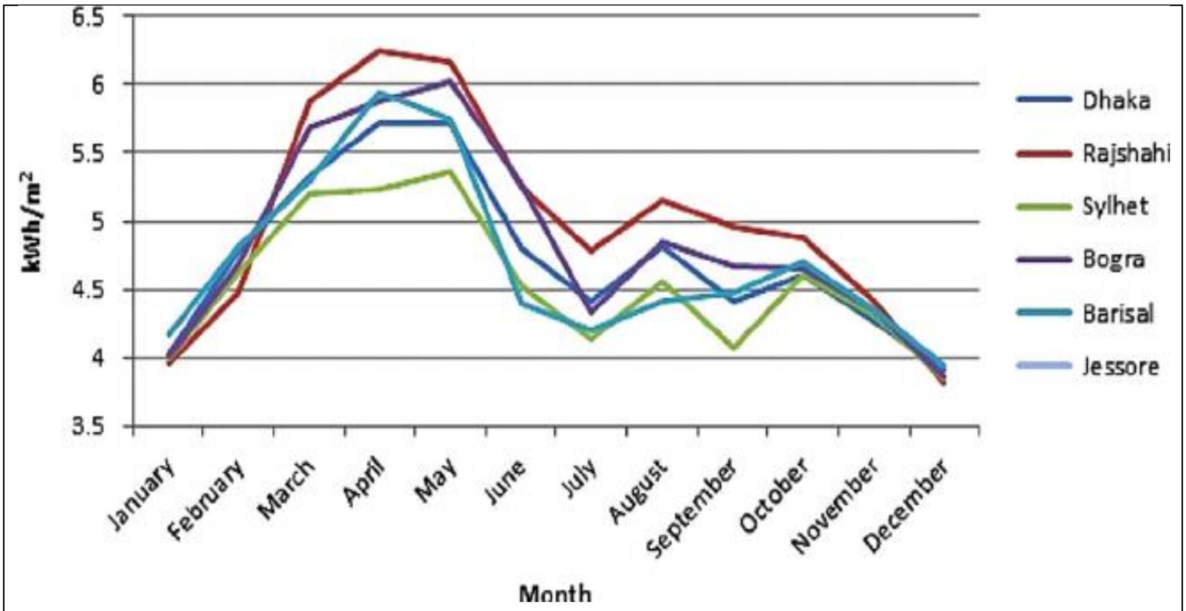

Figure 13: **Average monthly solar irradiation in Bangladesh**

1.11 Rock(Metal slag)property

Slag is the glass-like by-product left over after a desired metal has been separated (i.e., smelted) from its raw ore. Slag is usually a mixture of metal oxides and silicon dioxide. It is sometimes used as track ballast. The big chunks of rock crushed limestone or dolomite that engineers call ballast that keep railroad tracks in place look like a solid footing even as freight cars rumble overhead.[21] Traditionally, angular, crushed, hard stones and rocks, uniformly graded, free of dust and dirt, and not prone to cementing action have been considered good ballast materials. We have used ballast in our experiment.


Total rock weight = 2.46 kg
Density of the rock : (2.46 kg/1180cm^3) = 2.08 gm/cm^3
Absorber density per square centimeter= Total weight / basin area =2.46 kg/1520cm^2
=1.61gm/cm^2

Specific heat of rocks(ballast): 0.8 kJ/(kg K) to 3.4 kJ/(kg K)
High specific heat content is very effective for maximum heat absorption.

1.12 <u>Salt concentration in sea water</u>:

Seawater is water from a sea or ocean. On average, seawater in the world's oceans has a salinity of approximately 3.5% (35 g/L, 599 mM), or 35 parts per thousand. This means that for every 1 litre (1000 mL) of seawater there are 35 grams of salts (mostly, but not entirely, sodium chloride) dissolved in it.

Source: Wikipedia

1.12.1 <u>Water salinity based on dissolved salts</u>:				
Fresh water	Brackish water	Saline water	Brine	Sea water
< 0.05% or <1000 ppm TDS	0.05–3% or 1000-5000 ppm TDS	3–5% or 15000-30000 ppm TDS	> 5% or 40,000-300,000+ ppm TDS	30,000-40,000 ppm TDS

1.12.2 <u>Brackish water :</u> Brackish water is water that has more salinity than fresh water, but not as much as seawater. It may result from mixing of seawater with fresh water, as in estuaries, or it may occur in brackish fossil aquifers. Brackish water contains dissolved salts of about 2000-2500ppm.

1.12.3 <u>Potable water:</u> The drinking water that is supplied to our homes comes from either surface water or ground water. This water is fit for drinking, being free from contamination and not containing a sufficient quantity of saline material to be regarded as a mineral water. It has been either treated, cleaned or filtered and meets our local established drinking water standards. Or, it is assumed to be reasonably free of harmful bacteria and contaminants and also considered safe to use in cooking and baking. Typically in developed countries, tap water meets drinking water quality standards. Surface water collects in streams, rivers, lakes, and reservoirs. Ground water is water located below the ground where it collects in pores and spaces within rocks and in underground aquifers. We obtain ground water by drilling wells and pumping it to the surface. potable water should not contain dissolved salts more than 500 ppm

Chapter 2
Literature Review

The first “conventional” solar distillation device in the world was built in Chile(1872). It had an overall area of $4700m^2$, consisting of many cells of basic solar basin. Hirschmann gave a brief historic description about this . This device was in operation for about 40 years and yielded more than 4.9 kg of distilled water per square meter of the still surface on a typical summer day. It is worth noting that this output compares very well with the distilled water output from the present day solar stills.[2]

No work on solar distillation seems to have been published after 1880's till the end of the First World War. With the renewal of interest, several, types of devices have been described, e.g. roof type, V-covered, tilted wick, inclined tray, suspended envelope, tubular and air inflated stills etc. Use of metal coated reflectors as solar concentrators for application in solar distribution has been described by Kausch (1920); Pasteur (1928) also used several concentrators to focus solar rays onto a copper boiler containing water. During the Second World War, Telkes (1945) developed air inflated plastic stills for the U.S. Navy and Air Force for use in the emergency life-rafts.

Howe and Tleimat [9] reviewed 20 years of work on solar distillation carried out at the Seawater Conversion Laboratory, University of California is also a milestone in solar still studies.

Gomkale and Datta [6] designed a simple solar still, which produces 5–7 L/d of purified water using aluminum components and black polyethylene film as the base liner and insulation bed of sand and saw-dust at the bottom, an aluminum channel for distillate collection and an asbestos cement sheet as the bottom supporting plate. The unit has a double-sloped glass cover placed at an angle of 20º. The authors stated that over a year the unit had an annual average productivity of 2.5 L/m2d, i.e. an efficiency of 28% at Bhavnagar in India. The productivity of the still was rather low, mainly due to heat loss by convection currents in the large air space, and also due to loss of latent heat of condensation to the air via the glass cover..

The effects of coal and charcoal on solar-still performance is studied by Okeke, Egarievwe, and Animalu 1990 . Where fuels improve the still performance. The average daily productivity and efficiency of the still were 1.121/m2 and 16.5%, respectively.[7]

Fedali Saida, Bougriou Cherif (2010), presents the thermal analysis of passive solar still. Mathematical equations for water, absorber, glass and insulator temperatures yield and efficiency of single slope basin have been derived. The analysis is based on the basic energy balance for the solar still. A computer model has been developed to predict the performance of the solar still. The operation governing equations of a solar still are solved by a Runge-Kutta numerical method. The numerical calculations indicated that the wind speed has an influence on the glass cover temperature. It was noted that in sunshine duration, temperature of various components of the distiller follows the evolution of solar radiation. [8]

Rajesh Tripathi, G.N. Tiwari(2005), presented the thermal analysis of passive and active solar distillation system by using the concept of solar fraction inside the solar still with the help of AUTOCAD 2000 for given solar azimuth and altitude angle and latitude, longitude of the place. Experiments have been conducted for 24 h (9 am to 8 am) for New Delhi climatic conditions (latitude 28035' N, longitude 77012' E) during the months of November and December for different water depths in the basin (0.05, 0.1 and 0.15 m) for passive as well as active solar distillation system. Analytical expressions for water and glass cover temperatures and yield have been derived in terms of design and climatic parameters.[4][5]

We have conducted our experiment based on simple solar still construction by using black colored rock as absorber medium. Previously several study also carried out with absorber medium.

But before studying absorber effect, the common solar still property is studied below first.

The productivity of single slope an is higher than double slope studied by Grag and Mann(1976)[12] and double basin gives higher productivity than single basin studied by Mahadi (1992). From the study of Singh & Tiwari(2004)[4] we get an idea about basin inclination angle which is equal to the latitude to get maximum solar radiation. For Dhaka it is 23.5 degree. And decreasing glass cover thickness increase the temperature difference between water and inner glass cover . It should be 3 to 4 mm glass which result is studied by Ghoneyem and Ileri(1997).

And operational parameters like water depth should be low to get higher efficiency studied by Grag and Mann(1976)[12] and Phadatare and Verma(2007). Coloring (black) of water also gives some efficiency as it increases the temperature of water use inside of the still.

Charcoal and small black stones is used an experiment which is also gives a good efficiency researched by Abdallah et al. (2009). [3] where the overall average gain in the collected distilled water taking into the consideration the overnight water collections were 28%, 43% and 60% for coated and uncoated metallic wiry sponges and black rocks respectively.

By a study using charcoal as absorber medium gives 15% improvement in productivity worked by Mona M. Naima*, Mervat A. Abd El Kawib[10] Chemical Engineering Department, Faculty of Engineering, Alexandria University, Alexandria, Egypt.

In case of finned, corrugated and conventional absorbers solar stills under Egyptian conditions efficiency is 47.5%, 41%, 35% experimented by Z.M. Omera.[13]

Cooper(1972) Abdallah et al. (2009), analyzed an experiment by adding energy absorption and storing materials, where he used small (20–30mm) black stones or gravels as energy storage medium. [11]

Presently ,solar still plants, for desalination purpose, are not in use in Bangladesh. A plant operation was performed for the months of January to April, 1994 at the Department of Civil Engineering, Bangladesh University of Engineering and Technology, to observe the variation of diurnal distillate production of such a plant . The maximum and minimum diurnal experimental output of the plant as found in the study period was 0.211m2 to 2.3llm2 respectively with an average of 1.25 11m2. The estimated variation of efficiency was 3% to 40% with an average of 19%.The salinity removal by the plant is almost 100%. Therefore, the pure water obtained from solar still can be mixed up with feed water prior to consumption provided the feed water is free from other impurities. However, the mixture should not have salt concentration of more than 600 ppm.[1]

Another paper also published on BCAS journal which is an experimental study was carried out on solar distillation on the roof of the office building of Bangladesh Centre for Advanced Studies (BCAS), by A. Atiq Rahman, M. Eusuf.[32] during the period December 2011 to April 2012. The highest yield was 8.1 liters per day giving an efficiency of 36.4% based on average incident solar energy.

Objective

The application of solar energy to purify water is ancient. Investigators and researchers have applied many techniques and brought many modifications to enhance the outcome of solar stills.

To serve the same purpose the objective of this study is to enhance the performance of a simple solar still. To achieve the objective, certain modification is done on the simple passive solar distillation system, and experimental and theoretical parametric studies are performed. Black colored rocks were used as absorber medium and the effect of such absorber medium on the performance of a simple solar still was aimed to study.

Also the study aims:

1. To observe solar still performance in Bangladesh & its suitability in Bangladesh condition.

2. To observe the outcome of a simple passive solar still with no absorber medium.

3. To observe the outcome of a simple solar still even after the sun set.

4. To study the effect of a selective absorber medium (rock) on the performance of still.

5. To find the effect of black colored rock absorber medium during the period when the day light disappears.

6. Making solar still at low cost with good efficiency

Chapter 3
Methodology

A solar still distills water, using the heat of the Sun to evaporate, cool then collect the water .This paper attempts to improve the efficiency of a simple model of solar still. The heat trapping greenhouse effect is used as a main function of the still.

Distillation[16] operates by the escape of moving molecules from the water surface into the gases above it. Sensible heat the kind we can measure with a thermometer is caused by the movement of molecules, zig-zagging about constantly, except that they are not all moving at the same speed. Add energy and they move faster, and the fastest-moving ones may escape the surface to become vapor.

It takes a lot of energy for water to vaporize. While a certain amount of energy is needed to raise the temperature of a kilogram of water from 0 °C to 100 °C. It takes five and one-half times that much to change it from water at 100 °C to water vapor at 100 °C. Practically all this energy, however, is given back when the water vapor condenses.

The salts and minerals do not evaporate along with the water. Ordinary table salt, for example, does not turn into vapor until it gets over 1400 °C, so it remains in the brine when the water evaporates. This is the way we get fresh water in the clouds from the oceans, by solar distillation. All the fresh water on earth has been solar distilled.

It is not necessary for the water to actually boil to bring about distillation. Steaming it away gently does the same job as boiling, except that in the solar still, it will usually turn out even more pure, because during boiling the breaking bubbles may contaminate the product water with tiny droplets of liquid water swept along with the vapor.

Energy passing through a glass cover heats up the brine or sea water in a pan; this causes the water to vaporize. The vapor then rises and condenses on the underside of the cover and runs down into distillate troughs.

3.1 A more technical description follows:

1. The sun's energy in the form of short electromagnetic waves passes through a clear glazing surface such as glass. Upon striking a darkened surface, this light changes wavelength, becoming long waves of heat which is added to the water in a shallow basin below the glazing. As the water heats up, it begins to evaporate.

2. The warmed vapor rises to a cooler area. Almost all impurities are left behind in the basin.

3. The vapor condenses onto the underside of the cooler glazing and accumulates into water droplets or sheets of water.

4. The combination of gravity and the tilted glazing surface allows the water to run down the cover and into a collection trough, where it is channeled into storage.

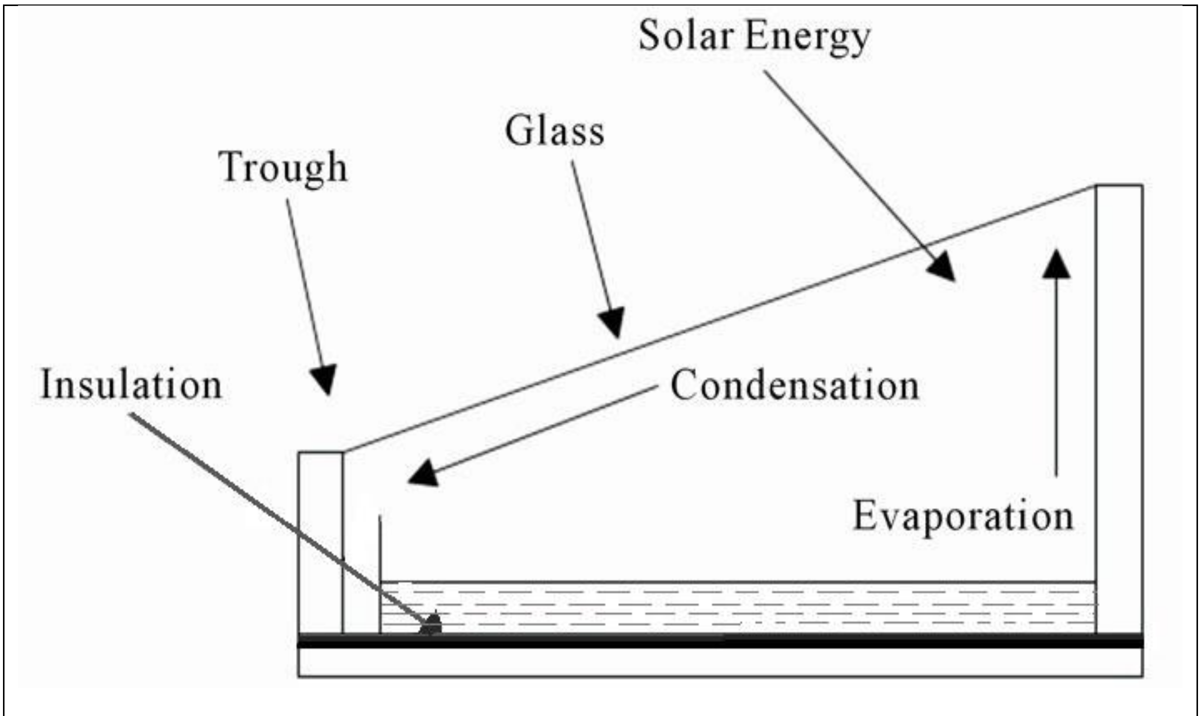

Figure 15: solar still principles

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3.2 Components of solar still:

1. Basin
   a. Condensate channel
   b. Feed water channel

2. Sealant materials: Sealant material is required to prevent leakage of water vapor and condensate. Glass pudding was used for this purpose. Silicone rubber is also used for joining glass pieces.

3. Black Liner: Solar radiation transmitted through transparent cover is absorbed in the black lining. Black bodies are good absorbers. Black paint is used as liner.

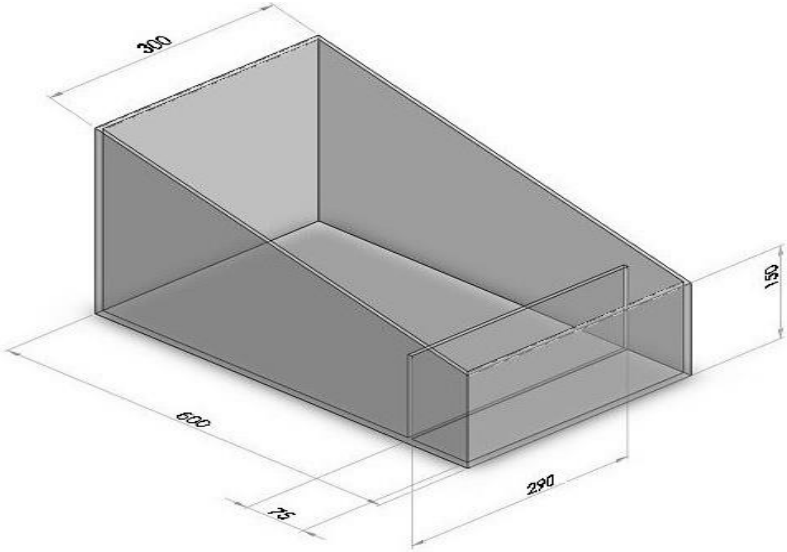
4. Temperature sensor

5. Scale (for measuring water depth)

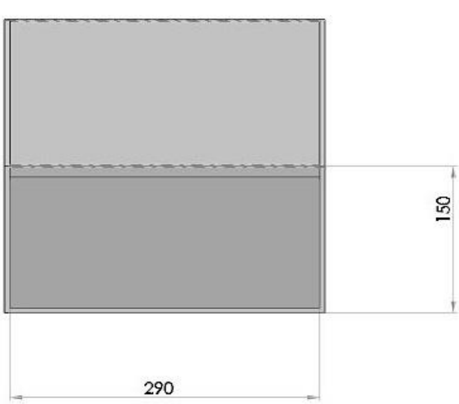
6. Table (for holding the still)

Solid works model design

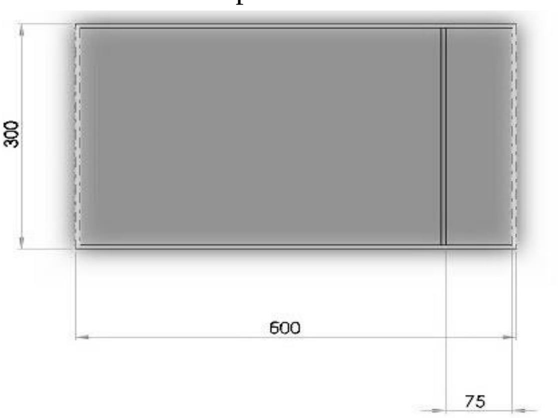
Isometric View



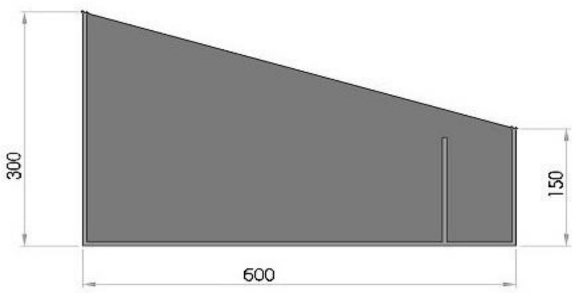
Front View



Top View

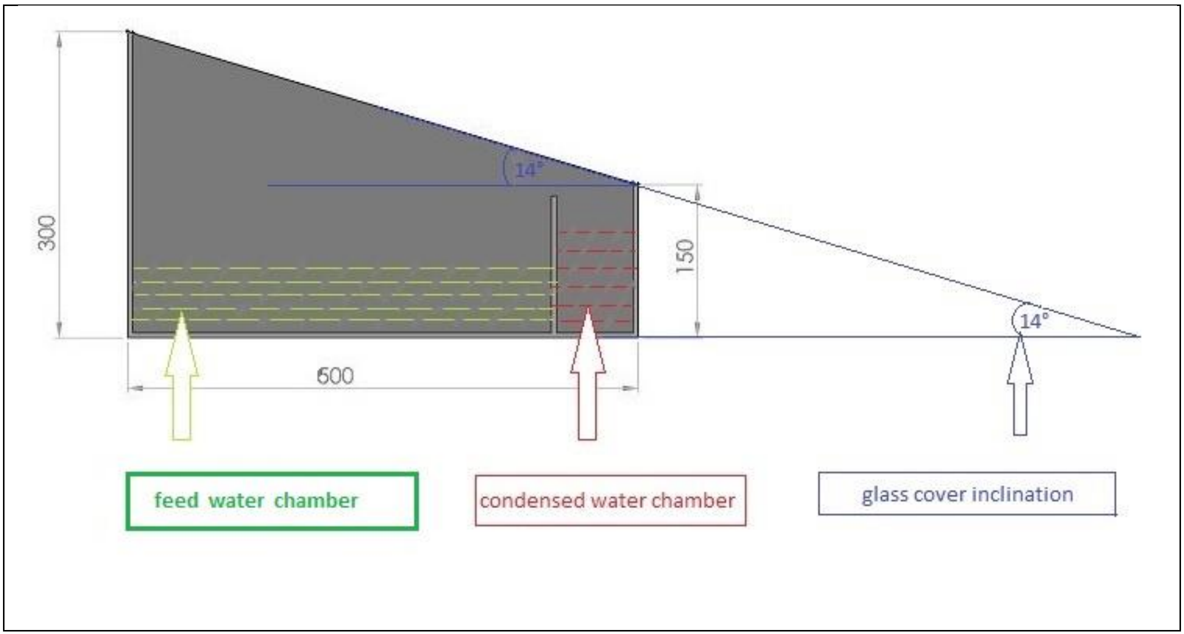


Left View



All the dimensions in mm

3.3 Specifications of the Solar Still :



Length, cm	60cm
Width, cm	30cm
Base area,cm^2	1520 cm^2
Glass cover inclination	14°
Glass depth, mm	5mm

Area of the feed water chamber :(52.5cm x 29cm)

=1520 cm^2

=.152m^2

Area of still condensed water chamber :(30cm x 7.5cm)

=225cm^2

=.0225m^2

3.4 Materials of the still:

1. 5mm transparent glass (Manufacturer-Nasir Glass BD)
2.Silicone rubber (for joining glass pieces)
3. Black polythene (used in the bottom surface as absorber)
4.Glass pudding(used for sealing)
5. Rocks

3.5 Glass property:

1. **5mm thick glass**
   (Manufacturer-Nasir Glass BD)

2. Color- clear & fully transparent.

3. Thermal Conductivity, k= 1 Watt/m·°C

4. Specific heat, C= 800J/kg·°C

5. Linear thermal expansion, α= (30-60) × 10^{-7}/ °C

6. Refractive index:
Some typical refractive indices for yellow light (wavelength equal to 589 nanometers [10^{-9}meter]) are the following:

a. Air-1.0003
b. Water- 1.333
c. Crown glass- 1.517
d. Dense flint glass- 1.655
e. Diamond-2.417

7. Transmission range-UV-C to near-IR
References-[29]

3.6 Experimental investigations :

Location of the exp: 23°50'17.3"N 90°21'28.6"E

Face : South Facing

Rock size : On average 100g to 140g

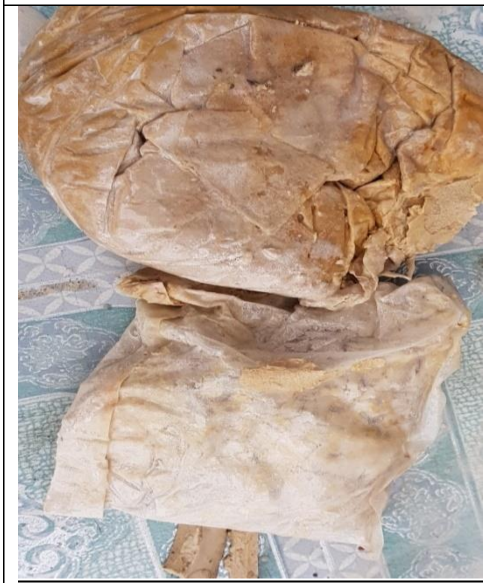
Total rock no: 22

Materials: Glass

3.7 Equipment used for collecting data:

1. Solar still(Basin)
2. sling psychrometer
3. Thermocouple sensor
4. Thermocouple Display
5. Thermometer
6. Scale
7. Clock

3.8 Pictures of working model

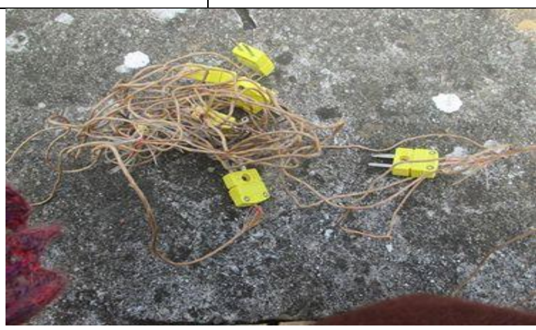


Glass pudding

Silicone rubber

Sling psychrometer

Thermocouple Display



Thermocouple wires

3.9 Experiment Procedure:

1. First of all, basin is set in south facing

2. Glass cover is removed and feed water get to the basin.

3. At a certain depth of water is set, and water inlet temp and the dry bulb and wet bulb temp is measured.

4. Then the glass covered is sealed by using pudding.

5. Then it was kept at a certain period for accumulating water in a sunny day.

6. After a long period, water accumulation is measured from outside by a scale. And converted it into the liter unit.

3.10 Experimental parameters:

1. Single slope (gives maximum output) **ref** :Garn and Mann 1992

2. Single basin (for easy making of still) **ref**: Mahde 1992

3. Inclination of glass cover: angle has to be equal to the latitude to get maximum normal solar radiation. For Dhaka the value is 23.5 degree. But our angle is 14° **ref**: Sing and Tiwari 2004

4. Low glass cover thickness (lowering the thickness increases the temperature difference between water and inner glass. **ref**: Ghoneyem and Iileri 1997.

5. Water depth(The lower the water depth, the higher the yield. **ref**:Grag & Mann(1976),Phadatare & Verna(2007), Tiwari & Tiwari(2007).

6. **Absorber medium**: In this experimental rocks were used as absorber medium.

Effect of using black colored stone as absorber medium is experimentally analyzed. The effect of such absorber medium on the productivity of solar still is analyzed by comparing the yield of a simple solar still without use of any absorber medium with yield of a simple solar still using rock as absorber medium. Outcome of each type of solar still was measured in terms of volume. The elevation of production of pure water states that using such type of absorber medium has a profound effect on the productivity of a solar still system.

3.11 Data & Calculation:

Date	Weather	Absorber medium	Initial time	Final time	Dry bulb temp (°C)	Wet bulb temp (°C)	Initial Height of feed water (cm)	Initial feed water temp ° (C)	Final feed water temp (°C)	Height of condensed water (cm)	Volume of condensed water cm^3/Litre
16/09/17	sunny	None	8.00 AM	5.00 PM	32	29	3	32	61	.80	180/.18L
18/09/17	sunny	None	8.00 AM	5.00 PM	31	28	2	32	64	.90	200/.2L
22/09/17	Sunny	None	8.00 AM	5.00 PM	33	28	2	33	65	1	220/.22L
23/09/17	Sunny	None	8.00 AM	5.00 PM	31	27	1.8	33	64	.95	210/.21L
06/10/17	Sunny	Rock	8.00 AM	5.00 PM	32	28	2	31	67	1.2	260/.26L
10/10/17	sunny	Rock	8.00 AM	5.00 PM	33	28	2	32	66	1.2	270/.27L
30/11/17	Partly cloudy	Rock	8.00 AM	8.00 AM	25	18	2	24	36	.5	150/.15L
01/12/17	Partly cloudy	none	8.00 AM	8.00 AM	23	18	2	23	34	.4	90/.09L

3.12 Efficiency Calculation:

Empirical relationship given by Schumacher Center For Technology & Development, UK for calculating efficiency:

$$E = \frac{Q \times 2.26}{G \times A} \times 100$$

This equation of a solar still is used by (Neil, 2002)[14]
Where,

E = Efficiency (%)

Q = Amount of distilled water collected per day (liter/day)

2.26 = Latent heat of vaporization of water (MJ/liter)

G = Daily global solar irradiation ($MJ/m^{2)}$

A = Aperture area of the still ie, the plan areas for a simple basin still (m^2)

For Dhaka,

3.13 Irradiation (G):

1. On September **G_{sept}= 4.67 kWh/m²** =16.81 MJ/m²

2. On October **G_{oct}= 4.5 kWh/m²** =16.2 MJ/m²

3. On November **G_{nov}= 4.6 kWh/m²** =16.56 MJ/m²

4. On December **G_{dec}= 4.25 kWh/m²** =15.3 MJ/m²

3.14 **Observation**:

1.Without Absorber (rocks)

Serial	Month	Date	$E = \frac{Q \times 2.26}{G \times A} \times 100$	**Efficiency (E)**	Dry bulb/ wet bulb(°C)	Relative Humidity
1.	September	16/09/17	$E = \frac{.18 \times 2.26 \times 100}{16.81 \times .152}\%$ =15.92%	**15.92%**	32 / 29	80%
2.	September	18/0917	$E = \frac{.2 \times 2.26 \times 100}{16.81 \times .152}\%$ =17.68%	**17.68%**	32 / 28	80%
3.	September	22/0917	$E = \frac{.22 \times 2.26 \times 100}{16.81 \times .152}\%$ =19.45%	**19.45%**	33 / 28	68%
4.	September	23/09/17	$E = \frac{.21 \times 2.26 \times 100}{16.81 \times .152}\%$ =18.57%	**18.57%**	31 / 28	74%
5.	December	01/12/17	$E = \frac{.09 \times 2.26 \times 100}{15.3 \times .152}\%$ =8.74%	**8.74%**	23 / 18	55%

2. With Absorber (rocks)

1.	October	06/10/17	$E = \frac{.26 \times 2.26 \times 100}{16.2 \times .152}\%$ =23.86%	**23.86%**	28 / 32	74%
2.	October	10/10/17	$E = \frac{.27 \times 2.26 \times 100}{16.2 \times .152}\%$ =24.7%	**24.7%**	33 / 28	68%
3.	November	30/11/17	$E = \frac{.15 \times 2.26 \times 100}{16.56 \times .152}\%$ =13.46%	**13.46%**	25 / 18	50%

3.15 Total surface area of the still:

= Top surface area + Bottom surface area + Right surface area + left surface area + Front surface + Back surface area

= $[30\times62 + 60\times30 + (60\times15 + .5\times60\times15) + (60\times15 + .5\times60\times15) + 30\times15 + 30\times30]cm^2$

= $7710cm^2$

≈ $8000cm^2 = 1240\ Inch^2 = 8.61\ ft^2$

3.16 Construction cost estimate of solar still:

1.glass box price: 8.61×60 =516 Tk

[As1 sq ft 5mm glass retail price = 60tk]

2. Black paint: 70 Tk

3.Sealant(waterproof)=50 Tk (silicone rubber sealant)

4.Rock cost= 50 Tk

5. Black polythene cost= 20Tk

Net cost of the project (for user production) per product=706 Tk

Chapter 4
RESULT & DISCUSSION

In this work the effect of using black colored rock as absorber medium on the performance of a simple solar still during the sun light period and after sun-set is examined experimentally.

The concept was that, using such absorber medium will increase the solar still because

1. Rocks have high heat capacity ranging from 0.8 kJ/(kg K) to 3.4 kJ/(kg K).
2. Choosing black color as coating will increase the heat absorption.

Considering all these properties of rock a prediction was made that using rock as absorber medium will increase the yield of solar still.

From the data obtained. It is quite clear that

1. A simple basin solar still operates at about 30% efficiency worldwide,[30] Where we get the efficiency in our experiment 15.92%, 17.68% , 19.45% ,18.57% ,23.86% ,24.7% ,13.46% ,8.74%. So our average result is very near to the world's average efficiency.

2. During the sun shine hours using the black colored rock absorber medium yields more fresh water compared to a solar still system that do not use any absorber medium.

3. The effect of black colored rock absorber medium remains even after the sun-set.

4. Environment Humidity also make certain changes in the output. Where output in November & December is very low.

5. As we have conducted our experiment in (June to December) when total sunshine hour or total irradiation is two third to the April. So this is another reason for lowering efficiency in November & December.

6. In October we have seen bubble formation in the water, but bubbles does not move to the upper surface or collapse. But we have not seen any bubbles in November or December.
7. As rock or water need a certain amount of time for heating, so for the accumulation of water also take some time. It at least takes 5 to 6 hour to start the condensation, which we can see in the form of droplets in the glass wall.
8. In this year due to the long rainy season we were unable to collect more data for our experiment.
9. Due to certain thermal properties of rock as mentioned earlier the absorber medium dissipates heat even after the sun light disappear
10. So we can say that solar still has a good future in our country . we can get a good performance of the still from February to October in 9 months.
11. Observing all the experimental results it can predicted that use of rock absorber medium along with other enhancements and modifications may increase the effectiveness of solar stills to a considerably higher extent.

In this work the experimental results obtained helps to establish the previously predicted effect of this certain modification on the performance of a simple solar still.

4.1 Conclusion

Access to pure and safe water is a basic human right. In Bangladesh a large number of people do not have the access to fresh water in the coastal regime. In our country mostly conventional methods like boiling, filtering, chlorination etc are used to purify water. Also use of solar energy to purify water is an excellent alternative. Solar energy is a clean, cheap, environment friendly, easily available alternative source of energy. The efficiency of a simple solar still is fair, around 30%. Due to the geographical location Bangladesh receives a significant amount of solar energy. Hence the potential of a solar still system is considerably high .In this paper the effect of black colored rock absorber medium on the productivity of a simple passive solar still is analyzed and also the optimum parameters are chosen for a cheap and effective design. The results obtained are hope stimulus packages. The results sate that

-using black colored rock as absorber medium increases the efficiency of solar still.

-It increases the production rate.

-It prolongs the output hour of the still.

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Appendix:

1 Inch=2.54 Centimetre

1 cm^3=.001 litre

1 cm^2=.0001 m^2

1 cm^2=.155 $Inch^2$

1 $Inch^2$=.00694 ft^2

ppm - parts per million (commonly used as a unit of concentration. ppm - is commonly used as a measure of small levels (concentrations) of pollutants in air, water, body fluids, etc.

TDS: Total Dissolved Solids

The Latent heat of vaporization/Condensation of water =2,260kJ/kg,= 40.8 kJ/mol

Table-shows some solar stills in various countries in the world. This table shows that most of the stills were built during the period 1960-1980 .[31]

Table - Some Basin Type Solar Stills in the World

Country	Location	Year	Basin Area (m^2)	Productivity (m^3/day)	(liter/m^2.day)	Cover
Australia	Muresk I	1963	372	0.83	2.30	Glass
	Muresk II	1966	372	0.83	2.30	Glass
	Coober Pedy	1966	3160	6.35	2.01	Glass
	Caiguna	1966	372	0.78	2.10	Glass
	Hamelin Pool	1966	557	1.21	2.17	Glass
	Griffith	1967	413	0.91	2.20	Glass
Chile	Las Salinas	1872	4460	14.76	3.31	Glass
	Quillagua	1968	100	0.40	4.0	Glass
	Quillagua	1969	103	0.40	3.88	Glass
Greece	Symi I	1964	2686	7.56	2.81	Plastic
	Aegina I	1965	1490	4.24	2.84	Plastic
	Salamis	1965	388	1.10	2.83	Plastic
	Patmos	1967	8600	26.11	3.04	Glass
	Kimolos	1968	2508	7.57	3.02	Glass
	Nisyros	1969	2005	6.06	3.02	Glass

India	Bhavnagar	1965	377	0.83	2.20	Glass
Mexico	Natividad Island	1969	95	0.38	4.0	Glass
	Puerta Chale	1974	300	1.00	3.33	Glass
	Punta Chucca	1974	470	1.50	3.19	Glass
Pakistan	Gwadar II	1972	9072	27.0	2.98	Glass
Spain	Las Marinas	1966	868	2.57	2.96	Glass
Tunisia	Chakmou	1967	440	0.53	1.20	Glass
	Mahdia	1968	1300	4.16	3.20	Glass
U.S.A	Daytona Beach	1959	224	0.53	2.37	Glass
	Daytona Beach	1961	246	0.57	3.20	Glass
	Daytona Beach	1961	216	0.38	1.76	Plastic
	Daytona Beach	1963	148	0.61	4.12	Plastic
U.S.S.R	BalchardenTurkmena	1969	600	1.62	2.70	Glass
WestIndies	Petit St.	1967	1710	4.92	2.88	Plastic
	Vincent Haiti	1969	223	0.76	3.41	Glass

Figure 16 : psychrometric chart

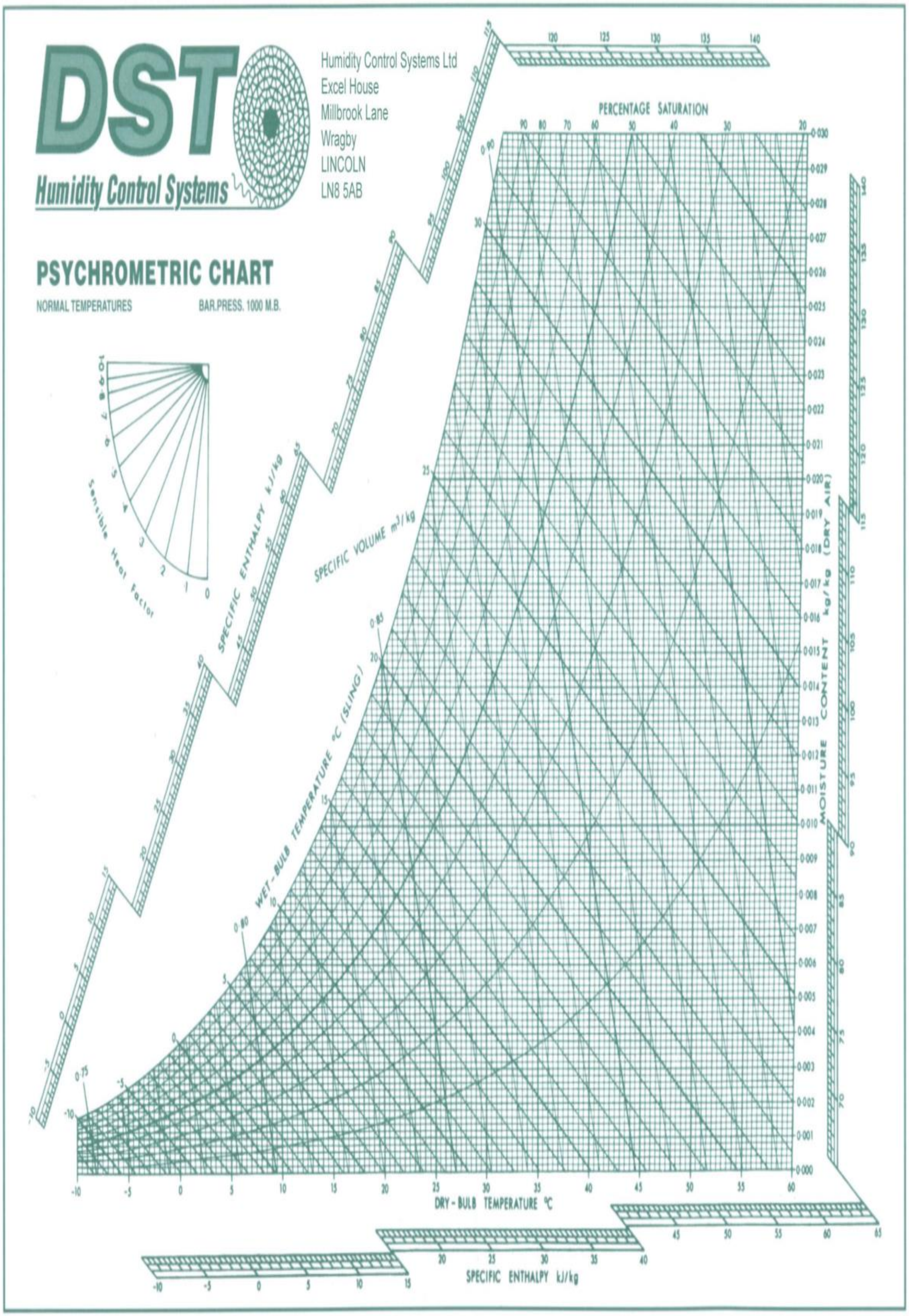

Figure 17: Pool boiling curve