Effect of Textile Cylinder on the Production of Distillate in Solar Desalination

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A project report submitted to the Department of Civil Engineering of Khulna University of Engineering & Technology (KUET). Khulna, Bangladesh in partial fulfillment of the requirements for the degree of

"Master of Science in Civil Engineering"

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Declaration

This is to certify that the Project Work entitled "**Effect of Textile Cylinder on the Production of Distillate in Solar Desalination**" has been carried out by **Mr. Md. Selim Reza**, in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above Project work has not been submitted anywhere for any award of degree or diploma.

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This is to certify that the Project Work submitted by **Md. Selim Reza** entitled as "**Effect of Textile Cylinder on the Production of Distillate in Solar Desalination**" has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering under Khulna University of Engineering & Technology, Khulna, Bangladesh in January, 2014.

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Abstract

Bangladesh has become one of the most populated and climate vulnerable countries in the world. The water scarcity coupled with a significant growth in population and climate vulnerability especially in coastal areas of Bangladesh and poses the serious problem of supplying fresh water. But in the world of these areas, water is available in abundance but most of them are saline that is why there is a shortage of potable water. Considering this issue, numerous technologies have been developed around the world to distillate water in which some of those are used in Bangladesh. The standard techniques, like multi-stage flash (MSF), multi-effect (ME) vapor compression (VC), and reverse osmosis (RO), are only reliable for large capacity ranges from 100–50,000 m^3/day, expensive for small amounts of fresh water production and cannot be used in locations where there are limited energy supplies. Due to the fossil-fuel-based energy consumption, emissions of greenhouse gases (e.g. CO_2, CO and SO_2) will always be an issue of environmental concern. Even though, in the coastal and remote areas of Bangladesh like St.Martin, Nijhoom Island which are located far away from the energy grid-lines require a local source of energy to desalinate water from its available sources. In the context of the crisis, solar desalination seems to be the most suitable solution option of salinity problem for the coastal areas of Bangladesh. Solar desalination technique would also have promising application because of its environment friendly nature. Thus, solar desalination has become one of the important non-conventional water resources that play a significant role in solving fresh water scarcity of the global community, especially the coastal areas of Bangladesh. But the main disadvantage of a simple solar desalination is its low production efficiency. The production efficiency depends on the temperature difference between the water surface and the glass covers, water surface area and other atmospheric parameters.

In this study, the evaporation surface area of the solar still has been taken into account and sought a way that how it can be increased. In the mean time, got an innovative idea to increase the evaporation surface area and that is outer surface area of a cylinder which seems to be a suitable option. To evaporate water from the outer surface of the cylinder, water must be retained or absorbed along its surface. That's why the textile has been selected and formed into cylindrical shape with the help of an aluminum wire cylindrical frame. The spiral frames have been made by using aluminum wires. The inner cylinder were covered by different types of textile and inserted into a transparent plastic outer cylinder. The whole system has been installed on the roof top of the 3-storey building of Environmental Engineering laboratory for monitoring its production efficiency. The distillate production rate (DPR) and distillate quality parameters, salinity, electric conductivity and pH have been monitored and the durability of the textiles has also been investigated in different salinity. The maximum DPR was found 11.11 L/m^2/day and water quality parameters were below the drinking water standard limit. The durability of the setup was observed 3-4 years and its durability would be increased by proper operation and maintenance. This textile cylinder can be used in the coastal areas of Bangladesh where the people are suffering from salinity problems. It can also be suitable for a few families or small groups in remote areas.

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Notation

CE	Civil Engineering
DPR	Distillate Production Rate
ED	Electro Dialysis
HD	Humidification-Dehumidification
KUET	Khulna University of Engineering & Technology
MD	Membrane Distillation
MED	Multiple Effect Distillation
MSF	Multiple Stage Flash
MVC	Mechanical Vapor Compression
RO	Reverse Osmosis
TCDU	Textile Cylinder Distillation Unit
TVC	Thermal Vapor Compression

CHAPTER 1: **INTRODUCTION**

1.1 General

Current global developments are not sustainable over the long term. The population growth and climate change every major ecosystem is going under threat at different timescales, impacting water, food, energy, biodiversity, and mineral resources. And it is known that the origin and continuation of human civilization is based on water. Water is essential for life and access to sufficient quantities of safe water for drinking and domestic uses and also for commercial and industrial applications is essential for healthful living, enhanced quality of life and well-being, and the opportunity to achieve human and economic development. But many regions of world are grossly deficient in the availability of water of sufficient quantity as well as quality. People in many areas of the world have historically suffered from inadequate access to safe water. Some must walk long distances just to obtain sufficient water to sustain life. In the world, billion people are now at risk from a lack of clean water and many people in the developing world die from water-related problems as well. In this harsh situation, Bangladesh has become one of the most populated and climate vulnerable countries in the world. The water scarcity coupled with a significant growth in population and climate vulnerability especially in coastal areas of Bangladesh and poses the serious problem of supplying fresh water. In these areas water is available in abundance but most of them are saline and that is why there is a shortage of potable water in those areas. The people of coastal area in our country are facing a severe problem of salinity in groundwater and also in surface water. Considering these issues, Bangladesh had achieved a remarkable success by providing 97% of the rural population with tube well water (Bari et al., 2009). Unfortunately, the tube well water in the coastal area of Bangladesh contains salinity at concentration higher than the suitable limit set for drinking purpose. Numerous technologies have been developed around the world to desalinate water in which some of them are used in Bangladesh. The standard techniques, like multi-stage flash (MSF), multi-effect (ME) vapor compression (VC), and reverse osmosis (RO), are only reliable for large capacity ranges from 100–50,000 m^3/day of fresh water production. These technologies are expensive for small amounts of fresh water production and cannot be used in locations where there are limited maintenance facilities and energy supplies (Nafey et al., 2004). Applications of these technologies consume a large amount of non-renewable energy such as coal, oil, gas etc. and require high skill operation. Due to the fossil-fuel-based energy consumption, emissions of greenhouse gases (e.g. CO_2, CO and SO_2) will always be an issue of environmental concern (Parekh et al., 2004). But in the coastal area of Bangladesh where energy is too expensive to run such desalination processes and also in remote areas in Bangladesh like St.Martin & Nijhoom Island which are located far from the energy grid-lines, require a local source of energy to desalinate water. Considering the above mentioned issues, solar desalination seems to be the most suitable solution of salinity problem for the coastal areas of Bangladesh and other areas around the world as well. Solar desalination technique would also have promising application because of its environment friendly nature. Thus, solar desalination has become one of the important non-conventional water resources that play an important role in solving fresh water scarcity in different regions in the world (Fath et al., 2003) such as the coastal areas of Bangladesh. But the main disadvantage of a simple solar desalination is its low production efficiency (Delyannis and Belessiotis, 2001). The production efficiency of solar desalination depends on the temperature difference between the water surface and the glass covers, water surface area and other atmospheric parameters (Dunkle, 1961).

In this study, the evaporation surface area of the solar still has been taken into account and sought a way that how its can be increased. In the mean time, got an innovative idea to increase the evaporation surface area and that is outer surface area of a cylinder which seems to be a suitable option. To evaporate water from the whole surface of the cylinder, water must be retained or absorbed along the whole surface of the cylinder. That's why the textile has been selected and formed into cylindrical shape with the help of an aluminum wire cylindrical frame. The spiral frames have been made by aluminum wires. The inner cylinder are covered by different types of textile and inserted into a transparent plastic outer cylinder. The whole system has been installed on the open space of an experimental station. Several parameters of the distillate have been determined and the durability of the textiles has also been investigated in different salinity. Therefore, an attempt should be taken to study the performance of the newly invented concept of textile cylinder in solar desalination for its potential application in the potable water scarce areas. In this chapter, it will be focused on the introductory discussion on the research work, its objectives and the scope of this study.

1.2 Objectives of the Research Work

The work has been carried out with the following specific objectives:

- To investigate the production rate of distillate using different types of textile cylinders.

- To determine the durability of different types of textiles for different salinity and duration.
- To assess the quality of raw and distillate water.
- To develop correlations for distillate production of different types of textile cylinder and other selected parameters.

1.3 Scope of the Study

This work has been focused mainly on the production rate of distillate in solar desalination which depends on various parameters and the evaporation surface area is an important one. That is why a cylindrical form i.e. textile cylinder has been selected. Due to the availability and economic sense various types of Textiles, Nylon chord, Aluminum wire, wooden bar etc. have been selected.

To achieve the above milestones or objectives of the study, a systematic approach consisting of four main interconnected phases have been framed:

1. Formation of textile cylinder
2. Trial setup of the experimental works at the open experimental station
3. Collection and analysis of various sample in the laboratory and
4. Observe the performance of the various textile cylinders.

The first phase covers the area of literature review and fabrication of textile cylinder. The second phase of this work consists of the number of experimental setup by trialing the previous one. The third setup consists of the collection of sample and performing various tests in the laboratory and forth setup covers the performance observation about the various textile cylinders by considering the production of distillate and various water quality parameters.

1.4 Organization of the Report

The chapter to chapter arrangement of this report has been made according to the available used format in which some pages have been added as a cover page prior to the chapter named introduction. The introductory discussion has been provided in chapter 1 and chapter 2 has been dealt with the literature related to this report. The working procedure that means methodology of this work has been presented in chapter 3. The findings of this research work has been presented in chapter 4 named as Results and Discussion. The operation and maintenance of this system has been discussed in the chapter 5 where conclusions and recommendations have been discussed in chapter 6 and this is the last chapter.

CHAPTER 2: **LITERATURE REVIEW**

2.1 General

With growth of the world population, the availability of the limited quantities of fresh water continually decreases as well as wraps up the world by water scarcity. According to the International Water Management Institute (IWMI), one in three people globally endures some form of water scarcity, one-quarter of the world's population lives in areas where water is physically scarce, and over one billion people live where water is economically scarce (Escobar and Schafer, 2010). Although water is one of the most abundant resources on earth, covering three-fourths of the planet's surface but about 97% of the earth's water is salt sea water and only 3% is fresh water (Rizzuti et al., 2006). This small percentage of the earth's water -to satisfy most of human and animal needs-, exists in ground water, lakes and rivers. The only nearly inexhaustible sources of water are the seas which, however, are of high saline, and groundwater that is high in total dissolved solids and either undesirable or unavailable for beneficial uses without the application of technologies capable of removing large portions of the salinity and dissolved solids. The Commercial desalination technology were introduced about 50 years ago and were able to expand access to water, but at high cost and also requires large amounts of energy which, if produced from fossil fuels, will harm the environment (Cotruvo et al., 2010). Therefore, there is a need to utilize environmentally-friendly energy sources to desalinate seawater. Renewable energy sources (RES) coupled to desalination offer a promising prospect for covering the fundamental needs of power and water especially in remote regions, where connection to the public electricity grid is either not cost effective or not feasible, and where the water scarcity is severe. By considering the issues of the availability of saline or brackish water, this chapter will be focused on desalination process, historical background of solar desalination, its present situation in all over the world.

2.2 Definition of Desalination Process

The desalination process involves the separation of nearly salt free fresh water from sea or brackish water, where the salts are concentrated in the rejected brine stream, Figure 2.2.1. It is worth mentioning that in electro-dialysis the positive and negative ions are separated from the salt water. The desalination process can be based on thermal or membrane separation methods. The thermal separation techniques include two main categories; the first is evaporation followed by condensation of the formed water vapor and the second involves freezing followed by melting of the formed water ice crystals. The former process is the most common in desalination and nearly at all cases it is coupled with power generation units, which may be based on steam or gas turbine systems. The evaporation process may take place over a heat transfer area and is termed as boiling or within the liquid bulk and is defined as flashing.

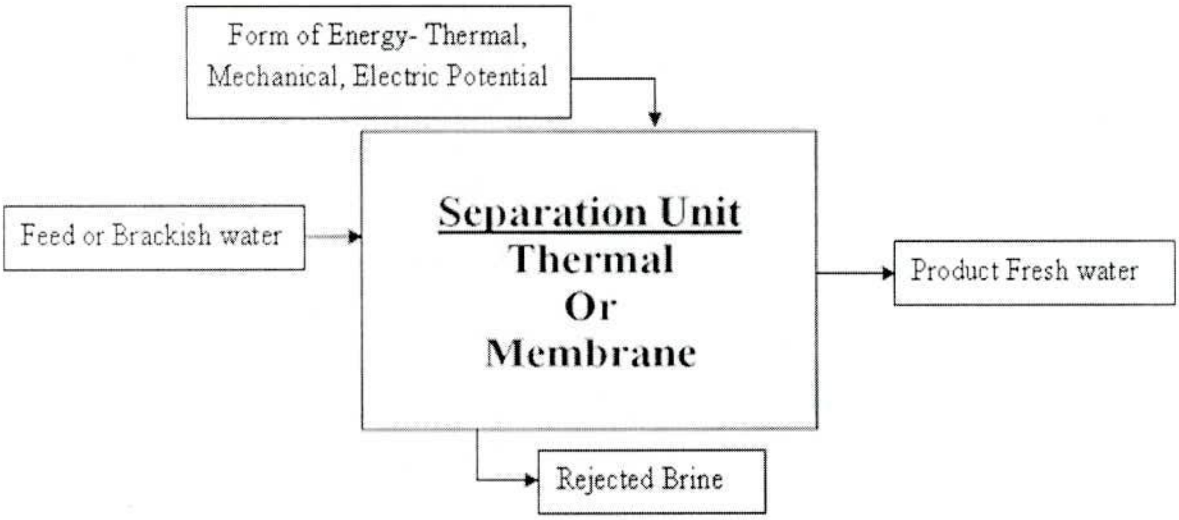

Figure 2.2.1: Definition sketch of desalination process (El-Dessouky and Ettouney, 2002).

2.3 Historical Background

Anyone may wonder why it is necessary to look back into the past. As engineers and scientists of the machine and computer era, we look toward future technological and economic developments. We promote technology for generations to come for the benefit of humanity, exactly the same way pioneers did in the past. At least if nothing else history will teach us humility and humanism. We must not forget what the wise man of China, Confucius (551–479 BC) once said: ''*Study the past in order to predict the future*'' (Delyannis, 2003). Basically history is our link to tomorrow's achievements. So the history of desalination concept can teach about the previous works those have been done by past researchers and make innovative to new comers.

2.3.1 Desalination Concept from Pre-Historic Times to Middle Ages

The first written description of desalination is traced to the Old Testament (Vetus T.), in Exodus about 1500 BC Moyses brought the sons of Israel from the Red Sea and they went to the desert of Sour. And they marched three days in the wildness and they found no water to drink. And then they arrived to Merra and they could not drink from the water of Merra, because they were bitter, therefore he gave to the place the name Bitterness. And the people murmured against Moyses. Saying: What shall we drink? Moyses cried onto the Lord. And the Lord showed him a wood and he put it into the water and the water became sweet.

It is conceivable that the ''wood'' mentioned above had ion-exchange properties.

The Greeks were the first to express philosophical ideas about the nature of water and energy (Delyannis, 2003). Thales of Militus (640–546 BC), the first of the seven wise men of antiquity wrote about water *it is fertile and molded*. The same philosopher said for seawater: *The immense sea that surrounds the earth is primary mother of all life*. Later on Embedokles (495–435 BC) developed the theory of the elements, describing that the world consists of four primary elements: *Fire, Air, Water and Earth*, which under our contemporary knowledge may be translated to: *Energy, Atmosphere, Water and Soil*, the four basic constituents that affect the quality of our lives (Delyannis and Belessiotis, 2000). Of all philosophers of antiquity it is the well-known sage and scientist, Aristotle (384–322 BC), who described in a surprisingly correct way the origin and properties of natural, brackish and seawater. He writes for the water cycle in nature (Aristotle, 1962): Now the sun moving, as it does, sets up processes of change and becoming and decay, and by its agency the finest and sweetest water is every day carried out and is dissolved into vapor and rises to the upper regions, where it is condensed again by the cold and so returns to the earth. This, as we have said before, is the regular cycle of nature.

Even today no better explanation is given for the water cycle in nature. Really, the water cycle is a huge solar energy open distillation plant in a perpetual operational cycle. For the seawater he writes (Aristotle, 1962): Salt water when it turns into vapor becomes sweet, and the vapor does not form salt water when it condenses again. This is known by experiment.

Until medieval times no important ideas or applications of desalination by solar energy existed, but during this period, solar energy was used to fire alembics in order to concentrate dilute alcoholic solutions or herbal extracts for medical applications, and also to produce wine and various perfume oils (Figure 2.3.1). The stills or alembics were discovered in Alexandria, Egypt, during the Hellenistic period (Delyannis, 2003).

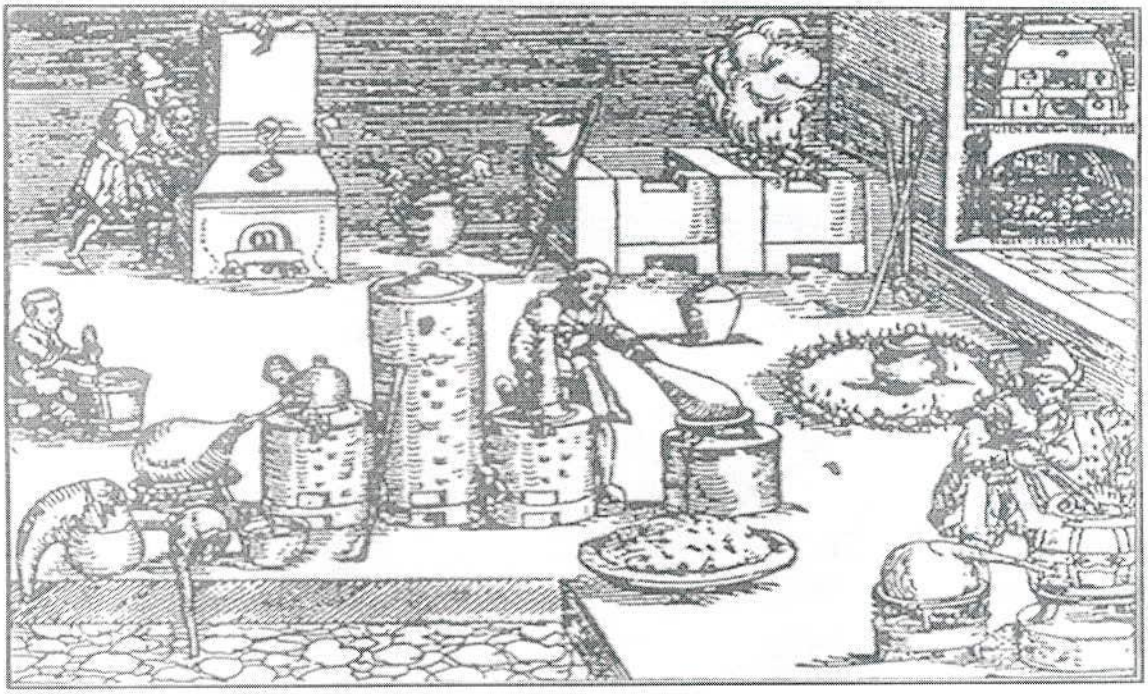

Figure 2.3.1: A mediaeval time distillation laboratory for the production of herbal extracts, wine and oil perfumes (Delyannis, 2003).

A well-known French scientist named Mouchot who experimented with solar energy, mentions in one of his numerous books that during medieval times Arab alchemists carried out experiments with polished Damascus concave mirrors to focus solar radiation onto glass vessels containing salt water in order to produce fresh water. He also reports on his own experimental work with solar energy to distill alcohol and about a metal mirror having a linear focus with a boiler located along the focal line (Mouchot, 1879).

2.3.2 Development of Solar Desalination during the Renaissance Period

The extraction of salt from salty water by means of natural evaporation has been practiced for a long time, dating from the time when salt, not water, was the precious commodity (Cooley et al., 2006). But during the Renaissance, Giovani Batista Della Porta (1535–1615), one of the most important scientists of his time wrote many books which were translated into French, Italian and German. In the first edition of his book *Magiae Naturalis* which appeared in 1558 he mentions three desalination systems. In 1589 he issued the second edition comprising 20 volumes.

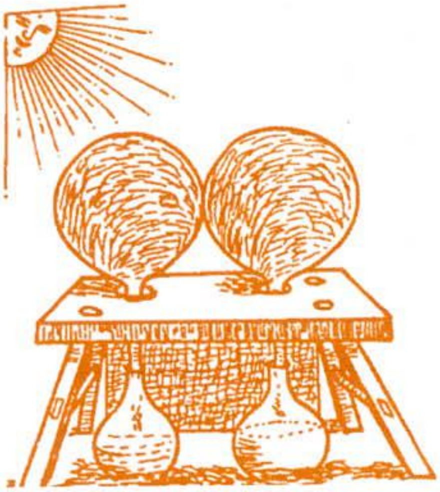

Figure 2.3.2: The Della Porta solar distillation apparatus, as presented in his book ''Magiae Naturalis'' (Mallik et al., 1982).

In the volume on distillation he mentions seven methods of desalination, but the most important reference is in the 19th volume where he describes a solar distillation apparatus that converted brackish water into fresh water. Figure 2.3.2 shows the Della Porta solar distillation unit (Nebbia and Menozzi, 1966). He also describes, in the second chapter of volume 20, a method to obtain fresh water from the air (nowadays called the humidification–dehumidification method). Up to the 1800 desalination was practiced on ship boards (El-Dessouky and Ettouney, 2002). The process involved using single stage stills operated in the batch mode. Energy is supplied from cock stoves or furnaces without recovering the heat of condensation. The equipment and product quality varied considerably and were dependent on the manufacturer and operator. Mist carryover was always a problem. The sugar industry established in the early 1800 resulted in considerable progress of evaporation processes. This involved development of more efficient and larger scale stills for production of syrup and sugar. In 1862, the great French chemist Lavoisier uses large glass lenses; mount on elaborated supporting structures, to concentrate solar energy on the contents of distillation flasks. The use of silver or aluminum coated glass reflectors to concentrate solar energy for distillation processes has also described by Mallik et.al. Thus, it appears that in 19th century scientists were familiar with harnessing solar energy for distillation not only by direct exposure to the sun but also by concentrating sun's rays by means of mirrors and lenses.

The conventional distillation plant, (commonly known as solar stills), was first designed and fabricated in 1872 near Las Salinas in Northern Chile by Carlos Wilson, a Swedish engineer (Harding, 1883). The plant was constructed to provide fresh water to the workers and their families of a saltpeter mine and a nearby silver mine. They used the saltpeter mine effluents, of very high salinity (140 g/kg or 140,000 ppm), as feed water to the stills. The plant was constructed of wood and timber framework covered with one sheet of glass. It consisted of 64 bays having a total surface area of 4450 m^2 and a total land surface area of 7896 m^2. It produced 22.70 m^3 of fresh water per day (Figure 2.3.3). The plant was in operation for about 40 years until the mines were exhausted. The device of plant was abandoned later on when cheaper and more convenient methods of desalination of water came into vogue. The major with the still was the rapid accumulation of salts in the basin making regular flushing of the still a necessity.

2.3.3 Achievements of the 20th Century

No work on solar desalination seems to have been published after 1880's till the end of the First World War (Mallik et al., 1982) and until the Second World War there existing only a few references about new solar distillation plants such as Abbot's work in developing a solar distillation device, similar to that of Mouchot. At the same time some research on solar distillation was undertaken in the USSR (Tekutchev, 1938). But in 1938, author name Abbot used cylindrical parabolic reflectors (aluminium coated surface) to focus solar energy onto evacuated tubes containing water. He also devised a 'clock-work' arrangement to track the motion of the sun. Although efficiency as high as 80% could be achieved, the boiling of water in the tubes created some problems (Abbot, 1944). Meanwhile during the years 1930–1940 the dryness in California awakened a new interest in desalination of saline water in general and some projects were started, but the depressed economy at that time did not permit any research or applications (Delyannis, 2003). Interest grew stronger during World War II, when hundreds of soldiers of the allied troops suffered from lack of drinking water while stationed in North Africa, the Pacific Ocean Islands and other isolated places (Telkes, 1945). After the war, the potential of desalination was recognized and more research work was continued in various countries. The American government, through creation and funding of the Office of Saline Water (OSW) in the early 1950s and its successor organization, the Office of Water Research and Technology (OWRT) in 1974, helped to provide much of the basic research and development of the different desalting technologies (NRC, 2008 and Buros, 1999).

A team at MIT led by Maria Telkes had already begun experiments with solar stills. Many patents were granted (Delano, 1946a; 1946b and Delano and Meisner, 1946), as practical individual small plastic solar distillation apparatuses were developed to be adaptable to lifeboats or rafts. These were used extensively by the US Navy during the War (Telkes, 1945). They were designed to float on seawater when inflated, saving many lives. Telkes continued to investigate various configurations of solar stills, glass covered and multiple-effect solar stills (Telkes, 1956a).

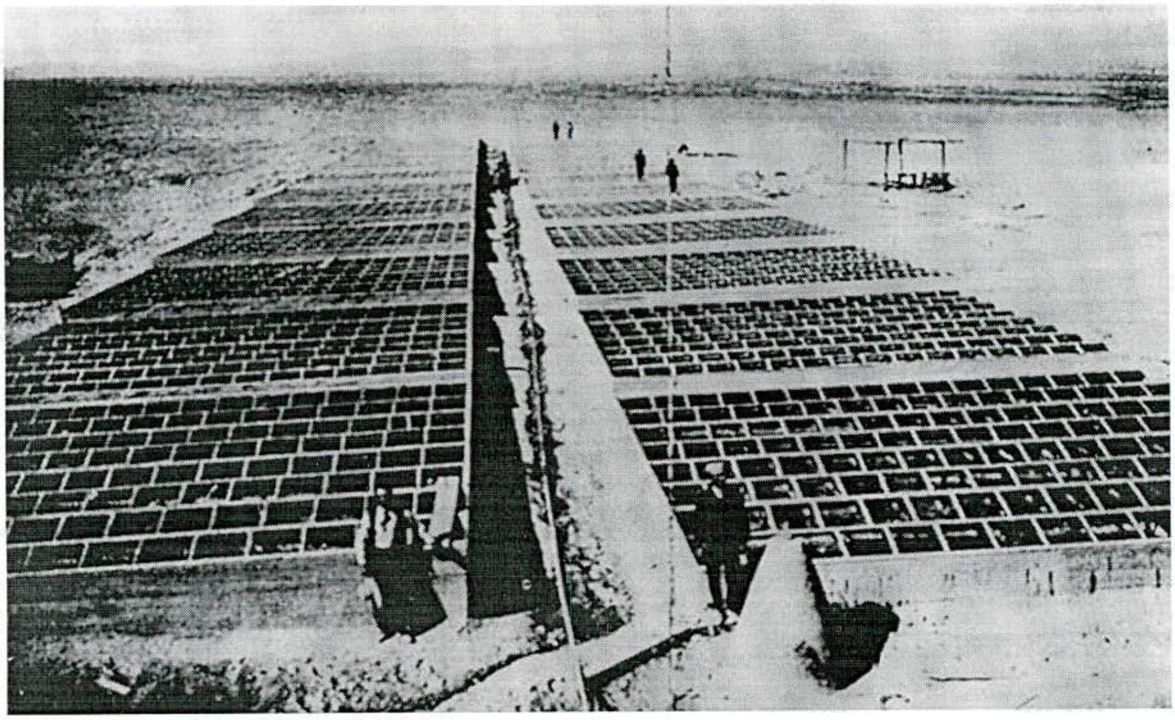

Figure 2.3.3: The world-wide first solar distillation plant at Las Salinas, Chile (Telkes, 1956b).

The next stage was to improve the operating efficiencies of the various types of solar distillation devices discussed in the article like (Virka et al., 2001; Al-Kharabsheh and Goswami, 2003; Wang and Ng, 2005 and Alnaser, 2004). Forced air circulation was tried in stills to enhance the vapor condensation rate (Kumar and Sinha, 1995). Several investigators have attempted to make use of the latent heat (Abu-Arabi and Zurigat, 2003) of the vaporization in either multi-effect systems or for preheating the brine to increase the output of the stills. Several large scale distillation plants (Bouchekima, 2003) and integrated schemes for combining electric power generation and desalination of water have also been suggested as a way of improving the overall operating efficiency of the plant. Several researchers and workers have investigated the effect of climatic, operational and design parameters on the performance of various stills. Several investigators have proposed a computer simulation for analyzing the performance of such a still (Chaibi, 2000 and El-Sebaii, 2004) and someone have also proposed a mathematical model for the still based on the various environmental and design parameters (Jubran et al., 2000; Nafey et al., 2004a and b).

Nowadays a lot of researches are being carried out on solar desalination and focused on their distillate production rate. In this consequence, the large capacity solar distillation plants have been constructed in recent years to provide fresh water for a large community. But on the other hand, if it is thinking about the fresh water supply in a small community as well as household level in the areas which are situated far away from the energy grid line and severely affected by the ground and surface water salinity like coastal areas of Bangladesh, then it is difficult to provide fresh water due to the lack of conventional desalination technique. Satisfactory completion of this work would be a good contribution in the research field of solar desalination and also an appropriate technique to provide fresh water in the coastal areas of Bangladesh.

2.4 An Overview of Desalination Processes

In order to produce freshwater from salt water a suitable separation process must be devised. The task can be accomplished in many different ways, all of them based on the principle that water and salts do not separate spontaneously, and thus require some kind of energy source to power the separation process. Historically, the first desalination units used for freshwater production were based on the evaporation of pure water via the addition of heat provided by the sun or by combustion processes. This principle, though implemented via complex and highly energy-integrated processes, still applies to current desalination technologies based on thermal separation processes.

In recent years, the development of modern polymer materials has led to the production of membranes which allow the selective passage of water (semi-permeable membranes) or ions (ionic exchange membranes), thus providing the basis for membrane desalination processes.

In general, desalination technologies can be classified according to three criteria: (1) *what is extracted* from the seawater; (2) the *type of separation process* adopted; (3) the *type of energy* used.

2.4.1 What is extracted from the Seawater?

Within the first classification desalination process technologies can be divided into two main groups: (i) processes in which water is removed from the main stream, thus producing a salt-free product; (ii) processes in which salts are removed from the main stream, thus leave the latter salt-free and this two groups also divided in various subgroup followed in the below figure 2.4.1. In the first group, some processes accomplish the separation with phase change of the produced freshwater; typically in the form of vapor and other accomplish the separation of freshwater from salt water without phase change, as in the case of pressure-driven membrane separation processes. Both the processes require a significant amount of energy given the high heat of vaporization of liquid water and the high pressure to drive liquid water through the membrane.

For the case of second group, salts can be removed from salty waters by using devices able to capture the ionic content of the stream, either by ionic exchange membranes or by ionic exchange resins. In the first case (Electro Dialyses process) ions are forced to pass through the membranes and thus separated from the main stream. In the second case (Ionic Exchange) ions are captured within the solid matrix of the resin. The processes would be discussed later separately.

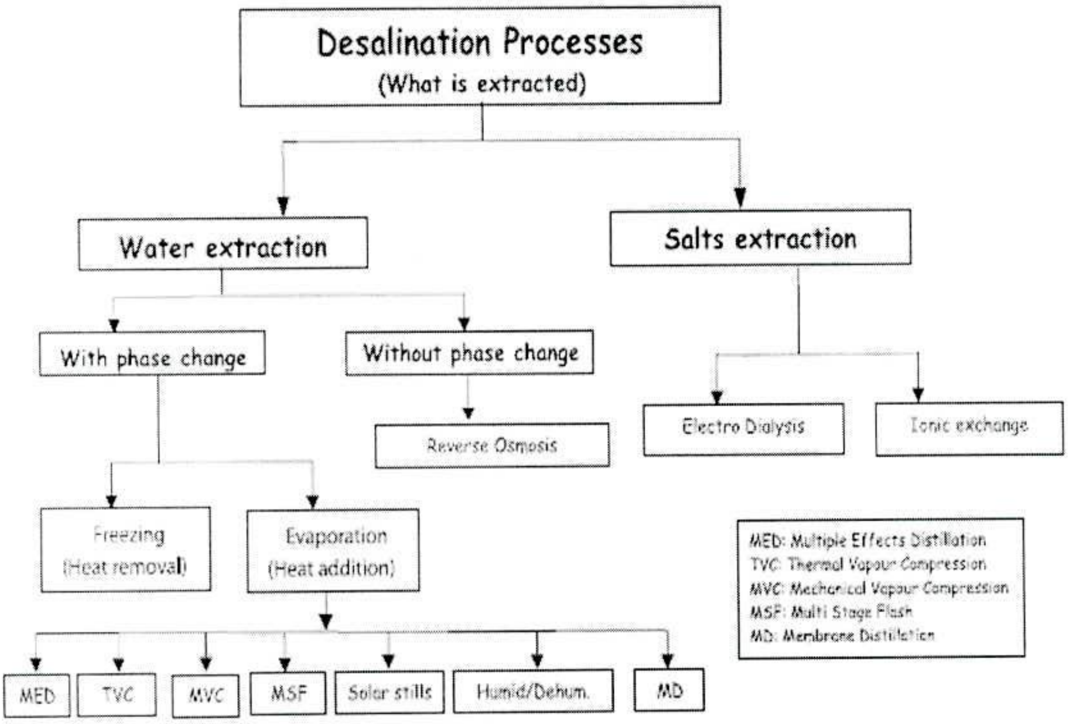

Figure 2.4.1: Desalination technologies classification based on what is extracted from the feed stream (Cipollina et al., 2009)

2.4.2 The Type of Separation Process Adopted

The second classification is made on the basis of the separation process adopted. The first group is made up of membrane processes where separation occurs by means of selective membranes. When semi-permeable membranes are used, water can pass through the membrane into the permeate stream, while salts are rejected. The second group is made up of thermal processes, where separation occurs by adding or removing heat to obtain pure water from the saline solution. Most commonly evaporation is adopted to produce pure water in the form of a vapor from liquid salty water. The vapor is then condensed, and the condensation heat is usually recovered to preheat the feed stream or to evaporate further vapor. Figure 2.4.2 shows the technologies classified according to the separation process adopted.

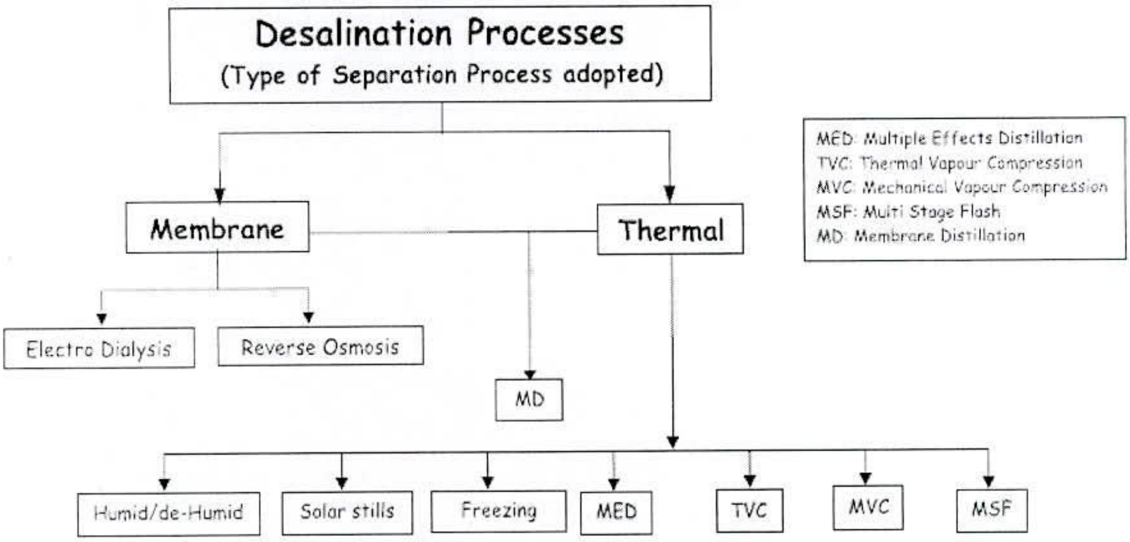

Figure 2.4.2: Desalination technologies classification based on the separation process adopted (Cipollina et al., 2009)

2.4.3 The Type of Energy Used

The third criterion classifies desalination technologies on the basis of the type of energy used, i.e. thermal, mechanical or electrical. Most evaporative processes need not only thermal energy, but also mechanical and electrical energy to power circulation pumps and auxiliary units. The present classification only accounts for thermal energy which is the prime mover for thermal technologies. It is worth noting that the classification criterion based on energy input requirements is of paramount importance when considering the possibility of coupling conventional desalination technologies with alternative sources of energy, for example in order to determine the coupling potential of desalination with solar thermal collectors, solar photovoltaic panels, wind turbines, etc. Figure 2.4.3 shows the classification based on the type of energy used.

It is observing that the desalination technologies for all three classifications are almost same but considered only from different angles. Basically, this report will be focused mainly on the solar desalination but for the better understanding and realization about the research gap, some thematic discussions on other desalination technologies will also be presented in the coming articles.

2.4.4 Multiple Effect Distillation (MED) Process

Multiple-effect distillation (MED) is the low temperature thermal process of obtaining fresh water by recovering the vapor of boiling sea water in a sequence of vessels, (called effects) each maintained at a lower temperature than the last. Because the boiling point of water decreases as pressure decreases, the vapor boiled off in one vessel can be used to heat the next one, and only the first one (at the highest pressure) requires an external source of heat (Multiple Effect Distillation). The MED evaporator consists of several consecutive cells maintained at a decreasing level of pressure (and temperature) from the first (hot) to the last (cold). Each cell (also called effect) contains a horizontal tube bundle. The top of the bundle is sprayed with sea water make-up that flows down from tube to tube by gravity. Heating steam is introduced inside the tubes. Since tubes are cooled externally by make-up flow, steam condenses into distillate (fresh water) inside the tubes. The heat released by the condensation (latent heat) warms up the sea-water outside the tubes and partly evaporates it. Due to evaporation, sea water slightly concentrates when flowing down the bundle and gives brine at the bottom of the cell. The vapor raised by sea-water evaporation is at a lower temperature than heating steam. However it can still be used as a heating medium for the next effect where the process repeats. In the last cell, the produced steam condenses in a conventional shell and tubes heat exchanger. This exchanger, called" distillate condenser" or "final condenser" is cooled by sea-water. At the outlet of the final condenser, part of the warmed sea-water is used as make-up of the unit; the other part is rejected to the sea. Brine and distillate are collected from cell to cell till the last one, where from they are extracted by centrifugal pumps. The heating steam of the first effect is generally low pressure condensing steam (as low as 0.3 bar abs). Other heating media (such as hot water) may be used. The whole schematic diagram of process description for MED is shown in Figure 2.4.4.

In MED, evaporation occurs on the external surface of a tube bundle which is heated by motive steam condensing inside the tubes. Vapor produced in one effect is then used as motive steam in the following effect, which operates at lower pressure and, therefore, at a lower boiling temperature. Such a heat integration arrangement allows the attainment of very high energy efficiency for the process. In order to enhance the process energy efficiency further, MED units can also be coupled to vapors recovery devices. Thermal Vapor Compression (TVC) and Mechanical Vapor Compression (MVC) are the most common systems. In TVC part of the vapor from the last effect is recompressed by a steam ejector (powered by mid-pressure steam), and then used as motive steam for the first effect, thus increasing the performance of distillate per kg of mid pressure motive steam fed into the ejector.

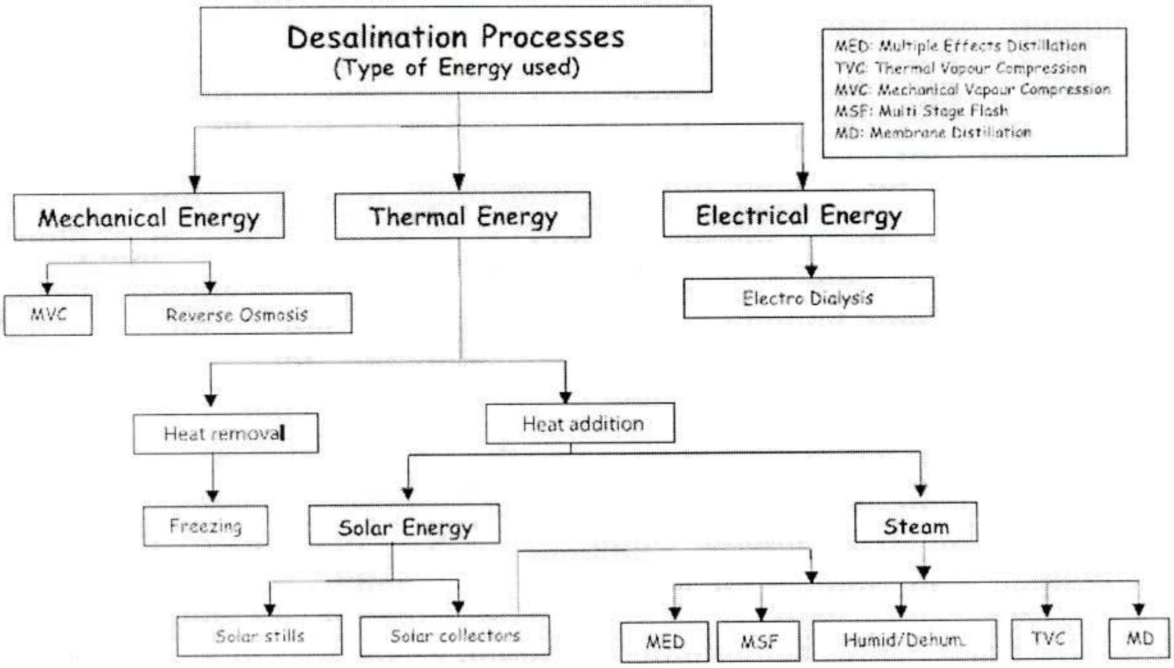

Figure 2.4.3: Desalination technologies classification based on the type of energy used (Cipollina et al., 2009)

In MVC all the vapor exiting from the last effect is directly compressed by a mechanical compressor, and then used as motive steam in the first effect. In this case only mechanical (or electrical) energy is used to power the process.

2.4.5 Thermal Vapor Compression (TVC) Process

TVC is a process used to remove salt from seawater, by evaporating it through a fine mesh filter that traps the brine particles so that the vapor can then be condensed in a relatively salt-free state (IDA, 2006). In this process a blower, compressor or jet ejector is used to compress, and thus, increase the pressure of the vapor produced. Since the pressure increase of the vapor also generates an increase in the condensation temperature, the same vapor can serve as the heating medium for its "mother" liquid or solution being concentrated, from which the vapor was generated to begin with. If no compression was provided, the vapor would be at the same temperature as the boiling liquid/solution, and no heat transfer could take place (Thermal vapor compression, (TVC)).

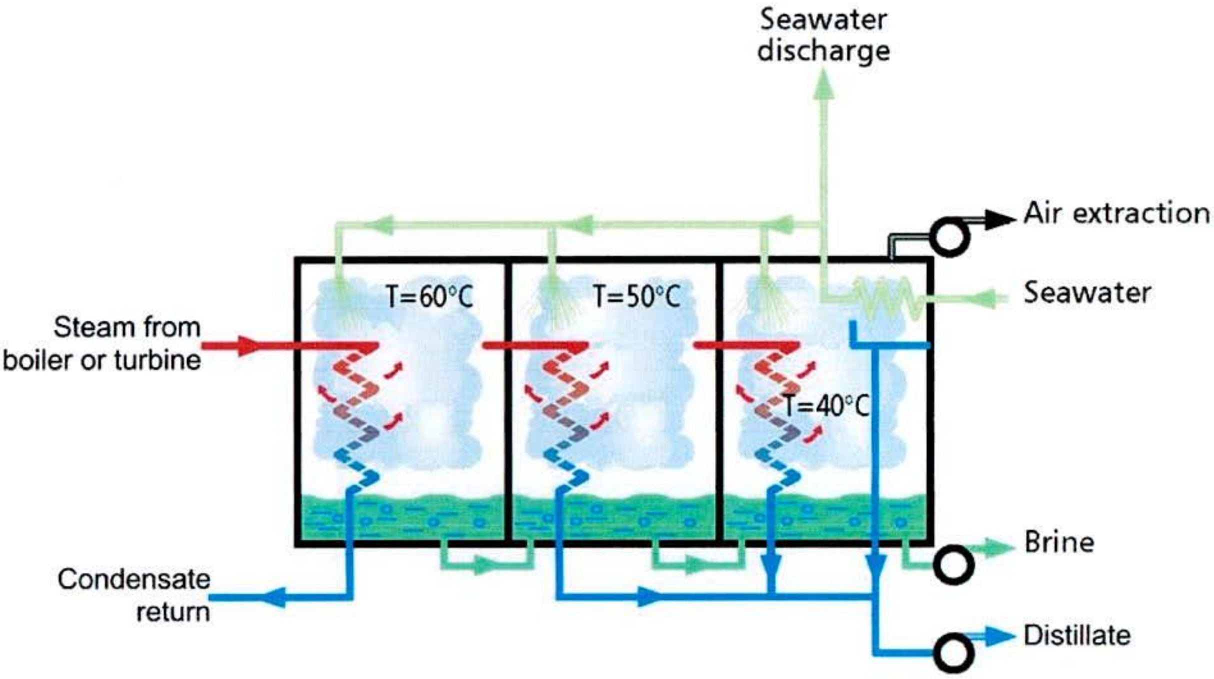

Figure 2.4.4: Schematic Diagram of Multiple-effect distillation (Multiple Effect Distillation)

Single effect thermal vapor compression (TVC) seawater desalination process in its simple form is illustrated schematically in Figure 2.4.5. The main components of the unit are the evaporator, the steam jet ejector, and the feed heater or the condenser. The evaporator consists of an evaporator/condenser heat exchanger, a vapor space, a water distribution system, and a mist eliminator. On the other hand, the steam jet ejector is composed of a steam nozzle, a suction chamber, a mixing nozzle, and a diffuser. The feed heater or the heat sink unit is usually a counter-current surface condenser in which the non-condensable gases leave at a temperature approaching the temperature of the feed water. This permit the cooling of the non-condensable gases to the minimum possible temperature, thereby, minimizing the amount of vapor that may escape with the gases and decreases the volume of pumped gases. In addition, it is possible to operate the counter-current condenser so that the exit water is within 3 to 5 ^{0}C of the condensation temperature of the saturated vapor. This improves the thermal performance of the unit and minimizes the mass flow rate of cooling water.

The intake seawater at a flow rate and salt concentration is introduced into the tube side of the condenser where its temperature increases. The cooling water is dumped back to the sea. The function of circulating the cooling water in the condenser is the removal of the excess heat added to the system in the form of motive steam necessary to drive the steam jet ejector. It is important to emphasize that the evaporator does not consume the supplied heat; instead, it simply degrades its quality. The heating of the feed seawater in the condenser is essential to increase the thermal performance of the process. The heat needed to warm the seawater inside the condenser is supplied by condensing a controlled portion of vapor formed by boiling in the evaporator. The vapor condensation temperature and consequently the pressure in the vapor space for both the evaporator and the condenser is controlled by

- The cooling water flow rate
- Feed water temperature,
- The available heat transfer area in the condenser.
- The overall heat transfer coefficient between the condensing vapor and the circulating seawater.

Accordingly, the condenser has three functions: (1) remove excess heat from the system, (2) improve the process performance ratio, PR, and (3) adjust the boiling temperature inside the evaporator. The feed seawater is chemically treated and desecrated before being pumped to the evaporator. The chemical treatment is needed to prevent the foaming and the tendency for scale formation in the evaporator. Both factors may seriously impair unit operation. Within, the evaporator, the feed water is sprayed at the top where it falls in the form of thin film down the succeeding rows of tubes arranged horizontally.

The feed water temperature is raised to the boiling temperature. The magnitude of boiling temperature is dictated by the nature of chemicals used to control the scale formation and the state of the heating steam. This temperature is mastered through settling the pressure in the vapor space of the evaporator. The vapor formed by boiling is free of salts. It generated therein flows through a knitted wire mist separator known as wire mesh demister to remove the entrained brine droplets. The vapor should be completely freed from brine droplets to prevent the contamination of both the product water and the heat transfer surfaces on which it condenses.

The conclusion drawn to compatible the above discussion with this report is that the single-effect thermal vapor compression is a desalination process but needs a high cost for the construction of evaporator, condenser, seawater pump and also for operation & maintenance of the process. But this study is going to focus on the household level desalination processes which will be the suitable alternative for fresh water supply in the coastal areas as well as the saline affected areas of Bangladesh.

2.4.6 Mechanical Vapor Compression (MVC) Process

Vapor compression desalination refers to a distillation process where the evaporation of sea or saline water is obtained by the application of heat delivered by compressed vapor. Since compression of the vapor increases both the pressure and temperature of the vapor, it is possible to use the latent heat rejected during condensation to generate additional vapor. The effect of compressing water vapor can be done by two methods where mechanical vapor compression (MVC) is one of them which compress water vapor by means of electrically driven mechanical device. The MVC process comprises two different versions: Vapor Compression (VC) and Vacuum Vapor Compression (VVC). VC designates those systems in which the evaporation effect takes place at manometric pressure, and VVC the systems in which evaporation takes place at sub-atmospheric pressures (under vacuum) (Vapor-compression desalination).

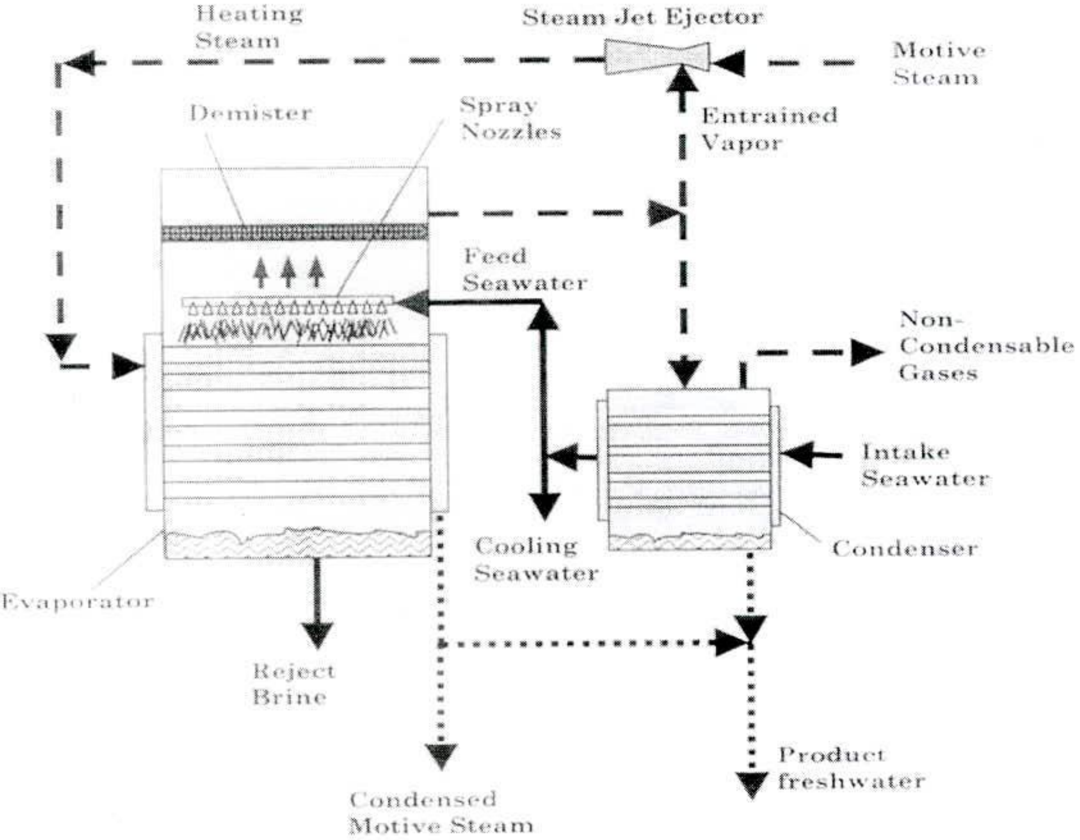

Figure 2.4.5: Single effect thermal vapor compression evaporator-desalination process (El-Dessouky and Ettouney, 2002)

The mechanical vapor-compression desalination process (MVC) is the most attractive among various single stage desalination processes. The MVC system is compact, confined, and does not require external heating source (Aly and El-Fiqi, 2003), which is opposite to thermal, absorption, or adsorption vapor compression. The system is driven by electric power; therefore, it is suitable for remote population areas with access to power grid lines.

The major part of literature studies of the MVC system will be focused on description of system characteristics but modeling and analysis will not be discussed although various authors (Al-Juwayhel et al., 1997; Veza, 1995 and Zimerman, 1994) have conducted their work on the modeling, performance and analysis of MVC system. The MVC system contains five major elements, which include mechanical vapor compressor, evaporator, preheaters for the intake seawater, brine and product pumps, and venting system. Figure 2.4.6 shows a schematic diagram for the system. As is shown, the compressor and evaporator form one single unit. The evaporator contains falling film horizontal tubes, spray nozzles, suction vapor tube, and wire-mesh mist eliminator.

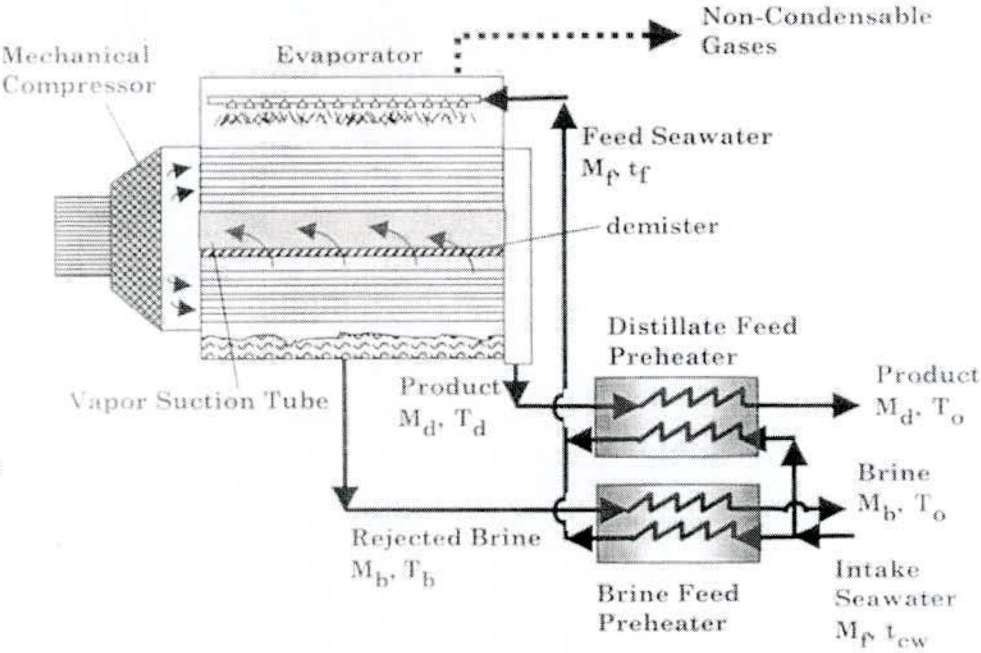

Figure 2.4.6: Single effect mechanical vapor compression (MVC) (El-Dessouky and Ettouney, 2002)

The feed preheaters are plate type heat exchanger, which operates on the intake seawater and the hot liquid streams leaving the evaporator. The feed seawater is entered the evaporator and is sprayed over the horizontal tubes. The spray forms a falling film over succeeding tube rows. Formation of the thin film enhances the heat transfer rate and makes the evaporation process more efficient. The seawater temperature increases before evaporation commences. The vapors transfer from the evaporator section to the compressor through the vapor suction tube, which is guarded by a wire-mesh mist eliminator. This is necessary to avoid entrainment of brine droplets in the vapor stream, which would result in damage of the compressor blades. Limited temperature depression occurs as the vapors flow through the demister. The vapors flow tangentially through the compressor, where it is superheated.

Upon compression, the vapors are forced inside the horizontal tubes, where it loses the superheat energy and its temperature drops. Condensation takes place and the released latent heat is transferred to the brine film. The temperature difference affects the compressor power consumption and is dictated by the temperature of the feed seawater. The balance of energy within the system is maintained by recovery of the thermal load in the rejected brine and product streams. This is achieved in the feed preheater, which a plate type heat exchanger. The rejected brine and product streams leaving the evaporator are at higher temperatures. As heat is exchanged between the three streams the temperature of the seawater is increased and the temperature of the rejected brine and product streams is reduced.

Inside the evaporator, the temperature of the feed seawater increases. The formed vapor is at the same boiling temperature, which is higher than the saturation temperature. The formed vapor is compressed and superheated. Condensation of the compressed vapor takes place at a specified temperature.

2.4.7 Multiple Stage Flash (MSF) Process

MSF plants are major contributors to the world desalting capacity. The principle of MSF is that heated water will boil rapidly (flash) when the pressure of the vapor is rapidly reduced below the vapor pressure of the liquid at that temperature. The vapor that is generated is condensed onto surfaces that are in contact with feed water, thus heating it prior to its introduction into the flash chamber. This will recover most of the heat of vaporization. Approximately 25%–50% of the flow is recovered as fresh water in multistage plants. Characteristics of MSF plants include high feed water volume and flow, corrosion and scaling in the plant, and high rates of use of treatment chemicals (Cotruvo et al., 2010).

An evaporator consists of several consecutive stages (Figure 2.4.7) maintained at decreasing pressures from the first stage (hot) to the last stage (cold). Sea-water flows through the tubes of the heat exchangers where it is warmed by condensation of the vapor produced in each stage. Its temperature increases from sea temperature to inlet temperature of the brine heater. The sea water then flows through the brine heater where it receives the heat necessary for the process (generally by condensing steam). At the outlet of the brine heater, when entering the first cell, sea water is overheated compared to the temperature and pressure of stage 1. Thus it will immediately "flash" i.e. release heat, and thus vapor, to reach equilibrium with stage conditions. The produced vapor is condensed into fresh water on the tubular exchanger at the top of the stage. The process takes place again when the water is introduced into the following stage, and so on until the last and coldest stage. The cumulated fresh water builds up the distillate production which is extracted from the coldest stage. Sea water slightly concentrates from stage to stage and builds up the brine flow which is extracted from the last stage.

The once-through flash type evaporator uses the sea-water flow both for purposes of cooling (sea-water is introduced into the evaporator at the sea temperature and is rejected at the brine temperature) and production of distillate (by flashing from the outlet temperature of the brine heater to the brine extraction temperature). This has two consequences on plant design:

- The whole sea water flow being heated to high temperature, it has to be treated with anti-scale which increases operating costs.
- As the sea water flow cannot be decreased below values allowing safe working conditions, the stages must be designed for winter operation, leading to an increased evaporator volume and thus increased investment costs.

These two points have led to the separation of the two functions (cooling and production). The cooling sea-water flows through the condensers of the two (or generally three) last stages, named "heat reject section". Upon leaving the evaporator, part of the warmed water is rejected to the sea, part is used as the make-up for the plant. Only this part of the water is treated instead of the whole cooling water. The production is insured by the brine recycling flow that is drawn from the last stage towards the condensers of the other stages, named "heat gain section", and then to the brine heater. The warmed water leaving the heat reject section may be used in winter to warm up the cooling sea-water, thus enabling the evaporator volume to be designed for a reasonably high temperature.

2.4.8 Membrane Distillation (MD)

A separation method in which a non-wetting, micro-porous membrane is used with a liquid feed phase on one side of the membrane and a condensing, permeate phase on the other side. Separation by membrane distillation is based on the relative volatility of various components in the feed solution. The driving force for transport is the partial pressure difference across the membrane. Separation occurs when vapor from components of higher volatility passes through the membrane pores by a convective or diffusive mechanism (McGraw-Hill Encyclopedia). Membrane distillation is a hybrid of thermal distillation and membrane processes best described as trans-membrane evaporation. The driving force is a temperature difference between the feed water and permeate which results in a vapor pressure differential across a hydrophobic porous membrane (in contrast to pressure as driving force for RO and electrical potential as driving force for ED). Vapor evolved from the feed solution passes through the pores of the membrane and is collected on the other side. Since liquid does not penetrate the hydrophobic membrane, dissolved ions are completely rejected by the membrane.

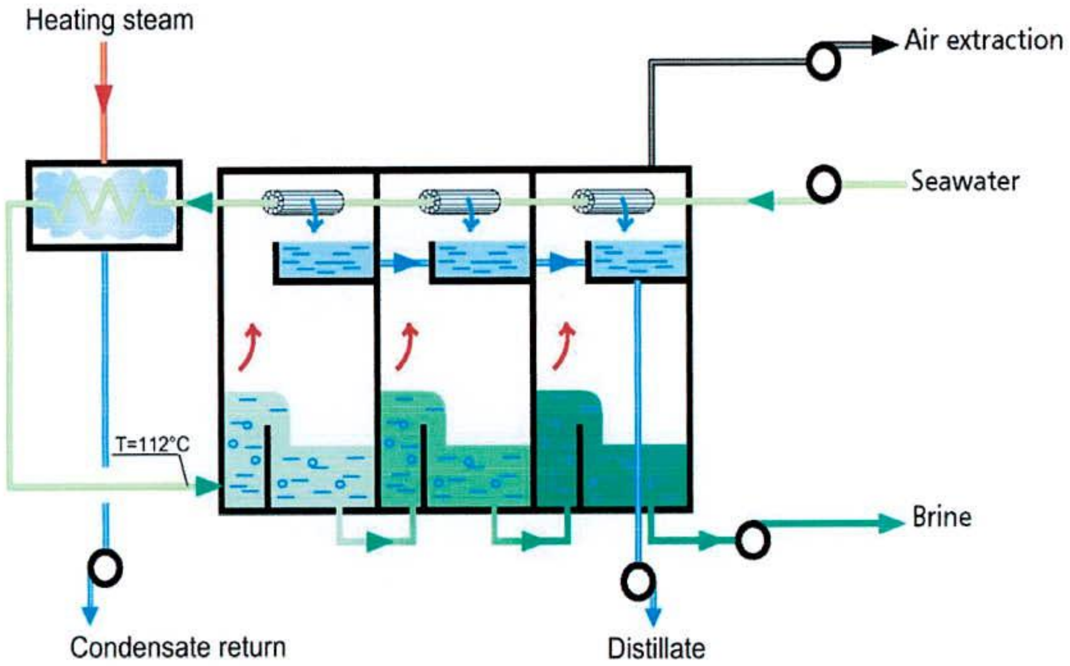

Figure 2.4.7: Desalination by Multi-stage Flush Process (Multiple Stage Flash Processes).

Methods for collecting the vapor permeate include immediate condensation within a colder liquid flowing on the second side of the membrane or condensation on a cold surface located at some distance from the membrane. In the latter situation, vacuum can be applied to draw more vapors through the membrane. The materials used most commonly to produce hydrophobic membranes suitable for membrane distillation are polypropylene (PP), polytetrafluoroethylene (PTFE), and polyvinyldeneflouride (PVDF). Nonetheless, the number of commercial applications of membrane distillation is small but growing. The main advantages of membrane distillation over conventional distillation process are: lower operating temperatures, compact modules, mist elimination, production of ultra pure water, and the possibility of overcoming corrosion problems by using plastic equipment. The process can use such available energy resources as solar energy or waste energy in industrial processes.

Bier et al. (1995) constructed solar powered membrane distillation (SPMD) using an air gap membrane distillation (AGMD) module instead of the direct contact membrane distillation (DCMD) module tested in the SPMD pilot plant. The latent heat recovery process in this late pilot plant was integrated with MD in a spiral-wound membrane module. However, the additional mass transfer resistance created by the air gap resulted in a large reduction in the trans-membrane water flux. Recently, Koschilkowski et al. (2003) used a similar membrane module to that used by Bier et al. in their study of a SPMD pilot plant. According to their calculations, without heat storage, the plant can distill 150 L/d of water in the summer in a southern country. Banat et al. (2002) integrated a MD module with a solar still to produce potable water from simulated seawater. In their investigations the solar still was used for both seawater heating and potable water production. The effect of some factors affecting flux of the membrane module was also investigated. Their experimental studies showed that the contribution of the solar still in the distillate production was no more than 20% of the total flux. The desalination performance and O&M procedures of an air-gap type membrane distillation system was tested (Walton et al., 2004) using low grade thermal energy (between 13 and 75°C) supplied by a salt-gradient solar pond. The entire system (an air gap membrane distillation module, 2.94 m^2 plus controlling pumps and heaters) built by SCARAB (Swedish firm http://www.hvr.se) was used in this study. Hot brine was pumped from the bottom of the solar pond and passed through a heat exchanger to supply heat. Cold water from the solar pond surface was passed through a heat exchanger to provide cooling. High and low temperatures for system operation were obtained by changing the flow rates for solar pond hot and cold water. The permeate flux was fluctuating and reached a maximum of 6 L/m^2.hr.

2.4.9 Reverse Osmosis (RO) Process

Reverse osmosis (RO) is a membrane technical filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution when it is on one side of a selective membrane. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective," this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as the solvent) to pass freely (Wikipedia on Answers.com). In the natural osmosis, diffusion of fluid (usually water) occurs through a semi-permeable membrane from a solution with a low solute concentration to a solution with a higher solute concentration until equilibrium of fluid concentration on both sides of the membrane is reached. The pressure difference between the two sides of the membrane equals to osmotic pressure of the solution. The chemical potential gradient across the membrane acts as the driving force for the water transport. By applying a pressure in excess of the osmotic pressure, pure water flows from the high solute concentration side through a membrane to the low solute concentration side and thus, the separation of water from the solution is achieved. This is the reverse of the normal osmosis process and termed as "reverse osmosis" (Figure 2.4.8). The membrane between the two liquid phases is semi-permeable which allows the passage of water but not the solutes. There are key differences between reverse osmosis and filtration. The predominant removal mechanism in membrane filtration is straining, or size exclusion, so the process can theoretically achieve perfect exclusion of particles regardless of operational parameters such as influent pressure and concentration (Reverse osmosis). Reverse osmosis, however, involves a diffusive mechanism so that separation efficiency is dependent on solute concentration, pressure, and water flux rate (Crittenden et al., 2005). Reverse osmosis is most commonly known for its use in drinking water purification from seawater, removing the salt and other substances from the water molecules.

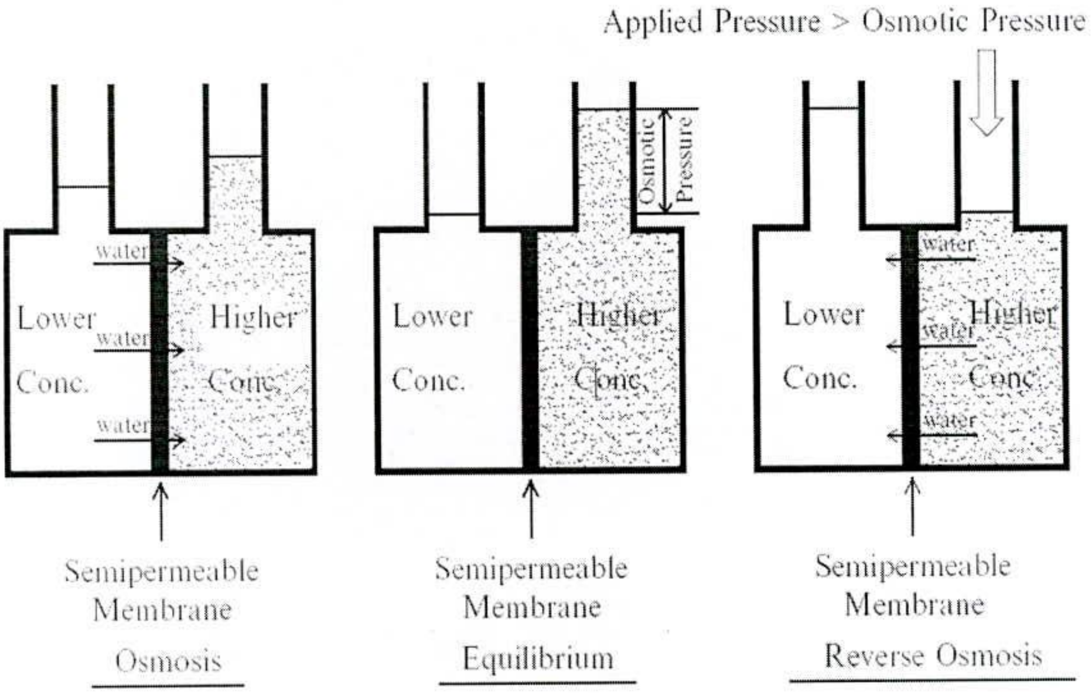

Figure 2.4.8: Definition diagram of Reverse Osmosis (RO) Process(Wikipedia on Answers.com)

The process of osmosis through semi-permeable membranes was first observed in 1748 by Jean Antoine Nollet. For the following 200 years, osmosis was only a phenomenon observed in the laboratory. In 1949, the University Of California At Los Angeles (UCLA) first investigated desalination of seawater using semi-permeable membranes. Researchers from both UCLA and the University of Florida successfully produced fresh water from seawater in the mid-1950s, but the flux was too low to be commercially viable (Glater, 1998). By the end of 2001, about 15,200 desalination plants were in operation or in the planning stages worldwide.

Operation Principle

The operation principle of reverse osmosis is a pressure driven process where a pressure difference greater than the osmotic pressure is applied across a suitable semi-permeable membrane. Fresh water passes from the concentrated salt solution to the dilute one. In practice, the saline feed water is pumped into a closed vessel where it is pressurized against the membrane. As a portion of the water passes through the membrane, the remaining feed water increases in salt content. At the same time, a portion of this feed water is discharged without passing through the membrane. The amount of the feed water discharged to waste in the brine stream varies from 20 to 70% of the feed flow, depending on the salt content of the feed water, pressure, and type of membrane. A typical recovery value for a seawater RO system is only 40% (Spiegler, and El-Sayed, 1994). An RO desalination plant essentially consists of four major systems:

- Pretreatment
- High-pressure pump
- Membrane assembly
- Post-treatment

To extend membrane life, extensive pretreatment is usually required to condition the feed seawater. Therefore, suspended solids must be removed and the water pretreated so that salt precipitation or microbial growth does not occur on the membranes. Usually, the pretreatment consists of fine filtration and the addition of acid or other chemicals to inhibit precipitation and the growth of microorganisms. The high-pressure pump supplies the pressure needed to enable the water to pass through the membrane and have the salts rejected. Pressurizing the saline water accounts for most of the energy consumed by RO. Since the osmotic pressure, and hence the pressure required to perform the separation is directly related to the salt concentration, RO is often the method chosen for brackish water, where only low to intermediate pressures are required. The operating pressure ranges from 15 to 25 bar (225 to 375 psi) for brackish water and from 54 to 80 bar (800 to 1180 psi) for sea water with an osmotic pressure of 25 bar (Buros, 2000). Energy recovery from the high-pressure brine leaving an RO plant plays an important part in reducing the total energy consumption for desalination, especially in large-scale RO plants for seawater desalination.

2.4.10 Electro Dialysis (ED) process

Electro-dialysis (ED) is used to transport salt ions from one solution through ion-exchange membranes to another solution under the influence of an applied electric potential difference. This is done in a configuration called an electro-dialysis cell. The cell consists of a feed (dilute) compartment and a concentrate (brine) compartment formed by an anion exchange membrane and a cation exchange membrane placed between two electrodes. In almost all practical electro-dialysis processes, multiple electro-dialysis cells are arranged into a configuration called an electro-dialysis stack, with alternating anion and cation exchange membranes forming the multiple electro-dialysis cells. Electro-dialysis processes are different compared to distillation techniques and other membrane based processes (such as reverse osmosis) in that dissolved species are moved away from the feed stream rather than the reverse. Because the quantity of dissolved species in the feed stream is far less than that of the fluid, electro-dialysis offers the practical advantage of much higher feed recovery in many applications (Strathmann, 2004).

Electro-dialysis (ED) has been in commercial use since 1952 for desalting brackish well water in the Arabian Desert, over 10 years prior to RO application. As illustrated in Figure 2.4.8, an electro-dialyzer comprises a stack of anion and cation exchange membrane pairs, with an anode at one end of the stack and a cathode at the other. When electrodes, in a solution of saline water, are connected to an external source of direct current, e.g. a battery, electrical current is carried through the solution, with the ions forced to migrate to the electrode with the opposite charge (positively charged ions migrate to the cathode and negatively charged ions migrate to the anode). The anions can move freely through the nearest anion exchange membrane, but their further progress toward the anode is blocked by the adjacent cation exchange membrane. In the same manner, the cations move in the opposite direction, through the nearest cation exchange membrane, but are then blocked from further progress by the adjacent anion exchange membrane. Via this arrangement, concentrated and dilute solutions are created in the spaces between the alternating membranes. Using this process, it is possible to feed brackish water into the dilution compartment inlet and obtain potable water at its outlet. Each stage in ED system has a salt removal rate of about 50%. Therefore several stages are often needed, depending on the feed water salinity and the desired product water quality. As the cost of the system increases dramatically with the number of stages required, ED systems are most cost-competitive for brackish water desalination. Pretreatment depends upon the quality of feed water. Post-treatment involves pH adjustment and disinfection. Routine maintenance includes cleaning of membranes to control scale and bio-fouling, usually by flushing the system with base and then with acid. Membranes must be replaced about every 10 years. Electrodes can degrade over time due to oxidation. Operation can be in continuous or batch mode; continuous mode is more common.

ED systems can be operated intermittently without any significant decrease in membrane life or efficiency, making them suitable for use as deferrable load. The membranes of ED units are subject to fouling, and thus some pretreatment of the feed water is usually necessary. The electro-dialysis reversal (EDR) process was developed to help eliminate membrane fouling. In the EDR process, the membrane polarity is reversed several times an hour. This has the effect of switching the brine channels to freshwater channels, and the freshwater channels to brine channels, and breaks up and flushes out deposits.

Hydrolysis and scaling represent the major obstacles to stable and efficient electro-dialyzer operation. Hydrolysis occurs in the electrolyte solution near the membrane surface, only if the current density exceeds a limit, which is determined by the ion depletion layer that forms near the surface of membranes in the dilution compartments.

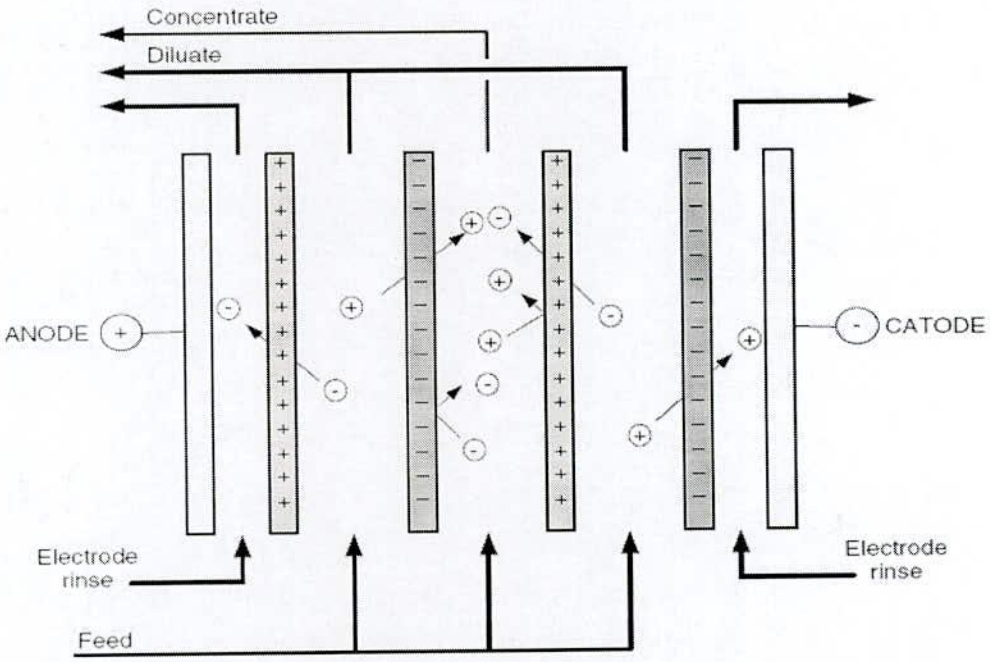

Figure 2.4.9: Flow diagram of a typical electro-dialysis operation (Cipollina et al., 2009).

Hydrolysis begins when Na^+ and Cl^- ions become unavailable at the membrane surface, and the resulting H^+ and OH^- ions are then transported through the cation and anion exchange membranes, respectively, into the concentration compartments: here $Mg(OH)_2$ may be deposited as scale, thus lowering the efficiency of ED. Because electro-dialysis operates by removing ionic solutes from the feed water, it has no effect on non-ionic solutes, such as organic matter, silica, and microorganisms. Therefore it cannot disinfect water. For water supplies with high silica levels, pretreatment is necessary to remove the silica. In such cases, RO might be a better choice than ED. Because electro-dialysis is only cost effective for brackish water desalination, it accounts for only 5.7% of world desalting capacity and comprises only 12.8% of desalination installations (Wangnick, 1995).

Electro-dialysis process has seen widespread applications for a number of purposes including the production of potable water which is one of the most important. Due to its modular structure, ED is available in a wide range of sizes, from small (down to 2 m^3/d) to large product water capacities (European Commission, 2002). ED is widely used in USA with 31% of the total installed capacity. In Europe ED process accounts for 15% while in the Middle East for 23% of the total installed capacity (Bier and Plantikow, 1995).

The disadvantages of ED compared with RO are that ED cannot remove non-ionic solutes such as microorganisms and silica; ED systems take up more space than RO; and ED becomes significantly more expensive at salinity above 5.000 ppm.

2.4.11 Humidification-Dehumidification (HD)

Nature uses solar energy to desalinate ocean water by means of the rain cycle. In the rain cycle, sea water gets heated (by solar irradiation) and humidifies the air which acts as a carrier gas. Then the humidified air rises and forms clouds. Eventually, the clouds 'dehumidify' as rain. The man-made version of this cycle is called the humidification-dehumidification desalination (HDH) cycle (Narayan et al., 2010).

Conventional HDH process is formed of three main parts, see Figure 2.4.10. These are the humidifier, where the intake air humidity is increased to saturation conditions, the condenser,

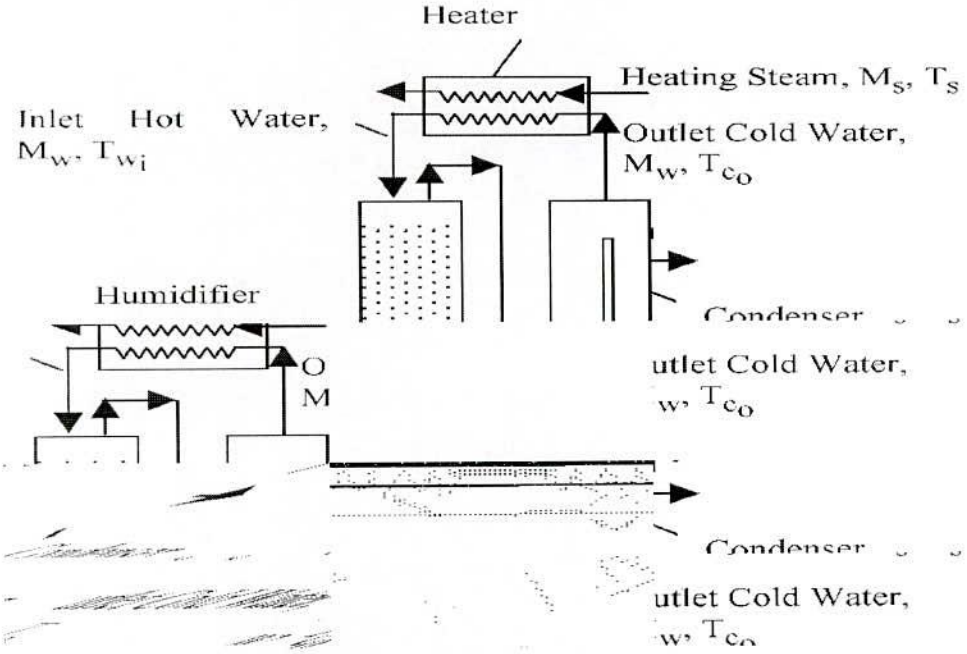

Figure 2.4.10: Conventional humidification-dehumidification desalination (HDH) cycle (Rizzuti et al., 2006).

where the humidified air is cooled to condense the product water, and the feed seawater heater. It should be noted that the intake seawater is preheated in the dehumidification unit. The feed seawater is further heated in the feed heater in order to achieve the desired design conditions. These are achieved with the aid of an external heat source, for example solar collector, heating steam, diesel engine, or other forms of low grade energy.

There are several other forms of the humidification-dehumidification desalination process, which include vapor compression, membrane separation, and desiccant absorption (Ettouney, 2005). A schematic for the vapor compression process is shown in Figure 2.4.11. This system was proposed by Vlachogiannis et al. (1999). In this configuration, the humidified air is compressed to higher pressure. This results in simultaneous increase in the air temperature and pressure. The compressed air is then cooled against the feed seawater. This results in water vapor condensation. The system includes the conventional air humidifier and the air/vapor compressor. The system shown in Figure 2.4.10 includes simultaneous heating of the humidifier air and water streams through exchange of heat with the compressed humidified air stream.

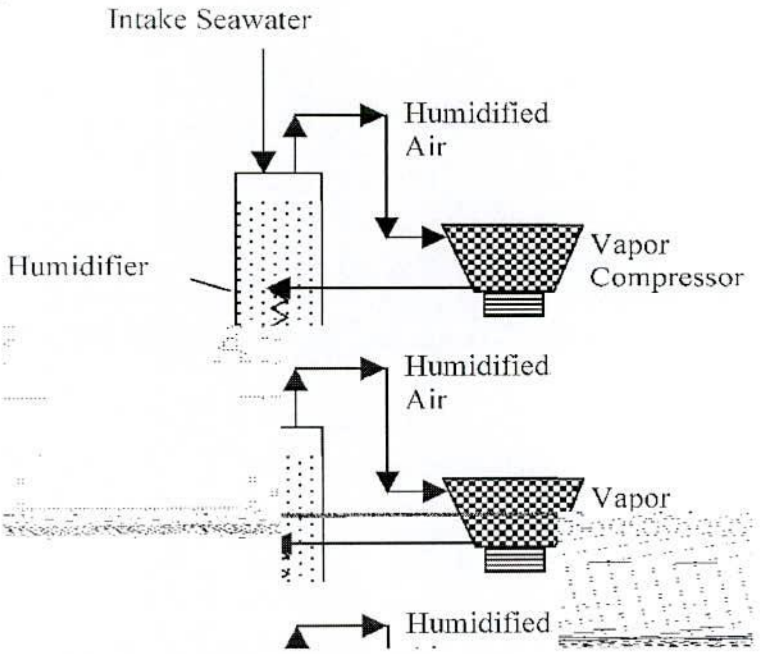

Figure 2.4.11: Humidification vapor compression (Rizzuti et al., 2006)

This setup can be modified by using a separate water preheater (water vapor condenser) system, as in the conventional HDH system. This is more technically feasible, since the air humidification unit and the water vapor condenser are not a specially designed system, as shown in the unit in Figure 2.4.11. A schematic for the humidification desiccant absorption/adsorption is shown in Figure 2.4.11 The desiccant material can be in liquid form, i.e., lithium bromide solution, or in a solid form, i.e., zeolite. The adsorption process is unsteady, therefore it is necessary to use two solid beds, one for the adsorption process and the second for regeneration or water vapor desorption. The main feature of the absorption/adsorption processes is the generation of a large amount of heat, which can be used for preheating the feed water. Desiccant regeneration requires use of an external heating source, which could be heating steam or a diesel engine. The main merit of this process is its proven high efficiency (Rizzuti et al., 2006). However, a main drawback is the lack of field experience in design, operation, and maintenance of the desiccant absorption units. Also, it is evident from the process diagram see Figure 2.4.11, the need to operate a large number of units, which include air humidifier, absorption/adsorption bed, regeneration unit, desiccant heat exchanger, and water vapor condenser.

The humidification membrane air drying system is shown in Figure 2.4.12. The humidifier characteristics are similar to those in the conventional HDH. As is shown, the humidified air stream is compressed and passed through the membrane unit. The selective properties of the membrane result in permeation of the air humidity from the feed to the permeate side. As shown in Figure 2.4.12, the compressed dried air leaves at the other end of the membrane drying unit. The literature includes a number of studies on the humidification dehumidification desalination systems. Findings in few of these studies are given in brief. Goosen et al. (2000) reviewed various layouts of thee humidification/dehumidification desalination systems as well as single/multiple effect solar desalination (Goosen et al., 2000). The authors stressed the fact that many of these units are limited to theoretical evaluation or prototype scale; however, increase in future demand for fresh water might make several of these processes viable for fresh water production. Müller -Holst et al. (1999) described the performance of an optimized humidification/dehumidification desalination system. A main feature of this patent configuration is that the flow of the air stream is driven by natural convection. The system is also associated with a solar collector. Therefore, continuous operation of the unit requires the use of a heat storage system. The system is designed for operation in remote areas with minimal maintenance requirements. This is achieved in part by low temperature operation, which minimizes the rate of scale formation. Farid and Al-Hajaj (1999) constructed a small-scale humidification dehumidification unit with a capacity of 2 L/m^2. Such capacity is much larger than that for a single basin solar still which is discussed later. The system utilized a combination of a water heater and a solar collector. Other studies by Al-Hallaj et al. (1998) and Nawayseh et al. (1997) covered additional aspects, which include modeling, evaluation of the heat and mass transfer coefficients, and field performance. Chafik (2004) evaluated the performance of a Multi-effect humidification dehumidification system, where the air is heated and humidified in a solar collector arrangement. This procedure increases the air humidity to very large values and increases the system productivity. The air humidity chart for this process is shown in Figure 2.4.12. As is shown, for a five effect system, the air humidity is increased from 0.0106 kg H_2O/kg dry air to 0.037kg H_2O/kg dry air. Chafik (2004) reported an optimum of five effects that produces the minimum cost for desalinated water.

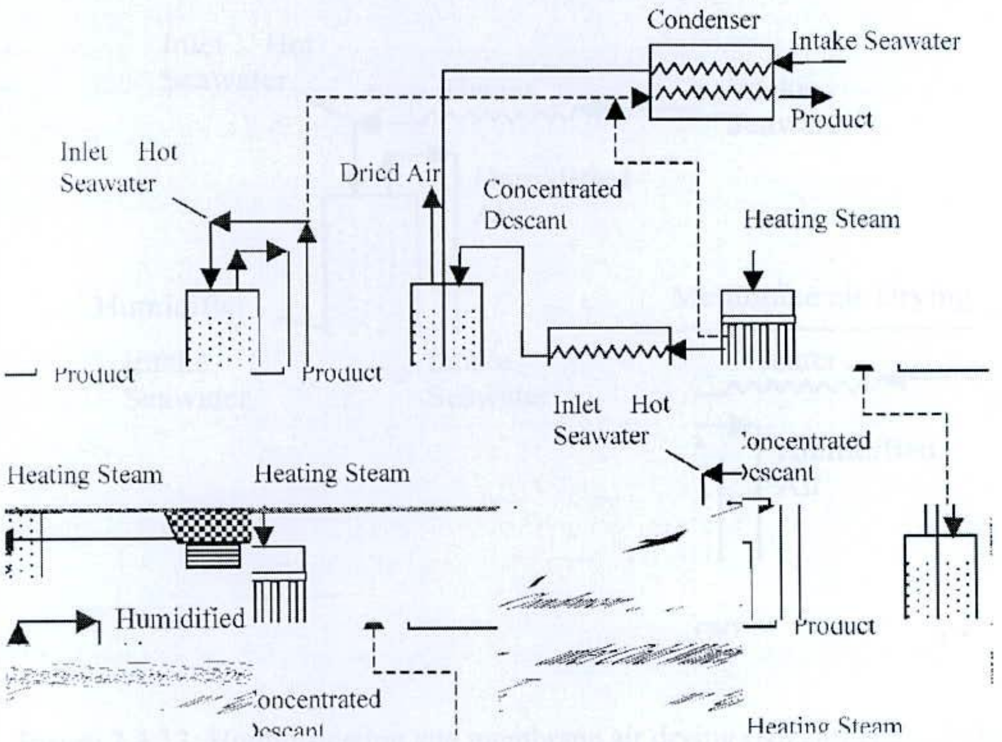

Figure 2.4.12: Conventional humidification dehumidification desalination process (Rizzuti et al., 2006).

Common findings among various literature studies indicate that production rate of distillate water increases as hot water temperature increases. Production rate of the distillate water reaches a maximum when air and water flow rates increase. In all cases increasing the air or water flow rates would improve mixing within the system and increase the humidification rate. At higher water or air flow rates the evaporation efficiency is decreased because of the increase in the sensible heat load of the system. This reduces the water evaporation rate and humidification efficiency. Reduction of the condenser heat transfer area requires use of finned tube configuration. This is necessary because of the low heat transfer coefficient on the humid air side; this is irrespective of water vapor condensation, which accounts for a very small percentage of the entire air stream.

Desalination combined with solar energy provides one of the most attractive sustainable sources of fresh water and energy. Researchers have investigated and developed several promising configurations. Although many of these systems have relatively high cost, when compared to conventional desalination or fossil fuel power, it is important to consider environmental benefits and source sustainability. Also, the higher cost is caused in part by the small scale of the tested units.

such as salts and heavy metals as well as eliminates microbiological organisms. The end result is water cleaner than the purest rainwater (Solar Still Basics, Wikipedia, 2011).

A conventional solar still has a simple geometry. The still is formed of a square or rectangular box, which is equipped with a sloped glass cover. The walls and base of the box must be made from materials that can withstand the elements. Materials such as wood, plastic, or metal are reported in literature studies. The top cover of the box is made of transparent glass to allow for the passage of solar energy. The desalination mechanism is similar to that of nature. A shallow pool of brackish or seawater absorbs solar energy and as a result vapor of fresh water is formed in the space above the water. The vapor condenses on the inside of the glass cover and is then collected in a side trough. Figure 2.4.14 shows a schematic of the most basic form of solar stills.

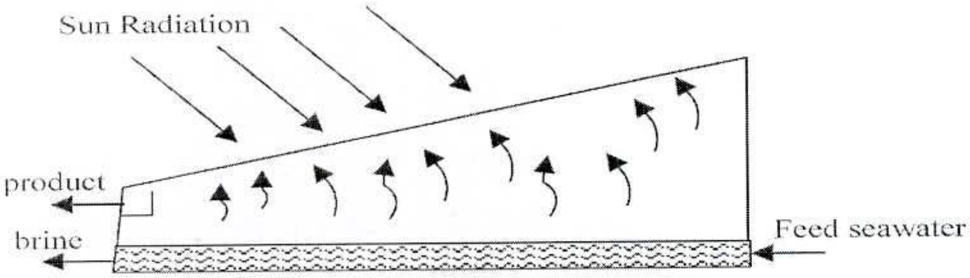

Figure 2.4.14: Schematic of simple solar still (Solar Still Basics, Wikipedia, 2011).

Vertical solar stills occupy smaller land area and can provide similar production rates. The performance of vertical solar stills in southern Algeria was being evaluated by Boukar and Harmim (2005). Their study is motivated by the need for a desalination system that has simple technology and minimum engineering skills. Several investigators studied the effect of combining solar collectors together with stills (Voropoulos et al., 2003). This configuration increased the production rate by up to 50%. Also, the system productivity became uniform and was not affected by day or night operation. Adding the collector to the solar still system would increase the capital cost, but the increase in production rate would offset the incurred cost.

The multistage solar stills seem to improve the system efficiency. Their design allows evaporation between the maximum possible temperatures, 90^0c, and lowest system temperature, of about 5^0c higher than the feed water. Although the performance of the multistage solar still requires more advanced engineering to construct and operate, it can provide up to 6 $L/m^2/d$ (Graeter et al., 2001). Adhikari and Kumar (1999) reported an optimum of 3 effects that provides the lowest water product cost.

Natural convection effects in vapor space in solar stills are studied by Omri et al. (2005). The analysis shows that adjustment of the glass cover inclination angle results in a maximum optimum for the water temperature in the system. A similar conclusion is made through experimental adjustment of the glass cover angle for a solar still system in India (Tiwari A. and Tiwari G., 2005).

The study by al-Hayek and Badran (2004) shows that use of the asymmetric solar still, where mirrors are added to the side walls, increases the system productivity by 20%. Aybar et al. (2005) used wick material in the inclined water still and system productivity increased by threefold due to the increase in residence time and the decrease in thermal resistance to absorption of solar radiation. Separation of evaporation and condensation zones was tested by Rahim (2001). Results showed two to threefold increase in system productivity upon separation of the condensation zone. This is because condensation on the glass cover increased the resistance for the passage of solar radiation. Another design adjustment considered by Rahim (2001) was to add a metal plate in the seawater/brackish water pool.

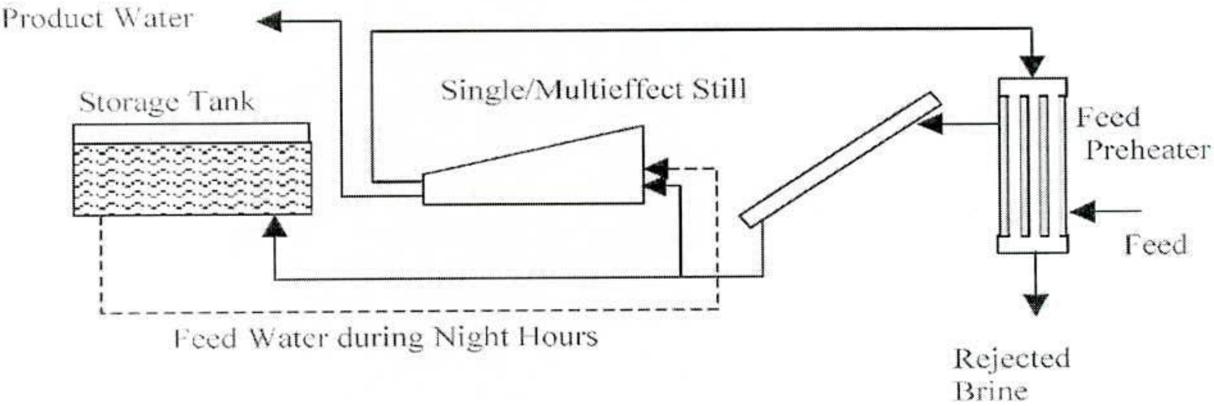

Figure 2.4.15: Schematic of a solar still configuration together with feed preheating, collector, and hot water storage.

This arrangement generated a shallow pool and a large storage volume which was able to maintain a uniform temperature through the system and sustain evaporation even during the hours. The above review cites but a few of the vast literature studies on solar stills. We concluded that the basic form of horizontal solar still could not be the optimum configuration. As discussed above, few modifications in the single stage still can provide higher yield.

Definitely, the multi-effect solar still is more efficient than a single stage; this is quite similar to the comparison of a single stage flashing or evaporation against a multistage 90° C, and lowest system temperature, of about 50° C higher than the feed system. Further improvement in the solar still system is achieved by combining it with a solar collector and large tank for storing hot water. The solar collector provides hot water, which can be used directly in the still or stored in a hot water storage tank, so obtaining uniform production rate during daytime or nighttime. Figure 2.4.15 shows a schematic of a solar still combined with a collector, storage tank, and feed pre-heater. The feed pre-heater can be omitted in the case of multi-effect solar still, where the brine reject temperature from the last effect reaches the feed water temperature.

2.5 Summary Discussion

It is not a matter of fact that how the above reviewed literature on the various desalination technologies is compatible for this study, even more all of those are desalination technology and every process requires a huge amount of energy supplied either from hydroelectric power generation plant or fossil fuel burning or from solar radiation. These technologies are well-known and working satisfactorily all over the world to desalinate the saline water but frequently used in those areas where there are available power supply like electricity or fossil fuel.

Solar energy coupled to desalination offers a promising prospect for covering the fundamental needs of power and water in remote regions, where connection to the public electric grid is either not cost effective or not feasible, and where the water scarcity is severe. Solar energy can be used for seawater desalination either by producing the thermal energy required to drive the phase-change membrane distillation process or by producing the electricity required to drive the RO and ED membrane processes. The proven RO and ED technologies require only electrical (no thermal) input energy while MD requires both thermal and electrical energy. ED is the most energy-efficient desalination method for brackish water with low non-ionic solute content, while RO can be used for brackish or seawater as long as the water has low potential for fouling the membranes. More research is needed to determine the competitiveness of membrane distillation with the more proven desalination technologies. Photovoltaic-powered reverse osmosis (PV-RO) is considered one of the more promising approaches, particularly for small systems where other technologies are less competitive. In practice however, solar power is intermittent and variable while RO plant is generally designed to run continuously and at constant flow. Batteries are often proposed, and indeed used, to address this, but batteries are very problematic in the field. In addition, energy recovery in small scale PV-RO system is a challenge.

But world-wide water scarcity, especially in the coastal areas of Bangladesh, indicates a pressing need to develop inexpensive, small-scale household based desalination technology which uses renewable resources of energy. This solar desalination technology would be a pretty appropriate contribution to provide safe drinking water in the coastal areas of world. These circumstances have driven the researchers to invest their important effort in the study of alternative, nonconventional means for obtaining water in prevision of drought periods, such as wastewater treatments, desalinization, or exploitation of deep groundwater, as well as the development of tools and strategies for conjunctive management and water saving that allow for optimizing the water resources management and preventing the scarcity periods.

CHAPTER 3: **Methodology**

3.1 General

Availability of the sources of good quality drinkable water has been reducing rapidly in many urban and rural areas in Bangladesh as the withdrawal rate is higher than the recharge rate. In the upcoming days, it would be a greater problem for the human being to supply adequate drinking water. The situation is becoming worst in a problematic area where both the sources of water, namely (i) ground water aquifer and (ii) surface water, contain high salinity and other impurities. Among the other impurities, removal of salinity by any conventional method is still costly. Researchers and policy makers have been thinking for all possible alternatives. One alternative is to produce distilled water by any low cost method and that distilled water can be mixed with available ground water to have the final water which will contain the salinity concentration within the allowable range for drinking water standard. One of the low cost methods to produce distillate is solar desalination. There are lot of works have been going on throughout the world on this topics which has been discussed in the previous chapter (Chapter 2). The production rate per square meter per day is still low. Research on different types of solar still/basin also has been carried out since 1994 in the Department of Civil Engineering, KUET, Khulna. The production was found ranged between 1.2 to 1.6 L/m^2-day. To improve the production rate, an innovative research project had also been started in 2009 by using ceramic porous media/blocks in a vertical transparent tube. The vertical column made of ceramic blocks can retain more moisture than that of a horizontal basin type surface. The distillate production rate was found ranged between 3.5 to 5.1 L/m^{2}day for an initial bench scale model. The present work is the modification and continuation of the Vertical Cylinder (Column) Ceramic Porous Media Solar Desalination Unit and here a textile cylinder has been used in place of ceramic porous cylinder. Finally to observe the effect of textile cylinder, an attempt has been undertaken on thorough study of full scale design, fabrication and monitoring of the Textile Cylinder Desalination Unit (TCDU).

3.2 Study Conducting Location

Bangladesh is a semi-tropical region lying in northeastern part of South Asia gets abundant sunlight year round. The average bright sunshine duration (Figure 3.2.1 and Figure 3.2.2) in Bangladesh in the dry season is about 7.6 hours a day, and that in the monsoon season is about 4.7 hours. The highest sunlight hours received is in Khulna with readings ranging from 2.86 to 9.04 hours (Khan et. al., 2012). A study has been conducted by an IUT research group to find out the ideal location for a solar power generation plant and they recommended about the Khulna region because of the highest sunlight hours received. So it becomes a potential benefit for conducting the present study in this area.

The present study has been conducted under the Department of Civil Engineering; Khulna University of Engineering & Technology (KUET), Khulna-9203 and the experimental setup has been installed on the roof of that 2-storey building (Environmental Engineering laboratory) at a place where sun light keeps shining in the whole day. The map of the study conducting location has been provided in the below Figure 3.2.3.

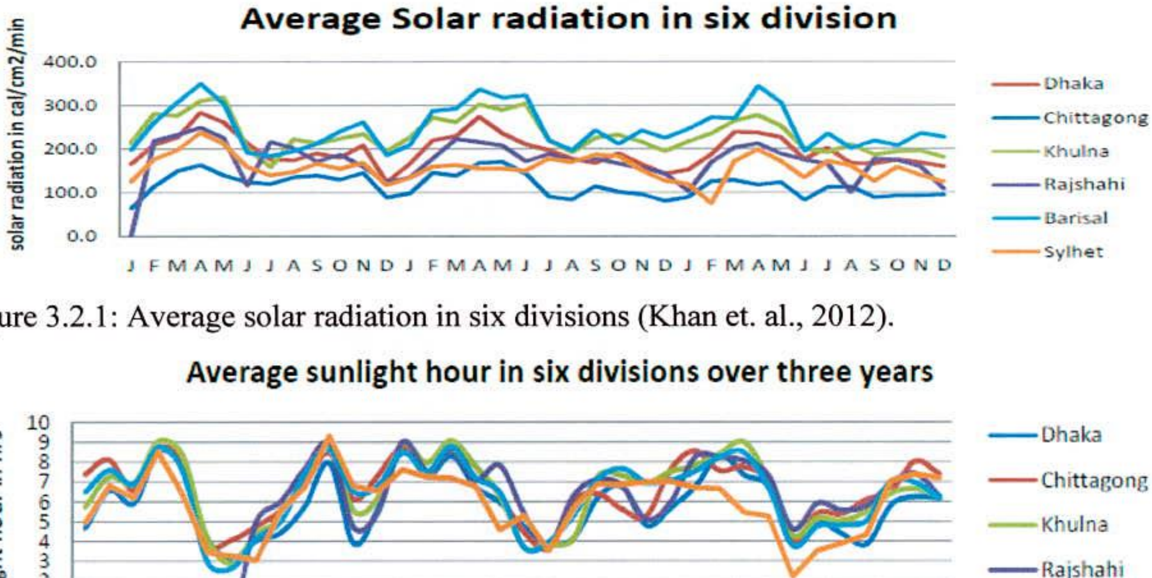

Figure 3.2.1: Average solar radiation in six divisions (Khan et. al., 2012).

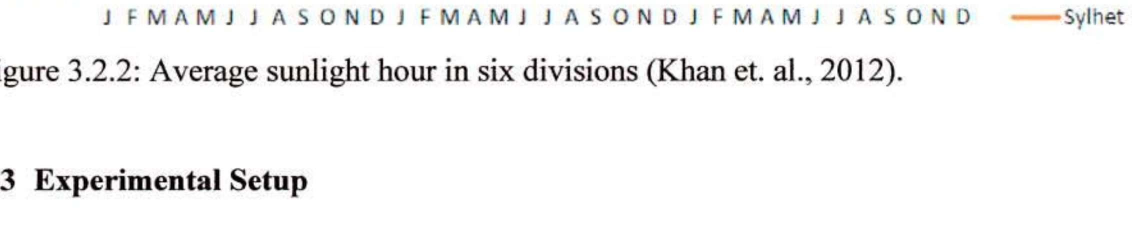

Figure 3.2.2: Average sunlight hour in six divisions (Khan et. al., 2012).

3.3 Experimental Setup

The complete experimental setup of this study has been fabricated in three consecutive periods and every time setup contains the following points:

i) Internal Cylinder or Textile Cylinder

ii) External Cylinder or Transparent Plastic Container

iii) Assembling of the Experimental Setup

iv) Installation of Setups

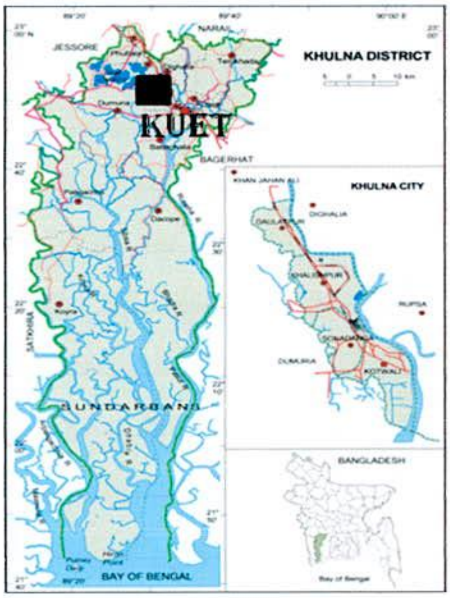

Figure 3.2.3: Map of Khulna District showing the Location of KUET.

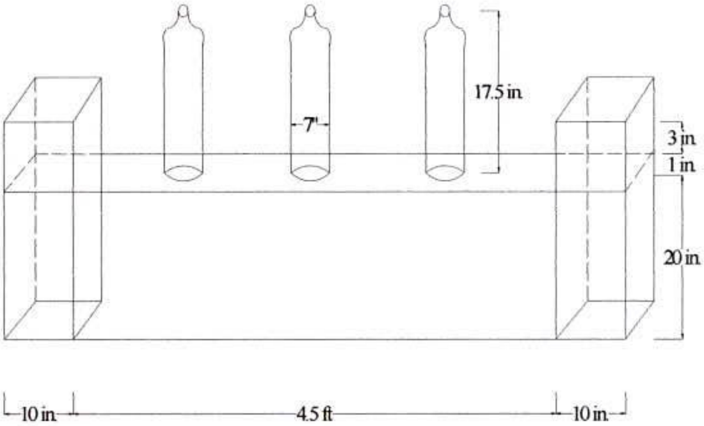

Figure 3.2.4: Sketch of Experimental setup.

3.3.1 Internal Cylinder or Textile Cylinder

The internal cylinder or textile cylinder is a cylindrical shape component inserted within the external cylinder and placed at its centre. It comprises of aluminum wire cylindrical frame and textile covers and these covers are taken the role for the absorption of water and heat. As the consequence of global warming as well as frequent occurrence of natural calamity, Bangladesh has become one of the most disaster porn area and also economically weak handed country all over the world that's why the materials for the preparation of internal cylinders and textile covers have been selected by considering the availability, durability and sustainability of the setup in the adverse environmental impact. The materials used for the preparation of cylindrical skeleton are wooden bars, aluminum wire and nylon chord. The wooden bars and nylon chord are more sustainable and durable in high saline water than the other locally available materials. The aluminum wire having high heat absorbing property is noncorrosive durable in high saline water. All these materials have been accumulated by a procedure; have been discussed in the coming articles.

Table 3.3.1: Specification for Internal Textile Cylinder

Installation	Textile Type	No. of Cylinders	Labeling of Cylinders	Dimension (cm)		Color	Water Content (%)
				Height	Diameter		
Run-01	Jean	2	A11, A21	24.0	11.50	Black	38
	Jute	2	B11, B21	24.0	11.50	Brown	46
	Cotton	2	C11, C21	24.0	11.50	Black	40
Run-02	Jeans	3	A31, A32, A33	24.0	11.50	Black	39
Run-03	Modified Jeans*	3	A41, A42, A43	24.0	11.50	Black	51

Figure 3.3.1: Making of aluminum wire frame

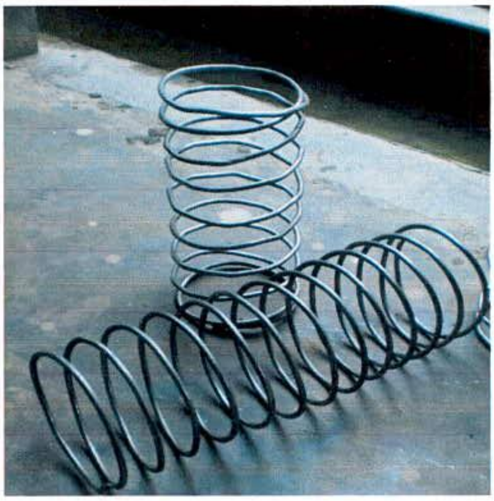

Figure 3.3.2: Aluminum wire flexible frame

Cylindrical Frame Preparation

The aluminum wire of arbitrary length has been taken to make the spring as well as the cylindrical shape by using a hollow iron cylinder about 10 cm diameter. The wire has been hold on the surface of the iron cylinder and run out through the plain surface to form the spring shown in Figure 3.3.2. The spring has been cut off with the dimension that the cylindrical frame makes its height of 24.0 cm and diameter 11.50 cm can be made easily.

These frames were very flexible which were totally unable to keep their dimension constant that's why these frames have to make as sufficient rigid as it can keep the cylindrical dimension unchanged in the whole experimental period. So the wooden bars have used to tie up and keep the spring sufficient strong. Three bars have been used in inner side of each spring and tied up by considering its proper dimension by nylon chord and those chords have been kept extended after completing the bar binding for proper handling of the textile cylinder. A flexible frame like a spring and a completed cylindrical frame have been shown in Figure 3.3.3 and Figure 3.3.4 respectively.

These frames are structurally much more rigid, stable and also non-corrosive type in saline water, so it has been used in this study to make the setup more sustainable. The frames have been inserted into the textile cover to make a textile cylinder and Figure 3.3.5 presenting the textile cover (jute).

Figure 3.3.3: Cylindrical Frame

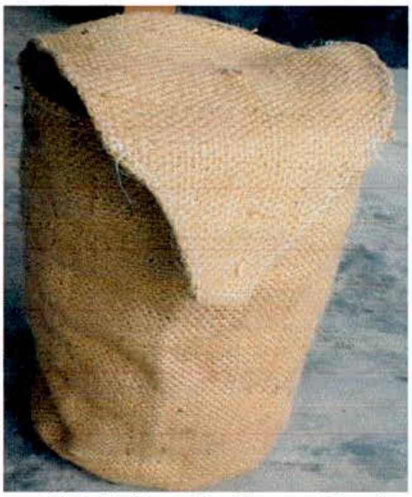

Figure 3.3.4: Textile Cover (Jute)

Preparation of Textile Cover

The textile cover is also a cylindrical shape cover which has been used to make a surface from where evaporation takes place. This surface can retain water where solar radiation falls and vaporize water. Firstly three kinds of textiles have been selected in this study by considering the availability, solar radiation absorbing capacity, price, and water retaining capacity, durability, workability etc. and those were jute textile, jeans textile and cotton textile. The cylindrical forms have been made by using these textiles from the tailor of a dimension as it's become of 24.0 cm height and 11.50 cm diameter. Finally total twelve (12) numbers of textile cover have been made from the tailor for this study and all have been used to make internal cylinder.

Preparation of Textile Cylinder

It has been mentioned in Chapter 2 that the evaporation rate depends on the various factors where evaporation surface area is one of the prime factor. The evaporation rate increases with the increase of evaporation surface area that's why textile cylinder has been selected as evaporation surface in this experimental study that can retain water at its surface for evaporation by providing higher surface area compared to its base area. To make the textile cylinder, the aluminum frame has been inserted into the cylindrical formed textile cover and extended chords have been ejected through the centre of the top cover. After that the top cover has been fixed by sewing with its surface. The total twelve numbers of textile cylinders of 24.0 cm height and 11.50 cm diameter have been made according to the experimental necessity and the experimental program and the detail specification shown in the Table 3.1.1. In the first run, six cylinders have been made using three different textiles (Jute, Jeans and Cotton) of two colors (Jute in brown and Jeans and Cotton in black color). Final setup has been fabricated by using these internal cylinder or textile cylinder.

The plan and elevation sketch in Figure 3.3.5 and textile cylinder in Figure 3.3.6 have been presented below:

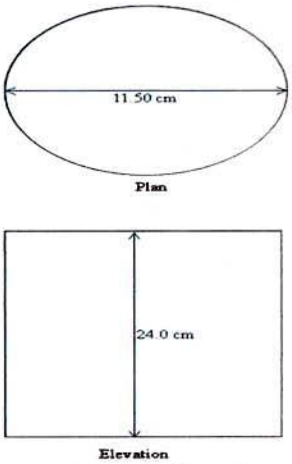

Figure 3.3.5: Plan & Elevation of Textile Cylinders

Figure 3.3.6: Textile Cylinders

3.3.2 *External Cylinder*

In this experimental study, bottle shape transparent plastic containers have been used to trap the vapor evaporated from the internal cylinder surface which are calling external cylinder. These cylinders provide condensation surface area for this system. The transparent plastic container has been selected as an external cylinder by considering their availability & price and bought from the retail store.

3.3.3 *Experimental Program*

The experimental program has been fixed arbitrarily to find out the maximum distillate production rate from the different textiles as well as different textile cylinders in the same atmospheric condition and total twelve setups have been installed after several numbers trialing. The program sequence has been presented in the Figure 3.3.7

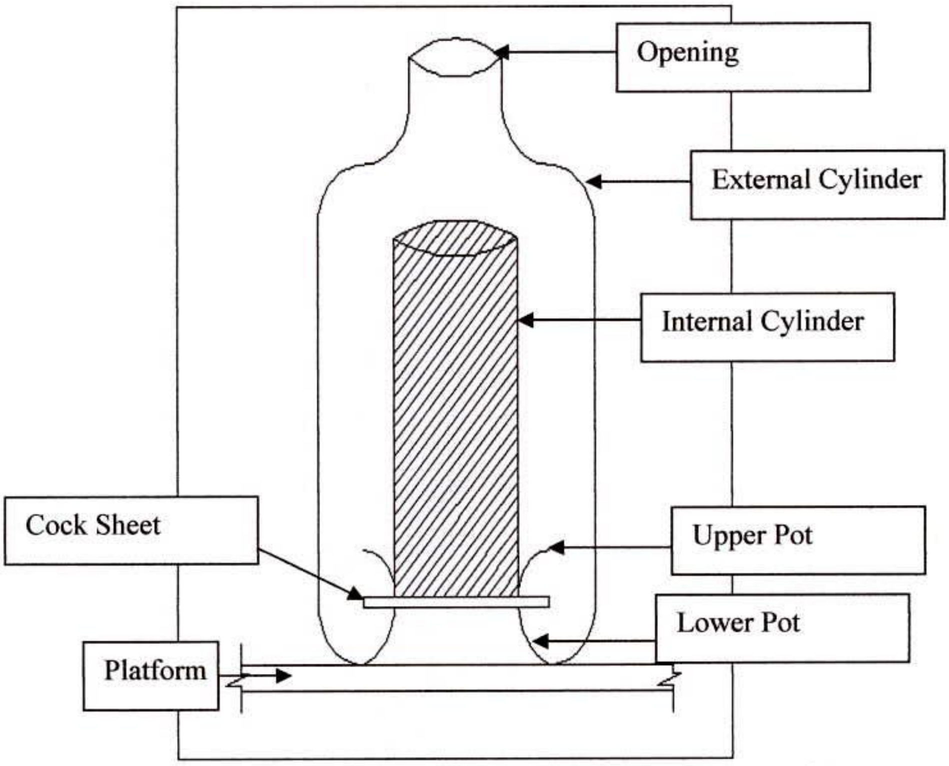

Figure 3.3.7: Schematic Diagram of an Experimental Setup

3.4 Assembling of Experimental Setup

The materials or stuffs which have been used to fabricate the experimental setups are textile cylinder, small size plastic bucket, poly-eurathene sheet (Local name cock sheet), bottle shaped transparent plastic container (volume 08 litres), PVC pipe, anti-cutter, glue etc. and shown in the Figure 3.4.1 and 3.4.2.

The bottle shaped transparent plastic containers have been cut off like a slice from 5 cm above its bottom and cleaned up to make its more transparent. A bore hole of size smaller than the PVC pipe outer diameter has been made in the lower portion of the container to fit for distillate collection pot and the seam of outer periphery of pipe and bore hole have been water tight by using the glue. The length of the pipe has been fixed arbitrarily for suitable placement of the distillate collection pot and the diameter of the pipe was 5.00 mm.

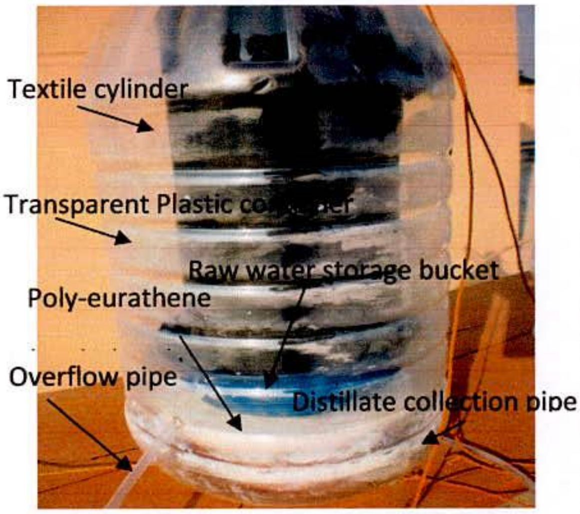

Figure 3.4.1: Full setup with its components

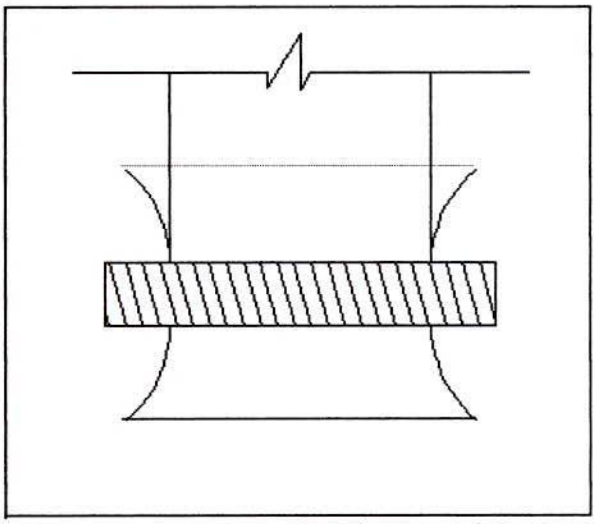

Figure 3.4.2: Schematic Diagram of the Setup

In every setup, two plastic pots have been used where lower one has been placed upside down to make the flat and stable surface for upper bucket. Then a circular cock sheet of diameter 7.50 cm has been placed above that lower container. The upper bucket has been placed on the cock sheet and a bore hole has been made to the wall of upper bucket from 2 cm down of its top. A bore hole has also been made to the wall of the upper portion of the container to set an overflow pipe which was same dimension of distillate collection pipe as shown in Figure 3.4.2. This hole has been located by considering the smooth discharging of overflow water from the upper bucket. A textile cylinder with a handling chord which was kept extended at the time of its making has been placed on the upper container as if it becomes vertical.

The upper and lower portions of the container have been set like it original shape and the joint has been water and air tight carefully by using glue. The Figure 3.4.2 & 3.4.3 show the bucket arrangement and fabrication setup.

According to the above description, six setups have been fabricated at first time by using three different kinds of textile cylinder (Jeans fabrics, Jute fabric & knit fabrics) marked as A11, B11, C11, A21, B21 and C21.

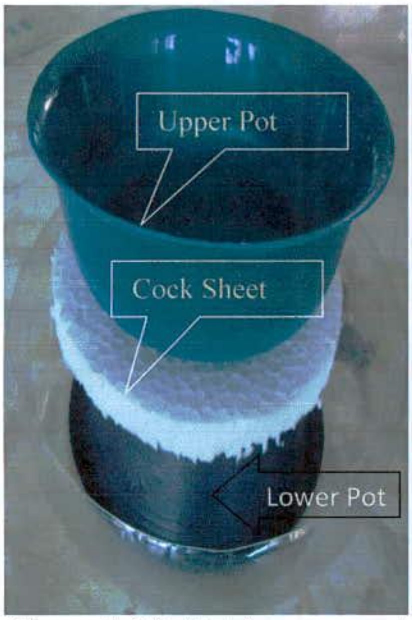

Figure 3.4.3: Pot Arrangement

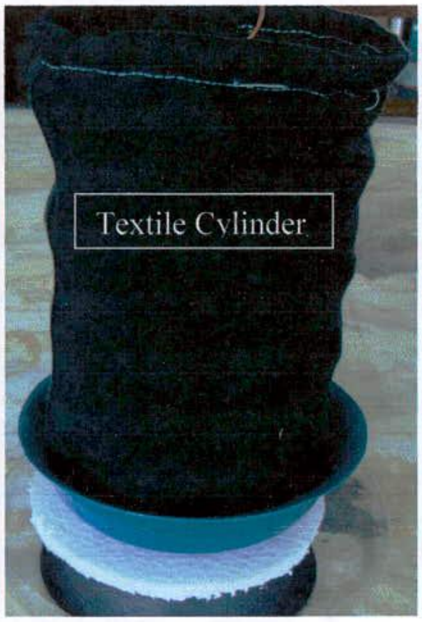

Figure 3.4.4: Textile Cylinder Placement

Figure 3.4.5: Full Experimental Setup

Figure 3.4.6: Experimental Setup on the Roof Top of CE Dept., KUET.

These setups have been placed on a wooden deck which made around 60 cm above the roof top of the Civil Engineering building, Khulna University of Engineering & Technology (KUET), Khulna. All experimental setups have been fastened to sustain against wind force or any atmospheric forces which can affect the setup physical configuration. The Figure 3.4.5 shows the experimental setup on the roof of the Civil Engineering building, KUET.

3.5 Water Tightness Testing

Before run, the water tightness of the setup has been investigated for upper pot hole, hole in lower portion of transparent plastic container and also the cutting joint of setup which making procedure have been described in the previous articles. Any of the above leakage may affect the distillate quality and its production rate and from this point of view water tightness testing was very important in this study. The testing procedures which were done in the Environmental Engineering Laboratory have been discussed separately in the next articles.

3.5.1 Water Tightness Testing for Upper Bucket

The upper bucket contains raw saline water and hold textile cylinder; its leakage can affect the distillate production rate (DPR) and quality.

This test was quite important for overall study and has been done in the environmental engineering laboratory, KUET. After setting up the overflow pipe with the upper pot, a tissue paper has been tied up with the periphery of the pipe at outer side of the pot from where leakage can be identified. Then the pot has been made full up to its top with tap water and kept for several hours. The tissue paper has been checked and confirmed its dryness. The Figure 3.5.1 shows the water tightness testing for upper pot.

Figure 3.5.1: Water tightness testing arrangement of Upper bucket in the laboratory

3.5.2 Water Tightness Testing for Joint of Plastic Container

The distillate production rate depends on the condensation of vapor in the system. Any leakage can affect the system performance. The water tightness test for the joint of transparent plastic container has been done before the run. All the setups have been installed on the wooden deck and made full with tap water. The water full setup had been keeping in observation for several hours that whether it leaks or not. The leaked setups have been either repaired sometimes according to the necessity or abandoned. The Figure 3.5.2 and 3.5.3 show the water tightness testing for joint of plastic container.

Figure 3.5.2: Water Tightness Testing of Joint

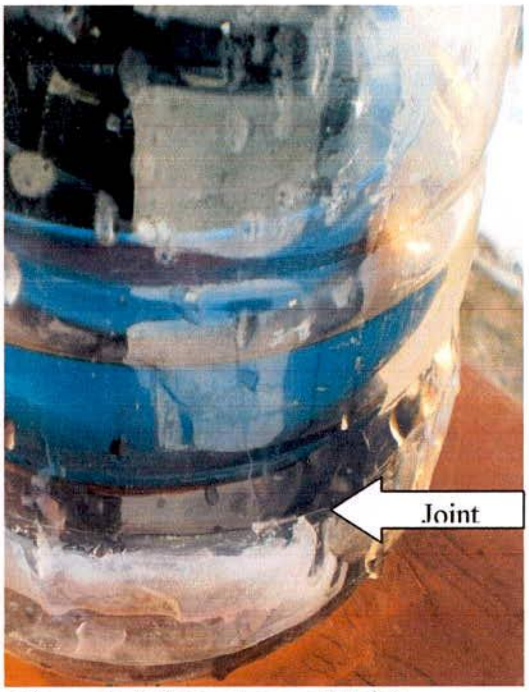

Figure 3.5.3: Leakage of Joint

3.6 Sampling Program

At the commencement of the run, tap water has been used as raw water for approximately one month and after that synthetic water has been used which were prepared in the Environmental Engineering Laboratory. Water sample collection or sampling program has been shown in the Table 3.6.1:

Table 3.6.1: Sampling Program

Water Sample Collection	**Wetting of Textile Cylinder**
• Every day before the sun rise, the stored distillate has been collected from the	• Every day after the sample collection, the textile cylinders have been wetted by

storage container and measured its volume. • Hourly distillate production rate has been taken once in a week from morning to evening. • Raw water has been collected in time after the wetting of textile cylinder and tested it's parameters in the laboratory.	pouring tap or synthetic water from the top of the setup up to the overflow occurs. • At the beginning, the surface of textile cylinder remained dry after wetting and affected the distillate production rate that's why wetting has been done as carefully as the whole surface of the textile cylinder wet uniformly.

3.7 Data Collection and Analysis

In this study, the parameters, Chloride (Cl^-) concentration, Electric Conductivity (EC) and pH of collected sample, distillate & raw (tap) water have been tested in the laboratory. The Chloride (Cl^-) has been measured by the **Argentometric Method**, Electric Conductivity (EC) by using HACH branded **sensION5 Conductivity/ TDS/Salinity Meter** and pH by using HACH branded **sensION156 Portable Multi-parameter Meter**. The detail results have been presented in the next chapter of this report.

Chapter 4: **Results and Discussion**

4.1 General

Before the commencement of monitoring, the external cylinder has been made full with tap water and kept soaked the dry textile cylinder under water around two or three hours due to the uniform wetting. If this wetting of textile completed before the sun set, then the produced distillate within that day did not count as a monitoring reading. Finally the monitoring of the setup started from the next day. In this study program, the data analysis and discussion about the results have been stated in the following articles.

4.2 Variation of Distillate Production Rate (DPR)

The distillate production rate is the main focusing parameter for this study as well as all solar desalination processes. This parameter has been investigated through the different phases of this study and modified the setup mechanism to get the better performance as well.

4.2.1 DPR for First Phase Setup

Firstly, a setup using three different kinds of textile have been installed as discussed in Chapter-03. Although the monitoring of the first phase setup has been continued up to the whole study period but the modification of textile cylinder has been done two months later. The variation of the distillate production rate for different textiles has been shown in the Figure 4.2.1 and 4.2.2 for the month of November and December, 2010 respectively-

The maximum average DPR for the month Dec'10 within the first band of setup was found 143.28 mL/d for A11 and standard deviation was 64.35. From both figures, it was observed that the A11 setup has been shown highest DPR through the whole period where B11 was the lowest and C11 showing the in-between value.

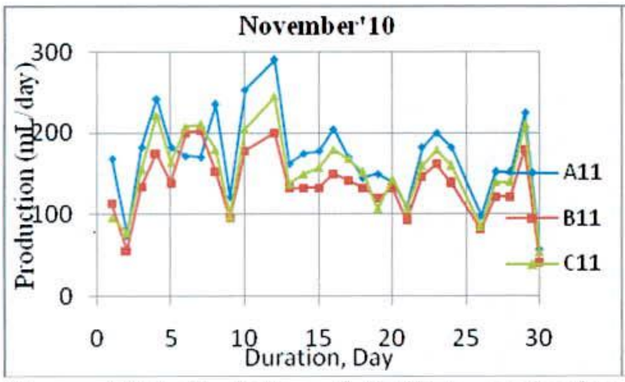

Figure 4.2.1: Variation of distillate production rate (DPR) for first phase setup (Nov.'10)

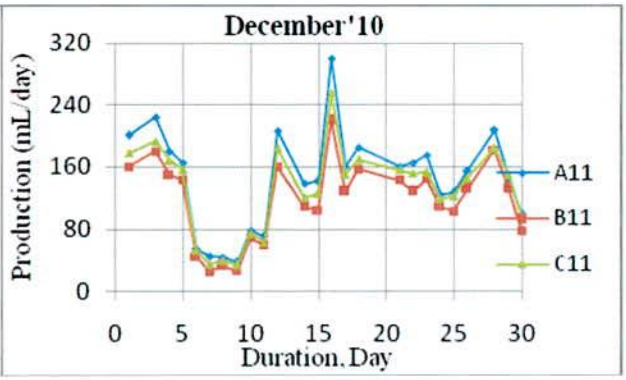

Figure 4.2.2: Variation of distillate production rate (DPR) for first phase setup (Dec.'10)

Within the month of November and December 2010, the maximum DPR of 300 mL/d was monitored for A11 in December 2010 as in Table 4.2.1. Not only that the setup A11 was produced the greater amount of DPR than the others in all circumstances where the setup B11 was given the lower amount of DPR. For making the investigation more clear, a replica has been installed for the parallel monitoring and those performances have been presented in the Figure 4.2.3 and 4.2.4 for the month January, 2011.

Table 4.2.1: Summary of Distillate Production Rate (DPR) in the Month of November and December, 2010

Month	Identification	Maximum DPR			Minimum DPR		
		mL/d	$L/m^2/d^*$	$L/m^2/d^{**}$	mL/d	$L/m^2/d^*$	$L/m^2/d^{**}$
November'10	A11	290	2.93	11.84	57	0.58	2.33
	B11	200	2.0	8.16	42	0.42	1.71
	C11	245	2.48	10.0	54	0.54	2.20
December'10	A11	300	3.03	12.24	37	0.37	1.51
	B11	220	2.20	8.98	25	0.25	1.02
	C11	255	2.58	10.41	34	0.34	1.39

---

[*] Distillate Production Rate with respect to the evaporation surface area (1000 cm^2)

[**] Distillate Production Rate with respect to the cross-sectional area (245 cm^2)

4.2.2 DPR for Second Phase Setup

It has been observed from the Figures 4.2.3 and 4.2.4 that the distillate rate of A11 & A21 was the highest through the entire month where B11 & B21 are lowest but C11 & C21 are in-between values. In the Table 4.2.2 maximum, average and minimum DPR have been shown. It is clear from the table that A11 & A21 setups are produced the better performance than the others. But A21 always gave higher value than A11. So it can be concluded that the setup A11 & its replica A21 have been selected for the next detail investigation and discussed in the next article.

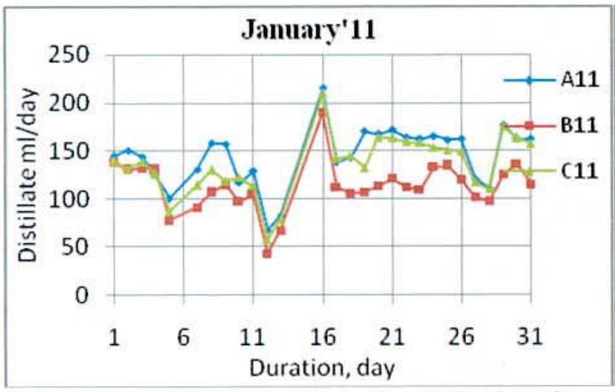

Figure 4.2.3: Variation of DPR for first phase setup in Jan'11

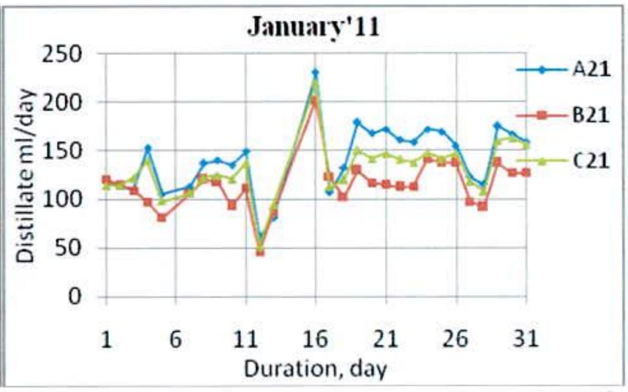

Figure 4.2.4: Variation of DPR for replica of first phase setup in Jan'11

Table 4.2.2: Summary of Distillate Production Rate (DPR) in the Month of January, 2011

Identification	Maximum DPR			Minimum DPR		
	mL/d	$L/m^2/d^*$	$L/m^2/d^{**}$	mL/d	$L/m^2/d^*$	$L/m^2/d^{**}$
A11	215	2.17	8.78	67	0.68	2.73
B11	190	1.90	7.76	43	0.43	1.76
C11	210	2.13	8.57	58	0.59	2.37
A21	230	2.33	9.41	61	0.62	2.49
B21	202	2.02	8.24	46	0.46	1.88
C21	220	2.23	8.98	51	0.52	2.08

---

[*] Distillate Production Rate with respect to the evaporation surface area (1000 cm^2)

[**] Distillate Production Rate with respect to the cross-sectional area (245 cm^2)

From both the Figure 4.2.5 and Figure 4.2.6, the slope of the all trend lines are positive that means the DPR in the month January, 2011 was increasing trend but the slope were not equal for all the setups. The slope of the trend lines drawn for the setup B11 and B21 are very small as compared with the other setup.

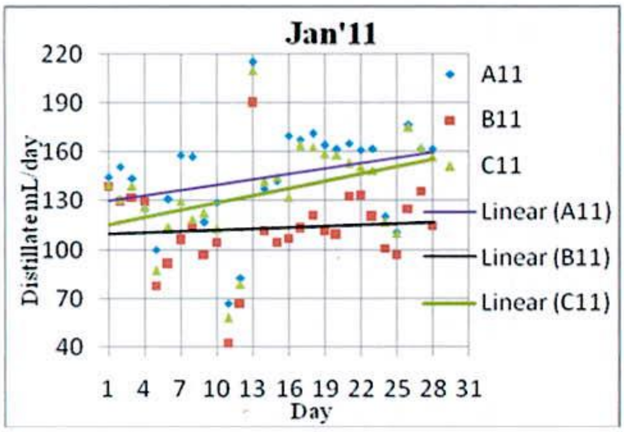

Figure 4.2.5: Trend line for first phase setup in Jan'11

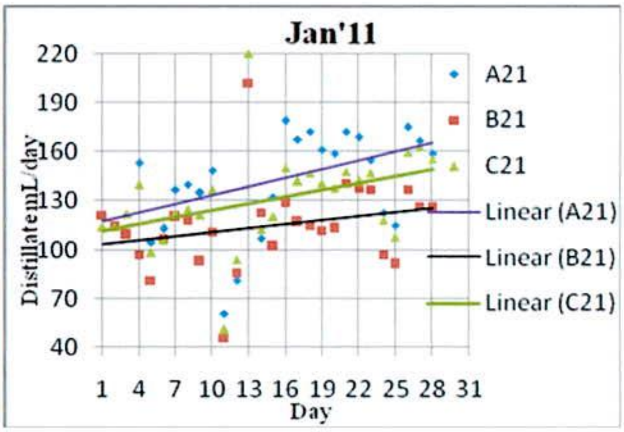

Figure 4.2.6: Trend line for second phase setup in Jan'11

4.2.3 DPR for Third Phase Setup

The third phase setup has been installed that discussed in detail in Chapter-3. This setup ran from early of February to November, 2011 and the variation of DPR has been presented for all the setup in the below Figure 4.2.5 and 4.2.6-

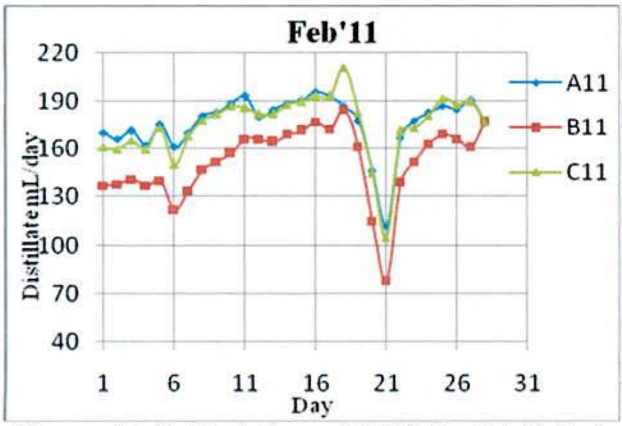

Figure 4.2.7: Variation of DPR for 1st & 2nd phase setup in Feb'11

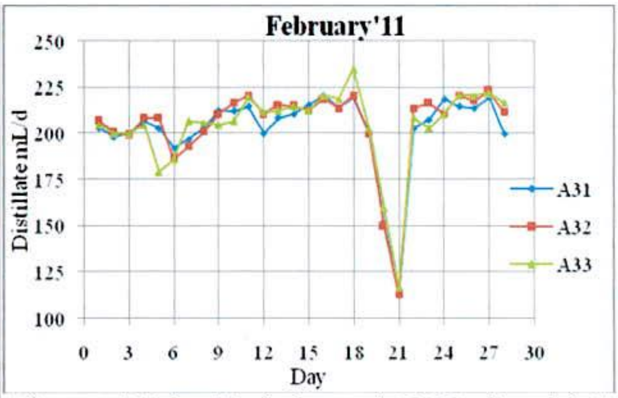

Figure 4.2.8: Variation of DPR for third phase setup in Feb'11

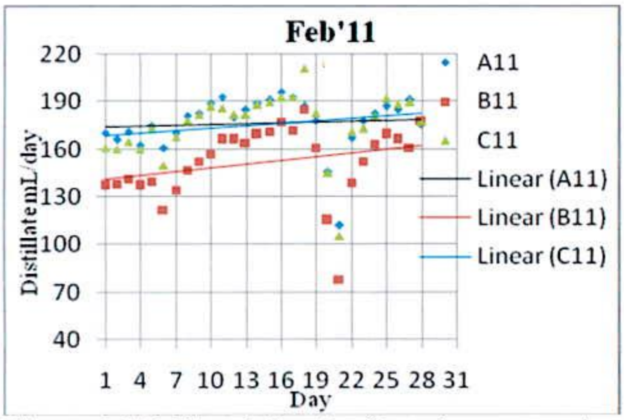

Figure 4.2.9: Trend line for first phase setup in Feb'11

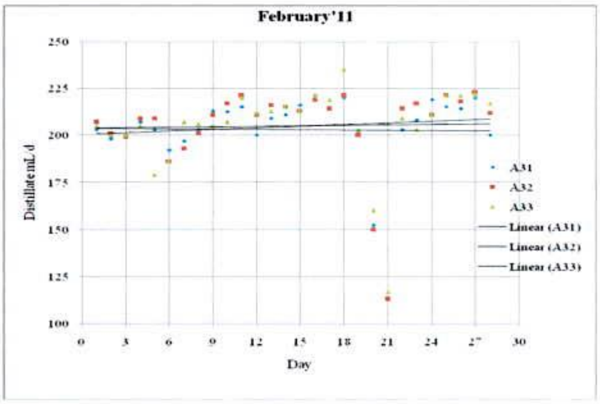

Figure 4.2.10: Trend line for second phase setup in Feb'11

From the Figure 4.2.7, it was found the similar nature of the curves throughout month where A11, C11, A21 & C21 showing more DPR than the B11 & B21 as always. The curves of third phase setup as in Figure 4.2.8 have also been shown the similar nature but most of the DPR value was little bit more than the previous setup as in Figure 4.2.7. For the case of 21st & 22nd February 2011, the DPR has been abruptly decreased due to the cloudy and foggy weather. Within all set ups, maximum DPR of 221 ml/day was found for A31, whereas for A11, the value was about 220ml/day. The maximum average DPR for the month Feb'11 was found of 207.07 mL/d for the setup A21 and the standard deviation was 23.15. At the time of monitoring, it was observed that most of the setups (2nd and 3rd phase) have been dried off that means the water has completely been evaporated from the surface of the textile cylinders. It was observed from the Figure 4.2.9 and 4.2.10, for both the setup the trend lines are almost flat that means the DPR was varied equally throughout this month. So that, the third setups have been modified and its fabrication has been discussed in detail in the Chapter 3. This newly fabricated setup, 4th phase setup has been monitored up to the end of this study and results have been discussed in next article. The other DPR variation curves for the month Mar'11 and Apr'11 have been attached in the Annex-1.

4.2.4 DPR for Fourth Phase Setup

The monitoring of the fourth phase setup has been started from May, 2011, firstly with tap water for two weeks and after that with the saline water of 35000 mg/L. The DPR variation of all phase setup has been presented in the Figure 4.2.11- 4.2.14 for May'11:

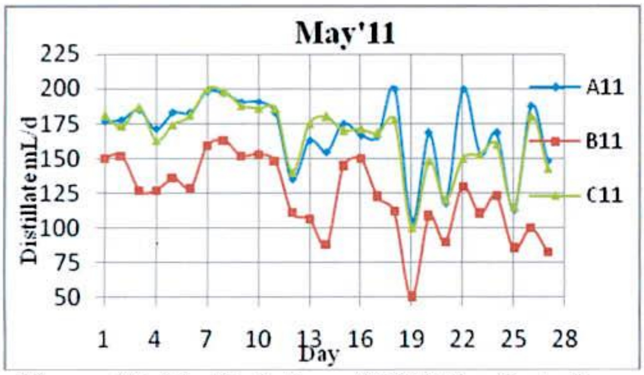

Figure 4.2.11: Variation of DPR for first phase setup in May'11

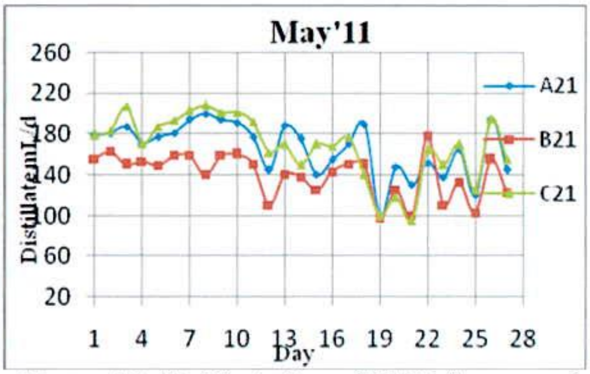

Figure 4.2.12: Variation of DPR for second phase setup in May'11

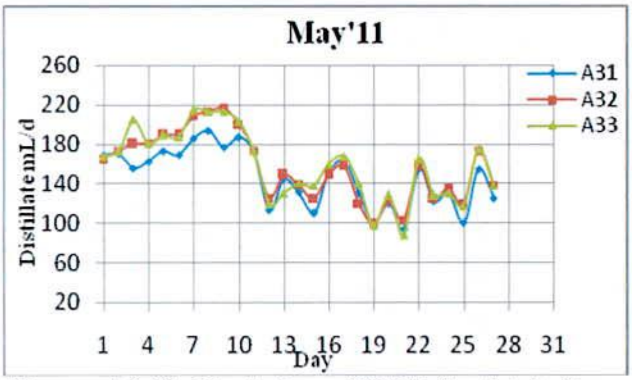

Figure 4.2.13: Variation of DPR for third phase setup in May'11

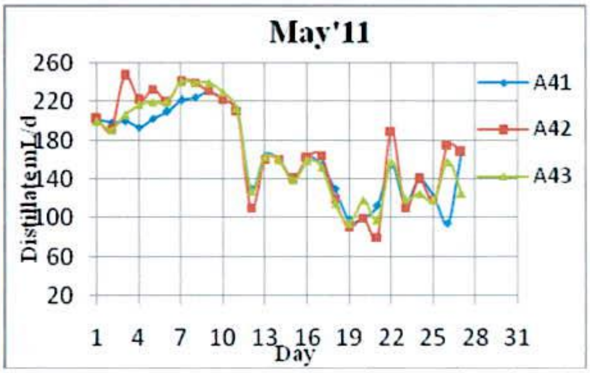

Figure 4.2.14: Variation of DPR for fourth phase setup May'11

From Figure 4.2.11 and 4.2.12, it has been observed that the variation of DPR for both first and second setup are almost similar throughout the entire month. The maximum average DPR in May'11 was found 172.41 mL/d for C21 where minimum for B21. For the case of Figure 4.2.11, the DPR was varied more in every individual day as compared with the DPR in figure 4.2.12. In May'11, the maximum DPR was found 247 mL/d for A42 and minimum of 50 mL/d was found for B11. In this month, it is observing that the nature of the curve getting similar as those are modified and found the more DPR as previous but got the decreasing trend for all the setups, presented in the Figure 4.2.15-18

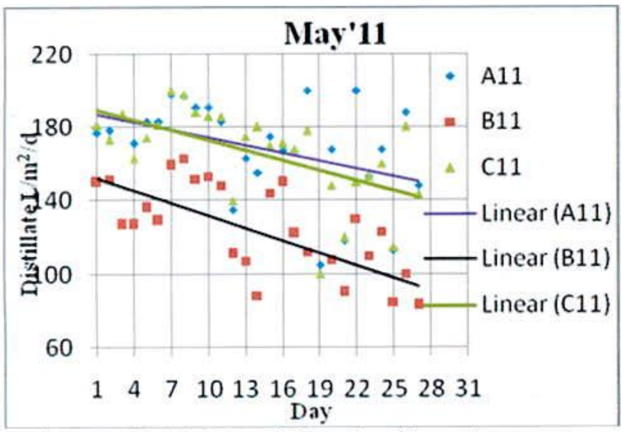

Figure 4.2.15: Trend line for first phase setup in May'11

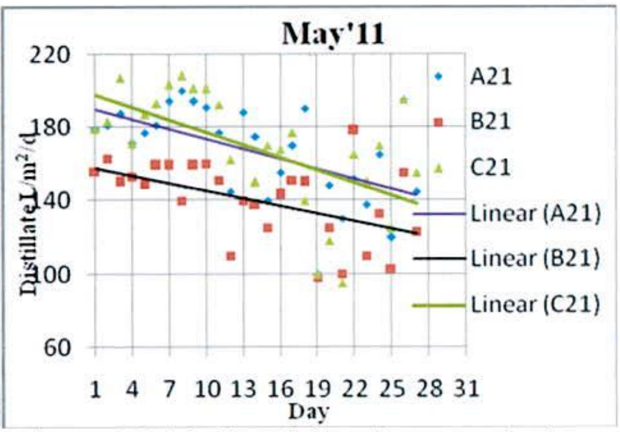

Figure 4.2.16: Trend line for second phase setup in May'11

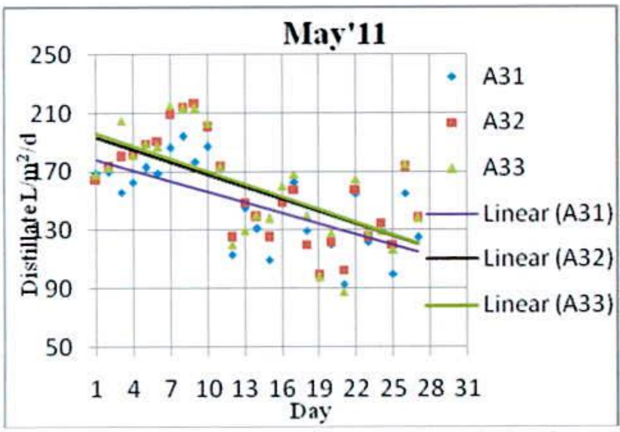

Figure 4.2.17: Trend line for third phase setup in May'11

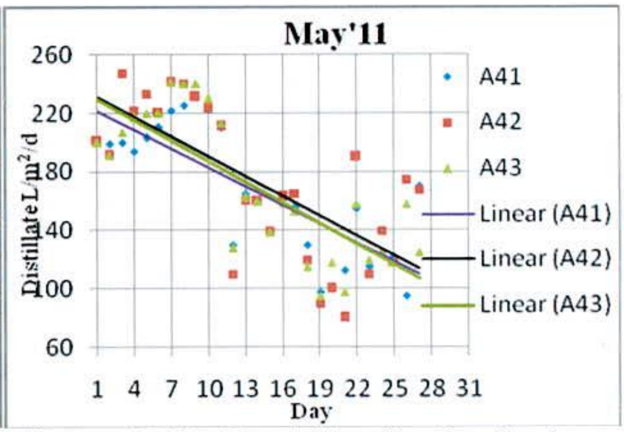

Figure 4.2.18: Trend line for fourth phase setup in May'11

All the trend lines shown the decreasing propensity but those are continuously getting more inclination as modified the setup e.g the trend line in Figure 4.2.18 is showing the highest decreasing trend where Figure 4.2.15 lowest decreasing trend. It is also observing from the above figures, for first phase setup, the DPR for individual setup were varied significantly but for second and third setup, the variation decreased and finally got almost closer for the fourth setup that's why the trend lines in Figure 4.2.18 are showing closer in position. The variation of the DPR of the month Jun'11 can also be presented in the Figure 4.2.19-4.2.22

For the month June 2011, all the setup have given the similar nature of the curve shown in the below Figure 4.2.19-22. The maximum DPR was found 230 mL/d for A11 from first phase setup, 225 mL/d for A21from second phase setup, 190 mL/d for A31 from third phase setup and 255 mL/d for A41 from fourth setup. In the similar way, it can also be found the minimum DPR as depicted in the all Figures.

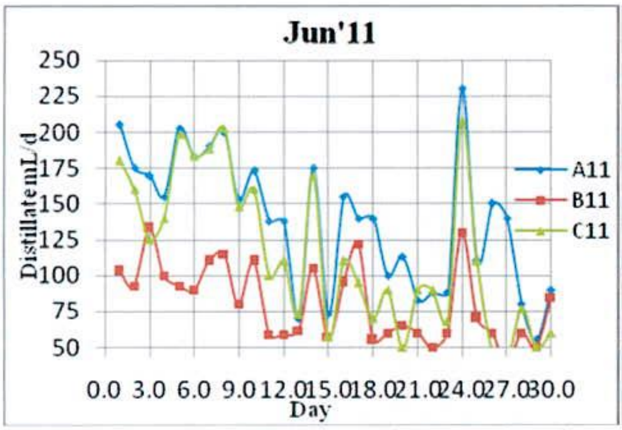

Figure 4.2.19: Variation of DPR for first phase setup in Jun'11

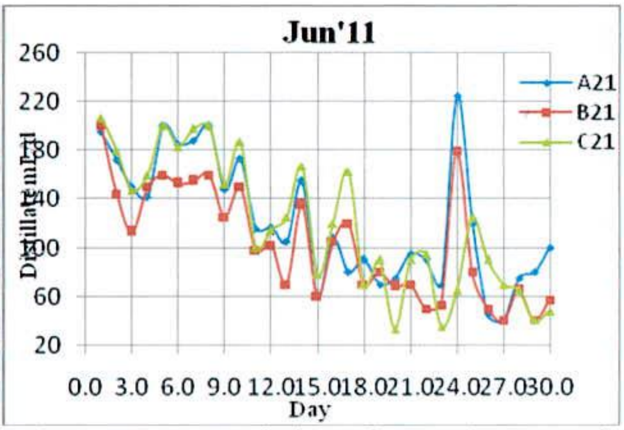

Figure 4.2.20: Variation of DPR for second phase setup in Jun'11

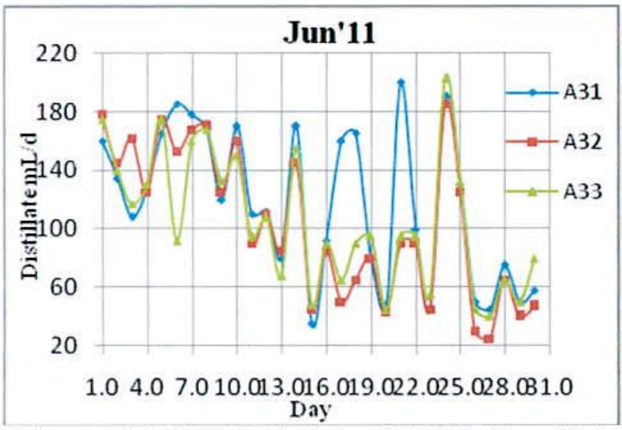

Figure 4.2.21: Variation of DPR for third phase setup in Jun'11

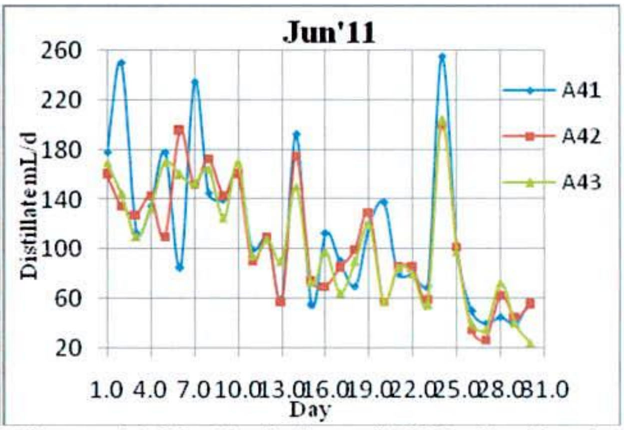

Figure 4.2.22: Variation of DPR for fourth phase setup in Jun'11

The natures of the DPR curves presented in the above Figures 4.2.15-18 were very scattered and it is difficult to define its nature as well. So the linear trends of the DPR for the month June'11 have been depicted in the below figures. The trend lines in Figure 4.2.23-26 have chronologically been got closer as those are modified. That means the DPR from the copy of the setup was almost same to each other in a particular day. The monitoring of the setup has been continued up to November'11 and similar type of the DPR curves has been found for all the respective setups although the DPR values differed from the month to month. The DPR data and curve of the remaining months have also been included in the Annex-I for the detail information.

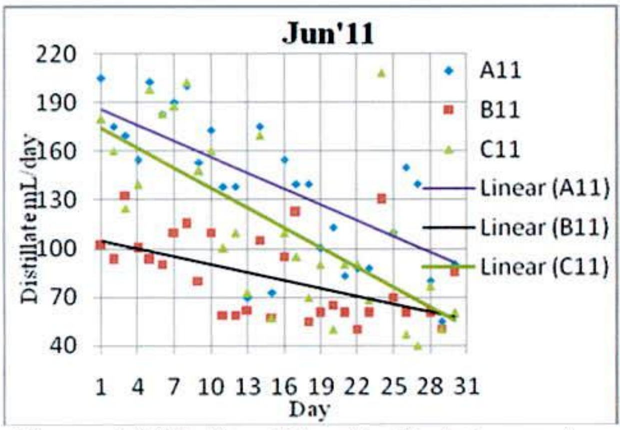

Figure 4.2.23: Trend line for first phase setup in Jun'11

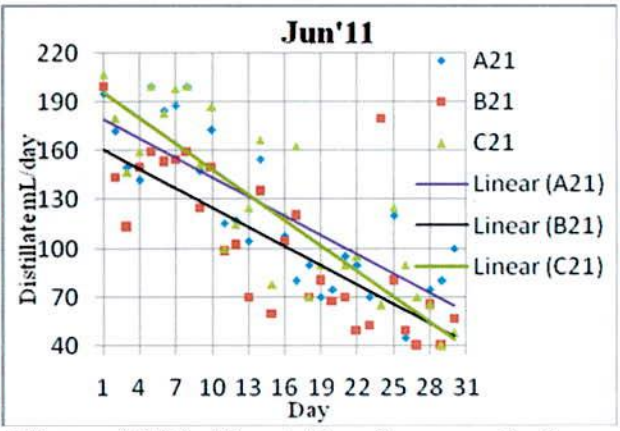

Figure 4.2.24: Trend line for second phase setup in Jun'11

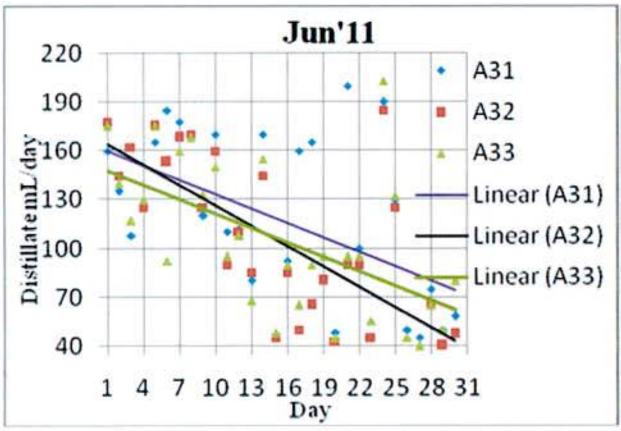

Figure 4.2.25: Trend line for third phase setup in Jun'11

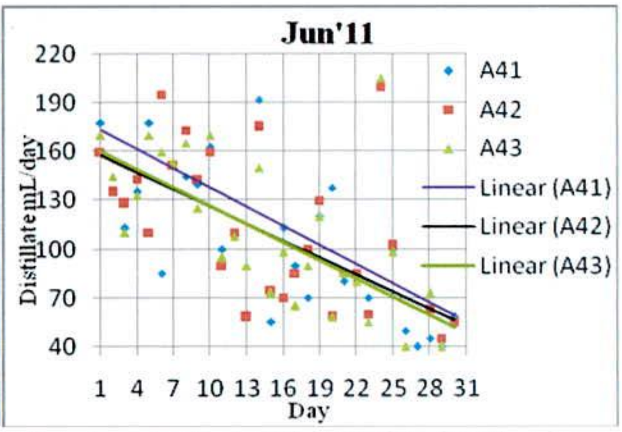

Figure 4.2.26: Trend line for fourth phase setup in Jun'11

4.2.5 Drying Trend Monitoring of the Textiles

Several weeks later from the installation of third phase setup, on 14th April 2011, the drying trend monitoring had been started where the textiles have been wetted one day and volume of distillate has been taken up to the textiles dried off, distillate production became zero. The drying trends of the textiles have been depicted in the following Figure 4.2.27. From the beginning of the drying trend monitoring, most of the textiles used in the setup have been shown the sharply decrease of DPR in the second day and decreasing continued up to third day but B11 and B21 shown different trend. For the case of B11, it has been produced 60±5 mL/day of distillate up to sixth day continuously, started decreasing after sixth day and got zero on ninth day. And for the case of B21, the DPR was decreased in the second day and again increased in the third day and then drastically decreased from fourth day of monitoring. The ninth day of the monitoring period, the DPR was found zero for all the setup.

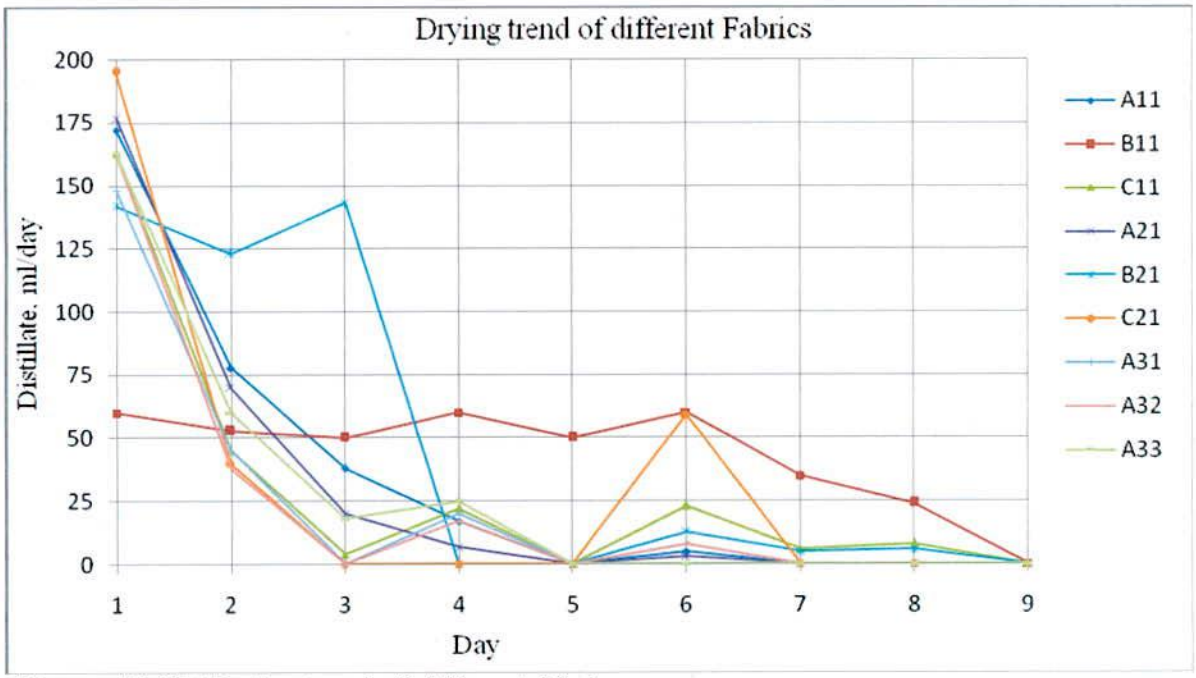

Figure 4.2.27: Drying trend of different fabrics

4.2.6 Sequence Summary and Physical Results of Experiment

The sequence summary and physical modification of the setup has been presented in the Table 4.2.3 on the basis of the distillate production rate.

Table 4.2.3: Sequence Summary and Physical Results of Experiment

A. Selection of Textile for Cylinder	**B. Effective Application of the Cylinder**	**C. Replication of the Setup**	**D. Modification of the selected Cylinder**
Run-01	**Trial Run-01**	**Run-02**	**Run-03**
✓ Considering the availability, cost and purpose served, three different kinds of textile have been selected for this experimental study primarily such as Jeans textile of black color, Jute textile of brown color and	✓ For trialing of the Run-01, another three experimental setup which are marked as A21, B21 and C21 have been installed by using the previously made textile cylinders and monitored around three months by using	✓ Considering the distillate production rate, three experimental setups have been installed by using black color jeans textile cylinder which are marked as A31, A32 and A33. ✓ These setups have	✓ Due to the hassles discussed in the previous column, the selected cylinders have been modified and made another three textile cylinders

A. Selection of Textile for Cylinder	**B. Effective Application of the Cylinder**	**C. Replication of the Setup**	**D. Modification of the selected Cylinder**
Run-01	**Trial Run-01**	**Run-02**	**Run-03**
Cotton textile of black color. In the Run-01, three setup have been installed which are marked as A11, B11 and C11. ✓ By using the above three different textiles, cylindrical shape textile covers have been constituted separately as if it's fitted with the outer periphery of the skeleton. ✓ These cylindrical shape covers have been employed to fabricate the textile cylinder and finally made three of those. ✓ The setups have been installed at a research station where sun shines in whole day on the roof of the Environmental	tap water as raw water and recorded distillate production daily. ✓ The DPR reading has been taken in every morning before the sun rises and after that these textile cylinders have been wetted up to the overflow occurs. ✓ The hourly reading has also been taken in one day within every week. ✓ From the daily reading of all installations, the maximum distillate production setup has been selected for detailed analysis and after these consequences, the black color jeans textile cylinder has been selected for replication.	been conducted by using tap water for around a week because of it smooth running and then synthetic water of 2000 mg/L of NaCl have been applied. ✓ Sometimes, it has been observed that the textile cylinder dry off before the sun set and affect the distillate production rate. ✓ It has also been observed that how the distillate contaminated with the raw water at the time of wetting. ✓ The above hassles may have been created due to the physical configuration of the textile cylinder that's why a	by using double layer textile which are marked as A41, A42 and A43. ✓ The outer layer was black color jeans and inner layer was white color cotton textile. ✓ The double layer textile cover absorbs more water and solves the problem of drying that's why increase distillate production rate. ✓ The top outer edge of the textile cylinder was initially leveled with the top surface but for final setup the top outer

A. Selection of Textile for Cylinder	B. Effective Application of the Cylinder	C. Replication of the Setup	D. Modification of the selected Cylinder
Run-01	**Trial Run-01**	**Run-02**	**Run-03**
Engineering Laboratory, Civil Engineering Building, KUET.		modification is needed in its physical configuration.	edge have been extended 1-2 cm from the top surface. ✓ After that a cork sheets have also been used under the final setup as if the atmospheric temperature can not affect the system productivity.

4.3 Temperature Variation

The monitoring of the setup had been started from the early November, 2010 and the temperature monitoring has been started from February 10, 2011 because of the limited number of thermocouple where there was twelve numbers of setup. At that time, it has been tried first to sort out the more efficient setup and that's why the first set of experimental setup have been run and finally the temperature monitoring started for the selected setup.

The temperature reading has been monitored in 15 min interval from two locations in the setup (temperature at evaporation surface and condensation air) and ambient temperature by using K-Type thermocouple. The maximum daily temperature variation during March 2011 has been shown in the Figure 4.3.1 and resting of temperature data and variation curves are shown in Annex-II. In the temperature monitoring period (Feb 10, 2011 to Jun 27, 2011), the maximum temperature was recorded 42.43^0C in ambient air where 59.71^0C on the surface of textile covers (T6) and 51.92^0C of the air within the setup. It has been observed from the recorded data that the temperature on the surface of textile covers was almost 20^{0}C greater and the temperature in air within the setup almost 15^{0}C greater than the ambient air temperature. The average daily temperature was recorded 33.84^{0}C in the ambient air, 34.06^{0}C on the surface textile covers (T6) and 34.06^{0}C in the air within the setup as in the Figure 4.3.1

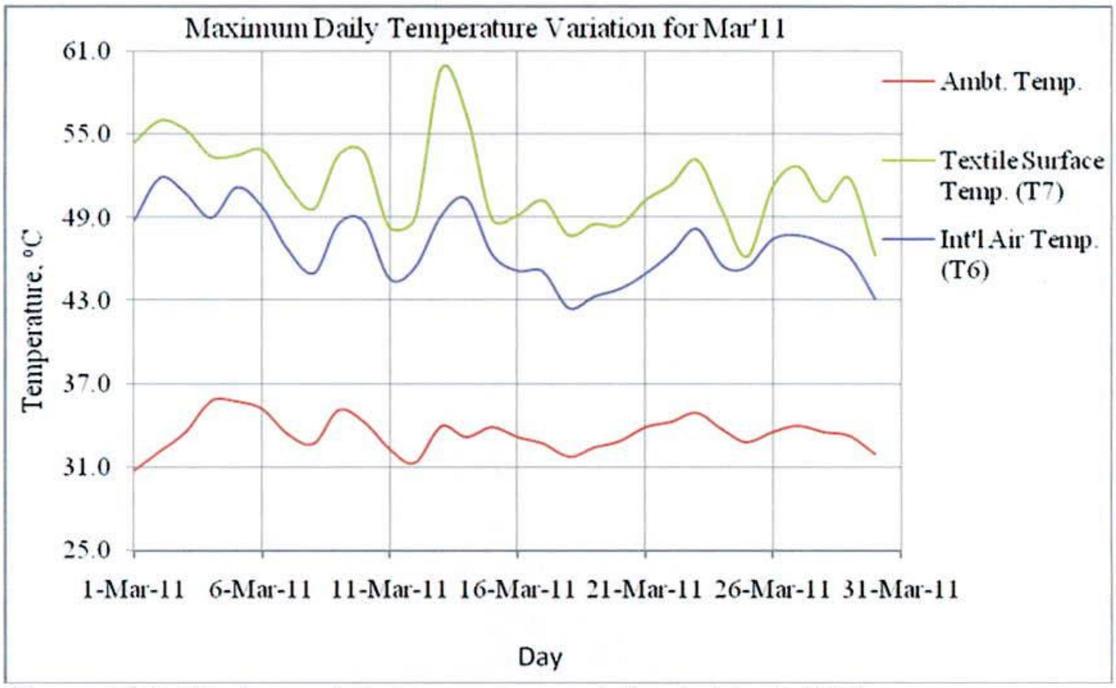

Figure 4.3.1: Maximum daily temperature variation in March 2011

From the average temperature data, it has been observed that these temperatures were varied in a small amount although the daily maximum varied significantly as in Figure 4.3.1. The temperature difference between the ambient and internal temperature was found 10-15 ^{0}C where ambient and textile surface temperature was found 15-20 ^{0}C. This temperature difference plays a significance role to produce DPR.

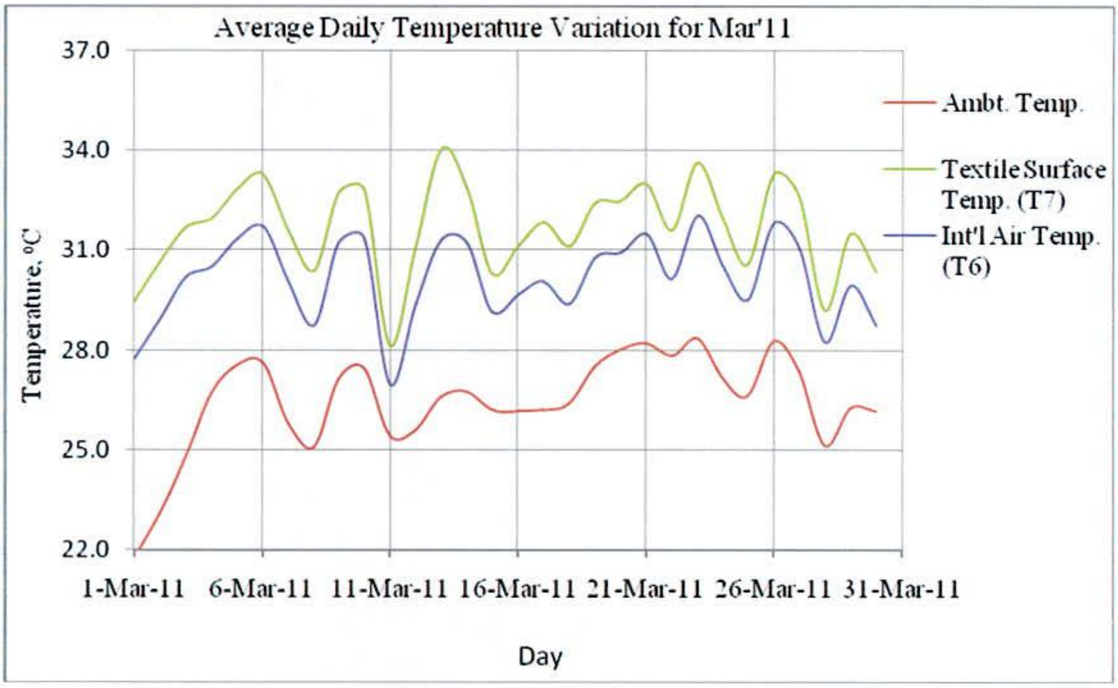

Figure 4.3.2: Average daily temperature variation in March 2011

The minimum daily temperature curves have been presented in the Figure 4.3.3. All the temperature variation curves were showing the similar nature throughout the entire month. For the case of minimum daily temperature, the temperature difference between ambient to internal air and textile surface temperature became lower than the case of maximum temperature. The rest of the temperature related data have been attached in Annex-II.

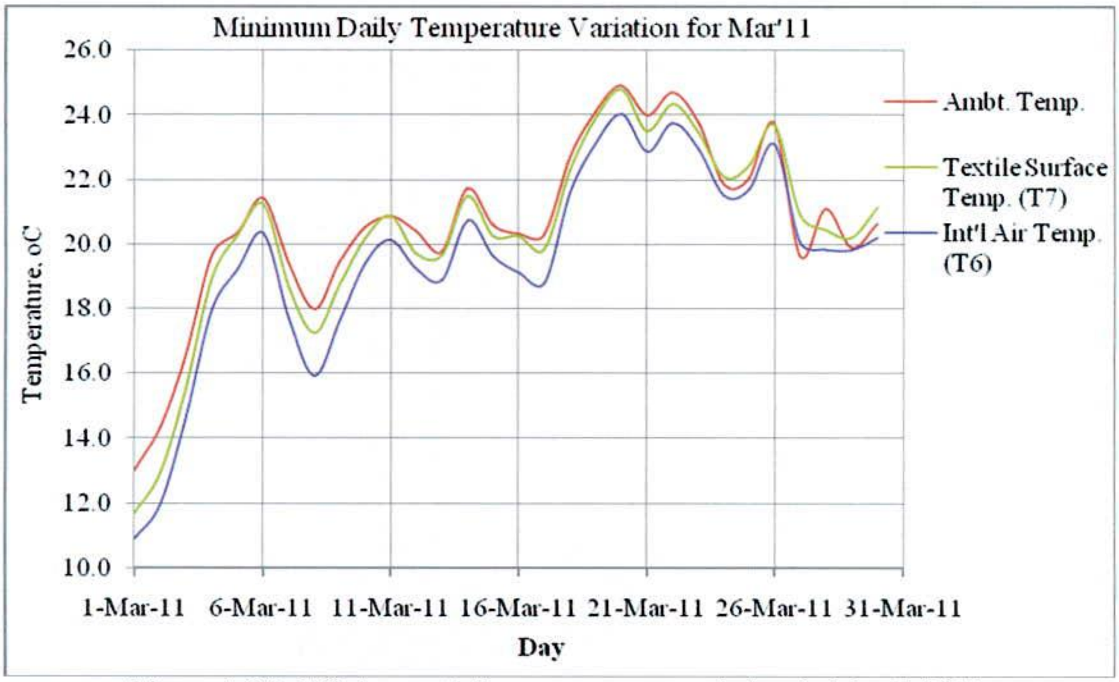

Figure 4.3.3: Minimum daily temperature variation in March 2011

4.4 Water Quality Monitoring

At the monitoring period, three parameters, salinity, electric conductivity and pH have been tested in the laboratory for the distillate and raw water and these parameters are discussed separately in below:

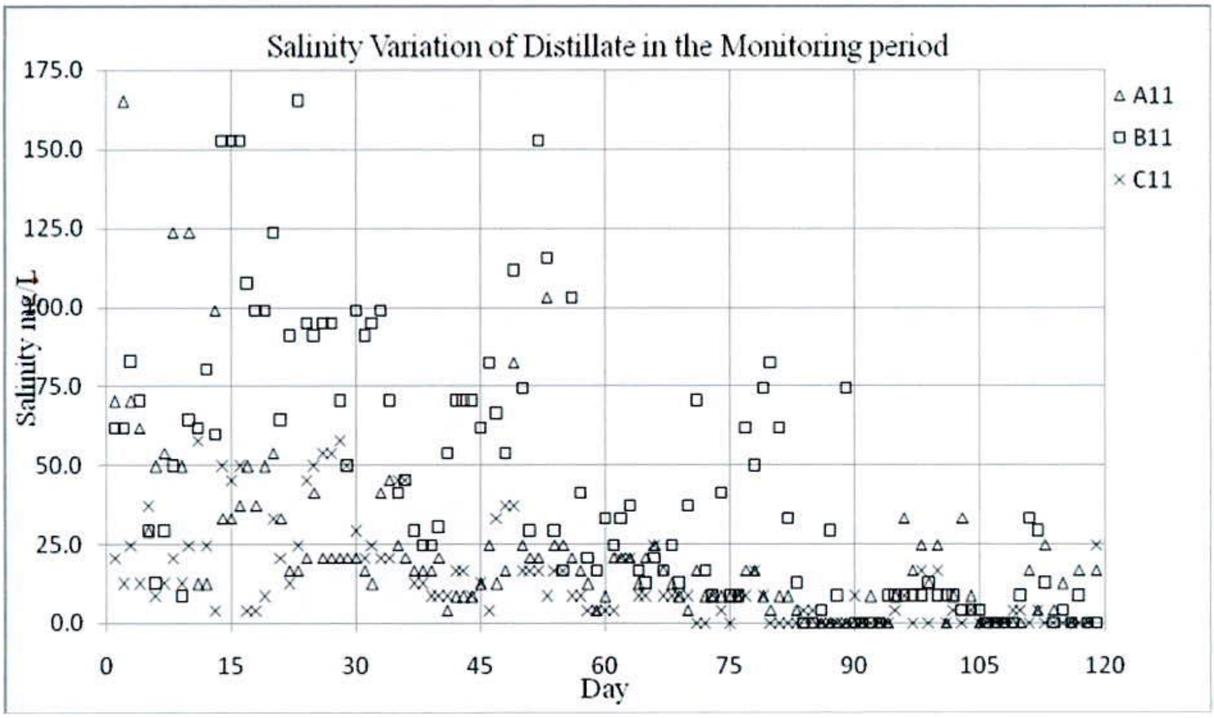

Figure 4.4.1: Salinity Variation of Distillate in the Monitoring period (Jan'11 to Jun'11)

4.4.1 Salinity of distillate

The salinity of the distillate has been measured by the hydrometric and argentometric method according to the 19th edition of the Standard Method for the Examination of Water and Wastewater. The test has been continued from Jan'11 to Jun'11 and the salinity level of the distillate for A11, B11 and C11 shown in the following Figure 4.4.1 and others have been shown in the Annex-III. The maximum salinity concentration has been recorded 170 mg/L for B11 setup where 168 mg/L for A11 where minimum was zero values. Although the theories say, the distillate never contain any salinity but there are some amount in here due to the contamination of raw water with the distillate at the time of the wetting of the setup. After that the overall concentration was under the drinking standard limit where some amount of raw water also can be mixed with the distillate to meet the drinking standard limit as well.

4.4.2 Electric Conductivity (EC) of distillate

The electric conductivity has been measured by using the Conductivity Meter, brand name-HACH of model-sensION5 (Multimeter model: sensION156). The conductivity variation for A11, B11 and C11 have been shown in Figure 4.4.2 where others in Annex-III.

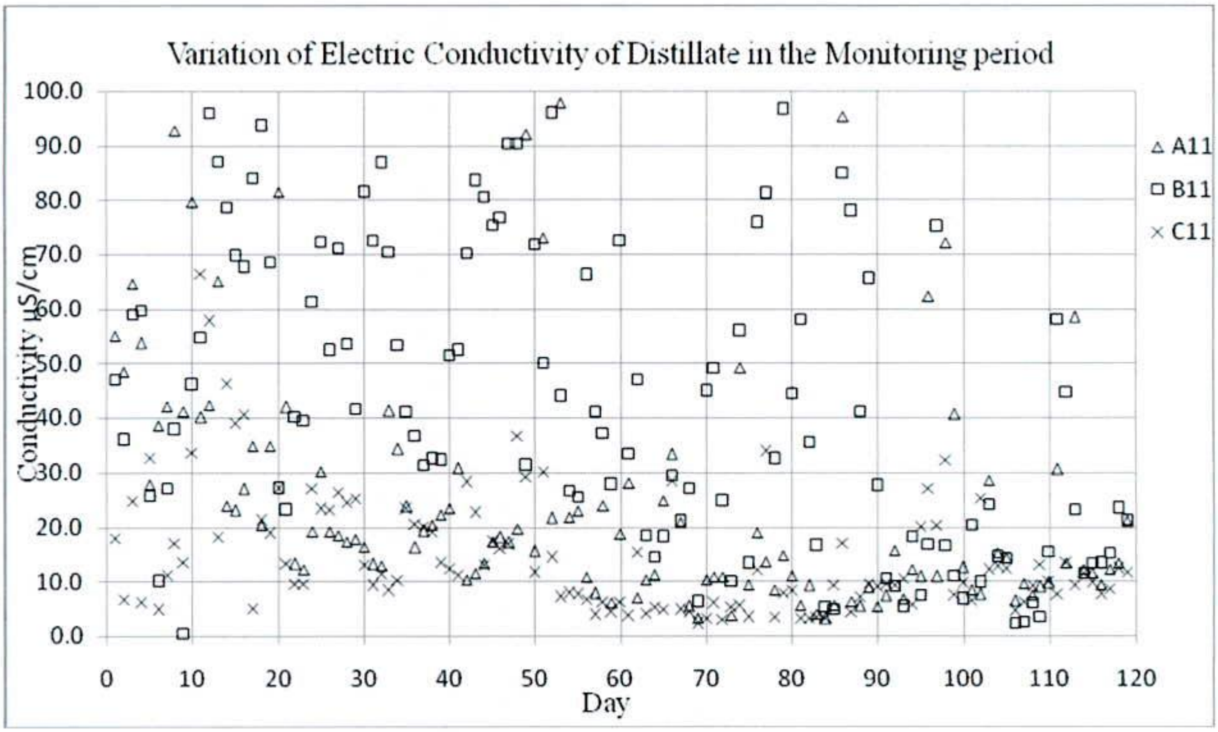

Figure 4.4.2: Electric Conductivity Variation of Distillate in the Monitoring period (Jan'11 to Jun'11)

The conductivity has been recorded ranging from 3.13-97.8 µS/cm for A11 setup, 0.4-96.5 mS/cm for B11 setup and 2.23-66.5 µS/cm for C11. All the recorded readings were significantly below the drinking water standard limit for conductivity consideration. So the raw water can be mixed with the distillate to meet the drinking water standard that would increase its volume as well as the setup performance.

4.4.3 pH of distillate

The pH of the distillate has been measured by using the HACH branded pH Meter of model-sensION1 and Multi-Meter of model-sensION156. The pH variation of distillate for A11, B11 and C11 have been shown in the Figure 4.4.3 and others are in Annex-III. The recorded readings were ranging from 5.05-8.40 for A11, 6.12-8.08 for B11 and 5.48-7.71 for C11. Most of the readings were in the range of drinking water standard limit (6.5-8.5) where some of those were below the range. So, the raw water can be mixed with these below ranged distillate to meet the drinking water standard requirement and also increase the volume of drinkable distillate.

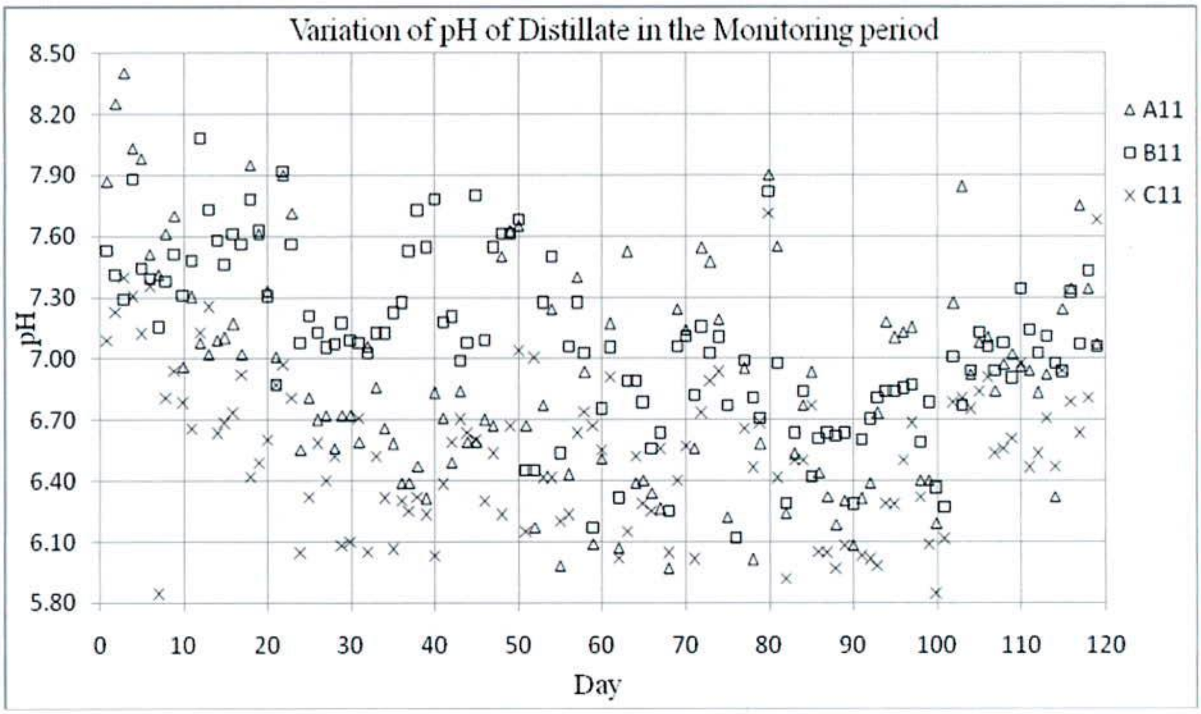

Figure 4.4.3: pH Variation of Distillate in the Monitoring period (Jan'11 to Jun'11)

4.5 Durability of the Setup

The durability of the setups have been observed, separately for the plastic containers, bucket, nylon chords, aluminum frame and the textiles cover used at the time of monitoring. During the running period, there was no significant change observed in the setup. The detail investigation has been presented in the following articles.

4.5.1 Durability of Plastic Container

It has been mentioned in previous that the study was started at Nov'10 and continued up to Nov'11. During this study period, the different parts of the plastic container have been observed and didn't get any physical change as well as any damage, which can make hamper the DPR. Two Figure 4.5.1 and 4.5.2 have been shown, presenting the physical condition of plastic container at the time of starting and ending of the monitoring respectively. In Figure 4.5.1, the physical condition of the container was strong enough, well transparent of its body and very good condition of air stopper as well. After one year of its successful working, its physical condition became almost unchanged like in the Figure 4.5.2. Although its body has seemed to be dimmed but its serviceability was as good as new one. From this circumstance, it can be concluded that a new container would be possible to use 3-4 years, as also confirmed from the another research by doing proper maintenance.

4.5.2 Durability of bucket

Two pots in the setup, one for making flat surface and another for overflow raw water storage have been used. After one year continuous working, its physical form was totally unchanged and looked like a new one. This is because the pots were kept wetted either by raw water or distillate although those have been faced very hot sun shine.

4.5.3 Durability of Cylindrical Frame

This cylindrical frame has been made by using aluminum wire, wooden bar and nylon chord. After one year of the monitoring period, all the staffs of the frame were also remained unchanged, looked like an original one. The Figure 4.5.3 and 4.5.4 showing two photos of the frame where one has been taken in Nov'10 and another in Nov'11 but interesting fact is that physical condition of the both frame is looking similar. That means these frame did not get any trouble after one of those working, either strength-stamina or appearance as well. So it can be concluded that these frame would be employed around 10 years uninterruptedly.

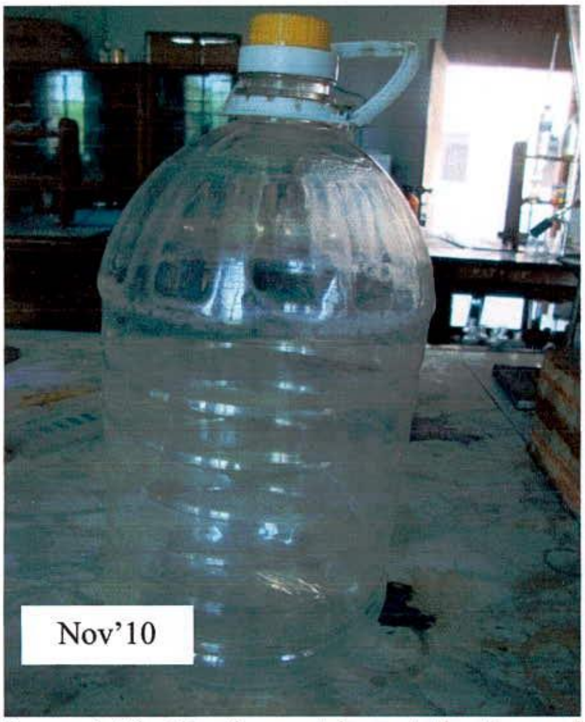

Figure 4.5.1: Plastic container at the time of installation (Nov'10)

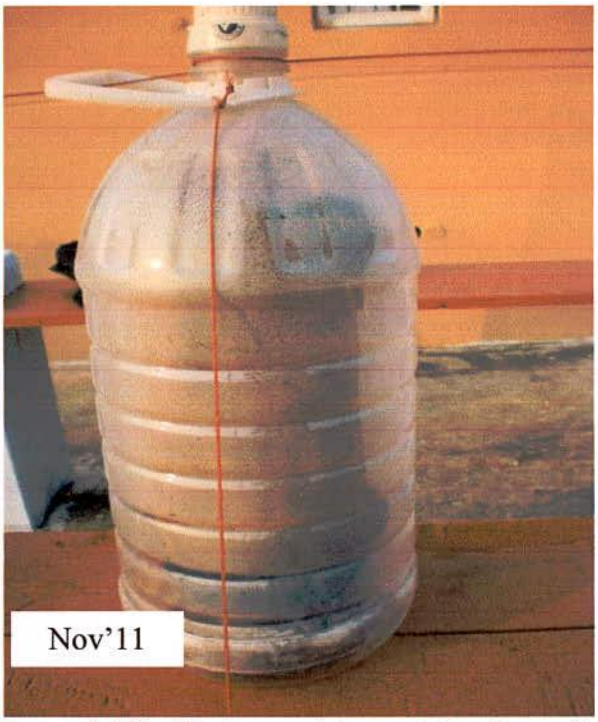

Figure 4.5.2: Plastic container at the time of monitoring ended (Nov'11)

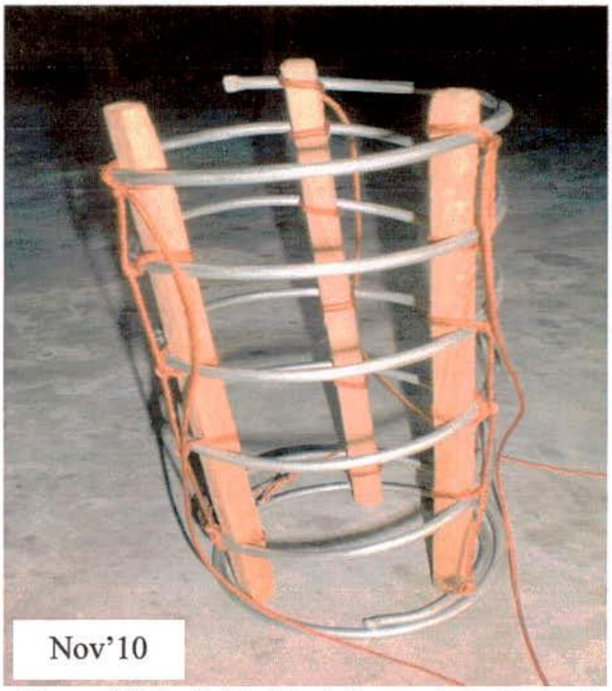

Figure 4.5.3: Cylindrical frame at the time of installation (Nov'10)

Figure 4.5.4: Cylindrical frame at the time of monitoring ended (Nov'11)

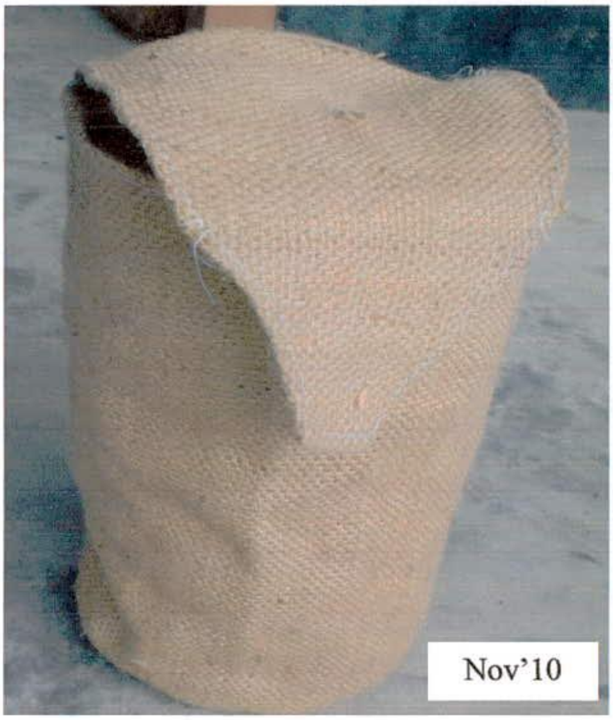

Figure 4.5.5: Textile cover (Jute fiber) before installation (Nov'10)

Figure 4.5.6: Textile cover after monitoring ended (Nov'11)

4.5.4 Durability of Textile Cover

Three types of textile covers have been used in this study, mentioned in the Chapter 3 and here only jute fiber case has been discussed. The physical condition of the covers have been observed, either it got any change or defected its surface due to precipitated salt throughout the whole monitoring period. In Figure 4.3.5 and 4.3.6, two snap shot have been shown at starting and ending of the monitoring respectively. Here only jute fiber discussion has been presented and other fibers have been shown the similar nature. After the monitoring ended the surface of the textile cover has become white in color due to the precipitation of salt on it. But its bottom portion has contained more salt than the body portion. Due to this precipitated salt, the body of the cover unchanged except its color. So the removal of this precipitated salt from its surface makes its once more employed with the increased efficiency. After one year of its continuous working, its physical condition has not been significantly defected and its inner side was looked like a new one as well. So this type of textile can be used around 3-4 years without any defect on it. Above these consequences, it has been concluded that the overall setup can be used minimum of 03 years although its different part showing different types of durability.

4.6 Variation of Different Parameters

The distillate production rate (DPR) has been depended on the various factors like temperature, solar radiation, relative humidity and wind speed. In this study, the main factor temperature difference has been measured. Temperature monitoring system has already been discussed in detail in the Chapter 3. Hourly DPR and temperature reading have been discussed in the following articles.

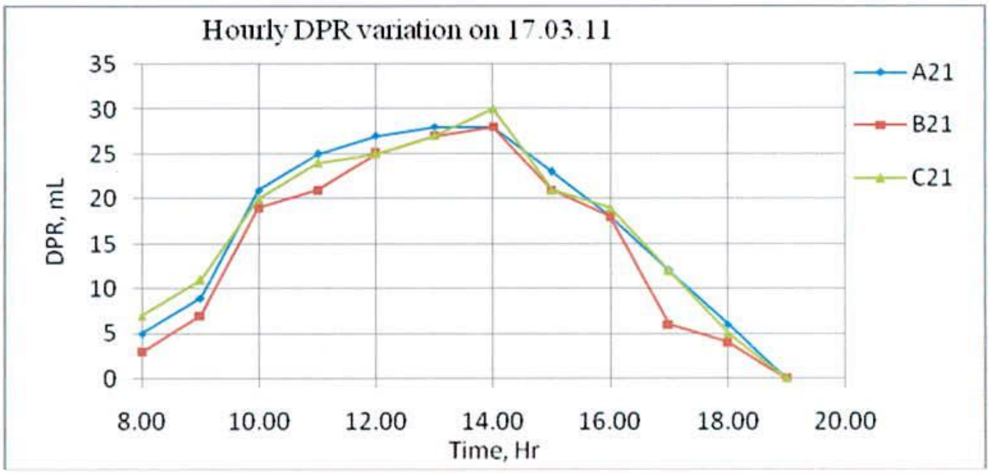

Figure 4.6.1: Hourly Distillate Production Rate (DPR) variation curve on 17/03/11

4.6.1 Variation of Hourly DPR with Daily Temperature

The hourly DPR has been monitored one day in a week for several months and those have been presented in the following figures 4.6.1 and 4.6.2. The DPR has been increased gradually and become maximum from 12.00 to 14.00 shown in the both figure. Then it has gradually been decreased up to the zero for all the setups at 19.00.

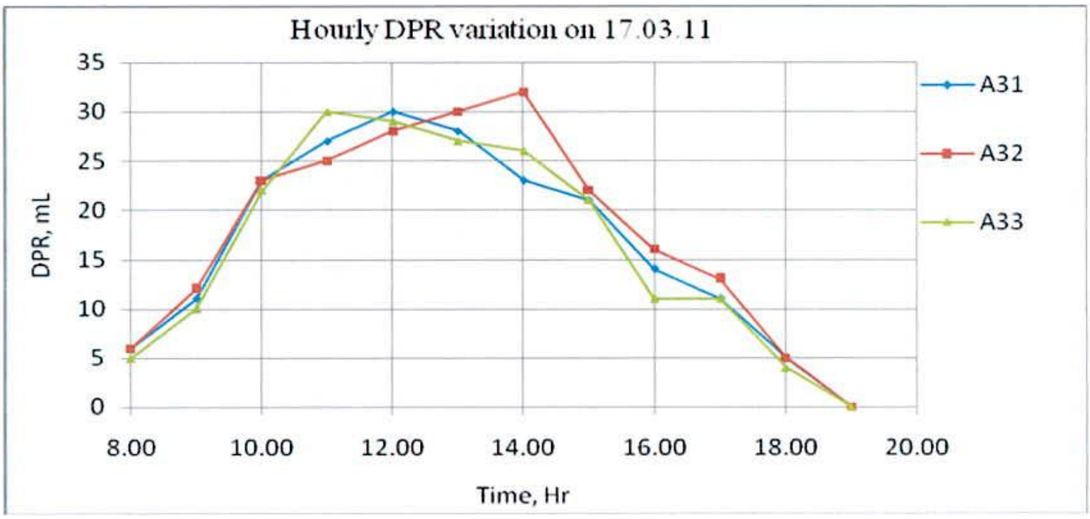

Figure 4.6.2: Hourly Distillate Production Rate (DPR) variation curve on 17/03/11

The other hourly DPR curves have been given the similar nature that's why those are incorporated in Annex. The temperature has only been monitored for A32 setup and presented in the following Figure 4.6.3 for 17.03.11:

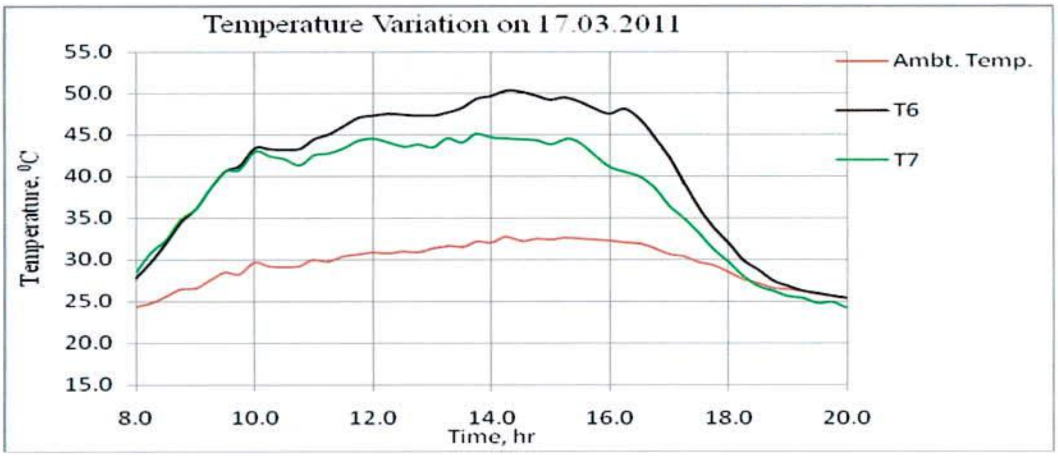

Figure 4.6.3: Hourly Temperature Variation on 17.03.2011 for A32

The temperature has been taken in every 15 minutes interval by using a K-type thermocouple. It was monitored uninterruptedly but shown in the Figure 4.6.3 during the hourly DPR monitoring period. In the Figure 4.6.3, red one represents the ambient temperature line, green one (T7) represents the temperature line of air within the setup and black one (T6) represents the temperature line. Both the temperatures within the setup have been increased with the ambient temperature but always found the difference from minimum of 5 ^{0}C to maximum of 20 ^{0}C, before a while maximum DPR was found in that day. On March 17, 2011, the maximum temperature was recorded on the textile surface.

From Figure 4.6.1-3, it has been observed that the DPR was increased with the increase of temperature and given the similar nature of curve. In the similar way, another day data analysis has also been depicted in the following discussion-

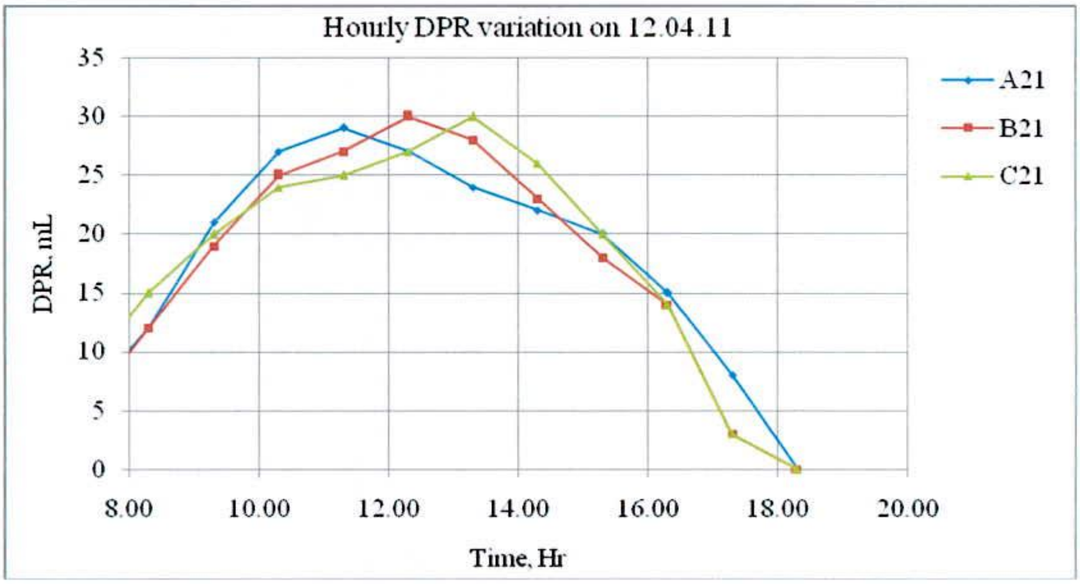

Figure 4.6.4: Hourly Distillate Production Rate (DPR) variation curve on 12.04.11

The variation of hourly DPR on 12.04.11 was almost similar with previously discussed one but the peak DPR was monitored within 12.00-14.00 and that was 30 mL for B21 & C21.

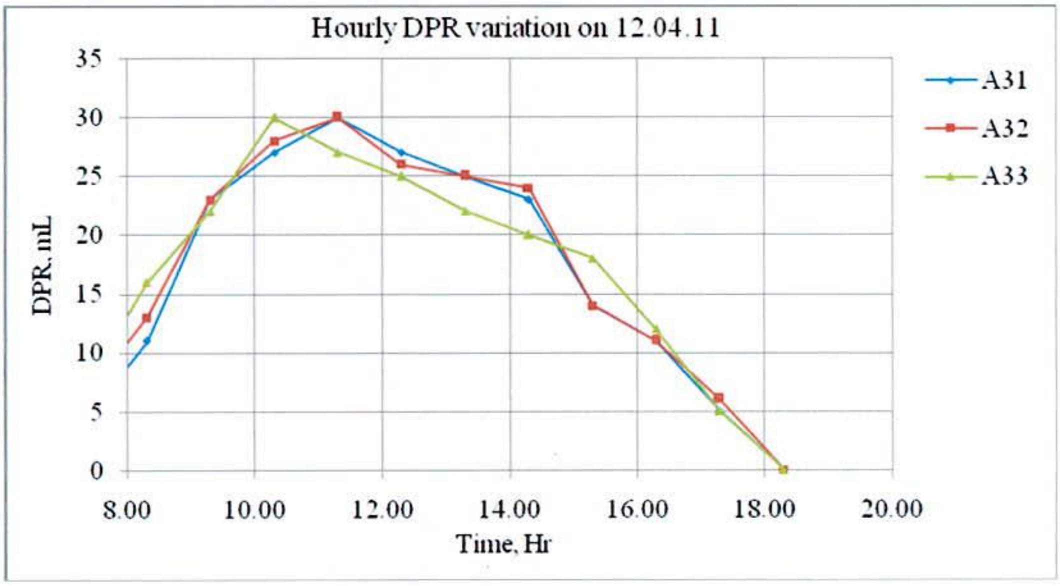

Figure 4.6.5: Hourly Distillate Production Rate (DPR) variation curve on 12.04.11

But from Figure 4.6.5, the peak DPR was monitored within 10.00-12.00 and that was 30 mL for A32 & A33 setup. All the setups got the peak earlier than those reached at lowest value.

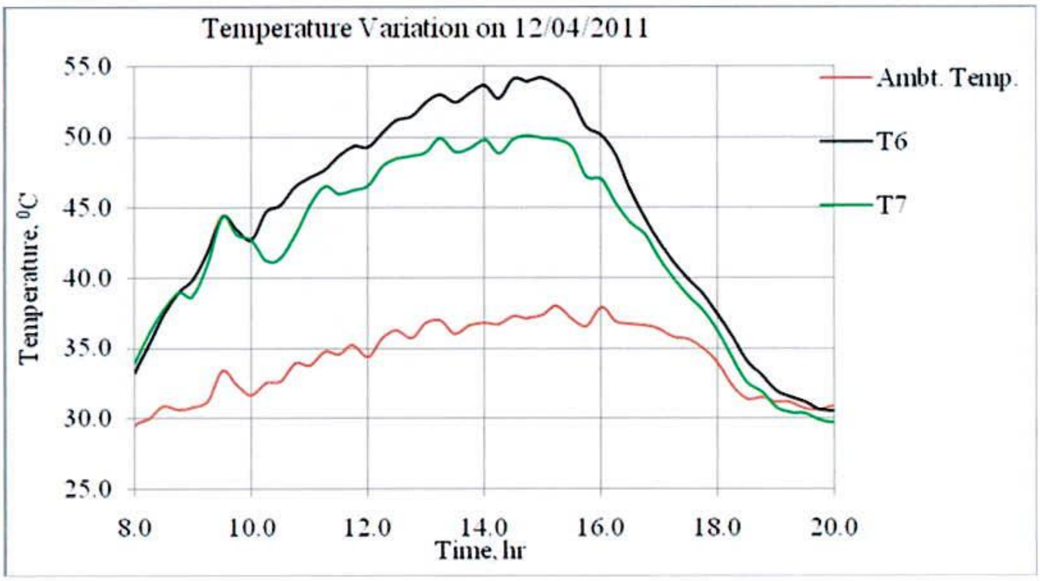

Figure 4.6.6: Hourly Temperature Variation on 12.04.2011 for A32

A closer look on the variation of hourly temperature shown in the Figure 4.6.3 and 4.6.6 for the date 17.03.11 and 12.04.11 respectively. The temperature was taken at the surface of the textile covers and the air in the setup including ambient. From the figure, it is clear that the the maximum temperature difference of 17.53^{0}C was found for ambient and textile surface temperature and 13.68^{0}C for ambient and air temperature in the setup. It was the significance findings this study.

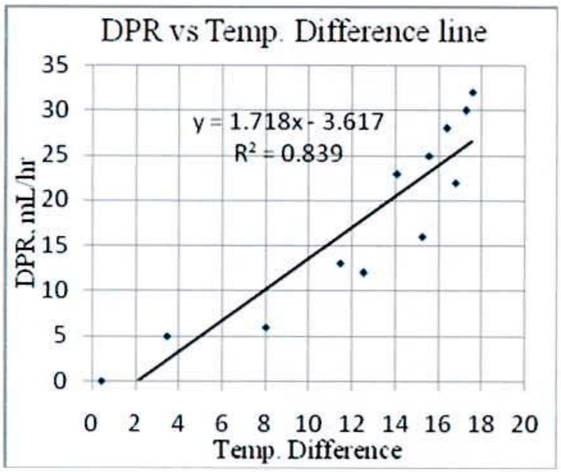

Figure 4.6.7: Hourly DPR vs Temp. Difference (Ambient & temp. on the textile surface) line on 17.03.11

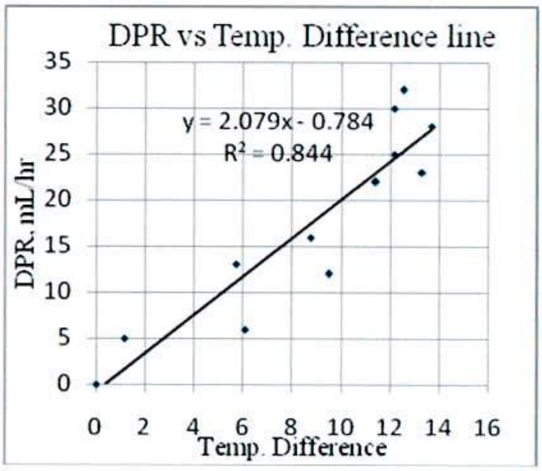

Figure 4.6.8: Hourly DPR vs Temp. Difference (Ambient & air temp. in the setup) line on 17.03.11

The Figures 4.6.7 & 4.6.8 have been depicted by the hourly DPR vs temperature difference, ambient and recorded internal temperature of the setup. From the both trend line equations, it is clear that the hourly DPR as well as the DPR is increased with the increase of temperature difference and the difference of ambient and internal air temperature gives the more DPR and this is also an another significance findings of this research work.

Chapter 5: **Operation and Maintenance of the System**

5.1 General

Water, the most plentiful natural resource on earth, has been a supporting actor on the worldwide stage of life far longer than most of us remember. In our lifetimes, however, we have relied on this valuable resource to help develop nations into international competitors, to grow crops for worldwide populations, and to quench our thirsts, whether we are working hard or playing hard. So, for some, it is very difficult to imagine that a world made up of so much water is running out of the drinking kind. The need for cost effective solutions to help solve worldwide shortages of fresh water especially in remote locations, such as coastal areas, desert facilities and small villages in the developing world can be logistically hard and complex but solar desalination can add a new direction to those thirsty people. In the consequence of available saline water, there are lots of solar desalination techniques which have been invented by the developed nations for the remote locations but most of them are community based and some are not suitable in operation & maintenance for those remote people like Bangladeshi coastal & island people. So, it is feeling a gap of a suitable desalination technique which will be made of locally available materials, user friendly, easy for operation & maintenance, cost effective for those low income remote people. In this study, it has been thought about the coastal people of southern part of Bangladesh who are severely affected by the salinity problem in their surface & ground water and has been introduced an innovative desalination technique for household level (known as Textile Cylinder Desalination Unit (TCDU) which would be a green solution for the thirsty world as well as for the people of coastal & island areas of Bangladesh and can meet their daily needs of drinking water. The technology involved in distillation of saline water using solar energy is relatively simple and operation & maintenance can be carried out by semi-skilled or unskilled operators. The materials used and the fabrication procedure of this desalination unit have been discussed in the Chapter-3 and in this chapter, operation & maintenance will be presented for its users in the household lever. The proper operation & maintenance of this system can increase the distillate production as well as its durability.

5.2 Installation of Textile Cylinder Desalination Unit (TCDU)

Before the system installation, its size has to be specified according to the drinking water requirement and that amounts depend on the family size & weather conditions. In the rural areas of Bangladesh, the water requirement for drinking purpose has been estimated as 2-3 lpcd. According to this estimation, a five member's family need the maximum amount of drinking water is 15 L/day. But from the results & discussion, the maximum amount of distillate have got of 0.25 L/day in summer season and minimum of 0.10 L/day in winter season where the cross-sectional area was only 245 cm^2, the evaporation surface area of 990 cm^2 and condensation surface area of 1920 cm^2. Since there is no chloride (Cl^-) concentration in the distillate but the chloride (Cl^-) concentration limit in drinking water is 1000 mg/L for coastal areas of Bangladesh where alternative sources is not available, so this chloride (Cl^-) can also be considered to fix up the size. To meet the above requirement of drinking water, the pure water obtained from the solar unit can be mixed up with the feed water prior to consumption and fix up the size & the number of unit. If the raw water is taken from the ground water source, its maximum chloride concentration would be 3000 mg/L. So 1.0L raw water can be added with the 2.0L distillate to meet the drinking water standard. Therefore, to meet the total demand of drinking water of that five member's family, the distillate production would be two-third of total demand. So the number or size of the TCDU is specified by considering two-third concept. After fixing the shape & model, the TCD system is installed at a safe placed where the sunlight keeps its shining in whole day. The total system is sufficiently fastened to protect from wind flow and other unexpected occurrence.

5.3 Operation of the Textile Cylinder Desalination Unit (TCDU)

The TCDU operation is very simple and do not need any special skill for its operation. After installing the TCDU at a suitable place, air tightness of all the joints are to be tested and confirmed fully air tight & availability of sunlight. In every morning before the sun rise, the textile cylinders are wetted carefully by raw water collected from the ground water source or saline surface water source and the opening of the unit is closed. The raw water is evaporated from the textile cylinder surface and condensed at the inner surface of the cover & stored in a container. The distillates are collected from the storage container and again employed that for the next collection. The wetting textile cylinder and collection of distillate is continued up to the unit life. The unit life depends on the proper maintenance which is discussed in the next article.

5.4 Maintenance of Textile Cylinder Desalination Unit (TCDU)

The maintenance of the unit is basically taken care of it for making it proper working and durable. For proper maintenance of the unit, it is made as rearrange able type that it can be reset after maintenance. Since the salts are kept back as a residue to the surface of the textile cylinder and degrade the textile durability, so a very thin layer of textile is wrapped on the cylinder surface which can be helpful for removing the residual salts at the maintenance period. It is better to clean the unit when the surface of textile is appeared white color of residual salts. All the segments of the unit are unfolded and washed out all residual salts by using raw water. After washing the segments are rearranged and installed at suitable place. It would be better to monitor the unit as much as possible for its any kinds of disturbance.

CHAPTER 6: **Conclusions and Recommendations**

6.1 General

This study has been started by considering the salinity problem in drinking water in the coastal areas of Bangladesh and tried to find out the way or mode of portable drinking water to the coastal people in the household level. In this study, household based newly introduced drinking water supply solar desalination unit has been monitored and drawn the following conclusions.

6.2 Conclusions

The conclusions of this study have been discussed point to point in the following articles.

1. *Distillate Production Rate (DPR)*
    - Three types of textiles or fabrics have been used in this study and all three types were shown the significant performance compared to the desalination system discussed in reviewed literature where jean textile shown the commendable performance.
    - For the Run-01 in the month November and December, 2010, the highest DPR was found 11.84 L/m^2/d for A11, 8.08 L/m^2/d for B11 & 10.02 L/m^2/d for C11 where the lowest values were 2.34 L/m^2/d, 1.70 L/m^2/d and 2.22 L/m^2/d accordingly. This lowest value found due to the cloudy and gloomy weather condition when atmospheric temperature became lower than its average temperature at that time.
    - From the Trial Run-01, the maximum DPR was of 8.77 L/m^2/d for A11 & 9.41 L/m^2/d for A21. A11 & A21 setups were showed the better performance than the others. But A21 always gave higher value than A11.
    - Up to the Run-02, the maximum DPR of 9.01 L/m^2/day was found for A31, whereas for A11, the value was about 8.89 L/m^2/day. Since the setups have been found dried off before the sunset, the configuration of Run-02 setups have been modified and found the maximum DPR 10.06 L/m^2/day for A42 where minimum of 3.27 L/m^2/day for A42. This minimum value has been found because of the cloudy and sun-shaded weather when atmospheric temperature became lower than its average temperature at that time.

- The area, considered above was cross-sectional area and the DPR would be increased without increasing of this area. There is a good advantageous provision to increase the DPR and that is extended in the vertical direction only. This concluding point would be a good step forward approach in the research field of solar desalination and this type of setup can be used adjacent to the building wall where there is sufficient sun light throughout the daytime as the area is densely populated.
- Most of the textiles became completely dry off within the fifth day from the starting except B11 where it became ninth day. The DPR for B11 in between period, fully wetted and dry off period, was found almost constant in every day but in ninth day it became zero.

2. *Durability of the setup*
    - The physical condition of plastic container was strong enough but it's cork became little bit weaker after one year of it successful use. And it was finally concluded that with the proper maintenance, these container would be used 3-4 years from the starting of setup as confirmed from the other research.
    - After one year continuous working, physical form of the buckets were totally unchanged and these would be possible to use around 03 years continuously by doing proper maintenance.
    - The cylindrical frames did not get any trouble after one of those working, either strength-stamina or appearance as well.
    - After one year of continuous working of the textile fibres, its physical condition has not been significantly defected and its inner side was looked like a new one as well. So this type of textile would be used around 3-4 years without any defect on it.
    - Above these consequences regarding durability, it has been concluded that the overall setup can be used minimum of 03 years although its different part showing different types of durability and used different salinity.
3. *Quality of Raw water and Distillate*
    - Whatever the quality of raw water, the parameters (salinity, electric conductivity and pH) of distillate tested in the laboratory were enough below the drinking water standard limit and to meet this drinking water standard, the distillate can be mixed with the raw water that result to increase the amount of drinkable water.
4. *Variation*

- The more DPR was found for the black color Jeans textiles than the others used in the setups and the latest setups were fabricated considering this point.
- From the hourly DPR and temperature analysis, the DPR was increased with the increased of temperature but the peak of the temperature has been occurred first and then the peak for DPR.
- The maximum temperature difference between ambient and textiles surface temperature was found of 17.53^{0}C where ambient and internal air temperature was 13.68^{0}C and this was one of a significance findings of this research.
- The DPR was increased with the increase of this temperature difference and the difference between ambient and internal air temperature was more significant. This was also the significance findings of this research work.

6.3 Recommendations

This study was conducted with its specific objectives and finally reached those but some research gaps have been experienced which may assist the researchers for further study. The gaps are as follows:

- In this study, only an open space laboratory investigation of the desalination system has been done but the mathematical modeling may be a great tool to get it's maximum efficiency of the system.
- Relative humidity of the air may also be incorporated in this study for a comprehensive understanding.
- The textile cylinders have been placed vertically in the setup but inclined placement may also be considered for the further detail investigation.
- Here tap and synthetic water were used as raw water but saline water from the river may also be the good investigation criterion for the coastal areas of our country.
- A large scale investigation may be conducted for the further continuation of this study to get more distillate production.
- For a large-scale investigation, an automated wetting system can be considered by using the energy generated solar panel.
- A trialing and error can be made considering the different surface areas like evaporation, condensation area to get the best efficiency from the setup.

Reference

Al-Hayek I., and Badran O., (2004), *The effect of using different designs of solar stills on water distillation*, Desalination, 169:121–127.

Abbot C.G., (1944) Smithsonian Inst. Ser., 2; U.S Patent No.2, 141,330 (Dec. 27, 1938).

Abu-Arabi M.K. and Zurigat Y.H., (2003), *Modelling and Performance Analysis of a Regenerative Solar Distillation Unit*, International Desalination Association BAH03-168.

Adhikari, R. S., and Kumar, A., (1999), *Cost optimization studies on a multi-stage stacked tray solar still*, Desalination, 125:115–121.

Al-Hallaj, S., Farid, M. M., and Tamimi, A., (1998), *Solar desalination with a humidification dehumidification cycle performance of the unit*, Desalination, 120:273–280.

Al-Juwayhel F., El-Dessouky H., and Ettouney H., (1997), *Analysis of single-effect evaporator desalination systems combined with vapor compression heat pumps*, 114(1997)253-275.

Al-Kharabsheh S. and Goswami D.Y., (2003), *Analysis of an innovative water desalination system using low-grade solar heat*, Elsevier, Desalination 156 (2003) 323-332.

Aly N.H. and El-Fiqi A.K., (2003), *Mechanical vapor compression desalination systems- a case study*, ELSEVIER, Desalination 158 (2003) 143-150.

Aristotle, (1962), Meteorological, Harvard University Press, Cambridge, MA. Book I (Chapter 91) pp. 127.

Aybar H., Egeliofglu F., and Atikol U., (2005), *An experimental study on an inclined solar water distillation system*, Desalination, 180:285–289.

Banat F., Jumah R. and Garaibeh M., (2002), *Exploitation of solar energy collected by solar stills from desalination by membrane distillation*, Renewable Energy. 25: 293-305.

Bari Q.H., Hassn K.M. and Hossain M.F. (2009). *Development of a low-cost and sustainable arsenic removal unit for the rural community in Bangladesh*, In the Proceedings of International Symposium on Southeast Asian Water Environment, Vol. 7, pp 1-6, Bangkok, Thailand.

Bier C. and Plantikow U., (1995), *Solar powered desalination by membrane distillation*, IDA World Congress on Desalination and Water Science, Abu Dhabi, pp. 397-410.

Bouchekima B., (2003), *A small solar desalination plant for the production of drinking water in remote arid areas of southern Algeria*, Elsevier, Desalination 159 (2003) 197-204.

Boukar, M., and Harmim, A., (2005), *Performance evaluation of a one-sided vertical solar still tested in the Desert of Algeria*, Desalination, 183:629–642.

Buros O., (2000), *The ABCs of Desalting*, Second Edition. International Desalination Association, Topsfield, Mass.

Buros O.K., (1999), *The ABCs of Desalting*, 2nd ed., FMC Corporation, International Desalination Association (IDA), Massachusetts and Saline Water Conversion Corporation (SWCC), Saudi Arabia.

Chafik, E., (2004), *Design of plants for solar desalination using the multistage heating/humidifying technique*, Desalination, 168:55–71.

Chaibi M.T., (2000), *Analysis by simulation of a solar still integrated in a greenhouse roof*, Elsevier, Desalination 128 (2000) 123-138.

Cipollina A., Micale G. and Rizzuti L., (2009), *Seawater Desalination: Conventional and Renewable Energy Processes*, Springer-Verlag Berlin Heidelberg, pp.5.

Cipollina, A.; Micale, G. and Rizzuti, L., (2009), *Seawater Desalination:Conventional and Renewable Energy Processes*, Springer, pp-58.

Cooley H., Gleick P. and Wolff G., (2006), *Desalination, With a Grain of Salt*, A California Perspective, Pacific Institute, California.

Cooper P.I. (1969), *Digital simulation of transient solar still processes*, Solar Energy, 12, 313.

Cotruvo J., Voutchkov N., Fawell J., Payment P., Cunliffe D. and Lattemann S., (2010), *Desalination Technology Health and Environmental Impacts*, IWA, CRC Press, pp.xi.

Crittenden, J.; Trussell, R.; Hand, D.; Howe, K. and Tchobanoglous, G. (2005), *Water Treatment Principles and Design*, Edition 2. John Wiley and Sons. New Jersey.

Delano W.R.P., (1946a), *Process and apparatus for distilling liquids*, US Patent 2.402.737, 25 June.

Delano W.R.P., (1946b), *Solar still with no fogging window*, US Patent 2.413.101, 24 December.

Delano W.R.P., and Meisner W.E., (1946), *Solar distillation apparatus*, US Patent 2.405.118, 5 August.

Delyannis E. and Belessiotis V., (2001), *Solar energy and desalination*, In: Goswami, D.Y. (Ed.), Advances in Solar Energy, An annual review of research and development, American Solar Energy Society, Inc, Boulder, Colorado, pp. 287–330.

Delyannis E., (2003), *Historic background of desalination and renewable energies*, Solar Energy, Elsevier, 75 (2003) 357–366.

Ding Z., Liu L., El-Bourawi M., and Ma R., (2005), *Analysis of a solar-powered membrane distillation system*. Desalination 172: 27-40.

Dunkle R.V., (1961), *Solar water distillation: The roof type still and a multiple effect diffusion still*, In: Proceedings of the International Conference of Heat Transfer, University of Colorado, Publication No. 108, pp. 895–902.

El-Dessouky H.T. and Ettouney H.M., (2002), *Fundamentals of Salt Water Desalination*, Elsevier Science b.V., First edition, p.28.

El-Sebaii A.A., (2004), *Effect of wind speed on active and passive solar stills*, Elsevier, Energy Conversion and Management 45 (2004) 1187–1204.

Energy, Contract number 4.1030/Z/01-081/2001.

Escobar I.C and Schafer A.I., (2010), *Sustainability Science and Engineering: Sustainable Water for the Future Water Recycling versus Desalination*, ELSEVIER SCIENCE B.V., First edition, Vol.2, p.3.

Ettouney, H. M., (2005), *Design and analysis of humidification dehumidification desalination process*, Desalination, 183:857–868.

European Commission, (2002), Renewable Energy Driven Desalination Systems.

Farid, M., and Al-Hajaj, A., (1999), *Solar desalination with a humidification-dehumidification cycle*, Desalination, 106:427–429.

Fath H.E.S., El-Samanoudy M., Fahmy K. and Hassaboud A. (2003), *Thermal-economic analysis and comparison between pyramid shaped and single-slope solar still configurations*, Desalination 159: 69- 79.

Glater, J. (1998). *"The early history of reverse osmosis membrane development"*, Desalination 117: 297–309. doi:10.1016/S0011-9164(98)00122-2.

Goosen, M. F. A., Sablani, S. S., Shayya, W. H., Paton, C., and Al-Hinai, H., (2000), *Thermodynamic and economic consideration in solar desalination*, Desalination, 129:63–89.

Graeter, F., Duerrbeck, M., and Rheinlaender, J., (2001), *Multi-effect-still for hybrid solar/fossil desalination of sea and brackish water*, Desalination, 138:111–119.

Harding J. (1883), *Apparatus for Solar Desalination*, Institute of Civil Engineers, 73, 284.

Hogan P., Sudjito A., Fane G., and Morrison G., (1991) Desalination by solar heated membrane distillation, Desalination. 81: 81-90.

IDA, (2006), Int. Desalination Association, Worldwide Desalting Plants Inventory, International Desalination Association.

Jubran B.A., Ahmed M.I., Ismail A.F. and Abakar Y.A., (2000), *Numerical modelling of a multi-stage solar still*, Pergamon, Energy Conversion & Management 41 (2000) 1107-1121.

Kalogirou S., (1997), *Survey of solar desalination systems and system selection*, Energy 22 (1), 69–81.

Khan, S.H., Rahman, T. and Hossain, S., (2012), *A brief study of the prospect of Solar energy in generation of Electricity in Bangladesh*, Journal of the Renewable and Sustainable Energy (JRSE), June Edition.

Koschikowski J., Wieghaus M. and Rommel M., (2003), *Solar thermal-driven desalination plants based on membrane distillation*, Desalination, 156: 295- 304.

Kumar S. and Sinha S., (1995), *Transient Model and Comparative Study of Concentrator Coupled Regenerative Solar Still in Forced Circulation Mode*, Pergamon, 01964904(95)00177-8.

Mallik M.A.S, Tiwari G.N, Kumar A.and Sodha M.S, (1982), *Solar Distillation a Practical Study of a Wide Range of Stills and Their Optimum Design*, Construction and performence, Pergamon press Ltd., First edition, pp.2.

McGraw-Hill Science & Technology Encyclopedia: Membrane distillation, http: //www.answers.com/topic/membrane-distillation. (Accessed on 10/25/2011)

Mouchot A., (1879), *La chaleur solaire et ses applications industrielles (Solar Heat and its Industrial Applications)*, Gauthier-Villars, Paris. pp .238 & pp. 233.

Müller-Holst, H., Engelhardt, M., and Scholkopf, W., (1999), *Small-scale thermal seawater desalination simulation and optimization of system design*, Desalination, 122:255–262.

Multiple Effect Distillation: http://www.sidem-desalination.com/en/process/MED (Accessed on 10/16/2011)

Multiple Stage Flash Processes, http://www.sidem-desalination.com/en/process/MSF. (Accessed on 10/21/2011).

Nafey A.S., Fath H.E.S., El-Helaby S.O. and Soliman A.M., (2004), *Solar desalination using humidification dehumidification processes*, Part I. A numerical investigation, Elsevier, Energy Conversion and Management 45 (2004) 1243–1261.

Nafey A.S., Fath H.E.S., El-Helaby S.O. and Soliman A.M. (2004), *Solar desalination using humidification dehumidification processes*, Part I. A numerical investigation, Energy Conversion and Management 45 1243–1261.

Nafey A.S., Fath H.E.S., El-Helaby S.O. and Soliman A.M., (2004), *Solar desalination using humidification dehumidification processes*, Part II. An experimental investigation, Elsevier, Energy Conversion and Management 45 (2004) 1263–1277.

Narayan G.P., Sharqawy M.H., Summers E.K., Lienhard J.H., Zubair S.M., and Antar M.A., (2010), *The potential of solar-driven humidification-dehumidification desalination for* *small-scale decentralized water production*, Elsevier, Renewable and Sustainable Energy Reviews 14.4 (2010): 1187-1201.

Nawayseh, N. K., Farid, M. M., Omar, A., Al-Hallaj, S. M., and Tamimi, A., (1997), *A simulation study to improve the performance of a solar humidification-dehumidification desalination unit constructed in Jordan*, Desalination, 109:277–284.

NRC, (2008), *Desalination: A National Perspective, Committee on Advancing Desalination Technology*, Water Science and Technology Board, National Research Council (NRC) of the U.S. National Academies, 2008.

Omri, A., Orfi, J., and Ben Nasrallah, S., (2005), *Natural convection effects in solar stills*, Desalination, 183:689–694.

Parekh S., Farid M.M., Selma J .R. and A l-Hallaj S. (2004), *Solar desalination with a humidification-dehumidification technique - a comprehensive technical review*, Desalination 160: 167-186.

Rahim N. H. A., (2001), *Utilization of new technique to improve the efficiency of horizontal solar desalination still*, Desalination, 138:121–128.

Reddes, Directorate-General for Energy and Transport Directorate General for Reverse osmosis, http://en.wikipedia.org/wiki/Reverse_osmosis#cite_note-water-0. (Accessed on 10/28/2011)

Rizzuti L.; Ettouney, H.M. and Cipollina A., (2006), *Solar Desalination for the 21st Century: A Review of Modern Technologies and Researches on Desalination Coupled to Renewable Energies*, Proceedings of the NATO Advanced Research Workshop on Solar Desalination for the 21st Century Hammamet, Tunisia 23--25 February 2006.

Solar Still Basics, http://www.solaqua.com/solstilbas.html. (Accessed on 10/24/2011).

Solar still, http://en.wikipedia.org/wiki/Solar_still. (Accessed on 10/24/2011).

Spiegler K., El-Sayed Y., (1994), *A Desalination Primer*, Balaban Desalination Publications, Santa Maria Imbaro, Italy.

Strathmann, H., (2004), *Ion-Exchange Membrane Separation Processes*, Elsevier, New York.

Tekutchev A.N., (1938), *Physical basis for the construction and calculation of a solar still with fluted surface*, Transactions of the Uzbekistan State University Samarkand 2.

Telkes M., (1945), *Solar Distiller for Life Rafts*, United States Office of Science, R & D Report No. 5225, P.B.21120.

Telkes M., (1945), *Solar distiller for life rafts,* US Office Technical Service, Report No. 5225 MIT, OSRD. Final Report, to National Defense Research Communication, 11.2, p. 24.

Telkes M., (1956a), *Research for methods on solar distillation*, OSW Report No. 13, PB 161388, pp.66.

Telkes M., (1956b), *Solar stills. In: Proceedings of World Symposium on Applied Solar Energy*, pp. 73–79.

Thermal vapor compression (TVC), http://www.theenergylibrary.com/node/4196, (Accessed on 10/23/2011)

Tiwari, A. K., and Tiwari, G. N., (2005), *Effect of the condensing cover's slope on internal heat and mass transfer in distillation: an indoor simulation*, Desalination, 180:73–88.

TThomas K., (1997) Overview of Village Scale, *Renewable Energy Powered Desalination*, NREL/TP-440-22083, UC Category: 1210 DE 97000240.

Vapor-compression desalination, http://en.wikipedia.org/wiki/Vapor compression desalination. (Accessed on 10/24/2011)

Vapor-compression evaporation, http://en.wikipedia.org/wiki/Vapor-compression_ evaporation. (Accessed on 10/23/2011)

Vetus T., M.DC.XXVIII. Secundum LXX, Sixti V. Pont Max (Ed.), Exodus Cap. XV, 22–25, *Tomus primus, Benfilienfi & Naui Aurea*, Litetiae Parisiorum.

Veza J.M., (1995) *Mechanical vapour compression desalination plants - A case study*, Desalination, 101(1995)1-10.

Virka G.S., Ford M.G., Dennessb B., Ridett A., and Huntefi A. (2001) Ambient energy for low-cost water desalination, Elsevier, Desalination1 37 (2001) 149-156.

Vlachogiannis, M., Bontozoglou, V., Georgalas, C., and Litinas, G., (1999), *Desalination by mechanical compression of humid air*, Desalination, 122:35–42.

Voropoulos, K., Mathioulakis, E., and Belessiotis, V., (2003), *Experimental investigation of the behavior of a solar still coupled with hot water storage tank*, Desalination, 156:315–322.

Walton J., Lu H., Turner C., Solis S., and Hein H., (2004), *Solar and Waste Heat Desalination by Membrane Distillation, Desalination and Water Purification Research and Development Program,* Report No. 81.College of Engineering, University of Texas at El Paso.

Wang X. and Ng K.C, (2005), *Experimental investigation of an adsorption desalination plant using low-temperature waste heat*, Elsevier, Applied Thermal Engineering 25 (2005) 2780–2789.

Wang, L.K.; Chen, J.P.; Hung, Y.T. and Shammas, N.K.; (VOLUME 13) *Handbook of Environmental Engineering: Membrane and Desalination Technologies*, Humana Press.

Wangnick, K., (1995) IDA Worldwide Desalting Plants Inventory, Topsfield, MA:

Wikipedia on Answers.com: Reverse osmosis, http://www.answers.com/topic/reverse-osmosis. (Accessed on 10/25/2011)

Zimerman Z., (1994) *Development of large capacity high efficiency mechanical vapor compression (MVC) units*, Desalination, 96(1994)51-58.

Annex-I

A_{cross}= Textile Cylinder Desalination Unit

(TCDU) Cross Sectional Area (245 cm²)

$A_{evp.}$ = Evaporation surface Area (1000 cm²)

$A_{cond.}$ = Condensation surface Area (1915cm²)

Table-A: Distillate Production Rate (DPR) During the Period November and December, 2010 (Run-01)

Date	Distillate Production rate (DPR)											
	A11				B11				C11			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
01.11.10	169	6.90	1.71	0.88	114	4.65	1.14	0.60	97	3.96	0.98	0.51
02.11.10	75	3.06	0.76	0.39	56	2.29	0.56	0.29	78	3.18	0.79	0.41
03.11.10	183	7.47	1.85	0.96	134	5.47	1.34	0.70	155	6.33	1.57	0.81
04.11.10	242	9.88	2.44	1.26	175	7.14	1.75	0.91	222	9.06	2.25	1.16
05.11.10	182	7.43	1.84	0.95	139	5.67	1.39	0.73	164	6.69	1.66	0.86
06.11.10	172	7.02	1.74	0.90	200	8.16	2.00	1.04	208	8.49	2.11	1.09
07.11.10	170	6.94	1.72	0.89	203	8.29	2.03	1.06	210	8.57	2.13	1.10
08.11.10	235	9.59	2.37	1.23	153	6.24	1.53	0.80	180	7.35	1.82	0.94
09.11.10	122	4.98	1.23	0.64	96	3.92	0.96	0.50	98	4.00	0.99	0.51
10.11.10	253	10.33	2.56	1.32	178	7.27	1.78	0.93	205	8.37	2.07	1.07
12.11.10	290	11.84	2.93	1.51	200	8.16	2.00	1.04	245	10.00	2.48	1.28
13.11.10	162.5	6.63	1.64	0.85	131.5	5.37	1.32	0.69	137.5	5.61	1.39	0.72
14.11.10	175	7.14	1.77	0.91	132.5	5.41	1.33	0.69	150	6.12	1.52	0.78
15.11.10	177.5	7.24	1.79	0.93	132.5	5.41	1.33	0.69	157	6.41	1.59	0.82
16.11.10	205	8.37	2.07	1.07	150	6.12	1.50	0.78	180	7.35	1.82	0.94

Date	Distillate Production rate (DPR)											
	A11				B11				C11			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
17.11.10	170	6.94	1.72	0.89	142	5.80	1.42	0.74	168	6.86	1.70	0.88
18.11.10	145	5.92	1.46	0.76	133	5.43	1.33	0.69	152	6.20	1.54	0.79
19.11.10	150	6.12	1.52	0.78	120	4.90	1.20	0.63	107	4.37	1.08	0.56
20.11.10	139	5.67	1.40	0.73	132	5.39	1.32	0.69	144	5.88	1.46	0.75
21.11.10	110	4.49	1.11	0.57	92.5	3.78	0.93	0.48	107.5	4.39	1.09	0.56
22.11.10	182	7.43	1.84	0.95	147	6.00	1.47	0.77	160	6.53	1.62	0.84
23.11.10	200	8.16	2.02	1.04	162	6.61	1.62	0.85	179	7.31	1.81	0.93
24.11.10	182	7.43	1.84	0.95	138	5.63	1.38	0.72	160	6.53	1.62	0.84
26.11.10	98	4.00	0.99	0.51	82	3.35	0.82	0.43	85	3.47	0.86	0.44
27.11.10	152	6.20	1.54	0.79	122	4.98	1.22	0.64	140	5.71	1.42	0.73
28.11.10	152	6.20	1.54	0.79	122	4.98	1.22	0.64	140	5.71	1.42	0.73
29.11.10	224	9.14	2.26	1.17	180	7.35	1.80	0.94	210	8.57	2.13	1.10
30.11.10	57	2.33	0.58	0.30	42	1.71	0.42	0.22	54	2.20	0.55	0.28
01.12.10	200	8.16	2.02	1.04	160	6.53	1.60	0.84	177.5	7.24	1.80	0.93
03.12.10	224	9.14	2.26	1.17	180	7.35	1.80	0.94	193	7.88	1.95	1.01
04.12.10	180	7.35	1.82	0.94	150	6.12	1.50	0.78	168	6.86	1.70	0.88
05.12.10	165	6.73	1.67	0.86	143	5.84	1.43	0.75	157	6.41	1.59	0.82
06.12.10	54	2.20	0.55	0.28	45	1.84	0.45	0.23	52.5	2.14	0.53	0.27
07.12.10	45	1.84	0.45	0.23	25	1.02	0.25	0.13	35	1.43	0.35	0.18
08.12.10	43	1.76	0.43	0.22	32	1.31	0.32	0.17	39	1.59	0.39	0.20
09.12.10	37	1.51	0.37	0.19	26	1.06	0.26	0.14	34	1.39	0.34	0.18

Date	Distillate Production rate (DPR)											
	A11				B11				C11			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
10.12.10	78	3.18	0.79	0.41	69	2.82	0.69	0.36	74	3.02	0.75	0.39
11.12.10	70	2.86	0.71	0.37	59	2.41	0.59	0.31	63	2.57	0.64	0.33
12.12.10	206	8.41	2.08	1.08	160	6.53	1.60	0.84	184	7.51	1.86	0.96
14.12.10	138	5.63	1.39	0.72	108	4.41	1.08	0.56	120	4.90	1.21	0.63
15.12.10	142	5.80	1.43	0.74	104	4.24	1.04	0.54	125	5.10	1.27	0.65
16.12.10	300	12.24	3.03	1.57	220	8.98	2.20	1.15	255	10.41	2.58	1.33
17.12.10	160	6.53	1.62	0.84	127.5	5.20	1.28	0.67	150	6.12	1.52	0.78
19.12.10	185	7.55	1.87	0.97	157	6.41	1.57	0.82	169	6.90	1.71	0.88
21.12.10	160	6.53	1.62	0.84	143	5.84	1.43	0.75	156	6.37	1.58	0.81
22.12.10	165	6.73	1.67	0.86	127.5	5.20	1.28	0.67	151	6.16	1.53	0.79
23.12.10	175	7.14	1.77	0.91	144	5.88	1.44	0.75	153	6.24	1.55	0.80
24.12.10	124	5.06	1.25	0.65	108	4.41	1.08	0.56	118	4.82	1.19	0.62
25.12.10	126	5.14	1.27	0.66	102	4.16	1.02	0.53	122	4.98	1.23	0.64
26.12.10	155	6.33	1.57	0.81	131	5.35	1.31	0.68	145	5.92	1.47	0.76
28.12.10	207	8.45	2.09	1.08	181	7.39	1.81	0.95	184	7.51	1.86	0.96
29.12.10	145	5.92	1.46	0.76	131	5.35	1.31	0.68	150	6.12	1.52	0.78
30.12.10	98	4.00	0.99	0.51	78	3.18	0.78	0.41	95	3.88	0.96	0.50

Table-B: Distillate Production Rate (DPR) During the Period January to November, 2011 (Run-01 and its replica)

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
01.01.11	145	5.92	1.465	0.757	139	5.67	1.393	0.726	140	5.71	1.417	0.731	120	4.90	1.212	0.627	121	4.94	1.212	0.632	114	4.65	1.154	0.595
02.01.11	151	6.16	1.525	0.789	130	5.31	1.303	0.679	131	5.35	1.326	0.684	115	4.69	1.162	0.601	115	4.69	1.152	0.601	114	4.65	1.154	0.595
03.01.11	144	5.88	1.455	0.752	132	5.39	1.323	0.689	139	5.67	1.407	0.726	110	4.49	1.111	0.574	109	4.45	1.092	0.569	122	4.98	1.235	0.637
04.01.11	125	5.10	1.263	0.653	130	5.31	1.303	0.679	126	5.14	1.275	0.658	153	6.24	1.545	0.799	97	3.96	0.972	0.507	140	5.71	1.417	0.731
05.01.11	100	4.08	1.010	0.522	78	3.18	0.782	0.407	87	3.55	0.881	0.454	105	4.29	1.061	0.548	81	3.31	0.812	0.423	98	4.00	0.992	0.512
07.01.11	131	5.35	1.323	0.684	91	3.71	0.912	0.475	114	4.65	1.154	0.595	113	4.61	1.141	0.590	106	4.33	1.062	0.554	106	4.33	1.073	0.554
08.01.11	158	6.45	1.596	0.825	106	4.33	1.062	0.554	130	5.31	1.316	0.679	137	5.59	1.384	0.715	120	4.90	1.202	0.627	122	4.98	1.235	0.637
09.01.11	157	6.41	1.586	0.820	115	4.69	1.152	0.601	119	4.86	1.204	0.621	140	5.71	1.414	0.731	118	4.82	1.182	0.616	125	5.10	1.265	0.653
10.01.11	117	4.78	1.182	0.611	97	3.96	0.972	0.507	122.5	5.00	1.240	0.640	135	5.51	1.364	0.705	92.5	3.78	0.927	0.483	121	4.94	1.225	0.632
11.01.11	129	5.27	1.303	0.674	105	4.29	1.052	0.548	113	4.61	1.144	0.590	149	6.08	1.505	0.778	111	4.53	1.112	0.580	137	5.59	1.387	0.715
12.01.11	67	2.73	0.677	0.350	43	1.76	0.431	0.225	58	2.37	0.587	0.303	61	2.49	0.616	0.319	46	1.88	0.461	0.240	51	2.08	0.516	0.266
13.01.11	83	3.39	0.838	0.433	67	2.73	0.671	0.350	79	3.22	0.800	0.413	81	3.31	0.818	0.423	86	3.51	0.862	0.449	94	3.84	0.951	0.491
16.01.11	215	8.78	2.172	1.123	190	7.76	1.904	0.992	210	8.57	2.126	1.097	230.5	9.41	2.328	1.204	202	8.24	2.024	1.055	220	8.98	2.227	1.149
17.01.11	138	5.63	1.394	0.721	112	4.57	1.122	0.585	142	5.80	1.437	0.742	107	4.37	1.081	0.559	123	5.02	1.232	0.642	112.5	4.59	1.139	0.587
18.01.11	142.5	5.82	1.439	0.744	105	4.29	1.052	0.548	145	5.92	1.468	0.757	132	5.39	1.333	0.689	102	4.16	1.022	0.533	120	4.90	1.215	0.627
19.01.11	170	6.94	1.717	0.888	107	4.37	1.072	0.559	132	5.39	1.336	0.689	179	7.31	1.808	0.935	129	5.27	1.293	0.674	150	6.12	1.518	0.783

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
20.01.11	167.5	6.84	1.692	0.875	113	4.61	1.132	0.590	164	6.69	1.660	0.856	167.5	6.84	1.692	0.875	117	4.78	1.172	0.611	142	5.80	1.437	0.742
21.01.11	171	6.98	1.727	0.893	121	4.94	1.212	0.632	163	6.65	1.650	0.851	172	7.02	1.737	0.898	115	4.69	1.152	0.601	147	6.00	1.488	0.768
22.01.11	164	6.69	1.657	0.856	112	4.57	1.122	0.585	159	6.49	1.609	0.830	161	6.57	1.626	0.841	112	4.57	1.122	0.585	141	5.76	1.427	0.736
23.01.11	162	6.61	1.636	0.846	109	4.45	1.092	0.569	158	6.45	1.599	0.825	159	6.49	1.606	0.830	113	4.61	1.132	0.590	138	5.63	1.397	0.721
24.01.11	165	6.73	1.667	0.862	133	5.43	1.333	0.695	153	6.24	1.549	0.799	172	7.02	1.737	0.898	141	5.76	1.413	0.736	148	6.04	1.498	0.773
25.01.11	161	6.57	1.626	0.841	134	5.47	1.343	0.700	151	6.16	1.528	0.789	169	6.90	1.707	0.883	138	5.63	1.383	0.721	142	5.80	1.437	0.742
26.01.11	162	6.61	1.636	0.846	120	4.90	1.202	0.627	149	6.08	1.508	0.778	155	6.33	1.566	0.809	137	5.59	1.373	0.715	147	6.00	1.488	0.768
27.01.11	120	4.90	1.212	0.627	101	4.12	1.012	0.527	117	4.78	1.184	0.611	123	5.02	1.242	0.642	97	3.96	0.972	0.507	118	4.82	1.194	0.616
28.01.11	111	4.53	1.12	0.58	97	3.96	0.97	0.51	110	4.49	1.11	0.57	115	4.69	1.16	0.60	91	3.71	0.91	0.48	108	4.41	1.09	0.56
29.01.11	177	7.22	1.79	0.92	125	5.10	1.25	0.65	175	7.14	1.77	0.91	175	7.14	1.77	0.91	137	5.59	1.37	0.72	160	6.53	1.62	0.84
30.01.11	162	6.61	1.64	0.85	136	5.55	1.36	0.71	163	6.65	1.65	0.85	167	6.82	1.69	0.87	127	5.18	1.27	0.66	163	6.65	1.65	0.85
31.01.11	162	6.61	1.64	0.85	115	4.69	1.15	0.60	157	6.41	1.59	0.82	159	6.49	1.61	0.83	127	5.18	1.27	0.66	156	6.37	1.58	0.81

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	A_{evp}	A_{cond}		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	A_{evp}	$A_{cond.}$
01.02.11	170	6.94	1.72	0.89	137	5.59	1.37	0.72	161	6.57	1.63	0.84	166	6.78	1.68	0.87	132	5.39	1.32	0.69	161	6.57	1.63	0.84
02.02.11	166	6.78	1.68	0.87	138	5.63	1.38	0.72	160	6.53	1.62	0.84	171	6.98	1.73	0.89	134	5.47	1.34	0.70	161	6.57	1.63	0.84
03.02.11	171	6.98	1.73	0.89	141	5.76	1.41	0.74	165	6.73	1.67	0.86	170	6.94	1.72	0.89	136	5.55	1.36	0.71	162	6.61	1.64	0.85

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
04.02.11	162	6.61	1.64	0.85	137	5.59	1.37	0.72	160	6.53	1.62	0.84	165	6.73	1.67	0.86	140	5.71	1.40	0.73	156	6.37	1.58	0.81
05.02.11	175	7.14	1.77	0.91	140	5.71	1.40	0.73	173	7.06	1.75	0.90	189	7.71	1.91	0.99	149	6.08	1.49	0.78	166	6.78	1.68	0.87
06.02.11	161	6.57	1.63	0.84	122	4.98	1.22	0.64	150	6.12	1.52	0.78	165	6.73	1.67	0.86	125	5.10	1.25	0.65	162	6.61	1.64	0.85
07.02.11	170	6.94	1.72	0.89	134	5.47	1.34	0.70	168	6.86	1.70	0.88	173	7.06	1.75	0.90	140	5.71	1.40	0.73	165	6.73	1.67	0.86
08.02.11	181	7.39	1.83	0.95	147	6.00	1.47	0.77	178	7.27	1.80	0.93	177	7.22	1.79	0.92	148	6.04	1.48	0.77	190	7.76	1.92	0.99
09.02.11	183	7.47	1.85	0.96	152	6.20	1.52	0.79	182	7.43	1.84	0.95	187	7.63	1.89	0.98	156	6.37	1.56	0.81	191	7.80	1.93	1.00
10.02.11	189	7.71	1.91	0.99	157	6.41	1.57	0.82	187	7.63	1.89	0.98	192	7.84	1.94	1.00	165	6.73	1.65	0.86	194	7.92	1.96	1.01
11.02.11	193	7.88	1.95	1.01	166	6.78	1.66	0.87	186	7.59	1.88	0.97	190	7.76	1.92	0.99	172	7.02	1.72	0.90	189	7.71	1.91	0.99
12.02.11	180	7.35	1.82	0.94	166	6.78	1.66	0.87	182	7.43	1.84	0.95	188	7.67	1.90	0.98	170	6.94	1.70	0.89	186	7.59	1.88	0.97
13.02.11	185	7.55	1.87	0.97	164	6.69	1.64	0.86	182	7.43	1.84	0.95	192	7.84	1.94	1.00	171	6.98	1.71	0.89	190	7.76	1.92	0.99
14.02.11	189	7.71	1.91	0.99	169	6.90	1.69	0.88	188	7.67	1.90	0.98	186	7.59	1.88	0.97	171	6.98	1.71	0.89	191	7.80	1.93	1.00
15.02.11	191	7.80	1.93	1.00	171	6.98	1.71	0.89	190	7.76	1.92	0.99	187	7.63	1.89	0.98	176	7.18	1.76	0.92	190	7.76	1.92	0.99
16.02.11	196	8.00	1.98	1.02	177	7.22	1.77	0.92	193	7.88	1.95	1.01	190	7.76	1.92	0.99	181	7.39	1.81	0.95	194	7.92	1.96	1.01
17.02.11	193	7.88	1.95	1.01	172	7.02	1.72	0.90	193	7.88	1.95	1.01	192	7.84	1.94	1.00	182	7.43	1.82	0.95	191	7.80	1.93	1.00
18.02.11	187	7.63	1.89	0.98	185	7.55	1.85	0.97	211	8.61	2.14	1.10	215	8.78	2.17	1.12	190	7.76	1.90	0.99	212	8.65	2.15	1.11
19.02.11	178	7.27	1.80	0.93	161	6.57	1.61	0.84	183	7.47	1.85	0.96	190	7.76	1.92	0.99	169	6.90	1.69	0.88	189	7.71	1.91	0.99
20.02.11	146	5.96	1.47	0.76	115	4.69	1.15	0.60	145	5.92	1.47	0.76	76	3.10	0.77	0.40	120	4.90	1.20	0.63	150	6.12	1.52	0.78
21.02.11	112	4.57	1.13	0.58	78	3.18	0.78	0.41	105	4.29	1.06	0.55	108	4.41	1.09	0.56	92	3.76	0.92	0.48	115	4.69	1.16	0.60
22.02.11	167	6.82	1.69	0.87	139	5.67	1.39	0.73	171	6.98	1.73	0.89	173	7.06	1.75	0.90	151	6.16	1.51	0.79	176	7.18	1.78	0.92
23.02.11	178	7.27	1.80	0.93	152	6.20	1.52	0.79	173	7.06	1.75	0.90	183	7.47	1.85	0.96	150	6.12	1.50	0.78	171	6.98	1.73	0.89
24.02.11	183	7.47	1.85	0.96	163	6.65	1.63	0.85	181	7.39	1.83	0.95	184	7.51	1.86	0.96	159	6.49	1.59	0.83	179	7.31	1.81	0.93

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
25.02.11	187	7.63	1.89	0.98	169	6.90	1.69	0.88	192	7.84	1.94	1.00	185	7.55	1.87	0.97	157	6.41	1.57	0.82	183	7.47	1.85	0.96
26.02.11	185	7.55	1.87	0.97	166	6.78	1.66	0.87	188	7.67	1.90	0.98	185	7.55	1.87	0.97	161	6.57	1.61	0.84	184	7.51	1.86	0.96
27.02.11	191	7.80	1.93	1.00	161	6.57	1.61	0.84	190	7.76	1.92	0.99	190	7.76	1.92	0.99	169	6.90	1.69	0.88	197	8.04	1.99	1.03
28.02.11	176	7.18	1.78	0.92	178	7.27	1.78	0.93	177	7.22	1.79	0.92	175	7.14	1.77	0.91	172	7.02	1.72	0.90	187	7.63	1.89	0.98
01.03.11	168	6.86	1.70	0.88	180	7.35	1.80	0.94	187	7.63	1.89	0.98	166	6.78	1.68	0.87	174	7.10	1.74	0.91	179	7.31	1.81	0.93
02.03.11	187	7.63	1.89	0.98	154	6.29	1.54	0.80	169	6.90	1.71	0.88	178	7.27	1.80	0.93	161	6.57	1.61	0.84	188	7.67	1.90	0.98
03.03.11	177	7.22	1.79	0.92	148	6.04	1.48	0.77	155	6.33	1.57	0.81	173	7.06	1.75	0.90	150	6.12	1.50	0.78	170	6.94	1.72	0.89
04.03.11	165	6.73	1.67	0.86	144	5.88	1.44	0.75	161	6.57	1.63	0.84	166	6.78	1.68	0.87	150	6.12	1.50	0.78	155	6.33	1.57	0.81
05.03.11	157	6.41	1.59	0.82	142	5.80	1.42	0.74	164	6.69	1.66	0.86	168	6.86	1.70	0.88	132	5.39	1.32	0.69	95	3.88	0.96	0.50
06.03.11	172	7.02	1.74	0.90	140	5.71	1.40	0.73	175	7.14	1.77	0.91	177	7.22	1.79	0.92	143	5.84	1.43	0.75	135	5.51	1.37	0.70
07.03.11	180	7.35	1.82	0.94	152	6.20	1.52	0.79	183	7.47	1.85	0.96	187	7.63	1.89	0.98	149	6.08	1.49	0.78	190	7.76	1.92	0.99
08.03.11	188	7.67	1.90	0.98	148	6.04	1.48	0.77	192	7.84	1.94	1.00	194	7.92	1.96	1.01	166	6.78	1.66	0.87	204	8.33	2.06	1.07
09.03.11	194	7.92	1.96	1.01	162	6.61	1.62	0.85	203	8.29	2.05	1.06	200	8.16	2.02	1.04	170	6.94	1.70	0.89	204	8.33	2.06	1.07
10.03.11	207	8.45	2.09	1.08	167	6.82	1.67	0.87	210	8.57	2.13	1.10	215	8.78	2.17	1.12	175	7.14	1.75	0.91	212	8.65	2.15	1.11
11.03.11	210	8.57	2.12	1.10	163	6.65	1.63	0.85	210	8.57	2.13	1.10	212	8.65	2.14	1.11	180	7.35	1.80	0.94	213	8.69	2.16	1.11
12.03.11	85	3.47	0.86	0.44	60	2.45	0.60	0.31	89	3.63	0.90	0.46	78	3.18	0.79	0.41	60	2.45	0.60	0.31	86	3.51	0.87	0.45
13.03.11	207	8.45	2.09	1.08	171	6.98	1.71	0.89	200	8.16	2.02	1.04	211	8.61	2.13	1.10	171	6.98	1.71	0.89	203	8.29	2.05	1.06
14.03.11	213	8.69	2.15	1.11	173	7.06	1.73	0.90	215	8.78	2.18	1.12	216	8.82	2.18	1.13	181	7.39	1.81	0.95	215	8.78	2.18	1.12
15.03.11	230	9.39	2.32	1.20	173	7.06	1.73	0.90	248	10.12	2.51	1.30	240	9.80	2.42	1.25	204	8.33	2.04	1.07	240	9.80	2.43	1.25
16.03.11	125	5.10	1.26	0.65	95	3.88	0.95	0.50	130	5.31	1.32	0.68	88	3.59	0.89	0.46	115	4.69	1.15	0.60	144	5.88	1.46	0.75
17.03.11	167	6.82	1.69	0.87	119	4.86	1.19	0.62	171	6.98	1.73	0.89	178	7.27	1.80	0.93	132	5.39	1.32	0.69	177	7.22	1.79	0.92

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
18.03.11	176	7.18	1.78	0.92	130	5.31	1.30	0.68	184	7.51	1.86	0.96	181	7.39	1.83	0.95	154	6.29	1.54	0.80	188	7.67	1.90	0.98
19.03.11	182	7.43	1.84	0.95	128	5.22	1.28	0.67	192	7.84	1.94	1.00	195	7.96	1.97	1.02	175	7.14	1.75	0.91	208	8.49	2.11	1.09
20.03.11	167	6.82	1.69	0.87	110	4.49	1.10	0.57	162	6.61	1.64	0.85	138	5.63	1.39	0.72	120	4.90	1.20	0.63	157	6.41	1.59	0.82
21.03.11	173	7.06	1.75	0.90	117	4.78	1.17	0.61	181	7.39	1.83	0.95	183	7.47	1.85	0.96	134	5.47	1.34	0.70	179	7.31	1.81	0.93
22.03.11	137	5.59	1.38	0.72	98	4.00	0.98	0.51	148	6.04	1.50	0.77	147	6.00	1.48	0.77	127	5.18	1.27	0.66	153	6.24	1.55	0.80
23.03.11	128	5.22	1.29	0.67	90	3.67	0.90	0.47	122	4.98	1.23	0.64	121	4.94	1.22	0.63	73	2.98	0.73	0.38	121	4.94	1.22	0.63
24.03.11	155	6.33	1.57	0.81	109	4.45	1.09	0.57	161	6.57	1.63	0.84	160	6.53	1.62	0.84	114	4.65	1.14	0.60	164	6.69	1.66	0.86
25.03.11	160	6.53	1.62	0.84	109	4.45	1.09	0.57	155	6.33	1.57	0.81	156	6.37	1.58	0.81	110	4.49	1.10	0.57	165	6.73	1.67	0.86
26.03.11	166	6.78	1.68	0.87	108	4.41	1.08	0.56	158	6.45	1.60	0.83	160	6.53	1.62	0.84	106	4.33	1.06	0.55	171	6.98	1.73	0.89
27.03.11	152	6.20	1.54	0.79	84	3.43	0.84	0.44	146	5.96	1.48	0.76	150	6.12	1.52	0.78	127	5.18	1.27	0.66	167	6.82	1.69	0.87
28.03.11	160	6.53	1.62	0.84	88	3.59	0.88	0.46	154	6.29	1.56	0.80	158	6.45	1.60	0.83	134	5.47	1.34	0.70	166	6.78	1.68	0.87
29.03.11	160	6.53	1.62	0.84	86	3.51	0.86	0.45	145	5.92	1.47	0.76	146	5.96	1.47	0.76	125	5.10	1.25	0.65	152	6.20	1.54	0.79
30.03.11	184	7.51	1.86	0.96	140	5.71	1.40	0.73	175	7.14	1.77	0.91	171	6.98	1.73	0.89	179	7.31	1.79	0.93	183	7.47	1.85	0.96
31.03.11	183	7.47	1.85	0.96	170	6.94	1.70	0.89	169	6.90	1.71	0.88	162	6.61	1.64	0.85	173	7.06	1.73	0.90	170	6.94	1.72	0.89
01.04.11	203	8.29	2.05	1.06	152	6.20	1.52	0.79	193	7.88	1.95	1.01	207	8.45	2.09	1.08	168	6.86	1.68	0.88	190	7.76	1.92	0.99
02.04.11	191	7.80	1.93	1.00	149	6.08	1.49	0.78	190	7.76	1.92	0.99	196	8.00	1.98	1.02	171	6.98	1.71	0.89	190	7.76	1.92	0.99
03.04.11	182	7.43	1.84	0.95	104	4.24	1.04	0.54	184	7.51	1.86	0.96	107	4.37	1.08	0.56	156	6.37	1.56	0.81	185	7.55	1.87	0.97
04.04.11	189	7.71	1.91	0.99	148	6.04	1.48	0.77	183	7.47	1.85	0.96	192	7.84	1.94	1.00	166	6.78	1.66	0.87	185	7.55	1.87	0.97
05.04.11	196	8.00	1.98	1.02	149	6.08	1.49	0.78	189	7.71	1.91	0.99	203	8.29	2.05	1.06	171	6.98	1.71	0.89	180	7.35	1.82	0.94
06.04.11	105	4.29	1.06	0.55	62	2.53	0.62	0.32	105	4.29	1.06	0.55	105	4.29	1.06	0.55	99	4.04	0.99	0.52	123	5.02	1.24	0.64
08.04.11	212	8.65	2.14	1.11	164	6.69	1.64	0.86	210	8.57	2.13	1.10	217	8.86	2.19	1.13	181	7.39	1.81	0.95	211	8.61	2.14	1.10

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
09.04.11	199	8.12	2.01	1.04	103	4.20	1.03	0.54	189	7.71	1.91	0.99	202	8.24	2.04	1.05	171	6.98	1.71	0.89	182	7.43	1.84	0.95
10.04.11	203	8.29	2.05	1.06	88	3.59	0.88	0.46	181	7.39	1.83	0.95	202	8.24	2.04	1.05	168	6.86	1.68	0.88	193	7.88	1.95	1.01
11.04.11	117	4.78	1.18	0.61	92	3.76	0.92	0.48	94	3.84	0.95	0.49	108	4.41	1.09	0.56	88	3.59	0.88	0.46	105	4.29	1.06	0.55
12.04.11	118	4.82	1.19	0.62	74	3.02	0.74	0.39	103	4.20	1.04	0.54	123	5.02	1.24	0.64	88	3.59	0.88	0.46	103	4.20	1.04	0.54
27.04.11	173	7.06	1.75	0.90	141	5.76	1.41	0.74	168	6.86	1.70	0.88	173	7.06	1.75	0.90	144	5.88	1.44	0.75	172	7.02	1.74	0.90
28.04.11	171	6.98	1.73	0.89	133	5.43	1.33	0.69	170	6.94	1.72	0.89	177	7.22	1.79	0.92	145	5.92	1.45	0.76	184	7.51	1.86	0.96
29.04.11	182	7.43	1.84	0.95	149	6.08	1.49	0.78	180	7.35	1.82	0.94	185	7.55	1.87	0.97	161	6.57	1.61	0.84	181	7.39	1.83	0.95
30.04.11	182	7.43	1.84	0.95	153	6.24	1.53	0.80	184	7.51	1.86	0.96	185	7.55	1.87	0.97	156	6.37	1.56	0.81	189	7.71	1.91	0.99
01.05.11	177	7.22	1.79	0.92	150	6.12	1.50	0.78	181	7.39	1.83	0.95	179	7.31	1.81	0.93	156	6.37	1.56	0.81	179	7.31	1.81	0.93
02.05.11	178	7.27	1.80	0.93	152	6.20	1.52	0.79	173	7.06	1.75	0.90	181	7.39	1.83	0.95	163	6.65	1.63	0.85	183	7.47	1.85	0.96
03.05.11	185	7.55	1.87	0.97	127	5.18	1.27	0.66	187	7.63	1.89	0.98	187	7.63	1.89	0.98	150	6.12	1.50	0.78	207	8.45	2.10	1.08
04.05.11	171	6.98	1.73	0.89	127	5.18	1.27	0.66	163	6.65	1.65	0.85	171	6.98	1.73	0.89	153	6.24	1.53	0.80	171	6.98	1.73	0.89
06.05.11	183	7.47	1.85	0.96	136	5.55	1.36	0.71	174	7.10	1.76	0.91	177	7.22	1.79	0.92	149	6.08	1.49	0.78	187	7.63	1.89	0.98
07.05.11	183	7.47	1.85	0.96	129	5.27	1.29	0.67	181	7.39	1.83	0.95	181	7.39	1.83	0.95	159	6.49	1.59	0.83	193	7.88	1.95	1.01
08.05.11	198	8.08	2.00	1.03	159	6.49	1.59	0.83	200	8.16	2.02	1.04	194	7.92	1.96	1.01	159	6.49	1.59	0.83	203	8.29	2.05	1.06
09.05.11	197	8.04	1.99	1.03	163	6.65	1.63	0.85	198	8.08	2.00	1.03	200	8.16	2.02	1.04	140	5.71	1.40	0.73	208	8.49	2.11	1.09
11.05.11	191	7.80	1.93	1.00	152	6.20	1.52	0.79	188	7.67	1.90	0.98	194	7.92	1.96	1.01	159	6.49	1.59	0.83	201	8.20	2.03	1.05
14.05.11	191	7.80	1.93	1.00	153	6.24	1.53	0.80	186	7.59	1.88	0.97	191	7.80	1.93	1.00	160	6.53	1.60	0.84	201	8.20	2.03	1.05
15.05.11	183	7.47	1.85	0.96	148	6.04	1.48	0.77	186	7.59	1.88	0.97	177	7.22	1.79	0.92	151	6.16	1.51	0.79	192	7.84	1.94	1.00
16.05.11	135	5.51	1.36	0.70	111	4.53	1.11	0.58	140	5.71	1.42	0.73	145	5.92	1.46	0.76	110	4.49	1.10	0.57	162	6.61	1.64	0.85
17.05.11	163	6.65	1.65	0.85	107	4.37	1.07	0.56	175	7.14	1.77	0.91	188	7.67	1.90	0.98	140	5.71	1.40	0.73	170	6.94	1.72	0.89

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
18.05.11	155	6.33	1.57	0.81	88	3.59	0.88	0.46	180	7.35	1.82	0.94	175	7.14	1.77	0.91	138	5.63	1.38	0.72	150	6.12	1.52	0.78
19.05.11	175	7.14	1.77	0.91	144	5.88	1.44	0.75	170	6.94	1.72	0.89	140	5.71	1.41	0.73	125	5.10	1.25	0.65	170	6.94	1.72	0.89
20.05.11	167	6.82	1.69	0.87	150	6.12	1.50	0.78	171	6.98	1.73	0.89	155	6.33	1.57	0.81	143	5.84	1.43	0.75	168	6.86	1.70	0.88
21.05.11	166	6.78	1.68	0.87	122	4.98	1.22	0.64	168	6.86	1.70	0.88	170	6.94	1.72	0.89	151	6.16	1.51	0.79	177	7.22	1.79	0.92
22.05.11	200	8.16	2.02	1.04	112	4.57	1.12	0.58	178	7.27	1.80	0.93	190	7.76	1.92	0.99	150	6.12	1.50	0.78	140	5.71	1.42	0.73
23.05.11	105	4.29	1.06	0.55	50	2.04	0.50	0.26	100	4.08	1.01	0.52	100	4.08	1.01	0.52	98	4.00	0.98	0.51	100	4.08	1.01	0.52
24.05.11	168	6.86	1.70	0.88	108	4.41	1.08	0.56	148	6.04	1.50	0.77	148	6.04	1.49	0.77	125	5.10	1.25	0.65	118	4.82	1.19	0.62
25.05.11	118	4.82	1.19	0.62	90	3.67	0.90	0.47	120	4.90	1.21	0.63	130	5.31	1.31	0.68	100	4.08	1.00	0.52	95	3.88	0.96	0.50
26.05.11	200	8.16	2.02	1.04	130	5.31	1.30	0.68	150	6.12	1.52	0.78	152	6.20	1.54	0.79	178	7.27	1.78	0.93	165	6.73	1.67	0.86
27.05.11	153	6.24	1.55	0.80	110	4.49	1.10	0.57	153	6.24	1.55	0.80	138	5.63	1.39	0.72	110	4.49	1.10	0.57	150	6.12	1.52	0.78
28.05.11	168	6.86	1.70	0.88	123	5.02	1.23	0.64	160	6.53	1.62	0.84	165	6.73	1.67	0.86	133	5.43	1.33	0.69	170	6.94	1.72	0.89
29.05.11	113	4.61	1.14	0.59	85	3.47	0.85	0.44	115	4.69	1.16	0.60	120	4.90	1.21	0.63	103	4.20	1.03	0.54	125	5.10	1.27	0.65
30.05.11	188	7.67	1.90	0.98	100	4.08	1.00	0.52	180	7.35	1.82	0.94	195	7.96	1.97	1.02	155	6.33	1.55	0.81	195	7.96	1.97	1.02
31.05.11	148	6.04	1.49	0.77	83	3.39	0.83	0.43	143	5.84	1.45	0.75	145	5.92	1.46	0.76	123	5.02	1.23	0.64	155	6.33	1.57	0.81
01.06.11	205	8.37	2.07	1.07	103	4.20	1.03	0.54	180	7.35	1.82	0.94	195	7.96	1.97	1.02	200	8.16	2.00	1.04	207	8.45	2.10	1.08
02.06.11	175	7.14	1.77	0.91	93	3.80	0.93	0.49	160	6.53	1.62	0.84	172	7.02	1.74	0.90	144	5.88	1.44	0.75	180	7.35	1.82	0.94
03.06.11	170	6.94	1.72	0.89	133	5.43	1.33	0.69	125	5.10	1.27	0.65	150	6.12	1.52	0.78	113	4.61	1.13	0.59	147	6.00	1.49	0.77
04.06.11	155	6.33	1.57	0.81	100	4.08	1.00	0.52	140	5.71	1.42	0.73	142	5.80	1.43	0.74	150	6.12	1.50	0.78	160	6.53	1.62	0.84
05.06.11	203	8.29	2.05	1.06	93	3.80	0.93	0.49	198	8.08	2.00	1.03	200	8.16	2.02	1.04	160	6.53	1.60	0.84	200	8.16	2.02	1.04
06.06.11	183	7.47	1.85	0.96	90	3.67	0.90	0.47	183	7.47	1.85	0.96	185	7.55	1.87	0.97	153	6.24	1.53	0.80	183	7.47	1.85	0.96
07.06.11	190	7.76	1.92	0.99	110	4.49	1.10	0.57	188	7.67	1.90	0.98	188	7.67	1.90	0.98	155	6.33	1.55	0.81	198	8.08	2.00	1.03

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m^{2}/day			mL/day	L/m^{2}/day			mL/day	L/m^{2}/day			mL/day	L/m^{2}/day			mL/day	L/m^{2}/day			mL/day	L/m^{2}/day		
		A_{cross}	A_{exp}	A_{cond}		A_{cross}	A_{exp}	A_{cond}		A_{cross}	A_{exp}	A_{cond}		A_{cross}	A_{exp}	A_{cond}		A_{cross}	A_{exp}	A_{cond}		A_{cross}	A_{exp}	A_{cond}
08.06.11	200	8.16	2.02	1.04	115	4.69	1.15	0.60	203	8.29	2.05	1.06	200	8.16	2.02	1.04	160	6.53	1.60	0.84	200	8.16	2.02	1.04
09.06.11	153	6.24	1.55	0.80	80	3.27	0.80	0.42	148	6.04	1.50	0.77	148	6.04	1.49	0.77	125	5.10	1.25	0.65	152	6.20	1.54	0.79
10.06.11	173	7.06	1.75	0.90	110	4.49	1.10	0.57	160	6.53	1.62	0.84	173	7.06	1.75	0.90	150	6.12	1.50	0.78	187	7.63	1.89	0.98
11.06.11	138	5.63	1.39	0.72	59	2.41	0.59	0.31	100	4.08	1.01	0.52	116	4.73	1.17	0.61	98	4.00	0.98	0.51	100	4.08	1.01	0.52
12.06.11	138	5.63	1.39	0.72	59	2.41	0.59	0.31	110	4.49	1.11	0.57	117	4.78	1.18	0.61	102	4.16	1.02	0.53	115	4.69	1.16	0.60
13.06.11	70	2.86	0.71	0.37	62	2.53	0.62	0.32	73	2.98	0.74	0.38	105	4.29	1.06	0.55	70	2.86	0.70	0.37	125	5.10	1.27	0.65
14.06.11	175	7.14	1.77	0.91	105	4.29	1.05	0.55	170	6.94	1.72	0.89	155	6.33	1.57	0.81	135	5.51	1.35	0.70	167	6.82	1.69	0.87
15.06.11	73	2.98	0.74	0.38	57	2.33	0.57	0.30	57	2.33	0.58	0.30	60	2.45	0.61	0.31	60	2.45	0.60	0.31	78	3.18	0.79	0.41
16.06.11	155	6.33	1.57	0.81	95	3.88	0.95	0.50	110	4.49	1.11	0.57	108	4.41	1.09	0.56	105	4.29	1.05	0.55	120	4.90	1.21	0.63
17.06.11	140	5.71	1.41	0.73	122	4.98	1.22	0.64	95	3.88	0.96	0.50	80	3.27	0.81	0.42	120	4.90	1.20	0.63	163	6.65	1.65	0.85
18.06.11	140	5.71	1.41	0.73	55	2.24	0.55	0.29	70	2.86	0.71	0.37	90	3.67	0.91	0.47	70	2.86	0.70	0.37	70	2.86	0.71	0.37
19.06.11	100	4.08	1.01	0.52	60	2.45	0.60	0.31	90	3.67	0.91	0.47	70	2.86	0.71	0.37	80	3.27	0.80	0.42	90	3.67	0.91	0.47
20.06.11	113	4.61	1.14	0.59	65	2.65	0.65	0.34	50	2.04	0.51	0.26	75	3.06	0.76	0.39	68	2.78	0.68	0.36	33	1.35	0.33	0.17
21.06.11	83	3.39	0.84	0.43	60	2.45	0.60	0.31	90	3.67	0.91	0.47	95	3.88	0.96	0.50	70	2.86	0.70	0.37	90	3.67	0.91	0.47
22.06.11	88	3.59	0.89	0.46	50	2.04	0.50	0.26	90	3.67	0.91	0.47	90	3.67	0.91	0.47	50	2.04	0.50	0.26	95	3.88	0.96	0.50
23.06.11	88	3.59	0.89	0.46	60	2.45	0.60	0.31	68	2.78	0.69	0.36	70	2.86	0.71	0.37	53	2.16	0.53	0.28	35	1.43	0.35	0.18
24.06.11	230	9.39	2.32	1.20	130	5.31	1.30	0.68	208	8.49	2.11	1.09	225	9.18	2.27	1.17	180	7.35	1.80	0.94	65	2.65	0.66	0.34
25.06.11	110	4.49	1.11	0.57	70	2.86	0.70	0.37	110	4.49	1.11	0.57	120	4.90	1.21	0.63	80	3.27	0.80	0.42	125	5.10	1.27	0.65
26.06.11	150	6.12	1.52	0.78	60	2.45	0.60	0.31	47	1.92	0.48	0.25	45	1.84	0.45	0.23	50	2.04	0.50	0.26	90	3.67	0.91	0.47
27.06.11	140	5.71	1.41	0.73	38	1.55	0.38	0.20	40	1.63	0.40	0.21	40	1.63	0.40	0.21	40	1.63	0.40	0.21	70	2.86	0.71	0.37
28.06.11	80	3.27	0.81	0.42	60	2.45	0.60	0.31	77	3.14	0.78	0.40	75	3.06	0.76	0.39	65	2.65	0.65	0.34	65	2.65	0.66	0.34

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	$L/m^2/day$			mL/day	$L/m^2/day$			mL/day	$L/m^2/day$			mL/day	$L/m^2/day$			mL/day	$L/m^2/day$			mL/day	$L/m^2/day$		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	A_{evp}	A_{cond}
29.06.11	55	2.24	0.56	0.29	50	2.04	0.50	0.26	50	2.04	0.51	0.26	80	3.27	0.81	0.42	40	1.63	0.40	0.21	40	1.63	0.40	0.21
30.06.11	90	3.67	0.91	0.47	85	3.47	0.85	0.44	60	2.45	0.61	0.31	100	4.08	1.01	0.52	57	2.33	0.57	0.30	48	1.96	0.49	0.25
01.07.11	100	4.08	1.01	0.52	90	3.67	0.90	0.47	90	3.67	0.91	0.47	80	3.27	0.81	0.42	70	2.86	0.70	0.37	100	4.08	1.01	0.52
02.07.11	60	2.45	0.61	0.31	48	1.96	0.48	0.25	40	1.63	0.40	0.21	40	1.63	0.40	0.21	30	1.22	0.30	0.16	43	1.76	0.44	0.22
03.07.11	62	2.53	0.63	0.32	35	1.43	0.35	0.18	33	1.35	0.33	0.17	33	1.35	0.33	0.17	27	1.10	0.27	0.14	35	1.43	0.35	0.18
04.07.11	80	3.27	0.81	0.42	70	2.86	0.70	0.37	55	2.24	0.56	0.29	52	2.12	0.53	0.27	45	1.84	0.45	0.23	40	1.63	0.40	0.21
05.07.11	80	3.27	0.81	0.42	40	1.63	0.40	0.21	75	3.06	0.76	0.39	70	2.86	0.71	0.37	65	2.65	0.65	0.34	70	2.86	0.71	0.37
06.07.11	175	7.14	1.77	0.91	155	6.33	1.55	0.81	160	6.53	1.62	0.84	165	6.73	1.67	0.86	115	4.69	1.15	0.60	167	6.82	1.69	0.87
07.07.11	158	6.45	1.60	0.83	105	4.29	1.05	0.55	163	6.65	1.65	0.85	160	6.53	1.62	0.84	125	5.10	1.25	0.65	170	6.94	1.72	0.89
08.07.11	170	6.94	1.72	0.89	92	3.76	0.92	0.48	85	3.47	0.86	0.44	130	5.31	1.31	0.68	60	2.45	0.60	0.31	148	6.04	1.50	0.77
09.07.11	240	9.80	2.42	1.25	110	4.49	1.10	0.57	140	5.71	1.42	0.73	160	6.53	1.62	0.84	130	5.31	1.30	0.68	155	6.33	1.57	0.81
10.07.11	175	7.14	1.77	0.91	110	4.49	1.10	0.57	180	7.35	1.82	0.94	180	7.35	1.82	0.94	135	5.51	1.35	0.70	190	7.76	1.92	0.99
11.07.11	170	6.94	1.72	0.89	115	4.69	1.15	0.60	150	6.12	1.52	0.78	170	6.94	1.72	0.89	135	5.51	1.35	0.70	177	7.22	1.79	0.92
12.07.11	142	5.80	1.43	0.74	95	3.88	0.95	0.50	148	6.04	1.50	0.77	122	4.98	1.23	0.64	133	5.43	1.33	0.69	125	5.10	1.27	0.65
13.07.11	135	5.51	1.36	0.70	98	4.00	0.98	0.51	150	6.12	1.52	0.78	118	4.82	1.19	0.62	115	4.69	1.15	0.60	95	3.88	0.96	0.50
14.07.11	160	6.53	1.62	0.84	92	3.76	0.92	0.48	158	6.45	1.60	0.83	163	6.65	1.65	0.85	113	4.61	1.13	0.59	180	7.35	1.82	0.94
15..07.11	155	6.33	1.57	0.81	90	3.67	0.90	0.47	160	6.53	1.62	0.84	160	6.53	1.62	0.84	90	3.67	0.90	0.47	160	6.53	1.62	0.84
16.07.11	70	2.86	0.71	0.37	60	2.45	0.60	0.31	80	3.27	0.81	0.42	80	3.27	0.81	0.42	65	2.65	0.65	0.34	75	3.06	0.76	0.39
17.07.11	105	4.29	1.06	0.55	73	2.98	0.73	0.38	90	3.67	0.91	0.47	85	3.47	0.86	0.44	87	3.55	0.87	0.45	100	4.08	1.01	0.52
18.07.11	148	6.04	1.49	0.77	70	2.86	0.70	0.37	117	4.78	1.18	0.61	135	5.51	1.36	0.70	80	3.27	0.80	0.42	135	5.51	1.37	0.70
19.07.11	100	4.08	1.01	0.52	60	2.45	0.60	0.31	100	4.08	1.01	0.52	100	4.08	1.01	0.52	72	2.94	0.72	0.38	100	4.08	1.01	0.52

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
20.07.11	160	6.53	1.62	0.84	58	2.37	0.58	0.30	45	1.84	0.46	0.23	38	1.55	0.38	0.20	40	1.63	0.40	0.21	42	1.71	0.43	0.22
21.07.11	171	6.98	1.73	0.89	75	3.06	0.75	0.39	90	3.67	0.91	0.47	75	3.06	0.76	0.39	163	6.65	1.63	0.85	115	4.69	1.16	0.60
22.07.11	153	6.24	1.55	0.80	83	3.39	0.83	0.43	105	4.29	1.06	0.55	146	5.96	1.47	0.76	160	6.53	1.60	0.84	112	4.57	1.13	0.58
23.07.11	171	6.98	1.73	0.89	119	4.86	1.19	0.62	155	6.33	1.57	0.81	170	6.94	1.72	0.89	135	5.51	1.35	0.70	177	7.22	1.79	0.92
24.07.11	142	5.80	1.43	0.74	101	4.12	1.01	0.53	151	6.16	1.53	0.79	122	4.98	1.23	0.64	133	5.43	1.33	0.69	125	5.10	1.27	0.65
25.07.11	135	5.51	1.36	0.70	98	4.00	0.98	0.51	154	6.29	1.56	0.80	118	4.82	1.19	0.62	115	4.69	1.15	0.60	95	3.88	0.96	0.50
26.07.11	153	6.24	1.55	0.80	96	3.92	0.96	0.50	158	6.45	1.60	0.83	163	6.65	1.65	0.85	113	4.61	1.13	0.59	180	7.35	1.82	0.94
27.07.11	159	6.49	1.61	0.83	90	3.67	0.90	0.47	160	6.53	1.62	0.84	160	6.53	1.62	0.84	90	3.67	0.90	0.47	160	6.53	1.62	0.84
28.07.11	148	6.04	1.49	0.77	112	4.57	1.12	0.58	167	6.82	1.69	0.87	158	6.45	1.60	0.83	112	4.57	1.12	0.58	162	6.61	1.64	0.85
29.07.11	150	6.12	1.52	0.78	116	4.73	1.16	0.61	160	6.53	1.62	0.84	163	6.65	1.65	0.85	132	5.39	1.32	0.69	165	6.73	1.67	0.86
30.07.11	145	5.92	1.46	0.76	120	4.90	1.20	0.63	167	6.82	1.69	0.87	164	6.69	1.66	0.86	137	5.59	1.37	0.72	158	6.45	1.60	0.83
31.07.11	157	6.41	1.59	0.82	123	5.02	1.23	0.64	171	6.98	1.73	0.89	164	6.69	1.66	0.86	141	5.76	1.41	0.74	149	6.08	1.51	0.78
01.08.11	187	7.63	1.89	0.98	113	4.61	1.13	0.59	178	7.27	1.80	0.93	182	7.43	1.84	0.95	125	5.10	1.25	0.65	177	7.22	1.79	0.92
02.08.11	143	5.84	1.44	0.75	88	3.59	0.88	0.46	143	5.84	1.45	0.75	148	6.04	1.49	0.77	145	5.92	1.45	0.76	165	6.73	1.67	0.86
03.08.11	45	1.84	0.45	0.23	35	1.43	0.35	0.18	45	1.84	0.46	0.23	45	1.84	0.45	0.23	35	1.43	0.35	0.18	55	2.24	0.56	0.29
04.08.11	132	5.39	1.33	0.69	48	1.96	0.48	0.25	100	4.08	1.01	0.52	125	5.10	1.26	0.65	100	4.08	1.00	0.52	90	3.67	0.91	0.47
05.08.11	100	4.08	1.01	0.52	100	4.08	1.00	0.52	75	3.06	0.76	0.39	60	2.45	0.61	0.31	65	2.65	0.65	0.34	70	2.86	0.71	0.37
06.08.11	58	2.37	0.59	0.30	42	1.71	0.42	0.22	60	2.45	0.61	0.31	55	2.24	0.56	0.29	50	2.04	0.50	0.26	58	2.37	0.59	0.30
07.08.11	163	6.65	1.65	0.85	83	3.39	0.83	0.43	80	3.27	0.81	0.42	165	6.73	1.67	0.86	75	3.06	0.75	0.39	70	2.86	0.71	0.37
08.08.11	149	6.08	1.51	0.78	117	4.78	1.17	0.61	167	6.82	1.69	0.87	156	6.37	1.58	0.81	136	5.55	1.36	0.71	163	6.65	1.65	0.85
09.08.11	154	6.29	1.56	0.80	115	4.69	1.15	0.60	158	6.45	1.60	0.83	155	6.33	1.57	0.81	145	5.92	1.45	0.76	161	6.57	1.63	0.84

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
10.08.11	150	6.12	1.52	0.78	113	4.61	1.13	0.59	161	6.57	1.63	0.84	155	6.33	1.57	0.81	132	5.39	1.32	0.69	160	6.53	1.62	0.84
11.08.11	151	6.16	1.53	0.79	109	4.45	1.09	0.57	156	6.37	1.58	0.81	161	6.57	1.63	0.84	123	5.02	1.23	0.64	173	7.06	1.75	0.90
12.08.11	162	6.61	1.64	0.85	108	4.41	1.08	0.56	162	6.61	1.64	0.85	156	6.37	1.58	0.81	123	5.02	1.23	0.64	167	6.82	1.69	0.87
13.08.11	160	6.53	1.62	0.84	98	4.00	0.98	0.51	153	6.24	1.55	0.80	161	6.57	1.63	0.84	115	4.69	1.15	0.60	167	6.82	1.69	0.87
14.08.11	118	4.82	1.19	0.62	137	5.59	1.37	0.72	158	6.45	1.60	0.83	135	5.51	1.36	0.70	120	4.90	1.20	0.63	171	6.98	1.73	0.89
15.08.11	163	6.65	1.65	0.85	141	5.76	1.41	0.74	149	6.08	1.51	0.78	153	6.24	1.55	0.80	123	5.02	1.23	0.64	167	6.82	1.69	0.87
16.08.11	160	6.53	1.62	0.84	136	5.55	1.36	0.71	163	6.65	1.65	0.85	159	6.49	1.61	0.83	117	4.78	1.17	0.61	158	6.45	1.60	0.83
17.08.11	158	6.45	1.60	0.83	145	5.92	1.45	0.76	161	6.57	1.63	0.84	148	6.04	1.49	0.77	115	4.69	1.15	0.60	161	6.57	1.63	0.84
18.08.11	163	6.65	1.65	0.85	132	5.39	1.32	0.69	160	6.53	1.62	0.84	150	6.12	1.52	0.78	113	4.61	1.13	0.59	156	6.37	1.58	0.81
19.08.11	164	6.69	1.66	0.86	123	5.02	1.23	0.64	173	7.06	1.75	0.90	145	5.92	1.46	0.76	109	4.45	1.09	0.57	162	6.61	1.64	0.85
20.08.11	164	6.69	1.66	0.86	123	5.02	1.23	0.64	167	6.82	1.69	0.87	157	6.41	1.59	0.82	108	4.41	1.08	0.56	153	6.24	1.55	0.80
21.08.11	156	6.37	1.58	0.81	115	4.69	1.15	0.60	166	6.78	1.68	0.87	149	6.08	1.51	0.78	98	4.00	0.98	0.51	158	6.45	1.60	0.83
22.08.11	155	6.33	1.57	0.81	120	4.90	1.20	0.63	166	6.78	1.68	0.87	154	6.29	1.56	0.80	100	4.08	1.00	0.52	157	6.41	1.59	0.82
01.10.11	175	7.14	1.77	0.91	105	4.29	1.05	0.55	160	6.53	1.62	0.84	165	6.73	1.67	0.86	105	4.29	1.05	0.55	167	6.82	1.69	0.87
02.10.11	142	5.80	1.43	0.74	90	3.67	0.90	0.47	138	5.63	1.40	0.72	148	6.04	1.49	0.77	105	4.29	1.05	0.55	150	6.12	1.52	0.78
03.10.11	175	7.14	1.77	0.91	103	4.20	1.03	0.54	152	6.20	1.54	0.79	158	6.45	1.60	0.83	115	4.69	1.15	0.60	170	6.94	1.72	0.89
04.10.11	220	8.98	2.22	1.15	120	4.90	1.20	0.63	203	8.29	2.05	1.06	215	8.78	2.17	1.12	135	5.51	1.35	0.70	225	9.18	2.28	1.17
05.10.11	185	7.55	1.87	0.97	100	4.08	1.00	0.52	165	6.73	1.67	0.86	175	7.14	1.77	0.91	113	4.61	1.13	0.59	180	7.35	1.82	0.94
06.10.11	111	4.53	1.12	0.58	110	4.49	1.10	0.57	145	5.92	1.47	0.76	160	6.53	1.62	0.84	115	4.69	1.15	0.60	160	6.53	1.62	0.84
07.10.11	175	7.14	1.77	0.91	102	4.16	1.02	0.53	160	6.53	1.62	0.84	165	6.73	1.67	0.86	108	4.41	1.08	0.56	175	7.14	1.77	0.91
08.10.11	225	9.18	2.27	1.17	105	4.29	1.05	0.55	217	8.86	2.20	1.13	240	9.80	2.42	1.25	130	5.31	1.30	0.68	235	9.59	2.38	1.23

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
09.10.11	183	7.47	1.85	0.96	105	4.29	1.05	0.55	170	6.94	1.72	0.89	178	7.27	1.80	0.93	120	4.90	1.20	0.63	185	7.55	1.87	0.97
10.10.11	150	6.12	1.52	0.78	85	3.47	0.85	0.44	135	5.51	1.37	0.70	145	5.92	1.46	0.76	90	3.67	0.90	0.47	150	6.12	1.52	0.78
11.10.11	160	6.53	1.62	0.84	85	3.47	0.85	0.44	148	6.04	1.50	0.77	150	6.12	1.52	0.78	103	4.20	1.03	0.54	155	6.33	1.57	0.81
12.10.11	142	5.80	1.43	0.74	90	3.67	0.90	0.47	125	5.10	1.27	0.65	135	5.51	1.36	0.70	100	4.08	1.00	0.52	125	5.10	1.27	0.65
13.10.11	185	7.55	1.87	0.97	95	3.88	0.95	0.50	170	6.94	1.72	0.89	175	7.14	1.77	0.91	110	4.49	1.10	0.57	185	7.55	1.87	0.97
14.10.11	205	8.37	2.07	1.07	105	4.29	1.05	0.55	185	7.55	1.87	0.97	198	8.08	2.00	1.03	122	4.98	1.22	0.64	198	8.08	2.00	1.03
15.10.11	175	7.14	1.77	0.91	100	4.08	1.00	0.52	165	6.73	1.67	0.86	170	6.94	1.72	0.89	108	4.41	1.08	0.56	175	7.14	1.77	0.91
16.10.11	182	7.43	1.84	0.95	100	4.08	1.00	0.52	170	6.94	1.72	0.89	182	7.43	1.84	0.95	110	4.49	1.10	0.57	187	7.63	1.89	0.98
17.10.11	150	6.12	1.52	0.78	87	3.55	0.87	0.45	140	5.71	1.42	0.73	140	5.71	1.41	0.73	95	3.88	0.95	0.50	140	5.71	1.42	0.73
18.10.11	157	6.41	1.59	0.82	92	3.76	0.92	0.48	150	6.12	1.52	0.78	160	6.53	1.62	0.84	102	4.16	1.02	0.53	150	6.12	1.52	0.78
19.10.11	72	2.94	0.73	0.38	47	1.92	0.47	0.25	67	2.73	0.68	0.35	70	2.86	0.71	0.37	50	2.04	0.50	0.26	75	3.06	0.76	0.39
20.10.11	180	7.35	1.82	0.94	105	4.29	1.05	0.55	170	6.94	1.72	0.89	185	7.55	1.87	0.97	100	4.08	1.00	0.52	187	7.63	1.89	0.98
21.10.11	160	6.53	1.62	0.84	90	3.67	0.90	0.47	150	6.12	1.52	0.78	165	6.73	1.67	0.86	100	4.08	1.00	0.52	170	6.94	1.72	0.89
22.10.11	100	4.08	1.01	0.52	50	2.04	0.50	0.26	85	3.47	0.86	0.44	100	4.08	1.01	0.52	60	2.45	0.60	0.31	110	4.49	1.11	0.57
23.10.11	130	5.31	1.31	0.68	77	3.14	0.77	0.40	128	5.22	1.30	0.67	130	5.31	1.31	0.68	85	3.47	0.85	0.44	135	5.51	1.37	0.70
24.10.11	200	8.16	2.02	1.04	105	4.29	1.05	0.55	182	7.43	1.84	0.95	198	8.08	2.00	1.03	112	4.57	1.12	0.58	205	8.37	2.07	1.07
25.10.11	193	7.88	1.95	1.01	112	4.57	1.12	0.58	185	7.55	1.87	0.97	195	7.96	1.97	1.02	115	4.69	1.15	0.60	195	7.96	1.97	1.02
26.10.11	165	6.73	1.67	0.86	107	4.37	1.07	0.56	155	6.33	1.57	0.81	167	6.82	1.69	0.87	115	4.69	1.15	0.60	175	7.14	1.77	0.91
27.10.11	115	4.69	1.16	0.60	80	3.27	0.80	0.42	115	4.69	1.16	0.60	115	4.69	1.16	0.60	75	3.06	0.75	0.39	120	4.90	1.21	0.63
28.10.11	182	7.43	1.84	0.95	103	4.20	1.03	0.54	162	6.61	1.64	0.85	205	8.37	2.07	1.07	110	4.49	1.10	0.57	175	7.14	1.77	0.91
29.10.11	178	7.27	1.80	0.93	112	4.57	1.12	0.58	180	7.35	1.82	0.94	189	7.71	1.91	0.99	119	4.86	1.19	0.62	175	7.14	1.77	0.91

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
30.10.11	167	6.82	1.69	0.87	113	4.61	1.13	0.59	171	6.98	1.73	0.89	166	6.78	1.68	0.87	120	4.90	1.20	0.63	175	7.14	1.77	0.91
31.10.11	120	4.90	1.21	0.63	82	3.35	0.82	0.43	115	4.69	1.16	0.60	115	4.69	1.16	0.60	88	3.59	0.88	0.46	115	4.69	1.16	0.60
01.11.11	160	6.53	1.62	0.84	100	4.08	1.00	0.52	155	6.33	1.57	0.81	167	6.82	1.69	0.87	100	4.08	1.00	0.52	170	6.94	1.72	0.89
02.11.11	175	7.14	1.77	0.91	115	4.69	1.15	0.60	152	6.20	1.54	0.79	172	7.02	1.74	0.90	103	4.20	1.03	0.54	177	7.22	1.79	0.92
03.11.11	175	7.14	1.77	0.91	103	4.20	1.03	0.54	163	6.65	1.65	0.85	175	7.14	1.77	0.91	107	4.37	1.07	0.56	175	7.14	1.77	0.91
04.11.11	132	5.39	1.33	0.69	75	3.06	0.75	0.39	125	5.10	1.27	0.65	130	5.31	1.31	0.68	77	3.14	0.77	0.40	135	5.51	1.37	0.70
05.11.11	120	4.90	1.21	0.63	85	3.47	0.85	0.44	113	4.61	1.14	0.59	115	4.69	1.16	0.60	80	3.27	0.80	0.42	110	4.49	1.11	0.57
10.11.11	188	7.67	1.90	0.98	88	3.59	0.88	0.46	175	7.14	1.77	0.91	191	7.80	1.93	1.00	103	4.20	1.03	0.54	188	7.67	1.90	0.98
11.11.11	187	7.63	1.89	0.98	87	3.55	0.87	0.45	175	7.14	1.77	0.91	191	7.80	1.93	1.00	100	4.08	1.00	0.52	187	7.63	1.89	0.98
12.11.11	175	7.14	1.77	0.91	94	3.84	0.94	0.49	160	6.53	1.62	0.84	168	6.86	1.70	0.88	104	4.24	1.04	0.54	165	6.73	1.67	0.86
13.11.11	175	7.14	1.77	0.91	92	3.76	0.92	0.48	160	6.53	1.62	0.84	167	6.82	1.69	0.87	103	4.20	1.03	0.54	165	6.73	1.67	0.86
14.11.11	185	7.55	1.87	0.97	105	4.29	1.05	0.55	172	7.02	1.74	0.90	185	7.55	1.87	0.97	110	4.49	1.10	0.57	190	7.76	1.92	0.99
15.11.11	160	6.53	1.62	0.84	95	3.88	0.95	0.50	137	5.59	1.39	0.72	150	6.12	1.52	0.78	92	3.76	0.92	0.48	155	6.33	1.57	0.81
16.11.11	90	3.67	0.91	0.47	65	2.65	0.65	0.34	77	3.14	0.78	0.40	85	3.47	0.86	0.44	55	2.24	0.55	0.29	90	3.67	0.91	0.47
17.11.11	70	2.86	0.71	0.37	48	1.96	0.48	0.25	65	2.65	0.66	0.34	67	2.73	0.68	0.35	45	1.84	0.45	0.23	60	2.45	0.61	0.31
18.11.11	140	5.71	1.41	0.73	80	3.27	0.80	0.42	127	5.18	1.29	0.66	137	5.59	1.38	0.72	92	3.76	0.92	0.48	140	5.71	1.42	0.73
19.11.11	120	4.90	1.21	0.63	67	2.73	0.67	0.35	110	4.49	1.11	0.57	120	4.90	1.21	0.63	67	2.73	0.67	0.35	130	5.31	1.32	0.68
20.11.11	125	5.10	1.26	0.65	68	2.78	0.68	0.36	120	4.90	1.21	0.63	130	5.31	1.31	0.68	68	2.78	0.68	0.36	130	5.31	1.32	0.68
21.11.11	125	5.10	1.26	0.65	125	5.10	1.25	0.65	85	3.47	0.86	0.44	120	4.90	1.21	0.63	133	5.43	1.33	0.69	75	3.06	0.76	0.39
22.11.11	155	6.33	1.57	0.81	57	2.33	0.57	0.30	155	6.33	1.57	0.81	172	7.02	1.74	0.90	75	3.06	0.75	0.39	173	7.06	1.75	0.90
23.11.11	173	7.06	1.75	0.90	102	4.16	1.02	0.53	152	6.20	1.54	0.79	170	6.94	1.72	0.89	105	4.29	1.05	0.55	170	6.94	1.72	0.89

Date	Production rate																							
	A11				B11				C11				A21				B21				C21			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}		A_{cross}	A_{evp}	A_{cond}
24.11.11	195	7.96	1.97	1.02	135	5.51	1.35	0.70	208	8.49	2.11	1.09	230	9.39	2.32	1.20	125	5.10	1.25	0.65	230	9.39	2.33	1.20
25.11.11	140	5.71	1.41	0.73	100	4.08	1.00	0.52	135	5.51	1.37	0.70	139	5.67	1.40	0.73	126	5.14	1.26	0.66	121	4.94	1.22	0.63

Table-C: Distillate Production Rate (DPR) During the Period February to November, 2011 (Run-02)

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
01.02.11	203	8.29	2.05	1.06	207	8.45	2.09	1.08	205	8.37	2.07	1.07
02.02.11	198	8.08	2.00	1.03	201	8.20	2.03	1.05	200	8.16	2.02	1.04
03.02.11	200	8.16	2.02	1.04	199	8.12	2.01	1.04	200	8.16	2.02	1.04
04.02.11	207	8.45	2.09	1.08	209	8.53	2.11	1.09	205	8.37	2.07	1.07
05.02.11	203	8.29	2.05	1.06	209	8.53	2.11	1.09	179	7.31	1.81	0.93
06.02.11	192	7.84	1.94	1.00	186	7.59	1.88	0.97	186	7.59	1.88	0.97
07.02.11	197	8.04	1.99	1.03	193	7.88	1.95	1.01	207	8.45	2.09	1.08
08.02.11	203	8.29	2.05	1.06	201	8.20	2.03	1.05	206	8.41	2.08	1.08
09.02.11	213	8.69	2.15	1.11	211	8.61	2.13	1.10	205	8.37	2.07	1.07
10.02.11	212.5	8.67	2.15	1.11	217	8.86	2.19	1.13	207	8.45	2.09	1.08
11.02.11	215	8.78	2.17	1.12	221	9.02	2.23	1.15	220	8.98	2.22	1.15

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
12.02.11	200	8.16	2.02	1.04	211	8.61	2.13	1.10	212	8.65	2.14	1.11
13.02.11	209	8.53	2.11	1.09	216	8.82	2.18	1.13	213	8.69	2.15	1.11
14.02.11	211	8.61	2.13	1.10	215	8.78	2.17	1.12	215	8.78	2.17	1.12
15.02.11	216	8.82	2.18	1.13	213	8.69	2.15	1.11	213	8.69	2.15	1.11
16.02.11	221	9.02	2.23	1.15	219	8.94	2.21	1.14	221	9.02	2.23	1.15
17.02.11	214	8.73	2.16	1.12	214	8.73	2.16	1.12	219	8.94	2.21	1.14
18.02.11	220	8.98	2.22	1.15	221	9.02	2.23	1.15	235	9.59	2.37	1.23
19.02.11	201	8.20	2.03	1.05	200	8.16	2.02	1.04	203	8.29	2.05	1.06
20.02.11	152	6.20	1.54	0.79	150	6.12	1.52	0.78	160	6.53	1.62	0.84
21.02.11	113	4.61	1.14	0.59	113	4.61	1.14	0.59	117	4.78	1.18	0.61
22.02.11	203	8.29	2.05	1.06	214	8.73	2.16	1.12	209	8.53	2.11	1.09
23.02.11	208	8.49	2.10	1.09	217	8.86	2.19	1.13	203	8.29	2.05	1.06
24.02.11	219	8.94	2.21	1.14	211	8.61	2.13	1.10	211	8.61	2.13	1.10
25.02.11	215	8.78	2.17	1.12	221	9.02	2.23	1.15	221	9.02	2.23	1.15
26.02.11	214	8.73	2.16	1.12	218	8.90	2.20	1.14	221	9.02	2.23	1.15
27.02.11	220	8.98	2.22	1.15	223	9.10	2.25	1.16	222	9.06	2.24	1.16
28.02.11	200	8.16	2.02	1.04	212	8.65	2.14	1.11	217	8.86	2.19	1.13
01.03.11	196	8.00	1.98	1.02	199	8.12	2.01	1.04	197	8.04	1.99	1.03
02.03.11	180	7.35	1.82	0.94	187	7.63	1.89	0.98	189	7.71	1.91	0.99
03.03.11	187	7.63	1.89	0.98	185	7.55	1.87	0.97	198	8.08	2.00	1.03
04.03.11	178	7.27	1.80	0.93	175	7.14	1.77	0.91	190	7.76	1.92	0.99

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
05.03.11	168	6.86	1.70	0.88	175	7.14	1.77	0.91	187	7.63	1.89	0.98
06.03.11	171	6.98	1.73	0.89	177	7.22	1.79	0.92	181	7.39	1.83	0.95
07.03.11	199	8.12	2.01	1.04	201	8.20	2.03	1.05	203	8.29	2.05	1.06
08.03.11	195	7.96	1.97	1.02	201	8.20	2.03	1.05	209	8.53	2.11	1.09
09.03.11	212	8.65	2.14	1.11	201	8.20	2.03	1.05	217	8.86	2.19	1.13
10.03.11	215	8.78	2.17	1.12	201	8.20	2.03	1.05	220	8.98	2.22	1.15
11.03.11	207	8.45	2.09	1.08	214	8.73	2.16	1.12	215	8.78	2.17	1.12
12.03.11	77	3.14	0.78	0.40	77	3.14	0.78	0.40	73	2.98	0.74	0.38
13.03.11	205	8.37	2.07	1.07	210	8.57	2.12	1.10	210	8.57	2.12	1.10
14.03.11	221	9.02	2.23	1.15	219	8.94	2.21	1.14	213	8.69	2.15	1.11
15.03.11	225	9.18	2.27	1.17	215	8.78	2.17	1.12	245	10.00	2.47	1.28
16.03.11	132	5.39	1.33	0.69	145	5.92	1.46	0.76	144	5.88	1.45	0.75
17.03.11	172	7.02	1.74	0.90	170	6.94	1.72	0.89	176	7.18	1.78	0.92
18.03.11	170	6.94	1.72	0.89	187	7.63	1.89	0.98	176	7.18	1.78	0.92
19.03.11	175	7.14	1.77	0.91	205	8.37	2.07	1.07	188	7.67	1.90	0.98
20.03.11	155	6.33	1.57	0.81	155	6.33	1.57	0.81	150	6.12	1.52	0.78
21.03.11	184	7.51	1.86	0.96	184	7.51	1.86	0.96	171	6.98	1.73	0.89
22.03.11	135	5.51	1.36	0.70	151	6.16	1.53	0.79	145	5.92	1.46	0.76
23.03.11	108	4.41	1.09	0.56	110	4.49	1.11	0.57	120	4.90	1.21	0.63
24.03.11	157	6.41	1.59	0.82	154	6.29	1.56	0.80	154	6.29	1.56	0.80
25.03.11	160	6.53	1.62	0.84	161	6.57	1.63	0.84	154	6.29	1.56	0.80

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
26.03.11	163	6.65	1.65	0.85	162	6.61	1.64	0.85	158	6.45	1.60	0.83
27.03.11	139	5.67	1.40	0.73	139	5.67	1.40	0.73	142	5.80	1.43	0.74
28.03.11	147	6.00	1.48	0.77	147	6.00	1.48	0.77	150	6.12	1.52	0.78
29.03.11	126	5.14	1.27	0.66	125	5.10	1.26	0.65	152	6.20	1.54	0.79
30.03.11	154	6.29	1.56	0.80	156	6.37	1.58	0.81	160	6.53	1.62	0.84
31.03.11	151	6.16	1.53	0.79	161	6.57	1.63	0.84	154	6.29	1.56	0.80
01.04.11	178	7.27	1.80	0.93	164	6.69	1.66	0.86	182	7.43	1.84	0.95
02.04.11	166	6.78	1.68	0.87	164	6.69	1.66	0.86	164	6.69	1.66	0.86
03.04.11	164	6.69	1.66	0.86	173	7.06	1.75	0.90	165	6.73	1.67	0.86
04.04.11	176	7.18	1.78	0.92	176	7.18	1.78	0.92	164	6.69	1.66	0.86
05.04.11	178	7.27	1.80	0.93	181	7.39	1.83	0.95	182	7.43	1.84	0.95
06.04.11	83	3.39	0.84	0.43	93	3.80	0.94	0.49	90	3.67	0.91	0.47
08.04.11	221	9.02	2.23	1.15	220	8.98	2.22	1.15	216	8.82	2.18	1.13
09.04.11	180	7.35	1.82	0.94	187	7.63	1.89	0.98	191	7.80	1.93	1.00
10.04.11	180	7.35	1.82	0.94	180	7.35	1.82	0.94	181	7.39	1.83	0.95
11.04.11	105	4.29	1.06	0.55	100	4.08	1.01	0.52	105	4.29	1.06	0.55
12.04.11	103	4.20	1.04	0.54	98	4.00	0.99	0.51	98	4.00	0.99	0.51
27.04.11	171	6.98	1.73	0.89	173	7.06	1.75	0.90	170	6.94	1.72	0.89
28.04.11	171	6.98	1.73	0.89	160	6.53	1.62	0.84	170	6.94	1.72	0.89
29.04.11	176	7.18	1.78	0.92	177	7.22	1.79	0.92	175	7.14	1.77	0.91
30.04.11	180	7.35	1.82	0.94	181	7.39	1.83	0.95	174	7.10	1.76	0.91

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
01.05.11	169	6.90	1.71	0.88	165	6.73	1.67	0.86	168	6.86	1.70	0.88
02.05.11	170	6.94	1.72	0.89	173	7.06	1.75	0.90	173	7.06	1.75	0.90
03.05.11	156	6.37	1.58	0.81	180	7.35	1.82	0.94	205	8.37	2.07	1.07
04.05.11	163	6.65	1.65	0.85	181	7.39	1.83	0.95	181	7.39	1.83	0.95
06.05.11	173	7.06	1.75	0.90	189	7.71	1.91	0.99	189	7.71	1.91	0.99
07.05.11	169	6.90	1.71	0.88	191	7.80	1.93	1.00	187	7.63	1.89	0.98
08.05.11	186	7.59	1.88	0.97	209	8.53	2.11	1.09	215	8.78	2.17	1.12
09.05.11	194	7.92	1.96	1.01	213	8.69	2.15	1.11	213	8.69	2.15	1.11
11.05.11	177	7.22	1.79	0.92	217	8.86	2.19	1.13	213	8.69	2.15	1.11
14.05.11	187	7.63	1.89	0.98	200	8.16	2.02	1.04	203	8.29	2.05	1.06
15.05.11	172	7.02	1.74	0.90	173	7.06	1.75	0.90	173	7.06	1.75	0.90
16.05.11	113	4.61	1.14	0.59	125	5.10	1.26	0.65	120	4.90	1.21	0.63
17.05.11	145	5.92	1.47	0.76	149	6.08	1.51	0.78	130	5.31	1.31	0.68
18.05.11	131	5.35	1.33	0.68	139	5.67	1.40	0.73	140	5.71	1.41	0.73
19.05.11	110	4.49	1.11	0.57	125	5.10	1.26	0.65	138	5.63	1.39	0.72
20.05.11	151	6.16	1.53	0.79	149	6.08	1.51	0.78	160	6.53	1.62	0.84
21.05.11	163	6.65	1.65	0.85	158	6.45	1.60	0.83	168	6.86	1.70	0.88
22.05.11	130	5.31	1.32	0.68	120	4.90	1.21	0.63	140	5.71	1.41	0.73
23.05.11	100	4.08	1.01	0.52	100	4.08	1.01	0.52	98	4.00	0.99	0.51
24.05.11	120	4.90	1.21	0.63	122	4.98	1.23	0.64	128	5.22	1.29	0.67
25.05.11	93	3.80	0.94	0.49	103	4.20	1.04	0.54	88	3.59	0.89	0.46

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
26.05.11	155	6.33	1.57	0.81	158	6.45	1.60	0.83	165	6.73	1.67	0.86
27.05.11	122	4.98	1.23	0.64	125	5.10	1.26	0.65	128	5.22	1.29	0.67
28.05.11	130	5.31	1.32	0.68	135	5.51	1.36	0.70	130	5.31	1.31	0.68
29.05.11	100	4.08	1.01	0.52	120	4.90	1.21	0.63	117	4.78	1.18	0.61
30.05.11	155	6.33	1.57	0.81	173	7.06	1.75	0.90	175	7.14	1.77	0.91
31.05.11	125	5.10	1.27	0.65	138	5.63	1.39	0.72	138	5.63	1.39	0.72
01.06.11	160	6.53	1.62	0.84	178	7.27	1.80	0.93	175	7.14	1.77	0.91
02.06.11	135	5.51	1.37	0.70	145	5.92	1.46	0.76	140	5.71	1.41	0.73
03.06.11	108	4.41	1.09	0.56	162	6.61	1.64	0.85	117	4.78	1.18	0.61
04.06.11	127	5.18	1.29	0.66	125	5.10	1.26	0.65	130	5.31	1.31	0.68
05.06.11	165	6.73	1.67	0.86	175	7.14	1.77	0.91	175	7.14	1.77	0.91
06.06.11	185	7.55	1.87	0.97	153	6.24	1.55	0.80	92	3.76	0.93	0.48
07.06.11	178	7.27	1.80	0.93	168	6.86	1.70	0.88	160	6.53	1.62	0.84
08.06.11	168	6.86	1.70	0.88	170	6.94	1.72	0.89	168	6.86	1.70	0.88
09.06.11	120	4.90	1.21	0.63	125	5.10	1.26	0.65	133	5.43	1.34	0.69
10.06.11	170	6.94	1.72	0.89	160	6.53	1.62	0.84	150	6.12	1.52	0.78
11.06.11	110	4.49	1.11	0.57	90	3.67	0.91	0.47	95	3.88	0.96	0.50
12.06.11	112	4.57	1.13	0.58	110	4.49	1.11	0.57	108	4.41	1.09	0.56
13.06.11	80	3.27	0.81	0.42	85	3.47	0.86	0.44	68	2.78	0.69	0.36
14.06.11	170	6.94	1.72	0.89	145	5.92	1.46	0.76	155	6.33	1.57	0.81
15.06.11	35	1.43	0.35	0.18	45	1.84	0.45	0.23	48	1.96	0.48	0.25

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
16.06.11	92	3.76	0.93	0.48	85	3.47	0.86	0.44	90	3.67	0.91	0.47
17.06.11	160	6.53	1.62	0.84	50	2.04	0.51	0.26	65	2.65	0.66	0.34
18.06.11	165	6.73	1.67	0.86	65	2.65	0.66	0.34	90	3.67	0.91	0.47
19.06.11	80	3.27	0.81	0.42	80	3.27	0.81	0.42	95	3.88	0.96	0.50
20.06.11	48	1.96	0.49	0.25	43	1.76	0.43	0.22	45	1.84	0.45	0.23
21.06.11	200	8.16	2.02	1.04	90	3.67	0.91	0.47	95	3.88	0.96	0.50
22.06.11	100	4.08	1.01	0.52	90	3.67	0.91	0.47	95	3.88	0.96	0.50
23.06.11	45	1.84	0.46	0.23	45	1.84	0.45	0.23	55	2.24	0.56	0.29
24.06.11	190	7.76	1.92	0.99	185	7.55	1.87	0.97	203	8.29	2.05	1.06
25.06.11	130	5.31	1.32	0.68	125	5.10	1.26	0.65	132	5.39	1.33	0.69
26.06.11	50	2.04	0.51	0.26	30	1.22	0.30	0.16	45	1.84	0.45	0.23
27.06.11	45	1.84	0.46	0.23	25	1.02	0.25	0.13	40	1.63	0.40	0.21
28.06.11	75	3.06	0.76	0.39	65	2.65	0.66	0.34	65	2.65	0.66	0.34
29.06.11	50	2.04	0.51	0.26	40	1.63	0.40	0.21	50	2.04	0.51	0.26
30.06.11	58	2.37	0.59	0.30	47	1.92	0.47	0.25	80	3.27	0.81	0.42
01.07.11	80	3.27	0.81	0.42	60	2.45	0.61	0.31	70	2.86	0.71	0.37
02.07.11	30	1.22	0.30	0.16	30	1.22	0.30	0.16	32	1.31	0.32	0.17
03.07.11	35	1.43	0.35	0.18	35	1.43	0.35	0.18	45	1.84	0.45	0.23
04.07.11	60	2.45	0.61	0.31	40	1.63	0.40	0.21	55	2.24	0.56	0.29
05.07.11	85	3.47	0.86	0.44	55	2.24	0.56	0.29	60	2.45	0.61	0.31
06.07.11	125	5.10	1.27	0.65	145	5.92	1.46	0.76	150	6.12	1.52	0.78

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
07.07.11	138	5.63	1.40	0.72	127	5.18	1.28	0.66	145	5.92	1.46	0.76
08.07.11	93	3.80	0.94	0.49	77	3.14	0.78	0.40	80	3.27	0.81	0.42
09.07.11	120	4.90	1.21	0.63	110	4.49	1.11	0.57	115	4.69	1.16	0.60
10.07.11	168	6.86	1.70	0.88	165	6.73	1.67	0.86	170	6.94	1.72	0.89
11.07.11	165	6.73	1.67	0.86	115	4.69	1.16	0.60	140	5.71	1.41	0.73
12.07.11	142	5.80	1.44	0.74	100	4.08	1.01	0.52	138	5.63	1.39	0.72
13.07.11	150	6.12	1.52	0.78	108	4.41	1.09	0.56	145	5.92	1.46	0.76
14.07.11	127	5.18	1.29	0.66	132	5.39	1.33	0.69	145	5.92	1.46	0.76
15..07.11	120	4.90	1.21	0.63	140	5.71	1.41	0.73	110	4.49	1.11	0.57
16.07.11	80	3.27	0.81	0.42	78	3.18	0.79	0.41	75	3.06	0.76	0.39
17.07.11	90	3.67	0.91	0.47	60	2.45	0.61	0.31	58	2.37	0.59	0.30
18.07.11	100	4.08	1.01	0.52	105	4.29	1.06	0.55	100	4.08	1.01	0.52
19.07.11	80	3.27	0.81	0.42	70	2.86	0.71	0.37	70	2.86	0.71	0.37
20.07.11	40	1.63	0.40	0.21	25	1.02	0.25	0.13	35	1.43	0.35	0.18
21.07.11	128	5.22	1.30	0.67	65	2.65	0.66	0.34	75	3.06	0.76	0.39
22.07.11	136	5.55	1.38	0.71	89	3.63	0.90	0.46	120	4.90	1.21	0.63
23.07.11	165	6.73	1.67	0.86	115	4.69	1.16	0.60	140	5.71	1.41	0.73
24.07.11	142	5.80	1.44	0.74	100	4.08	1.01	0.52	138	5.63	1.39	0.72
25.07.11	150	6.12	1.52	0.78	108	4.41	1.09	0.56	145	5.92	1.46	0.76
26.07.11	127	5.18	1.29	0.66	132	5.39	1.33	0.69	145	5.92	1.46	0.76
27.07.11	120	4.90	1.21	0.63	140	5.71	1.41	0.73	110	4.49	1.11	0.57

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
28.07.11	126	5.14	1.28	0.66	142	5.80	1.43	0.74	118	4.82	1.19	0.62
29.07.11	130	5.31	1.32	0.68	142	5.80	1.43	0.74	123	5.02	1.24	0.64
30.07.11	143	5.84	1.45	0.75	145	5.92	1.46	0.76	132	5.39	1.33	0.69
31.07.11	152	6.20	1.54	0.79	148	6.04	1.49	0.77	143	5.84	1.44	0.75
01.08.11	152	6.20	1.54	0.79	160	6.53	1.62	0.84	152	6.20	1.54	0.79
02.08.11	113	4.61	1.14	0.59	123	5.02	1.24	0.64	125	5.10	1.26	0.65
03.08.11	30	1.22	0.30	0.16	33	1.35	0.33	0.17	35	1.43	0.35	0.18
04.08.11	100	4.08	1.01	0.52	123	5.02	1.24	0.64	90	3.67	0.91	0.47
05.08.11	60	2.45	0.61	0.31	45	1.84	0.45	0.23	45	1.84	0.45	0.23
06.08.11	45	1.84	0.46	0.23	45	1.84	0.45	0.23	45	1.84	0.45	0.23
07.08.11	87	3.55	0.88	0.45	70	2.86	0.71	0.37	53	2 16	0.54	0.28
08.08.11	145	5.92	1.47	0.76	151	6.16	1.53	0.79	134	5.47	1.35	0.70
09.08.11	142	5.80	1.44	0.74	143	5.84	1.44	0.75	134	5.47	1.35	0.70
10.08.11	147	6.00	1.49	0.77	148	6.04	1.49	0.77	143	5.84	1.44	0.75
11.08.11	138	5.63	1.40	0.72	132	5.39	1.33	0.69	151	6.16	1.53	0.79
12.08.11	148	6.04	1.50	0.77	146	5.96	1.47	0.76	151	6.16	1.53	0.79
13.08.11	118	4.82	1.19	0.62	126	5.14	1.27	0.66	142	5.80	1.43	0.74
14.08.11	123	5.02	1.24	0.64	130	5.31	1.31	0.68	142	5.80	1.43	0.74
15.08.11	132	5.39	1.34	0.69	143	5.84	1.44	0.75	145	5.92	1.46	0.76
16.08.11	143	5.84	1.45	0.75	152	6.20	1.54	0.79	148	6.04	1.49	0.77
17.08.11	134	5.47	1.36	0.70	145	5.92	1.46	0.76	151	6.16	1.53	0.79

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
18.08.11	134	5.47	1.36	0.70	142	5.80	1.43	0.74	143	5.84	1.44	0.75
19.08.11	143	5.84	1.45	0.75	147	6.00	1.48	0.77	148	6.04	1.49	0.77
20.08.11	151	6.16	1.53	0.79	138	5.63	1.39	0.72	132	5.39	1.33	0.69
21.08.11	151	6.16	1.53	0.79	148	6.04	1.49	0.77	146	5.96	1.47	0.76
22.08.11	148	6.04	1.50	0.77	151	6.16	1.53	0.79	143	5.84	1.44	0.75
01.10.11	150	6.12	1.52	0.78	170	6.94	1.72	0.89	120	4.90	1.21	0.63
02.10.11	140	5.71	1.42	0.73	133	5.43	1.34	0.69	150	6.12	1.52	0.78
03.10.11	152	6.20	1.54	0.79	150	6.12	1.52	0.78	160	6.53	1.62	0.84
04.10.11	205	8.37	2.07	1.07	203	8.29	2.05	1.06	200	8.16	2.02	1.04
05.10.11	160	6.53	1.62	0.84	148	6.04	1.49	0.77	155	6.33	1.57	0.81
06.10.11	160	6.53	1.62	0.84	165	6.73	1.67	0.86	165	6.73	1.67	0.86
07.10.11	158	6.45	1.60	0.83	153	6.24	1.55	0.80	148	6.04	1.49	0.77
08.10.11	220	8.98	2.23	1.15	215	8.78	2.17	1.12	210	8.57	2.12	1.10
09.10.11	177	7.22	1.79	0.92	175	7.14	1.77	0.91	170	6.94	1.72	0.89
10.10.11	127	5.18	1.29	0.66	127	5.18	1.28	0.66	127	5.18	1.28	0.66
11.10.11	143	5.84	1.45	0.75	148	6.04	1.49	0.77	148	6.04	1.49	0.77
12.10.11	130	5.31	1.32	0.68	135	5.51	1.36	0.70	130	5.31	1.31	0.68
13.10.11	165	6.73	1.67	0.86	162	6.61	1.64	0.85	150	6.12	1.52	0.78
14.10.11	188	7.67	1.90	0.98	185	7.55	1.87	0.97	185	7.55	1.87	0.97
15.10.11	158	6.45	1.60	0.83	160	6.53	1.62	0.84	153	6.24	1.55	0.80
16.10.11	165	6.73	1.67	0.86	167	6.82	1.69	0.87	158	6.45	1.60	0.83

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
17.10.11	125	5.10	1.27	0.65	128	5.22	1.29	0.67	128	5.22	1.29	0.67
18.10.11	150	6.12	1.52	0.78	152	6.20	1.54	0.79	145	5.92	1.46	0.76
19.10.11	48	1.96	0.49	0.25	55	2.24	0.56	0.29	45	1.84	0.45	0.23
20.10.11	150	6.12	1.52	0.78	160	6.53	1.62	0.84	155	6.33	1.57	0.81
21.10.11	150	6.12	1.52	0.78	145	5.92	1.46	0.76	145	5.92	1.46	0.76
22.10.11	110	4.49	1.11	0.57	110	4.49	1.11	0.57	110	4.49	1.11	0.57
23.10.11	115	4.69	1.16	0.60	105	4.29	1.06	0.55	85	3.47	0.86	0.44
24.10.11	180	7.35	1.82	0.94	185	7.55	1.87	0.97	127	5.18	1.28	0.66
25.10.11	185	7.55	1.87	0.97	185	7.55	1.87	0.97	177	7.22	1.79	0.92
26.10.11	165	6.73	1.67	0.86	170	6.94	1.72	0.89	175	7.14	1.77	0.91
27.10.11	97	3.96	0.98	0.51	105	4.29	1.06	0.55	103	4.20	1.04	0.54
28.10.11	178	7.27	1.80	0.93	172	7.02	1.74	0.90	157	6.41	1.59	0.82
29.10.11	175	7.14	1.77	0.91	165	6.73	1.67	0.86	175	7.14	1.77	0.91
30.10.11	163	6.65	1.65	0.85	163	6.65	1.65	0.85	162	6.61	1.64	0.85
31.10.11	105	4.29	1.06	0.55	112	4.57	1.13	0.58	115	4.69	1.16	0.60
01.11.11	153	6.24	1.55	0.80	165	6.73	1.67	0.86	155	6.33	1.57	0.81
02.11.11	157	6.41	1.59	0.82	122	4.98	1.23	0.64	157	6.41	1.59	0.82
03.11.11	170	6.94	1.72	0.89	175	7.14	1.77	0.91	163	6.65	1.65	0.85
04.11.11	107	4.37	1.08	0.56	112	4.57	1.13	0.58	112	4.57	1.13	0.58
05.11.11	107	4.37	1.08	0.56	113	4.61	1.14	0.59	100	4.08	1.01	0.52
10.11.11	150	6.12	1.52	0.78	143	5.84	1.44	0.75	170	6.94	1.72	0.89

Date	Distillate Production Rate (DPR)											
	A31				A32				A33			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$		A_{cross}	$A_{evp.}$	$A_{cond.}$
11.11.11	188	7.67	1.90	0.98	145	5.92	1.46	0.76	162	6.61	1.64	0.85
12.11.11	155	6.33	1.57	0.81	164	6.69	1.66	0.86	160	6.53	1.62	0.84
13.11.11	155	6.33	1.57	0.81	163	6.65	1.65	0.85	150	6.12	1.52	0.78
14.11.11	177	7.22	1.79	0.92	187	7.63	1.89	0.98	172	7.02	1.74	0.90
15.11.11	135	5.51	1.37	0.70	148	6.04	1.49	0.77	140	5.71	1.41	0.73
16.11.11	25	1.02	0.25	0.13	72	2.94	0.73	0.38	65	2.65	0.66	0.34
17.11.11	48	1.96	0.49	0.25	60	2.45	0.61	0.31	52	2.12	0.53	0.27
18.11.11	65	2.65	0.66	0.34	140	5.71	1.41	0.73	142	5.80	1.43	0.74
19.11.11	75	3.06	0.76	0.39	122	4.98	1.23	0.64	110	4.49	1.11	0.57
20.11.11	75	3.06	0.76	0.39	123	5.02	1.24	0.64	120	4.90	1.21	0.63
21.11.11	137	5.59	1.39	0.72	55	2.24	0.56	0.29	117	4.78	1.18	0.61
22.11.11	100	4.08	1.01	0.52	157	6.41	1.59	0.82	140	5.71	1.41	0.73
23.11.11	155	6.33	1.57	0.81	165	6.73	1.67	0.86	170	6.94	1.72	0.89
24.11.11	230	9.39	2.33	1.20	240	9.80	2.42	1.25	255	10.41	2.58	1.33
25.11.11	132	5.39	1.34	0.69	133	5.43	1.34	0.69	134	5.47	1.35	0.70

Table-D: Distillate Production Rate (DPR) During the Period May to November, 2011 (Run-03)

Date	Distillate Production Rate (DPR)											
	A41				A42				A43			
	mL/day	L/m²/day			mL/day	L/m²/day			mL/day	L/m²/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}

Date	Distillate Production Rate (DPR)											
	A41				A42				A43			
	mL/day	$L/m^2/day$			mL/day	$L/m^2/day$			mL/day	$L/m^2/day$		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
01.05.11	202	8.24	2.04	1.05	202	8.24	2.04	1.05	200	8.16	2.02	1.04
02.05.11	199	8.12	2.01	1.04	192	7.84	1.94	1.00	191	7.80	1.93	1.00
03.05.11	200	8.16	2.02	1.04	247	10.08	2.49	1.29	207	8.45	2.09	1.08
04.05.11	194	7.92	1.96	1.01	222	9.06	2.24	1.16	217	8.86	2.19	1.13
06.05.11	203	8.29	2.05	1.06	233	9.51	2.35	1.22	220	8.98	2.22	1.15
07.05.11	210	8.57	2.12	1.10	221	9.02	2.23	1.15	220	8.98	2.22	1.15
08.05.11	222	9.06	2.24	1.16	242	9.88	2.44	1.26	241	9.84	2.43	1.26
09.05.11	225	9.18	2.27	1.17	240	9.80	2.42	1.25	240	9.80	2.42	1.25
11.05.11	231	9.43	2.33	1.21	231	9.43	2.33	1.21	240	9.80	2.42	1.25
14.05.11	223	9.10	2.25	1.16	223	9.10	2.25	1.16	230	9.39	2.32	1.20
15.05.11	210	8.57	2.12	1.10	211	8.61	2.13	1.10	213	8.69	2.15	1.11
16.05.11	130	5.31	1.31	0.68	110	4.49	1.11	0.57	128	5.22	1.29	0.67
17.05.11	165	6.73	1.67	0.86	161	6.57	1.63	0.84	163	6.65	1.65	0.85
18.05.11	160	6.53	1.62	0.84	161	6.57	1.63	0.84	160	6.53	1.62	0.84
19.05.11	140	5.71	1.41	0.73	140	5.71	1.41	0.73	139	5.67	1.40	0.73
20.05.11	163	6.65	1.65	0.85	163	6.65	1.65	0.85	159	6.49	1.61	0.83
21.05.11	155	6.33	1.57	0.81	165	6.73	1.67	0.86	153	6.24	1.55	0.80
22.05.11	130	5.31	1.31	0.68	120	4.90	1.21	0.63	115	4.69	1.16	0.60
23.05.11	98	4.00	0.99	0.51	90	3.67	0.91	0.47	95	3.88	0.96	0.50
24.05.11	100	4.08	1.01	0.52	100	4.08	1.01	0.52	118	4.82	1.19	0.62
25.05.11	113	4.61	1.14	0.59	80	3.27	0.81	0.42	98	4.00	0.99	0.51

Date	Distillate Production Rate (DPR)											
	A41				A42				A43			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
26.05.11	155	6.33	1.57	0.81	190	7.76	1.92	0.99	158	6.45	1.60	0.83
27.05.11	115	4.69	1.16	0.60	110	4.49	1.11	0.57	120	4.90	1.21	0.63
28.05.11	140	5.71	1.41	0.73	140	5.71	1.41	0.73	125	5.10	1.26	0.65
29.05.11	121	4.94	1.22	0.63	118	4.82	1.19	0.62	118	4.82	1.19	0.62
30.05.11	95	3.88	0.96	0.50	175	7.14	1.77	0.91	158	6.45	1.60	0.83
31.05.11	170	6.94	1.72	0.89	168	6.86	1.70	0.88	125	5.10	1.26	0.65
01.06.11	178	7.27	1.80	0.93	160	6.53	1.62	0.84	170	6.94	1.72	0.89
02.06.11	250	10.20	2.53	1.31	135	5.51	1.36	0.70	145	5.92	1.46	0.76
03.06.11	113	4.61	1.14	0.59	128	5.22	1.29	0.67	110	4.49	1.11	0.57
04.06.11	135	5.51	1.36	0.70	143	5.84	1.44	0.75	133	5.43	1.34	0.69
05.06.11	178	7.27	1.80	0.93	110	4.49	1.11	0.57	170	6.94	1.72	0.89
06.06.11	85	3.47	0.86	0.44	195	7.96	1.97	1.02	160	6.53	1.62	0.84
07.06.11	235	9.59	2.37	1.23	152	6.20	1.54	0.79	153	6.24	1.55	0.80
08.06.11	145	5.92	1.46	0.76	173	7.06	1.75	0.90	165	6.73	1.67	0.86
09.06.11	140	5.71	1.41	0.73	143	5.84	1.44	0.75	125	5.10	1.26	0.65
10.06.11	163	6.65	1.65	0.85	160	6.53	1.62	0.84	170	6.94	1.72	0.89
11.06.11	100	4.08	1.01	0.52	90	3.67	0.91	0.47	95	3.88	0.96	0.50
12.06.11	110	4.49	1.11	0.57	110	4.49	1.11	0.57	108	4.41	1.09	0.56
13.06.11	60	2.45	0.61	0.31	58	2.37	0.59	0.30	90	3.67	0.91	0.47
14.06.11	192	7.84	1.94	1.00	175	7.14	1.77	0.91	150	6.12	1.52	0.78
15.06.11	55	2.24	0.56	0.29	75	3.06	0.76	0.39	73	2.98	0.74	0.38

Date	Distillate Production Rate (DPR)											
	A41				A42				A43			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
16.06.11	113	4.61	1.14	0.59	70	2.86	0.71	0.37	98	4.00	0.99	0.51
17.06.11	90	3.67	0.91	0.47	85	3.47	0.86	0.44	65	2.65	0.66	0.34
18.06.11	70	2.86	0.71	0.37	100	4.08	1.01	0.52	90	3.67	0.91	0.47
19.06.11	120	4.90	1.21	0.63	130	5.31	1.31	0.68	120	4.90	1.21	0.63
20.06.11	138	5.63	1.39	0.72	58	2.37	0.59	0.30	58	2.37	0.59	0.30
21.06.11	80	3.27	0.81	0.42	85	3.47	0.86	0.44	85	3.47	0.86	0.44
22.06.11	80	3.27	0.81	0.42	85	3.47	0.86	0.44	80	3.27	0.81	0.42
23.06.11	70	2.86	0.71	0.37	60	2.45	0.61	0.31	55	2.24	0.56	0.29
24.06.11	255	10.41	2.58	1.33	200	8.16	2.02	1.04	205	8.37	2.07	1.07
25.06.11	100	4.08	1.01	0.52	102	4.16	1.03	0.53	98	4.00	0.99	0.51
26.06.11	50	2.04	0.51	0.26	35	1.43	0.35	0.18	40	1.63	0.40	0.21
27.06.11	40	1.63	0.40	0.21	27	1.10	0.27	0.14	35	1.43	0.35	0.18
28.06.11	45	1.84	0.45	0.23	63	2.57	0.64	0.33	73	2.98	0.74	0.38
29.06.11	40	1.63	0.40	0.21	45	1.84	0.45	0.23	40	1.63	0.40	0.21
30.06.11	58	2.37	0.59	0.30	55	2.24	0.56	0.29	25	1.02	0.25	0.13
01.07.11	50	2.04	0.51	0.26	80	3.27	0.81	0.42	70	2.86	0.71	0.37
02.07.11	30	1.22	0.30	0.16	30	1.22	0.30	0.16	35	1.43	0.35	0.18
03.07.11	50	2.04	0.51	0.26	33	1.35	0.33	0.17	25	1.02	0.25	0.13
04.07.11	32	1.31	0.32	0.17	32	1.31	0.32	0.17	42	1.71	0.42	0.22
05.07.11	55	2.24	0.56	0.29	75	3.06	0.76	0.39	80	3.27	0.81	0.42
06.07.11	115	4.69	1.16	0.60	125	5.10	1.26	0.65	115	4.69	1.16	0.60

Date	Distillate Production Rate (DPR)											
	A41				A42				A43			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
07.07.11	150	6.12	1.52	0.78	138	5.63	1.39	0.72	142	5.80	1.43	0.74
08.07.11	85	3.47	0.86	0.44	85	3.47	0.86	0.44	75	3.06	0.76	0.39
09.07.11	200	8.16	2.02	1.04	117	4.78	1.18	0.61	120	4.90	1.21	0.63
10.07.11	145	5.92	1.46	0.76	172	7.02	1.74	0.90	165	6.73	1.67	0.86
11.07.11	170	6.94	1.72	0.89	155	6.33	1.57	0.81	150	6.12	1.52	0.78
12.07.11	113	4.61	1.14	0.59	113	4.61	1.14	0.59	100	4.08	1.01	0.52
13.07.11	110	4.49	1.11	0.57	130	5.31	1.31	0.68	118	4.82	1.19	0.62
14.07.11	163	6.65	1.65	0.85	160	6.53	1.62	0.84	143	5.84	1.44	0.75
15..07.11	130	5.31	1.31	0.68	125	5.10	1.26	0.65	135	5.51	1.36	0.70
16.07.11	70	2.86	0.71	0.37	80	3.27	0.81	0.42	95	3.88	0.96	0.50
17.07.11	77	3.14	0.78	0.40	88	3.59	0.89	0.46	83	3.39	0.84	0.43
18.07.11	100	4.08	1.01	0.52	115	4.69	1.16	0.60	115	4.69	1.16	0.60
19.07.11	80	3.27	0.81	0.42	75	3.06	0.76	0.39	80	3.27	0.81	0.42
20.07.11	42	1.71	0.42	0.22	42	1.71	0.42	0.22	35	1.43	0.35	0.18
21.07.11	115	4.69	1.16	0.60	73	2.98	0.74	0.38	80	3.27	0.81	0.42
22.07.11	118	4.82	1.19	0.62	79	3.22	0.80	0.41	80	3.27	0.81	0.42
23.07.11	170	6.94	1.72	0.89	155	6.33	1.57	0.81	150	6.12	1.52	0.78
24.07.11	113	4.61	1.14	0.59	113	4.61	1.14	0.59	100	4.08	1.01	0.52
25.07.11	110	4.49	1.11	0.57	130	5.31	1.31	0.68	118	4.82	1.19	0.62
26.07.11	163	6.65	1.65	0.85	160	6.53	1.62	0.84	143	5.84	1.44	0.75
27.07.11	130	5.31	1.31	0.68	125	5.10	1.26	0.65	135	5.51	1.36	0.70

Date	Distillate Production Rate (DPR)											
	A41				A42				A43			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
28.07.11	154	6.29	1.56	0.80	172	7.02	1.74	0.90	145	5.92	1.46	0.76
29.07.11	154	6.29	1.56	0.80	170	6.94	1.72	0.89	151	6.16	1.53	0.79
30.07.11	150	6.12	1.52	0.78	173	7.06	1.75	0.90	155	6.33	1.57	0.81
31.07.11	153	6.24	1.55	0.80	165	6.73	1.67	0.86	163	6.65	1.65	0.85
01.08.11	148	6.04	1.49	0.77	163	6.65	1.65	0.85	160	6.53	1.62	0.84
02.08.11	125	5.10	1.26	0.65	150	6.12	1.52	0.78	130	5.31	1.31	0.68
03.08.11	40	1.63	0.40	0.21	40	1.63	0.40	0.21	40	1.63	0.40	0.21
04.08.11	90	3.67	0.91	0.47	95	3.88	0.96	0.50	100	4.08	1.01	0.52
05.08.11	55	2.24	0.56	0.29	57	2.33	0.58	0.30	60	2.45	0.61	0.31
06.08.11	40	1.63	0.40	0.21	55	2.24	0.56	0.29	50	2.04	0.51	0.26
07.08.11	100	4.08	1.01	0.52	78	3.18	0.79	0.41	75	3.06	0.76	0.39
08.08.11	147	6.00	1.48	0.77	152	6.20	1.54	0.79	149	6.08	1.51	0.78
09.08.11	142	5.80	1.43	0.74	152	6.20	1.54	0.79	155	6.33	1.57	0.81
10.08.11	142	5.80	1.43	0.74	168	6.86	1.70	0.88	163	6.65	1.65	0.85
11.08.11	153	6.24	1.55	0.80	172	7.02	1.74	0.90	170	6.94	1.72	0.89
12.08.11	157	6.41	1.59	0.82	171	6.98	1.73	0.89	170	6.94	1.72	0.89
13.08.11	151	6.16	1.53	0.79	154	6.29	1.56	0.80	170	6.94	1.72	0.89
14.08.11	155	6.33	1.57	0.81	150	6.12	1.52	0.78	173	7.06	1.75	0.90
15.08.11	163	6.65	1.65	0.85	153	6.24	1.55	0.80	165	6.73	1.67	0.86
16.08.11	149	6.08	1.51	0.78	147	6.00	1.48	0.77	152	6.20	1.54	0.79
17.08.11	155	6.33	1.57	0.81	142	5.80	1.43	0.74	152	6.20	1.54	0.79

Date	Distillate Production Rate (DPR)											
	A41				A42				A43			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
18.08.11	163	6.65	1.65	0.85	142	5.80	1.43	0.74	168	6.86	1.70	0.88
19.08.11	170	6.94	1.72	0.89	153	6.24	1.55	0.80	172	7.02	1.74	0.90
20.08.11	170	6.94	1.72	0.89	157	6.41	1.59	0.82	171	6.98	1.73	0.89
21.08.11	157	6.41	1.59	0.82	160	6.53	1.62	0.84	167	6.82	1.69	0.87
22.08.11	162	6.61	1.64	0.85	140	5.71	1.41	0.73	157	6.41	1.59	0.82
01.10.11	132	5.39	1.33	0.69	125	5.10	1.26	0.65	142	5.80	1.43	0.74
02.10.11	125	5.10	1.26	0.65	133	5.43	1.34	0.69	125	5.10	1.26	0.65
03.10.11	130	5.31	1.31	0.68	130	5.31	1.31	0.68	132	5.39	1.33	0.69
04.10.11	182	7.43	1.84	0.95	195	7.96	1.97	1.02	185	7.55	1.87	0.97
05.10.11	145	5.92	1.46	0.76	150	6.12	1.52	0.78	148	6.04	1.49	0.77
06.10.11	140	5.71	1.41	0.73	140	5.71	1.41	0.73	133	5.43	1.34	0.69
07.10.11	135	5.51	1.36	0.70	142	5.80	1.43	0.74	135	5.51	1.36	0.70
08.10.11	185	7.55	1.87	0.97	205	8.37	2.07	1.07	195	7.96	1.97	1.02
09.10.11	155	6.33	1.57	0.81	155	6.33	1.57	0.81	155	6.33	1.57	0.81
10.10.11	117	4.78	1.18	0.61	125	5.10	1.26	0.65	118	4.82	1.19	0.62
11.10.11	130	5.31	1.31	0.68	140	5.71	1.41	0.73	130	5.31	1.31	0.68
12.10.11	108	4.41	1.09	0.56	95	3.88	0.96	0.50	110	4.49	1.11	0.57
13.10.11	133	5.43	1.34	0.69	158	6.45	1.60	0.83	135	5.51	1.36	0.70
14.10.11	142	5.80	1.43	0.74	155	6.33	1.57	0.81	150	6.12	1.52	0.78
15.10.11	118	4.82	1.19	0.62	135	5.51	1.36	0.70	122	4.98	1.23	0.64
16.10.11	118	4.82	1.19	0.62	135	5.51	1.36	0.70	125	5.10	1.26	0.65

Date	Distillate Production Rate (DPR)											
	A41				A42				A43			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
17.10.11	95	3.88	0.96	0.50	115	4.69	1.16	0.60	110	4.49	1.11	0.57
18.10.11	120	4.90	1.21	0.63	133	5.43	1.34	0.69	123	5.02	1.24	0.64
19.10.11	48	1.96	0.48	0.25	52	2.12	0.53	0.27	50	2.04	0.51	0.26
20.10.11	123	5.02	1.24	0.64	145	5.92	1.46	0.76	135	5.51	1.36	0.70
21.10.11	105	4.29	1.06	0.55	120	4.90	1.21	0.63	110	4.49	1.11	0.57
22.10.11	80	3.27	0.81	0.42	80	3.27	0.81	0.42	82	3.35	0.83	0.43
23.10.11	82	3.35	0.83	0.43	110	4.49	1.11	0.57	100	4.08	1.01	0.52
24.10.11	155	6.33	1.57	0.81	140	5.71	1.41	0.73	140	5.71	1.41	0.73
25.10.11	140	5.71	1.41	0.73	150	6.12	1.52	0.78	150	6.12	1.52	0.78
26.10.11	113	4.61	1.14	0.59	140	5.71	1.41	0.73	125	5.10	1.26	0.65
27.10.11	85	3.47	0.86	0.44	90	3.67	0.91	0.47	85	3.47	0.86	0.44
28.10.11	122	4.98	1.23	0.64	130	5.31	1.31	0.68	128	5.22	1.29	0.67
29.10.11	125	5.10	1.26	0.65	138	5.63	1.39	0.72	135	5.51	1.36	0.70
30.10.11	132	5.39	1.33	0.69	132	5.39	1.33	0.69	141	5.76	1.42	0.74
31.10.11	75	3.06	0.76	0.39	93	3.80	0.94	0.49	92	3.76	0.93	0.48
01.11.11	125	5.10	1.26	0.65	140	5.71	1.41	0.73	130	5.31	1.31	0.68
02.11.11	135	5.51	1.36	0.70	160	6.53	1.62	0.84	142	5.80	1.43	0.74
03.11.11	130	5.31	1.31	0.68	148	6.04	1.49	0.77	140	5.71	1.41	0.73
04.11.11	105	4.29	1.06	0.55	103	4.20	1.04	0.54	103	4.20	1.04	0.54
05.11.11	118	4.82	1.19	0.62	105	4.29	1.06	0.55	98	4.00	0.99	0.51
10.11.11	125	5.10	1.26	0.65	155	6.33	1.57	0.81	145	5.92	1.46	0.76

Date	Distillate Production Rate (DPR)											
	A41				A42				A43			
	mL/day	L/m^2/day			mL/day	L/m^2/day			mL/day	L/m^2/day		
		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}		A_{cross}	$A_{evp.}$	A_{cond}
11.11.11	115	4.69	1.16	0.60	155	6.33	1.57	0.81	145	5.92	1.46	0.76
12.11.11	123	5.02	1.24	0.64	145	5.92	1.46	0.76	141	5.76	1.42	0.74
13.11.11	122	4.98	1.23	0.64	145	5.92	1.46	0.76	141	5.76	1.42	0.74
14.11.11	145	5.92	1.46	0.76	150	6.12	1.52	0.78	150	6.12	1.52	0.78
15.11.11	120	4.90	1.21	0.63	132	5.39	1.33	0.69	122	4.98	1.23	0.64
16.11.11	75	3.06	0.76	0.39	70	2.86	0.71	0.37	72	2.94	0.73	0.38
17.11.11	50	2.04	0.51	0.26	55	2.24	0.56	0.29	55	2.24	0.56	0.29
18.11.11	110	4.49	1.11	0.57	95	3.88	0.96	0.50	103	4.20	1.04	0.54
19.11.11	91	3.71	0.92	0.48	100	4.08	1.01	0.52	93	3.80	0.94	0.49
20.11.11	91	3.71	0.92	0.48	100	4.08	1.01	0.52	94	3.84	0.95	0.49
21.11.11	110	4.49	1.11	0.57	100	4.08	1.01	0.52	98	4.00	0.99	0.51
22.11.11	110	4.49	1.11	0.57	137	5.59	1.38	0.72	117	4.78	1.18	0.61
23.11.11	112	4.57	1.13	0.58	125	5.10	1.26	0.65	125	5.10	1.26	0.65
24.11.11	155	6.33	1.57	0.81	170	6.94	1.72	0.89	175	7.14	1.77	0.91
25.11.11	133	5.43	1.34	0.69	141	5.76	1.42	0.74	136	5.55	1.37	0.71

Annex-II

Table-A: Temperature Data- Daily Maximum (T_{Max}), Average (T_{Avg}), Minimum (T_{Min}) and Standard Deviation (Std. Div.)

Date	Ambient Temperature				Internal Air Temperature				Temperature at Evaporation Surface			
	T_{Max}	T_{Avg}	T_{Mim}	Std Div.	T_{Max}	T_{Avg}	T_{Mim}	Std. Div.	T_{Max}	T_{Avg}	T_{Min}	Std. Div.
10.02.11	29.50	22.24	16.76	4.14	50.46	28.35	15.88	12.75	46.58	27.00	15.12	11.78
11.02.11	29.38	21.53	14.26	5.14	52.40	28.20	13.10	14.42	49.69	26.79	12.35	13.39
12.02.11	29.51	21.72	14.50	4.91	55.19	29.47	13.72	15.51	51.33	28.03	13.02	14.36
13.02.11	29.97	22.35	16.32	4.37	52.41	29.47	15.63	13.58	47.80	27.47	14.68	12.38
14.02.11	31.41	23.83	19.53	3.90	56.44	31.59	18.80	14.08	51.45	29.91	17.67	12.89
15.02.11	32.12	25.68	21.23	3.86	56.44	33.11	21.17	12.90	51.88	31.22	20.23	11.48
16.02.11	31.31	25.58	21.74	3.36	48.46	31.15	21.32	10.19	43.62	29.35	20.26	9.11
17.02.11	30.00	23.58	18.81	3.35	47.98	28.74	18.85	9.96	44.32	27.17	17.71	9.23
18.02.11	28.43	21.84	16.99	3.80	46.54	27.05	16.58	10.54	42.30	25.58	15.72	9.67
19.02.11	29.75	23.41	18.26	3.81	48.03	28.23	18.29	9.85	43.51	26.56	17.28	8.80
20.02.11	29.59	23.39	20.32	2.58	46.34	26.77	20.35	6.77	41.74	25.34	19.59	6.06
21.02.11	24.93	21.25	17.47	1.68	32.15	22.59	17.12	3.21	30.62	21.53	15.98	3.17
22.02.11	29.63	21.69	14.45	5.12	47.91	27.26	14.39	12.18	43.43	25.62	12.96	11.31
23.02.11	30.18	22.07	14.64	5.07	50.07	28.22	14.00	13.09	44.98	26.34	12.87	11.85
24.02.11	29.65	21.98	15.15	5.19	52.43	29.14	14.29	14.67	48.96	27.37	13.15	13.67
25.02.11	30.95	22.13	13.91	5.73	55.16	29.84	13.18	15.77	50.53	28.00	12.05	14.58
26.02.11	31.81	23.58	16.62	5.49	55.42	30.65	15.66	14.82	50.05	28.73	14.52	13.48
27.02.11	31.21	23.65	17.74	4.83	53.86	30.04	16.82	13.46	49.25	28.19	15.89	12.20
28.02.11	30.54	22.86	16.22	4.99	52.96	30.25	14.94	14.73	48.73	28.47	14.19	13.47
01.03.11	30.81	21.77	13.01	5.81	54.44	29.49	11.69	15.72	48.80	27.73	10.93	14.46
02.03.11	32.11	23.10	14.36	6.17	56.04	30.67	12.94	15.93	51.92	28.93	11.98	14.68

Date	Ambient Temperature				Internal Air Temperature				Temperature at Evaporation Surface			
	T_{Max}	T_{Avg}	T_{Mim}	Std Div.	T_{Max}	T_{Avg}	T_{Mim}	Std. Div.	T_{Max}	T_{Avg}	T_{Min}	Std. Div.
03.03.11	33.52	24.80	16.61	5.71	55.34	31.68	15.61	14.60	50.73	30.19	14.70	13.59
04.03.11	35.79	26.70	19.69	5.49	53.48	31.97	18.96	12.36	48.97	30.53	17.98	11.38
05.03.11	35.71	27.56	20.36	5.18	53.55	32.85	20.27	11.83	51.23	31.37	19.25	10.83
06.03.11	35.16	27.62	21.43	4.72	53.88	33.29	21.22	11.93	49.74	31.73	20.33	10.93
07.03.11	33.37	25.80	19.40	4.55	51.21	31.58	18.64	12.31	46.61	30.04	17.69	11.47
08.03.11	32.74	25.08	17.99	5.07	49.68	30.40	17.26	11.97	45.00	28.75	15.93	11.12
09.03.11	35.10	27.14	19.44	5.40	53.53	32.75	18.71	12.53	48.57	31.23	17.58	11.49
10.03.11	34.27	27.45	20.51	4.53	53.69	32.83	20.16	11.36	48.73	31.36	19.41	10.30
11.03.11	32.30	25.43	20.87	2.98	48.31	28.14	20.90	7.61	44.58	26.99	20.14	6.92
12.03.11	31.37	25.61	20.41	3.73	49.03	31.08	19.72	10.74	45.43	29.35	19.23	9.60
13.03.11	33.94	26.59	19.77	4.59	59.71	34.06	19.67	13.88	49.13	31.32	18.89	11.10
14.03.11	33.13	26.76	21.72	3.87	56.50	32.88	21.50	11.43	50.36	31.24	20.74	10.27
15.03.11	33.93	26.20	20.60	3.89	48.93	30.29	20.25	9.13	46.36	29.14	19.63	8.59
16.03.11	33.20	26.16	20.34	4.47	49.21	31.12	20.25	10.72	45.15	29.65	19.11	9.81
17.03.11	32.73	26.20	20.31	3.94	50.26	31.85	19.87	11.01	45.10	30.06	18.82	9.60
18.03.11	31.76	26.40	22.73	3.08	47.76	31.14	22.31	8.99	42.46	29.39	21.61	7.63
19.03.11	32.41	27.50	24.13	2.72	48.54	32.44	23.91	8.74	43.35	30.77	23.15	7.39
20.03.11	32.86	28.02	24.91	2.53	48.49	32.49	24.79	8.17	43.87	30.93	24.03	6.97
21.03.11	33.89	28.20	24.01	3.16	50.28	33.00	23.51	9.08	44.92	31.49	22.89	7.90
22.03.11	34.29	27.83	24.69	2.88	51.44	31.61	24.34	8.26	46.45	30.16	23.77	6.95
23.03.11	34.92	28.36	23.76	3.63	53.19	33.64	23.47	10.28	48.21	32.04	22.96	8.97
24.03.11	33.69	27.12	21.85	3.85	49.44	31.92	22.10	9.58	45.49	30.51	21.51	8.57
25.03.11	32.84	26.61	22.06	2.94	46.17	30.58	22.46	7.61	45.38	29.52	21.70	7.13

Date	Ambient Temperature				Internal Air Temperature				Temperature at Evaporation Surface			
	T_{Max}	T_{Avg}	T_{Mim}	Std Div.	T_{Max}	T_{Avg}	T_{Mim}	Std. Div.	T_{Max}	T_{Avg}	T_{Min}	Std. Div.
26.03.11	33.55	28.25	23.75	3.39	51.25	33.29	23.70	9.71	47.42	31.81	23.11	8.68
27.03.11	33.96	27.36	19.64	4.33	52.71	32.61	20.91	10.64	47.73	31.07	20.05	9.41
28.03.11	33.56	25.13	21.09	4.11	50.18	29.21	20.45	9.92	47.17	28.24	19.84	9.46
29.03.11	33.25	26.26	19.92	4.71	51.88	31.49	20.21	11.05	46.13	29.95	19.83	9.82
30.03.11	31.93	26.17	20.63	3.63	46.24	30.37	21.16	8.48	43.16	28.76	20.22	7.52
31.03.11	32.60	25.98	21.19	3.72	47.40	30.32	21.04	9.02	44.16	28.84	20.23	8.10
01.04.11	33.56	27.54	22.15	3.97	52.93	33.31	22.10	10.67	45.99	31.44	21.38	9.29
02.04.11	33.67	28.34	24.32	3.14	50.07	33.51	24.31	9.29	45.59	31.91	23.36	8.19
03.04.11	33.72	29.66	24.06	3.18	50.11	33.33	24.04	9.44	45.52	31.67	23.28	7.96
04.04.11	35.48	27.69	21.96	4.52	53.50	33.48	22.43	10.80	49.63	31.62	21.79	9.41
05.04.11	31.31	25.33	21.32	3.31	44.88	29.08	21.77	7.86	41.43	27.67	20.96	7.27
06.04.11	34.73	30.00	25.59	3.14	34.73	30.00	25.59	3.14	34.73	30.00	25.59	3.14
07.04.11	35.52	30.68	26.60	3.01	35.52	30.68	26.60	3.01	35.52	30.68	26.60	3.01
08.04.11	35.45	31.09	27.01	2.79	35.45	31.09	27.01	2.79	35.45	31.09	27.01	2.79
09.04.11	34.88	30.91	27.03	2.69	34.88	30.91	27.03	2.69	34.88	30.91	27.03	2.69
10.04.11	36.30	31.71	27.48	2.95	36.30	31.71	27.48	2.95	36.30	31.71	27.48	2.95
11.04.11	37.08	32.18	28.46	2.82	37.08	32.18	28.46	2.82	37.08	32.18	28.46	2.82
12.04.11	38.01	32.97	28.28	3.49	38.01	32.97	28.28	3.49	38.01	32.97	28.28	3.49
13.04.11	37.39	33.44	29.87	2.40	37.39	33.44	29.87	2.40	37.39	33.44	29.87	2.40
14.04.11	37.80	33.40	29.93	2.59	37.80	33.40	29.93	2.59	37.80	33.40	29.93	2.59
15.04.11	36.65	32.00	27.71	3.03	36.65	32.00	27.71	3.03	36.65	32.00	27.71	3.03
16.04.11	37.85	33.37	29.73	2.71	37.85	33.37	29.73	2.71	37.85	33.37	29.73	2.71
17.04.11	38.32	33.69	29.91	2.79	38.32	33.69	29.91	2.79	38.32	33.69	29.91	2.79

Date	Ambient Temperature				Internal Air Temperature				Temperature at Evaporation Surface			
	T_{Max}	T_{Avg}	T_{Mim}	Std Div.	T_{Max}	T_{Avg}	T_{Mim}	Std. Div.	T_{Max}	T_{Avg}	T_{Min}	Std. Div.
18.04.11	37.03	33.84	30.54	2.20	37.03	33.84	30.54	2.20	37.03	33.84	30.54	2.20
19.04.11	36.57	31.83	27.14	3.17	36.57	31.83	27.14	3.17	36.57	31.83	27.14	3.17
20.04.11	34.04	31.46	28.48	1.48	34.04	31.46	28.48	1.48	34.04	31.46	28.48	1.48
21.04.11	36.02	30.71	26.69	3.18	36.02	30.71	26.69	3.18	36.02	30.71	26.69	3.18
22.04.11	33.65	30.13	26.74	2.46	33.65	30.13	26.74	2.46	33.65	30.13	26.74	2.46
23.04.11	36.07	31.58	28.37	2.56	36.07	31.58	28.37	2.56	36.07	31.58	28.37	2.56
24.04.11	34.70	31.34	28.26	2.20	34.70	31.34	28.26	2.20	34.70	31.34	28.26	2.20
25.04.11	33.19	28.95	24.88	2.24	33.19	28.95	24.88	2.24	33.19	28.95	24.88	2.24
26.04.11	33.53	27.96	23.17	3.91	33.53	27.96	23.17	3.91	33.53	27.96	23.17	3.91
27.04.11	34.43	30.22	25.66	2.67	34.43	30.22	25.66	2.67	34.43	30.22	25.66	2.67
28.04.11	33.53	30.29	27.60	1.53	33.53	30.29	27.60	1.53	33.53	30.29	27.60	1.53
29.04.11	35.05	29.57	25.06	3.61	35.05	29.57	25.06	3.61	35.05	29.57	25.06	3.61
30.04.11	34.73	31.66	28.51	2.12	34.73	31.66	28.51	2.12	34.73	31.66	28.51	2.12
01.05.11	36.20	32.03	28.55	2.58	36.20	32.03	28.55	2.58	36.20	32.03	28.55	2.58
02.05.11	35.82	32.46	29.26	2.07	35.82	32.46	29.26	2.07	35.82	32.46	29.26	2.07
03.05.11	35.62	31.63	27.71	2.72	35.62	31.63	27.71	2.72	35.62	31.63	27.71	2.72
04.05.11	30.45	29.04	27.66	0.78	30.45	29.04	27.66	0.78	30.45	29.04	27.66	0.78
05.05.11	35.37	29.91	25.88	3.24	35.37	29.91	25.88	3.24	35.37	29.91	25.88	3.24
06.05.11	39.11	30.82	25.62	4.31	45.50	29.40	19.70	9.21	44.65	29.87	21.47	7.96
07.05.11	42.12	31.18	25.28	4.83	46.91	28.78	19.97	8.16	44.87	29.62	21.37	7.44
08.05.11	42.43	32.26	24.77	5.48	48.03	30.42	19.18	9.86	46.74	31.56	20.58	9.19
09.05.11	40.33	32.35	25.59	4.93	46.91	30.71	20.03	9.42	44.58	31.40	21.60	8.38
10.05.11	40.23	32.21	26.06	4.46	45.90	30.01	20.02	8.42	43.74	30.77	21.80	7.39

Date	Ambient Temperature				Internal Air Temperature				Temperature at Evaporation Surface			
	T_{Max}	T_{Avg}	T_{Mim}	Std Div.	T_{Max}	T_{Avg}	T_{Mim}	Std. Div.	T_{Max}	T_{Avg}	T_{Min}	Std. Div.
11.05.11	36.47	28.36	23.47	3.34	38.01	24.84	18.72	5.77	38.29	25.92	19.75	5.41
12.05.11	40.09	31.15	24.13	5.07	46.07	29.21	18.60	9.10	43.67	29.68	20.04	7.91
13.05.11	40.83	32.85	25.13	4.42	51.71	32.61	20.22	10.23	45.93	32.32	21.62	8.18
14.05.11	40.16	31.53	24.15	5.02	52.61	31.42	18.78	11.06	46.74	31.07	19.95	8.98
15.05.11	40.91	33.05	27.63	4.16	45.32	31.01	22.32	7.96	45.18	32.31	23.65	7.53
16.05.11	40.09	33.38	27.96	4.16	45.43	31.27	22.18	8.08	45.14	32.81	23.95	7.47
17.05.11	40.45	32.88	27.06	4.00	45.79	31.21	21.30	8.42	45.65	32.73	23.15	7.73
18.05.11	38.53	31.44	27.19	3.65	42.43	29.20	21.49	7.34	42.68	30.72	23.20	6.87
19.05.11	29.86	25.82	21.07	2.58	34.03	22.86	15.93	5.03	34.27	24.28	17.71	4.72
20.05.11	33.25	28.89	24.44	2.91	39.52	27.28	18.50	7.26	39.38	28.56	20.19	6.71
21.05.11	34.73	29.16	22.73	3.94	40.79	27.27	17.56	8.25	40.66	28.57	19.34	7.73
22.05.11	34.86	29.61	23.50	3.49	39.30	27.31	17.72	6.80	39.54	28.69	19.39	6.43
23.05.11	37.86	30.87	27.25	3.08	45.08	28.67	21.96	7.65	45.32	30.02	23.74	7.08
24.05.11	34.61	29.76	25.90	2.38	39.55	27.26	20.08	6.00	40.17	28.74	21.85	5.62
25.05.11	37.29	29.75	25.20	4.51	44.53	28.38	19.31	9.62	44.11	29.64	21.09	8.96
26.05.11	36.65	29.72	24.91	3.56	42.72	27.59	19.02	7.55	42.97	29.02	20.62	7.14
27.05.11	35.98	30.05	25.98	2.86	42.05	28.20	19.98	7.15	42.17	29.74	21.76	6.72
28.05.11	37.04	29.44	26.43	2.85	45.02	27.04	20.65	6.78	44.50	28.62	22.43	6.41
29.05.11	36.02	30.52	25.94	3.32	43.20	29.07	20.11	7.90	43.06	30.56	21.85	7.41
30.05.11	37.41	30.86	26.13	3.17	44.51	29.26	20.44	7.69	44.37	30.75	22.22	7.15
31.05.11	37.92	30.47	25.19	3.99	45.15	29.19	20.27	9.07	45.01	30.51	22.05	8.48
01.06.11	37.46	30.88	25.42	3.72	46.20	29.45	19.63	8.35	45.68	30.82	21.13	7.84
02.06.11	36.61	30.34	26.87	2.63	44.46	28.36	21.19	6.91	44.32	29.73	22.96	6.43

Date	Ambient Temperature				Internal Air Temperature				Temperature at Evaporation Surface			
	T_{Max}	T_{Avg}	T_{Mim}	Std Div.	T_{Max}	T_{Avg}	T_{Mim}	Std. Div.	T_{Max}	T_{Avg}	T_{Min}	Std. Div.
03.06.11	37.36	30.02	26.70	3.04	46.11	28.00	20.97	7.76	46.35	29.34	22.56	7.30
04.06.11	37.87	31.71	27.32	3.20	45.48	30.42	21.25	8.13	45.72	31.89	22.98	7.60
05.06.11	38.48	32.36	28.15	3.06	45.33	31.09	22.08	7.77	45.19	32.62	23.86	7.25
06.06.11	39.07	32.90	27.77	3.55	46.68	31.72	21.80	8.46	46.92	33.38	23.58	8.06
07.06.11	36.76	31.66	27.39	2.81	44.11	30.54	21.70	7.67	43.36	32.00	23.48	7.17
08.06.11	38.23	31.22	27.46	3.06	44.37	29.53	21.77	7.36	44.55	30.89	23.43	6.85
09.06.11	39.16	31.74	26.68	3.59	47.69	30.91	20.99	8.79	47.55	32.24	22.77	8.20
10.06.11	39.20	33.04	29.05	3.18	47.57	32.15	23.11	8.15	47.43	33.57	24.89	7.60
11.06.11	35.86	28.57	24.42	2.85	42.11	24.90	20.26	5.66	42.73	26.37	21.92	5.53
12.06.11	34.75	29.34	25.69	2.43	40.44	26.46	19.95	5.49	41.44	27.99	21.44	5.35
13.06.11	37.16	31.52	26.47	3.46	48.25	31.30	20.51	9.49	47.34	32.50	22.22	8.66
14.06.11	35.90	28.78	26.80	2.28	40.88	25.24	21.20	5.20	41.88	26.74	22.98	4.98
15.06.11	34.16	28.83	26.18	2.25	39.47	25.98	20.78	5.41	39.72	27.32	22.51	5.00
16.06.11	31.53	27.83	26.18	1.38	32.27	24.02	20.98	3.08	33.28	25.51	22.44	3.07
17.06.11	29.58	27.08	26.03	0.76	28.81	22.36	20.67	1.88	30.20	23.96	22.11	1.85
18.06.11	29.97	27.65	25.74	1.20	28.82	22.90	20.28	2.36	29.83	24.52	21.82	2.17
19.06.11	31.44	28.45	26.01	1.09	34.63	24.36	21.08	3.25	35.26	25.95	22.47	2.99
20.06.11	33.12	28.15	25.22	2.23	35.77	24.34	19.59	4.57	36.39	25.70	21.05	4.32
21.06.11	32.92	28.35	25.66	1.75	37.84	25.31	20.78	4.82	38.46	26.71	22.22	4.50
22.06.11	33.98	29.08	26.25	2.23	38.53	26.49	20.55	5.86	38.74	27.71	21.95	5.41
23.06.11	35.98	30.43	27.60	2.31	44.34	28.73	21.90	7.01	44.58	30.00	23.30	6.56
24.06.11	69.20	28.60	25.80	2.43	40.12	25.16	20.58	5.76	40.36	26.63	22.20	5.55
25.06.11	32.77	28.13	26.19	1.93	39.22	24.92	20.59	5.22	39.85	26.27	22.20	4.91

Date	Ambient Temperature				Internal Air Temperature				Temperature at Evaporation Surface			
	T_{Max}	T_{Avg}	T_{Mim}	Std Div.	T_{Max}	T_{Avg}	T_{Mim}	Std. Div.	T_{Max}	T_{Avg}	T_{Min}	Std. Div.
26.06.11	28.40	26.82	25.56	0.78	26.17	22.02	20.25	1.53	27.94	23.62	21.89	1.51
27.06.11	31.34	27.85	26.84	1.20	33.98	23.05	20.76	3.50	34.99	24.75	22.52	3.25