HARVESTING CONDENSED WATER IN DRY AREAS

Ranim Kaja

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TAMPEREEN AMMATTIKORKEAKOULU
Tampere University of Applied Sciences

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Environmental Engineering

RANIM KAJA:
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ABSTRACT

Water issues have become a disturbing worldwide problem in the current era, but it is more complicated in the arid areas, where it rains rarely and there is hardly any fresh water source at all. Hence, there is a serious need to find new, sustainable, alternative ways to get drinking water.

One of the most interesting methods to get clean water is harvesting humidity from thin air. Many new initiatives have been taken to develop this old way of getting water, and in so many ways it has potential to solve the challenge of getting a new, sustainable and renewable source of fresh water in desert areas.

However, the theme in this thesis will focus on many different ideas and inventions for harvesting humidity. Some of these ideas are very old and very basic, whereas others are more developed and advanced, but all of them are based on the same principle: extracting the humidity particle by making the humid air reaches its dew point. The difference between the different methods is in the way of attracting humidity directly from thin air before the distillation stage. Some of those methods use very simple and cheap ways to hunt humidity from air, which make them the most preferred methods especially in the poorest areas. On the other hand, other methods use very expensive devices; this makes these methods more applicable as investments than as ways of assisting people in arid areas to get water to drink.

Nevertheless, these ideas, devices, and prototypes still need lots of development before we can say that the water problem is on its way to being solved, but at least, the existence of this main principle for extracting water from air means that we are on the right path towards solving this serious problem.

Key words:
Water, humidity, harvesting, air, energy, arid, dry areas, collecting, thin air, fog, sustainable, renewable, Air conditioning, water device.

FOREWORD

In this few lines I write here, I really want to thank my teacher and supervisor Eeva-Liisa Viskari for helping and supporting me to do this thesis. She was patient with me through the rough time I was experiencing while writing this thesis, and I highly appreciate that of her.

I also want to thank my loving parents and brother who were on my side in my moments of weakness. They supported me and helped me when needed to finalize this work in the best possible way, where distance did not prevent them from full filling the love of family I needed.

Finally, I would like to express my deep thanks to Finland, and Tampere University of Applied Sciences who gave me the honor of studying here, and gave me the chance to have a better future.

Tampere, May 2012

Ranim Kaja

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ABBREVIATIONS AND TERMS

A	Ampere
AC	Air Conditioning
BTU	British Thermal Units
C	Cool
COP	Coefficient of Performance
g	Gram
h	Hour
H	Heat
Hz	Hertz
IGB	Fraunhofer Institute for Interfacial Engineering and Biotechnology
Kg	Kilo gram
Kj	Kilojoules
KW	Kilowatt
L	Litre
M	Meter
ml	Milliliter
Oz	Ozone
PhD	philosophiae doctor (Doctor of Philosophy)
RH	Relative Humidity
s	Second
UN	United Nations
USA	United States of America
V	Volt
W	Watt

1 INTRODUCTION

The water issue is a very controversial topic in our century, and several countries in the world are trying to get the highest possible amount of water, where in some cases it caused some political conflicts with the neighboring countries about the fresh water source that they might share. All of that is happening because of the fresh water scarcity in the world, in spite of the fact that more than 70% of our planet is covered with water, but only less than 1% of this water is drinkable. Based on that, we need to find new ways of purifying water to make it drinkable, and find new sources of fresh water to cover up the incredibly increasing number people around the world. Although many countries in the world suffer from the fresh water scarcity, but some of them actually face worse situations in that aspect, such as the desert in Namibia that receives less than 20 mm of rainfall per year to be of the driest areas in the world (HEINE, 2005).

Fresh water used to be considered inexhaustible, and that is why people drained it badly. The incredibly increasing number of people around the world is demanding more sources of fresh water, while factories, sewages, and other polluting sources are damaging lakes and rivers by dumping their wastes in them. All these reasons and more, started to push the humanity for reconsidering their behavior, and looking for new sources of water, find new ways of purifying water, and even making conflicts with the neighbor countries like the case of the Nile basin countries when the upstream countries decided to have a bigger share of the Nile water (BBC, 2010).

Nevertheless, and even with the count of 1 billion people who do not have an access to clean water (Varis, 2008), and the UN estimation that is expecting 66 percent of the people in the world to suffer from water shortage by the year 2025 (Jolly, 2010), the United Nation still does not want to mention water as a human right in a direct way, but instead, they mention it in an indirect way in the Article 25: “Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical car and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control” (Varis, 2008).

Despite that, in November 2002, the UN Committee on Economic Social and Cultural Rights used the term “the right to water” for the first time in a clear way, and defined this term to be “the right of everyone to have at his or her disposal sufficient clean, acceptable, accessible and obtainable water for personal and domestic uses” (Irujo, 2008).

However, though the future seems to suffer from water shortage, but the humanity will not give up and wait for that to happen. This thesis concentrates on new ways of getting water which can be considered as a new source of drinkable water, which is sustainable and renewable.

These ideas are mainly using the same principle; they are standing on the fact that it is possible to harvest humidity from thin air under certain conditions of temperature and humidity by condensing it to be in water form. The amount of water can be harvested from the humidity in thin air is reliable in most of the conditions even if it depends on the temperature and humidity at the place. Although the relative humidity in a certain place might be relatively low, it is still possible to get some fresh water out of it by using the right humidity harvesting method. The method of harvesting humidity can cover people basic needs from clean water in the dry areas, and especially is the coastal areas where there is a high humidity, but no source of fresh water. This way can support the traditional fresh water sources in the targeted areas, and in the future it might even be able to replace certain methods of getting fresh water such as desalination of seawater if it was well developed.

1.1 Objective of Study

The target of this work is to provide clean and renewable source of fresh water for people in dry areas, with consideration to the cost of this water and the sustainability of the method used to get it. Hence, it will be an easy and cheap way for people in areas with low income. Using harvesting humidity method can support or replace some traditional ways of getting fresh water in the arid areas where there is a relatively high humidity and temperature, and low rainfall rate.

1.2 Scope

Several ways of harvesting humidity from thin air could provide a solution for the most arid areas in the world. Each way is suitable for certain conditions which gives the chance of every area in the world to pick the best option for it.

1.3 Outlines

In this thesis work, chapter 2 talks about the theory of harvesting humidity from thin air and provide examples methods of collecting the water. Chapter 3 talks about the simplest way of harvesting humidity which is harvesting fog. Chapter 4 talks about the modern humidity harvesting methods. Chapter 5 talks about AC water. Finally Chapter 6 is the conclusion.

2 THEORY

The idea of collecting humidity from thin air is actually not new; there are several tries which were done in order to get the water from the air humidity.

They key principle of extracting humidity from air is based on the dew point phenomenon which is the temperature where the air humidity will condense forming water (Gertz, Emily & Di Justo, Patrick, 2012). This principle is used in the water collecting inventions where a cold surface is used to make the warmer humid air reaches the dew point and forms water drops on it in order to collect this water to be used for drinking purposes.

In the past twenty years, lots of different ideas came up about how to get water from thin air. One simple idea was published in the year 1993 as a PhD thesis for D. Ahmad Mohammad Hamed in Russia. In his idea, he used the solar power to provide the energy needed for extracting humidity from thin air. The idea was based on the use of a cooling unite that works with the solar power placed inside a pipe where the surrounding air can move inside it from the top part of it, and the cold air will go outside it from the bottom. The cooling unit works when the sun comes to the solar panel, and it will cool down the air inside the pipe, which will make the cold air move downward to the other side of the pipe, and the humidity will start to condense on the pipe sides. Finally, the water condensed on the pipe inner side will leak in to a collector that will lead it into a tank (Al-Jazirah, 2002).

In Egypt 2000, Al-Mansoura city, the previous idea was developed by Dr. Hamed's student Ebrahim Al-Sharqawi. At this stage, he used the salt as a humidity absorber. He used a box of glass, and inside it he put a tortuous fabric saturated with a salt solution. At night time, the lid will be left open so the humidity can be absorbed by the salt from the air, and at the day time the lid will be closed. When the sun shines in the morning and the temperature increases the glass box will start heating up, and that will make the water evaporate from the fabric and move to the sides of the glass box and condense on it forming water drops, then these drops will leak to a collector that will take it to a tank (Al-Jazirah, 2002).

The amount of water gotten in these ways was relatively sufficient, but despite this, the ideas were not put into use. In my opinion, the reason might be not having enough advertising for the ideas, and maybe the glass box invention was not implemented because of the relatively big space needed for it and the fact that it needs to be placed outdoor which is not always possible.

However, the attempts to get water from thin air in the most arid areas in the world did not stop. More ideas are coming up every day for sustainable, clean, cheap, and renewable fresh water solutions, providing people of the poor arid areas with reliable fresh water sources. One of them is the idea of harvesting humidity from thin air that is able in the to provide drinking water in the future so women and children will not need to walk for several kilometers to get couple of liters of water. In this thesis, different ways about harvesting humidity from air will be discussed.

3 HARVESTING FOG

PICTURE 1. Fog harvesting meshes in a dry area (Lummerich, 2010).

Harvesting fog is an old and most popular way of extracting water from thin air. It has been used in Chile for almost 30 years, where local people used to use their nets to “hunt” fog in some areas where there is a heavy fog. This way provided locals with a reliable source of pure water and saved them from walking several kilometers to get fresh water. (Al-Khatib, 2010; Theobald, Nierenberg, Styslinger, Kane, & Massey, 2011).

Today, the funny expression of “hunting fog” became one of the projects that the UN is trying to apply to every dry area that has fog and now drinking water sources in South America, Africa, and Asia.

The principle of this idea stand on the fact that when the wind blows the fog passes through a mesh with approximate percentage of shading 70% to 80% placed in a way that faces the wind, then water particles in the fog will leak on the mesh plastic threads forming bigger drops, and they will leak to a collector in the bottom of the mesh that will lead the water to a tank (Ashqar, 2010).

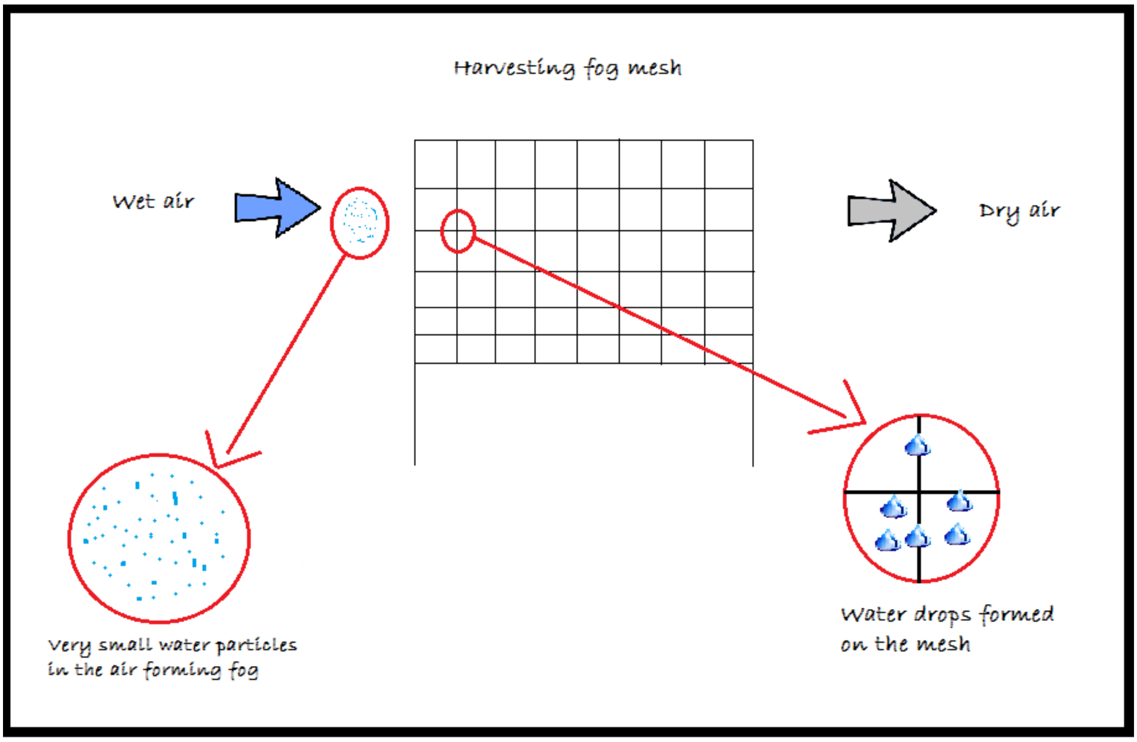


FIGURE 1. The principle of harvesting fog.

In fact, the fog particles in this case are not going to be condensed on the mesh surface, but the water will simply leak on it because it is already in a liquid form and not in a gaseous form, but it is just in the form of very small drops (Fields, 2009).

In Eretria, in the towns of Seidici, Arborobu, Nefasit and Embatkala, German scientists from Munich Re Foundation started a pilot project in 2005 to find out the amount of water they can get by harvesting fog in one village over there. The first nets installed over there were in the size of 1m^2 per each, and the single net was able to provide about 29L of fresh water every day. Later, they installed nets with the size of 40 m^2, and they found that one net was able to harvest between 170 and 200 liters of pure water every day, and with this amount of water it is possible to cover the drinking water need for all the people in the village (Al-Khatib, 2010; Munich Re Foundation).

The amount of water that can be gotten from harvesting fog varies from area to another, and from country to another; for example, the average amount of water collected in the fog season in Chile was 3.0 l/m^2/day, where in Peru it was 9.0 l/m^2/day (UNEP, 1997)

In Zafar city, Sultanate of Oman, the Ministry of Environment and Climate Affairs worked on fighting against desertification in the city by using the method of harvesting fog. They established three harvesting stations on the mountains chain of Zafa, focusing on the period between Jun and September where it is the best season of fog. They collected the water in the summer time, and then used it in the fall to plant about 250 trees (Ashqar, 2010).

Amazingly, using the fog harvested water to plant arid areas showed a great effect on those areas.

PICTURE 2. A tree watered with the fog water in Zafar, and the green grass started to grow under it (Ashqar, 2010).

Starting with the planted trees, they began to work as fog harvesters their selves! The humidity started to be condensed on the trees leaves, and water drops fall down on the ground, which allowed the grass to grow underneath of them, and as a result, there was a green circle under each tree in that area. Also, harvesting fog helped protecting the groundwater, either by supplying it when watering the trees, or by stopping draining it (Ashqar, 2010). In the other hand, the mesh can be used for providing shade for crops where it is needed, and by knowing that the cost of installing one mesh is approximately 10€, it looks like a perfect solution for water in the poor dry areas (Al-Khatib, 2010).

Nevertheless, because of different reasons, it is not always possible to harvest the fog, in some areas there are many obstacles that prevent starting this project. For example, it might be not possible to start a fog harvesting project in the areas where fog is very low, because makes it will be in contact with the ground that is polluted with fertilizers. In this case, the tiny fog particles might hold this pollutant with it, which will make the water harvested from this fog not drinkable and even toxic (Al-Khatib, 2010). However, I could not find any project or studies about harvesting fog in regions with contaminated soil to confirm this issue.

PICTURE 3. Fog harvesting mesh, and the water is collected by pipes (Jolly, 2010).

However, this method can be used for small villages and communities where there is enough space for the nets, and the good air and fog quality usually, but it is not applicable for big cities, as it will need a massive number of nets to provide the amount of water needed in big cities (Fields, 2009).

The method of collecting drinking water by harvesting fog is maybe one of the best solutions for arid areas where people cannot afford expensive water devices. This low technology can provide clean water with reasonable price, and the simplicity of its principle makes it possible for local people to make the meshes their selves, and take care of its maintenance when needed, and all what is needed to be provided to those people in this case is the idea, and the knowledge of how to do it.

In 1997 – 1998 there was a harvesting fog project in the west coast of South Africa, and the harvested water was analyzed to find whether it was drinkable or not. The quality of water harvested from fog was generally good. It was found that the water was free from all kinds of disease causers like (E.Coli). The heterotrophic organisms were present in big number, but it was not important since it is possible to remove it with sand filter, also there are no caveats about the amount of heterotrophic organisms that can be harmful (Olivier, 2002). The following table was taken from the results found on 1998, as the possible mistakes happened in the first analyze of 1997 were avoided in the next year:

TABLE 1. The chemical analysis of Cape Columbine fog water in 1998 (Olivier, 2002).

Chemical analysis	**Results in 1998**
Potassium, K (mg/l)	1,9
Sodium, Na (mg/l)	44
Calcium, Ca (mg/l)	33
Magnesium, Mg (mg/l)	5,7
Ammonia, N (mg/l)	0,3
Sulphate, SO_4 (mg/l)	17
Chloride, Cl (mg/l)	77
Alkalinity, $CaCO_3$ (mg/l)	177
Nitrate, N (mg/l)	0,4
Conductivity (mS/m)	45
pH	7,3
Saturation pH (pHs 200C)	8
Total dissolved solids (calc) mg/l	288
Total hardness, $CaCO_3$ (mg/l)	106
% difference	1,86
Cations (meq/l)	4,81

Anions (meq/l)	4,89

There was no data for the microbial analysis in 1998, hence, the 1997 analysis are:

TABLE 2. The microbial analysis of Cape Columbine fog water in 1997 (Olivier, 2002).

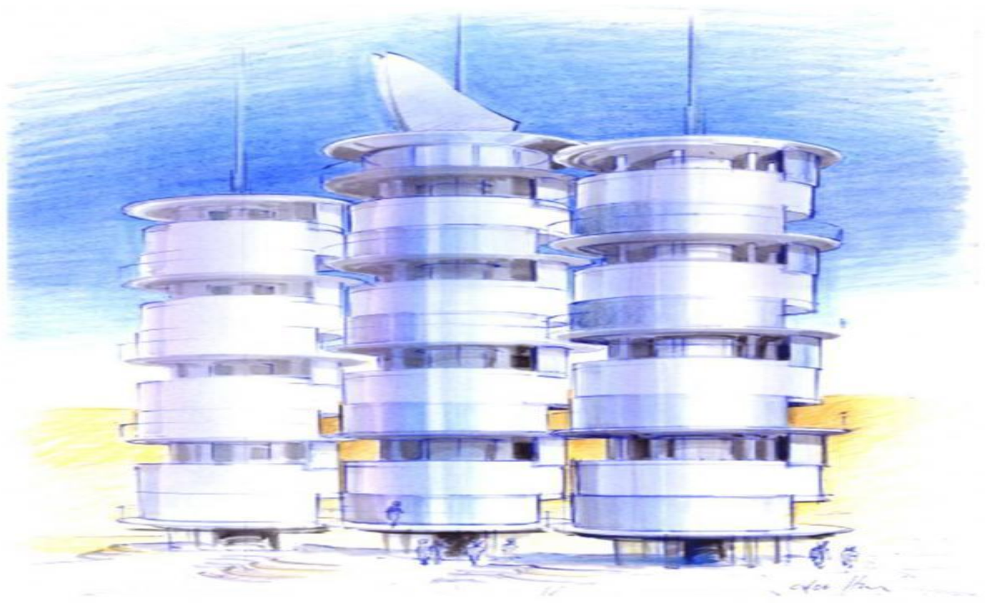
The microbial analysis	Result
Heterotrophic P/C po 1 m_ at 35°C	± 450 000
Total coliforms per 100 ml	0
Faecal coliforms per 100 ml	0

4 MODERN HUMIDITY HARVESTING METHODS

There are several inventions which are for extracting water from air, some of them were put into practice already, and others still prototypes, or maybe just an idea on paper. In this work, some of those inventions will be explained in a way that gives a clear idea about the working process for each one of them.

Almost all of the new invented devices work on the same key principle. This principle stands on the fact that depending on the temperature of an area and the humidity percentage, it is possible to condense the water vapor particles from the thin air and collect it in tanks to make it accessible for drinking purposes. The main point of it stands on the fact that when a hot humid air face a condition where its temperature drops to the dew point or below it, the water humidity will be condensed on the cold surface, and then it will be transformed to the liquid form, hence, all what is need to be done is to find the best, and the most efficient sustainable way to do that.

4.1 Tower shaped collectors



PICTURE 4. Tower shaped collector uses renewable energy (ScienceDaily, 2009).

This innovation uses the renewable energy only (ScienceDaily, 2009), which makes it eligible to be used in the desert areas or far away rural areas where there is no access to public electricity. The main principle of this idea is more like a development of Ebrahim Al-Sharqawi master thesis of the glass box and the tortuous fabric saturated with a salt solution. It uses brine strings with a great interface with the surrounding air and the longest time possible to insure that the brine was able to absorb the maximum amount of humidity. After that, the brine will flow slowly downward with the power of gravity and pass in multiple-stage vacuum evaporation (Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB), 2012).

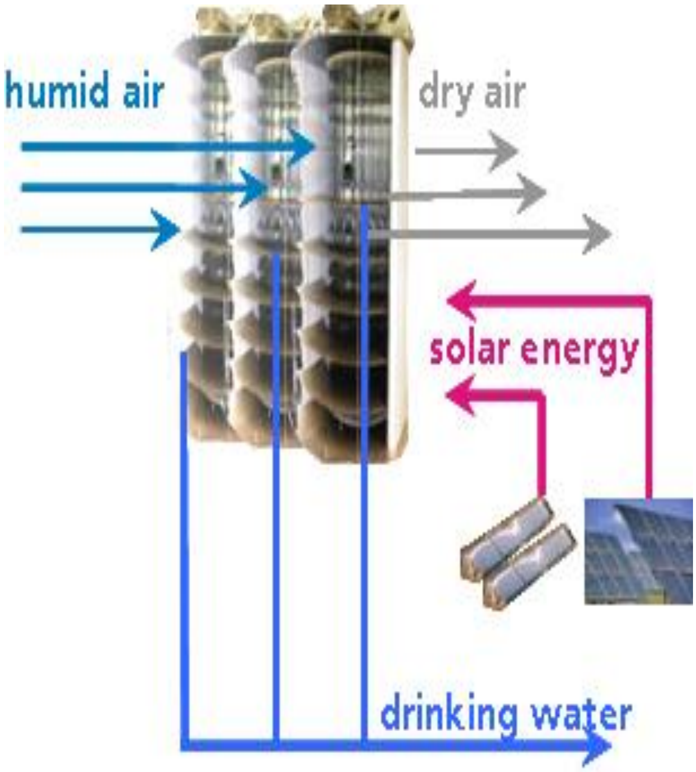


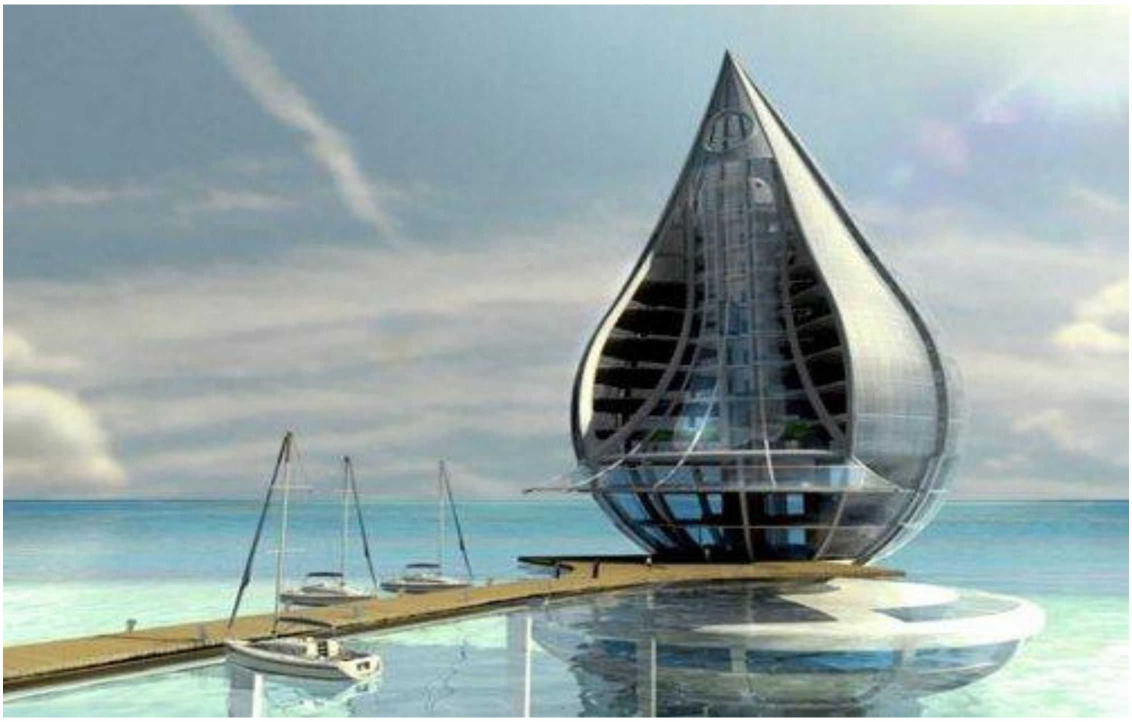
FIGURE 2. The working process of the tower shaped water collector (Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB), 2012).

When the brine strings pass in vacuumed areas, the boiling temperature of water will drop down because of the low pressure, and that will help to minimize the needed energy to heat the brine up, so the solar energy can provide enough energy to heat the water up to evaporation point. Also, it is possible to use the same energy to heat up different stages with different levels of pressure.

In the other hand, it will be possible to use the gravity with the brine flow to provide the needed vacuum, which will save the energy needed to provide it (Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB), 2012). Finally, when the diluted brine is heated up, the water will evaporate leaving the brine, and then it will condense making a highly pure drinking water (Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB), 2012).

This method of collecting water is totally environmentally friendly and sustainable. There is zero emissions resulted from this process, beside that there is absolutely no waste coming out at the end of the process. The process is also self-dependent, so no need for regular maintenance, or checking out, which makes it perfect for the arid areas (Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB), 2012). However, the idea was not implemented yet.

4.2 Water building resort



PICTURE 5. A virtual picture of the Water Building Resort design (Jolly, 2009).

An architecturally amazing building, which is designed by architect Orlando de Urrutia in a shape of water drop, and it is supposed to be able to provide a drinking water from the air by using solar energy when it is put into use (Schwartz, 2010).

In De Urrutia design, the southern side of the building will consist of massive number of photovoltaic glass that will cover the building totally from that side in order to gain the maximum benefit from the sun rays to produce solar power (Schwartz, 2010), and at the same time it will also allow the sunlight to inter the building from that side (Garvey, 2009). The northern side will have lattices in order to provide good aeration for the building, and also the needed air for producing water (Garvey, 2009). The air coming from the northern side will be handled by Teex Micron Atmospheric Water Generators, which will work on transferring the humidity in air into pure water for drinking, and those generators can produce from 35,000 to 109,000 gallons of water every day at their maximum (Schwartz, 2010). At the bottom of the building, there will be a water thermal faculty where sea and rain water will be purified; also there will be a control center to insure the water quality (Kain, 2011).

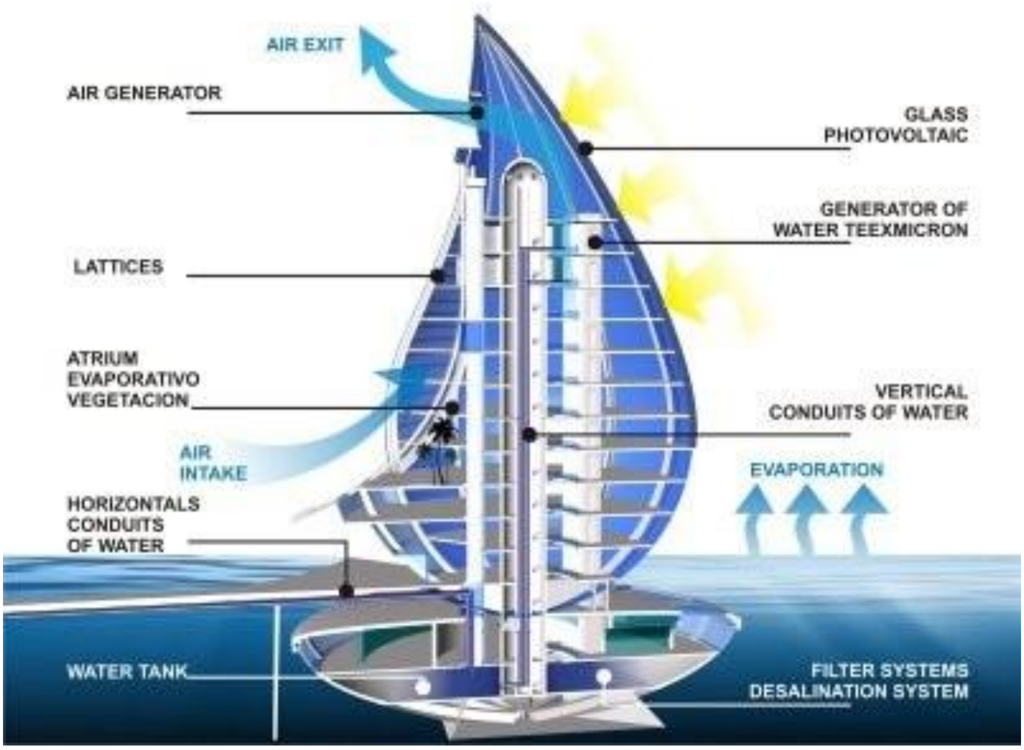


FIGURE 3. Working system of the Water Building Resort design (Garvey, 2009).

This building is actually designed for both scientific purposes, entertainment, and touristic purposes (Schwartz, 2010), and that makes it a great opportunity for a good business with an environmentally friendly reputation, which will make people more interested in visiting it and spend some money as it will be the first building in the world the uses an environmentally friendly source of water (Garvey, 2009).

4.3 Airdrop Design

Edward Linacre, the winner of James Dyson grand prize for the year 2011 invented a device that can provide water for farms by mimicking the Namib beetle which lives in the most arid area in the planet, and provides itself with fresh water by condensing humidity from the air on its hydrophilic back skinned and absorbing it in early mornings (Dillow, 2011).

FIGURE 4. Working system of the Airdrop design (Dolasia, 2001).

The main principle of Linacre invention is very simple. He actually used the fact that the arid areas have a hot temperature, where the underground soil is actually cooler. Hence, he made a pumping device that pushes the surrounding air with humidity under the ground to pass through pipes network where the humidity will start condensing on the internal walls of pipes, then, the water drops will leak from the pipes directly to the roots of plants in that field (Dillow, 2011).

Based on Linacre's calculations, the device should be able to provide approximately 11.5 ml of water for every one cubic meter of are (Dillow, 2011).

This invention is indeed one of the most useful devices mimicking the nature (Heimbuch, 2011)[15], and that is because it provides a simple way to overcome the difficult nature in the desert. Also, it is possible to use an environmentally friendly source of energy to harvest the humidity (Heimbuch, 2011), and in deed, the solar energy would be the best for that.

4.4 Wind turbine

PICTURE 6. Wind turbineWM1000 which can harvest humidity from air (Macguire, 2012).

One of the newest humidity harvesting inventions, and the producing company of these wind turbines WM1000 "Eole" is supposed to start selling them sometime in this year 2012 as they just started working on advertising for the product (Macguire, 2012).

In this method of harvesting humidity, the company adjusted the normal wind power turbine in order to be capable of collecting water from thin air (Macguire, 2012). With 24 meter high turbine, it was possible to collect about 62 liters in an hour in the desert near Abu-Dhabi in UAE, but depending on the relative humidity, the temperature, and the speed of wind, it can produce water up to 1000 liters every day which is enough to cover the drinking water need for a small community of 2000 to 3000 people (Macguire, 2012).

At the moment, it is possible to use those turbines to provide drinking water for small communities and remote communities, where in the future, it might be possible to develop those devices to provide drinking water for bigger communities (Macguire, 2012).

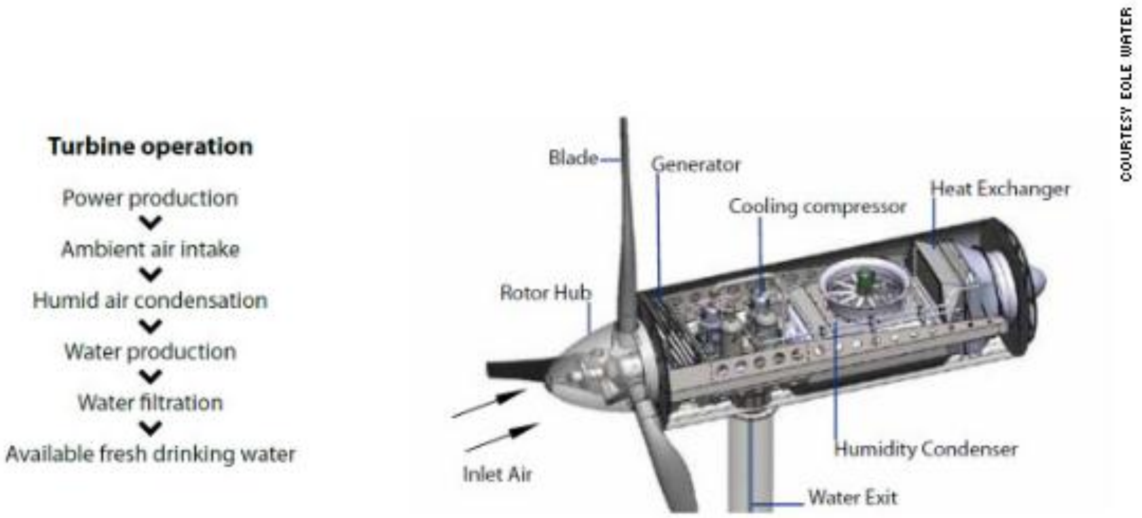


FIGURE 5. The inside machinery of the wind turbine WM1000 (Macguire, 2012).

The working process of this device start when the air gets inside the turbine through the nose (air blower), then it moves to the cooling compressor where the humidity will be separated from the thin air and condensed to make a pure water. The collected water then will be transferred via stain-less steel pipes to a filter placed in the base of the turbine, and finally, the water will be ready for use (Macguire, 2012).

This method of harvesting humidity from thin air is sustainable, and the energy needed to produce the water is actually generated by the same turbine, so there is no energy cost when using this method, and the only cost needed after putting it into use is the cost of maintenance. Nevertheless, the cost of these turbines is not cheap, and especially for the areas that need that source of fresh water, they are most probably unable to afford it (Macguire, 2012). The price of one unite of the water turbines is between €500,000 and €600,000, and that makes it for the “rich” countries, but even in Europe it would be not reasonable to pay all that amount of money for 1000 liters of clean water per day (Macguire, 2012). However, the company believes that the product development in the future can help to cut down the cost (Macguire, 2012).

4.5 Home water collecting devices

There are several devices for harvesting humidity that meant for home use, some of them make good amount of water where others are not reasonable to buy, also some of them are extremely expensive which makes them lose the point of having them. However, in this section, some of these devices will be mentioned.

4.5.1 WaterMill

This device can harvest up to 3.2 gallons of drinking water per day which can cover the fresh water needed for a medium family with a price of 11USA cents for 1 gallon. The device has a very good filtration system so it can be used inside or outside home, and it is very sustainable and environmentally friendly (Tomasulo, Lee, 2008).

PICTURE 7. WaterMill, a home device that can harvest about 3.2 gallons of water per day (Tomasulo, Lee, 2008).

4.5.2 KONIA WATER

In this device, the water generator is separated from the purifier and they can be sold separately. The water generators can make from 30L – 74L per day depending on the device, where the purifiers can make from 4,5L – 8L of cold water, and 1,3L – 5L of hot water depending on the purifier you chose (KONIA WATER, 2009).

The purifiers of KONIA uses a very strong filtration system, the water generated from the air goes through sediment filtration, pre-carbon, ultra filter, post-carbon, and a pi filter (KONIA WATER).

PICTURE 8. KONIA water generators and purifiers (KONIA WATER, 2009).

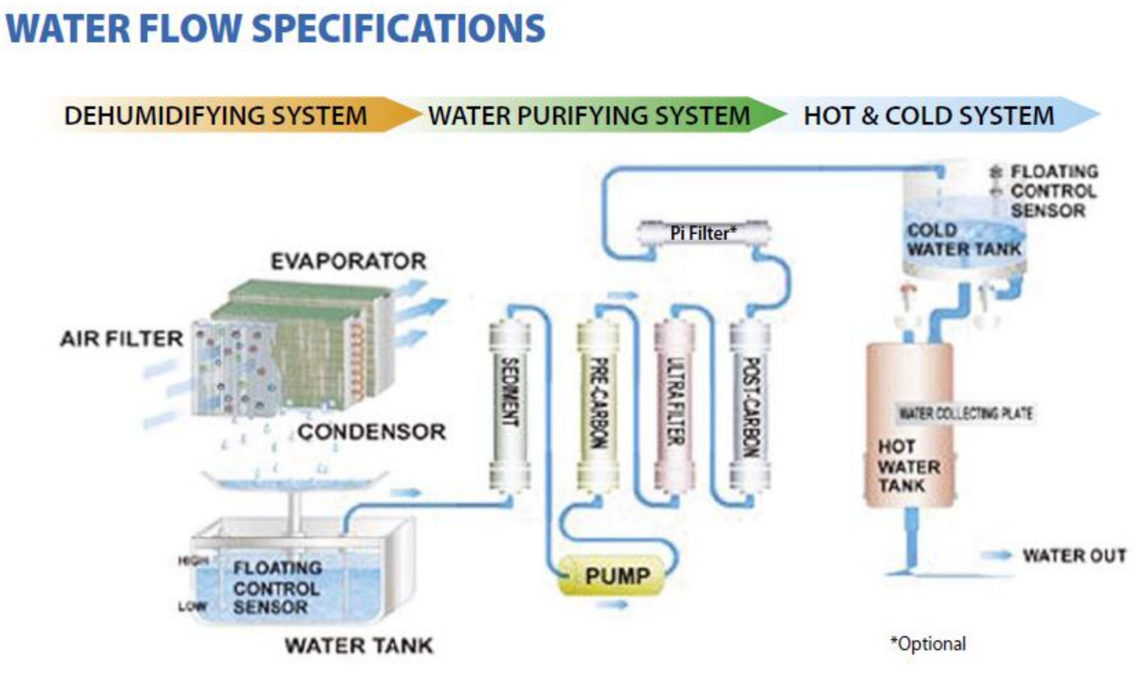


FIGURE 6. The working process of KONIA devices (KONIA WATER).

4.5.3 The WaterMicron

This company also produces also different types of devices that make water from thin air. The C-Series of this bran can make pure water from 250L – 5000L per day, but it can work only in the temperature between 15°C or 20°C to 38°C, and with RH between 40% and 95% (WaterMicron, 2012).

PICTURE 9. The WaterMicron water device. C-Series (WaterMicron, 2012).

Although the amount of water we can get with this device is big, but it needs electricity input power between 5Kw and 115Kw, and it weights from 320Kg to more than 4000Kg which means that it needs to be placed in a big place (WaterMicron, 2012).

However, there are many other devices that can be mentions, and all of them have the same principle. Unfortunately, there was no prices mentioned in the products official websites, but when checking the buying/selling websites there was some products for sale, and the prices ranged between 1000€ and 19000€.

5 WATER FROM AIR CONDITIONING

Air conditioning devices are also able to produce water with different amounts depending on the relative humidity and the temperature of the air. This water resulting from air conditioning process is usually considered to be unwanted, hence, users try to find ways to dispose this water, and finally the water ends in the sink.

Nevertheless, if users start to collect the water coming out from their ACs, they actually would be able to save a huge amount of water that they are paying for.

5.1 ACs WORKING PROCESS

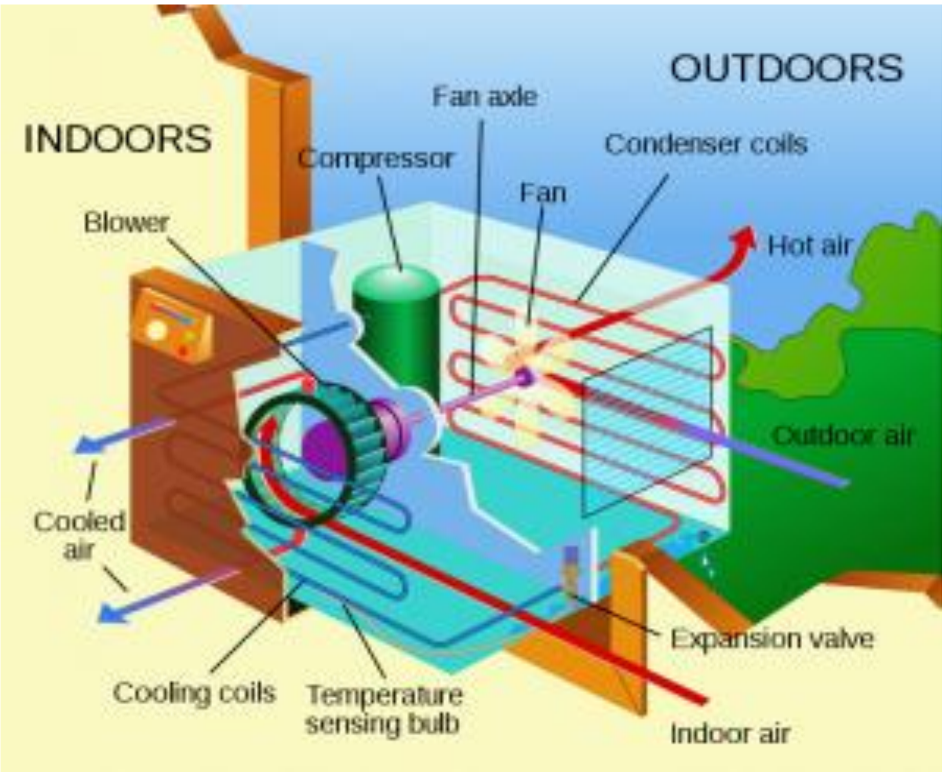


FIGURE 7. The Ac device process (HVAC Training 2008).

In the ACs devices, there is a cooling intermediate used inside the cooling pipes. One property of this intermediate is that when it is exposed to high pressure it heats up, and when applying low pressure on it, it cools down, so when it is used for cooling the room temperature, it moves from the compressor to the outside part of the device, then when the pressure becomes lower it moves to the inside part where the fan pushed the air through the cold pipes and then out the room. When the device is needed for heating the room temperature, the gas will move in the opposite direction (Kujjah, 2010).

The main principle of air conditioning process starts in the compressor where the cooling intermediate will be exposed to a very high pressure which will makes it in a gas form and will heat it up to be hotter than the surrounding environment which will make a heat exchange between the intermediate and the outdoor air while it passing in the pipes, so it will start to cool down. When the intermediate cools down it changes to be in the liquid form and it will move through an expansion valve where it will expand and the valve will control the amount of intermediate passing to the next stage, where at this point the intermediate will be could. In the next stage, the cold intermediate will pass through the evaporator that has the mission of transforming it from the liquid form to the gas form without changing its temperature. Finally, the intermediate will go back to the compressor again (Kujjah, 2010).

The water condensation happens always on the cold part of the pipes, and for that, it happens in the indoor part when the device is used for cooling the room and in the outdoor part when it is used for heating.

5.2 Collecting AC water

The amount of water that can be gotten from an Ac can be calculated by using Mollier curve. However, if we take the city of Aleppo, Syria as an example of a city in dry area, we will get the following results:

TABLE 3. The climate of Aleppo for temperature and relative humidity (Climate & Temperature).

Type	Value
The Warmest temperature in the year in August	37 °C
The lowest temperature in the year in January	2°C
Average year temperature	17.4 °C
The lowest relative humidity in the year in August	39%
The highest relative humidity in the year in January	79%
The average relative humidity in the year	55.7%

Another way to explain the weather of Aleppo is in this figure:

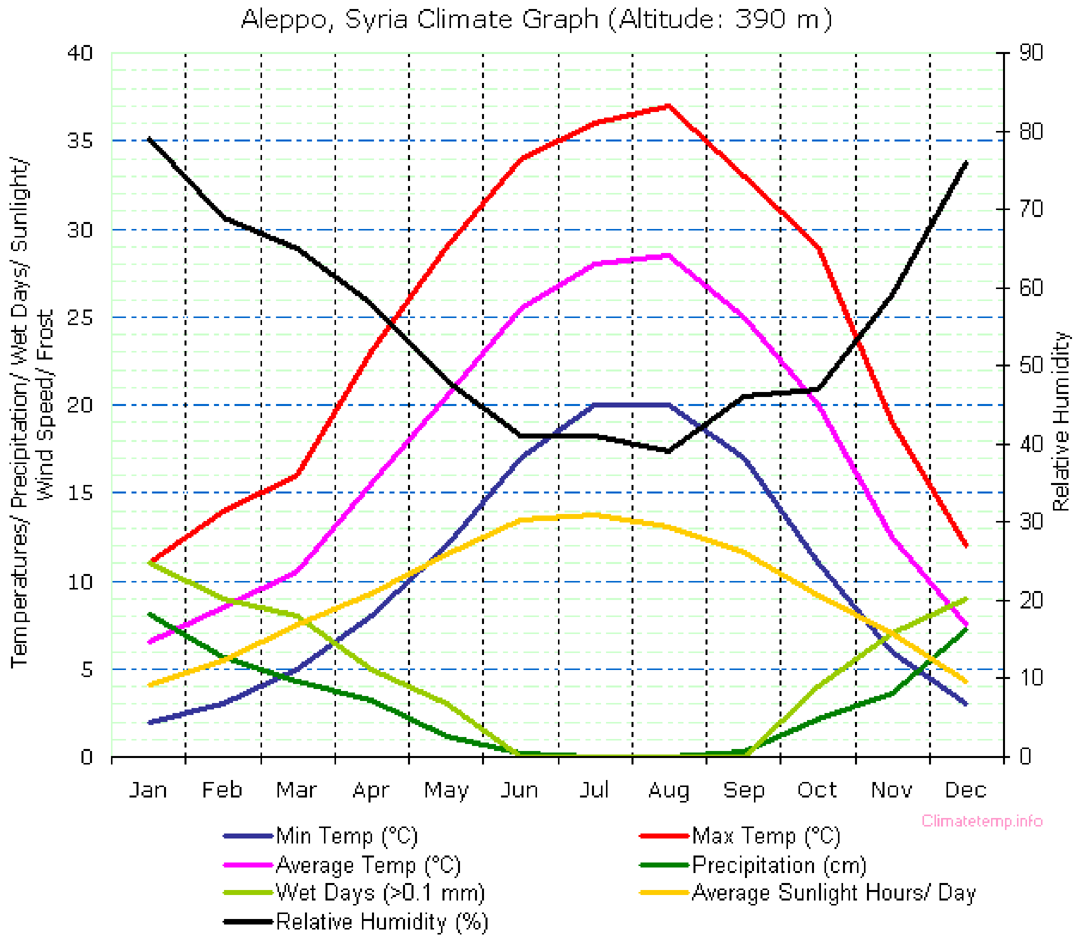


FIGURE 8. The climate annual reading of Aleppo (Climate & Temperature).

From Mollier curve, if we use the AC in the cooling mode and cool the room temperature down to 18 °C, the amount of water we can got in August is:

$t1 = 37$ °C, $t2=18$ °C
RH= 39%
$X1 = 0{,}014$ Kg/Kg
$X2 \approx 0{,}005$ Kg/ Kg
$\rightarrow \Delta X = X1 - X2 = 0{,}014$ Kg/Kg - 0,005 Kg/ Kg = 0,009 Kg/ Kg = 9 g/Kg
This means that we can get 9 g of water from each 1 Kg of air in August in Aleppo.

Hence, in the case of cooling, the amount of electricity we need to get this water based on Molier curve is:

$t1 = 37$ °C, $t2=18$ °C
RH= 39%

$\rightarrow$ h1= 75 Kj/Kg, h2= 30 Kj/Kg
$\Delta h = h1 - h2 = 75$ Kj/Kg - 30 Kj/Kg = 45 Kj/Kg Cooling energy
If the air flow: Q= 1m^3/s
Density is: $\rho \approx 1{,}3$ Kg/ m^3

The cooling capacity (P) will be:
$P = \Delta h \times Q \times \rho = 45$ Kj/Kg × 1m^3/s × 1,3 Kg/ m^3 = 58,5 KW

If we take the average COP = 3 the needed energy will be:
58,5 KW ÷ 3 = 19,5 KW

In the winter time, when the AC is used for heating the room up, the amount of water we can get in January if we raise the temperature up to 25°C will be:

$t1 = 2$ °C, $t2= 25$ °C
RH= 79%
$X1 = 0{,}0033$ Kg/Kg

X2≈ 0,0143 Kg/ Kg

→ ΔX = X2 – X1 = 0,0143 Kg/Kg - 0,0033 Kg/ Kg = 0,011 Kg/ Kg = 11 g/Kg

This means that we can get 11 g of water from each 1 Kg of air in January in Aleppo. Hence, in the case of heating, the amount of energy we need to get this water based on Mollier curve, and using the same data is 22,1 KW.

From the results we can see that the energy needed to get water is approximately the same for summer and winter time, but it is possible to get more water in the winter time than in the summer as the humidity is higher. However, the AC devices will keep giving water anyway and under any conditions, and the amount of it varies depending on the surrounding conditions. Also it is important to notice that if the device keep getting the air from the same room without any open source of air, the humidity in that room will drop and it will not be possible to get the same amount of water at the beginning and the end.

5.3 Example from Aleppo

By using a house AC in Aleppo with the following specifications:

TABLE 4. Information about the AC used in Aleppo for getting water.

Model	UQT18BORE
Capacity (Cool/Heat)	18000/20000 BTU/h
VOL TAGE / Frequency	220-240V-, 50Hz
Current (C/H)	9.5/ 10,0 A
Power input (C/H)	2000 / 2100 W
Refrigerant	R22, 1500g (52.9oz)
Energy consumption KW/h	5,2
Climate class	T1
Splash proof	APX4

It was possible to get approximately 2liters per hour of water in the summer time which makes 48 liters per day and 3 Liters per hour of water in the winter time which makes 72 liters per day. However, biggest devices can make more water than small ones, and this AC is considered to be a small one.
The price of Similar device in Aleppo now a days is about 19000 Syrian Pounds which is between 200 and 250€, and that makes it one of the cheapest water devices if not the cheapest of all.

PICTURE 10. The inside part of the AC used in Aleppo for getting water.

PICTURE 11. The outside part of the AC used in Aleppo for getting water.

To calculate the price of generating water from the AC in the summer and winter, we can use the device value of energy consumption (5,2 KW/h). The amount of water we got in the summer is 2L/h so the energy needed for 1L is 2,6 KW/h, and for winter we got 3L/h, so the energy needed for 1L is 1,83 KW/h.

TABLE 5. The price of the water generated by the AC in 1 hour for the summer and winter in Aleppo.

Electricity segments (KW/h)	**Price in Syrian pound**	**The cost of 1L of water in summer**	**The cost of 1L of water in winter**
1 -100	0,25	0,65	0,46
101 - 200	0,35	0,91	0,64
201 – 400	0,50	1,3	0,92
401 – 600	0,75	1,95	1,37
601 – 800	2	5,2	3,66
801 – 1000	3	7,8	5,49
1001 – 2000	3,5	9,1	6,41
2001 – above	7	18,2	12,81

If I euro is 81,5 Syrian Pound, then the cost of 1L/h in the summer is from 0,008€ to 0,22€, and in the winter is from 0,0056€ to 0,157€.

5.4 Example from Muscat

The information about weather in Muscat can be found in the following table:

TABLE 6. The climate of Muscat for temperature and relative humidity (Climate & Temperature).

Type	Value
The lowest relative humidity in the year in May	60%
The average maximum temperature in May	37°C
The highest relative humidity in the year	80%

in August	
The average maximum temperature in August	33°C

From Mollier diagram, the amount of water in the air when we drop the temperature to 18°C in August:

Δh = 16 g/Kg water

And in May it will be:

Δh = 16,5 g/Kg water

When the amount of water in the air was 9g/Kg in Aleppo, the device was able to give 2L of water per hour. Hence, if we use the same device in Muscat when the water in the air is 16 g/Kg, the amount of water will be 3,6L per hour which is 86,4L per day. If the price of electricity in Muscat is 0,016 Omani Rial, then the cost of 1L is 0,0224 Omani Rial which is 0,046€.

Nevertheless, when we know that in some areas the ACs are kept working 24 hours per day, and all the water coming out of it is thrown to the sink, we will find out that the price of this water is paid anyway, but the water is not in use. The amount of water gotten in Aleppo was very sufficient in fact, where this city is considered to have a dry air generally, so thinking of the amount of water we can get in a country like Qatar where the RH reach up to 90% (RasGas Magazine, 2011) and ACs are in use all the daylong in every single room of any apartment, should make us think about the water we are wasting in everyday of our lives. If we think in numbers, we will find that the population of Qatar for example is about 1790000 (Statistic Authority, 2012), then there is at least 1000000 AC in the country working for at least 16 hours a day, and if each one collected 60L every day of the highly humid days (and it will for sure collect more than this number due the high humidity in that area), it means that we are throwing 60000000L of water every day, and that is 60000m^3 per day though we are paying approximately the full price of producing it plus the price of the same amount of water that we get from water taps!

5.5 The water quality

The quality of water coming from the ACs can be good if some adjustments were added to the device. For example, if the metal used in the pipes was replaced with another one usable for drinking purposes like Stainless steel, but more studies are needed to be done about that before it can be implemented for drinking purposes.

In comparison with the quality of harvesting fog water, the quality of water collected by ACs should be good after taking care of hygienic matters for the device inner parts. However, the AC water quality should be analyzed in the target area first, and even if the water was good in some countries, we still have to analyze it every time we start a project in a new place.

It might good to use some water filtrations to remove different partials and sediments, but the type of filtration needed for water depends on the area conditions. For example, from my experience in Kano, Nigeria, the public water coming to the apartment is usually not clean, so locals have to clean their own water by their selves, and it is considered to be enough if they boil the water then use normal sand filtration at home to drink the water. Hence, the filtration stage depends also on what people think it is enough, because when we think about some water devices that use ultra-filters to clean the water for example, we need to know that even the best public water companies do not purify the water with ultra-filters.

In the other hand, it might be needed to add some minerals to the water to make it drinkable in case it was soft as it is condensed water, like appropriate amount of calcium and magnesium, but so far, there was no water device that needed to add any minerals to the produced water. However, analyzing the condensed water will give the needed answer about this point.

6 CONCLUSION

New weather patterns appeared in our world in the past century, and that caused lots of confusion for humans who used to expect only one weather pattern per season in a certain areas. However, this is not the case in the current days, which means that people have to change their behaviors in so many ways if they want to have a good life quality for the future generations. However, it is obvious that finding sustainable alternatives of the traditional natural sources is one of the most important issues that should be studied and developed, whether for energy source, or water sources.

Finally, in this thesis we talked about different way of harvesting water from thin air, and these ideas mentioned above can solve the poorer arid areas water problems with cheap prices inventions that they can buy or maybe produce their selves. Every idea of these ideas can fit perfectly for a certain area, either with simplicity like the case of hunting fog, or with business investment like the case of the water hotel building.

However, more hard work and studies should be invested in this issue as it is the perfect solution for arid areas, and it will be a great waste if not given adequate attention to these ideas. We have now a way to solve different fresh water problems using one simple principle, because with these ideas there will be no need to worry about the far distance, purification stations, or any kind of pollutants that might affect the traditional water sources.

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