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Atmospheric Water Generator

Sajan C[*1], Mohammed Muhsin T[*2], Vaishnav P[*3],
Abhinand C Vijayan[*4], Yaroshkha M[*5]

[*1]*Faculty of department of Mechancal Engineering, Eranad Knowledge city technical campus, Manjeri, Malappuram, Kerala, India*
[*2,*3,*4,*5]*Students of department of Mechancal Engineering, Eranad Knowledge city technical campus, Manjeri, Malappuram, Kerala, India*
Corresponding Author : Sajan C

Abstract
Water scarcity affects1.2 billion people on a global scale, representing nearly one fifth of the human population. In some regions, current water sources are being depleted faster than they are renewed and the majority of this depletion is being used for irrigation and agricultural purposes. At any given time, the atmosphere contains 3400 trillion gallons of water vapor, which would be enough to cover the entire Earth in 1 inch of water. Herein, we describe the design of an innovative solution to water scarcity in regions with medium to high humidity - Atmospheric Water Generators (AWG). This device converts water vapor into liquid water and is designed for agricultural and irrigation purposes in regions where water scarcity exists.

Keywords: *Atmospheric water generator, AWG, water scarcity*

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I. INTRODUCTION

A growing number of the world's population lack access to clean water. About 844 million people lack access to safe water, a large proportion coming from underdeveloped African countries ("Water Crisis," n.d.). Those with access to water in these countries of ten have to walk several hours each day to collect clean water. Even developed nations struggle with access to safe water. For example, about 75 percent of Mexico's population drinks packaged water, and in the United States and China, over 10 billion gallons of bottled water are consumed every year as a result of increasing population coupled with climate change and pollution issues (Illsley, 2016). Consequently, the world demand for water treatment products is increasing about seven percent annually ("World Water Treatment," n.d.).

A common process used to generate clean water is desalination, although desalination processes for water treatment are energy intensive and are not economically suitable for areas of the world in need of clean water. Two widespread methods for desalination include membrane filtration and distillation. Reverse osmosis and nanofiltration desalination require pressures up to 1,000 psi as driving forces for the membrane filtration system, while distillation requires an abundant amount of heat to evaporate and condense the water for mineral separation (Cordova, Furukawa, O'Keeffe and Yaghi, 2013). Along with being extremely costly, these processes pose a threat to the environment and result in a waste solution that requires disposal. These water purification methods also require access to a localbody of water, which may not be available.

Atmospheric water generation using dehumidification technology is an alternative to high energy desalination systems. These systems could be used to generate potable water in any location with an external power source or renewable energy resources. Dehumidification systems would also be extremely effective when used in greenhouses due to their high humidity levels. In fact, the long-term scope of the work done in this project, incorporated with the work done at collaborating universities (Texas A&M and University of Illinois), will culminate into a greenhouse hydroponic system, where the water source is our *scaled* VCC. The vapor compression cycle will feed potable water from the greenhouse air to consumers in a community. From there, the wastewater will be treated and sent back to provide nutrients to a hydroponic greenhouse, which will also provide food for the community. The project goal isn't solely about atmospheric water generation, but a holistic and fully integrated approach to delivering food, water, and energy in an environmentally conscious and clean way.

1.1 Schematic diagram

This project is designed on the basis of vapor compression refrigeration principle as well as thermoelectric cooling technique. The main components of this hybrid atmospheric water generator are, compressor, condenser, capillary tube, evaporator, thermoelectric module, switched mode power supply (SMPS) and frame which support the entire system. Each component is test-ed and assembled as shown in the line diagram.

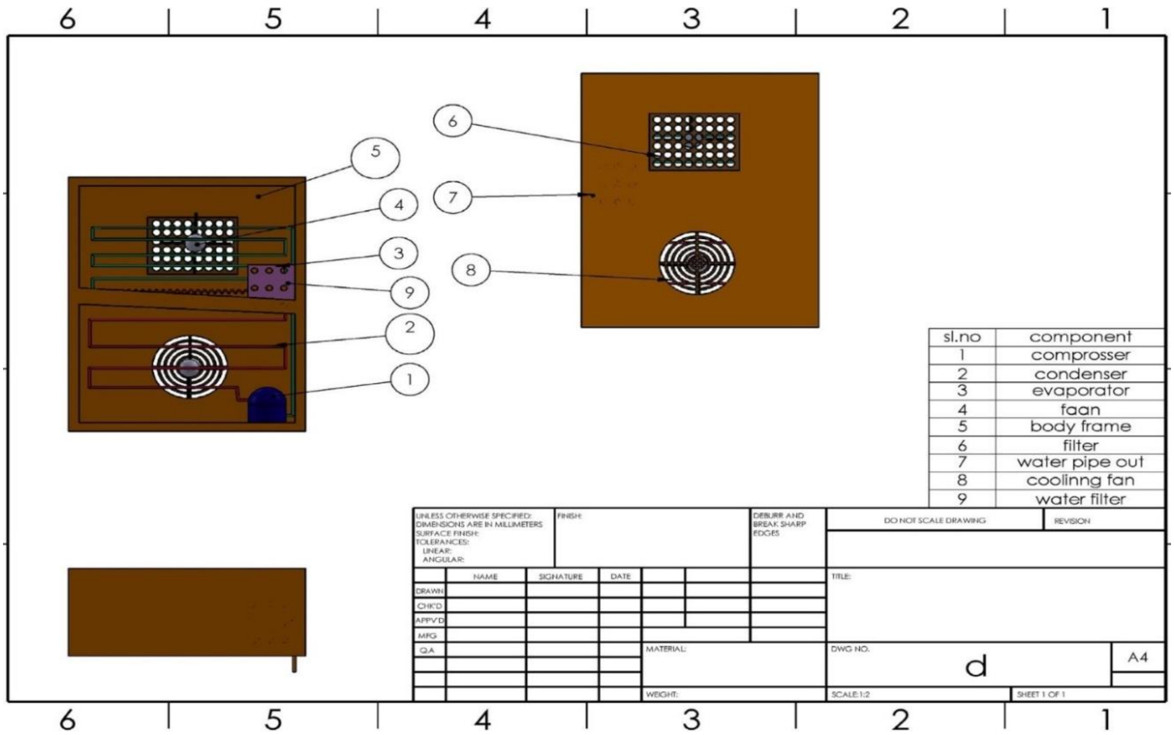

Figure 1: Schematic CAD diagram of Atmospheric Water Generator

1.2COMPNONENTS AND SPECIFICATIONS

1.2.1 Compressor

It is a mechanical device that increases the pressure of a gas by reducing its volume. An air compressor is a specific type of gas compressor. Compressors are similar to pumps: both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. Liquids are relatively incompressible, while some can be compressed, the main action of a pump is to pressurize and transport liquids.

Specifications:

i. Capacity – 200 Litres
ii. Manufacturer - LG

A small hermetically sealed compressor in a common consumer refrigerator or freezer typically has a rounded steel outer shell permanently welded shut, which seals operating gases inside the system, in this case an R22 refrigerant. There is no route for gases to leak, such as around motor shaft seals. On this model, the plastic top section is part of an auto defrost system that uses motor heat to evaporate the water

Compressors used in refrigeration systems must exhibit near zero leakage to avoid the loss of the use of very effective seals, or even the elimination of all seals and openings to form a hermetic system. These compressors are often described as being hermetic, open, or semi-hermetic, to describe how the compressor is enclosed and how the motor drive is situated in relation to the gas or vapor being compressed. Some compressors outside of refrigeration service may also be hermetically sealed to some extent, typically when handling toxic, polluting, or expensive gasses, with most non refrigeration applications being in the petrochemical industry.

Figure 2: Compressor

In hermetic and most semi hermetic compressors, the compressor and motor driving the compressor are integrated, and operate within the pressurized gas envelope of the system. The motor is designed to operate in, and be cooled by, the refrigerant gas being compressed. Open compressors have an external motor driving a shaft that passes through the body of the compressor and rely on rotary seals around the shaft to retain the internal pressure.

The difference between the hermetic and semi-hermetic, is that the hermetic uses a one- piece welded steel casing that cannot be opened for repair; if the hermetic fails it is simply replaced with an entire new unit. A semi-hermetic uses a large cast metal shell with gasket covers with screws that can be opened to replace motor and compressor components. The primary advantage of a hermetic and semi-hermetic is that there is no route for the gas to leak out of the system.

The main advantages of open compressors is that they can be driven by any motive power source, allowing the most appropriate motor to be selected for the application, or even non electric power sources such as an internal combustion engine or steam turbine, and secondly the motor of an open compressor can be serviced without opening any part of the refrigerant system.

An open pressurized system such as an automobile air conditioner can be more susceptible to leak its operating gases. Open systems rely on lubricant in the system to splash on pump components and seals. If it is not operated frequently enough, the lubricant on the seals slowly evaporates, and then the seals begin to leak until the system is no longer functional and must be recharged.

By comparison, a hermetic or semi- hermetic system can sit unused for years, and can usually be started up again at any time without requiring maintenance or experiencing any loss of system pressure. Even well lubricated seals will leak a small amount of gas over time, particularly if the refrigeration gasses are soluble in the lubricating oil.

1.2.2 Condenser

In systems involving heat transfer, a condenser is a heat exchanger used to condense a gaseous substance into a liquid state through cooling. In so doing, the latent heat is released by the substance and transferred to the surrounding environment. Condensers are used for efficient heat rejection in many industrial systems. Condensers can be made according to numerous designs, and come in many sizes ranging from rather small (hand- held) to very large (industrial-scale units used in plant processes). For example, a refrigerator uses a condenser to get rid of heat extracted from the interior of the unit to the outside air.

Specifications:

i. Material - Copper

Figure 3: Condenser

Condensers are used in air conditioning, industrial chemical processes such as distillation, steam power plants and other heat exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers. A condenser unit used in central air conditioning systems typically has a heat exchanger section to cool down and condense incoming refrigerant vapor into liquid, a compressor to raise the pressure of the refrigerant and move it along, and a fan for blowing outside air through the heat exchanger section to cool the refrigerant inside. A typical configuration of such a condenser unit is as follows: The heat exchanger section wraps around the sides of the unit with the compressor inside. In this heat exchanger section,18 the refrigerant goes through multiple tube passes, which are surrounded by heat transfer fins through which cooling air can circulate from outside to inside the unit. There is a motorized fan inside the condenser unit near the top, which is covered by some grating to keep any objects from accidentally falling inside on the fan. The fan is used to pull outside cooling air in through the heat exchanger section at the sides and blow it out the top through the grating. These condenser units are located on the outside of the building they are trying to cool, with tubing between the unit and building, one for vapor refrigerant entering and another for liquid refrigerant leaving the unit. Of course, an electric power supply is needed for the compressor and fan inside the unit.

1.2.3 Evaporator

Evaporator is an important component together with other major components in a refrigeration system such as compressor, condenser and expansion device. The reason for refrigeration is to remove heat from air, water or other substance. It is here that the liquid refrigerant is expanded and evaporated. It acts as a heat exchanger that transfers heat from the substance being cooled to a boiling temperature.

The fins are added to the bare-tube to increase the heat transfer capability. They act as heat collector that pick up heat from the surrounding air and conduct it to the refrigerant inside the tube hence improving the efficiency in cooling the air of the surrounding. They are best used in the air-cooling space where the temperature is around Having fins mean the surface area for heat transfer has been extended. This means that the finned coils can have more compact in design compared to the bare tube type of similar capacity. In summary, finned coils help to reduce coil cost, size and weight.

Specifications:

i. Material: Aluminium alloy

Figure 4: Finned type evaporator

Good thermal contact between the fins and tubes is a must to ensure efficient heat transfer. They can be soldered together. The other more practical method is to expand the fins by pressure such that they bite into the tube surface hence a good thermal contact is established. The spacing of the fin depend on the operating temperature of the coil. Low temperature application uses only 1 fin. In air conditioning application, 14-16 fins per inch may be used as long it is designed in such a way that frost does not accumulates in the coils. Excessive fining may reduce the capacity of the evap. by restricting the flow of air over the coil hence the design engineers must do a proper system calculation and simulation at design stage.

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1.2.4 Capillary tube

Capillary Tube is one of the most commonly used throttling devices in the refrigeration and the air conditioning systems. The capillary tube is a copper tube of very small internal diameter. It is of very long length and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for the refrigeration and air conditioning applications varies from 0.5 to 2.28 mm (0.020 to 0.09 inches). Capillary tube used as the throttling device in the domestic refrigerators, deep freezers, water coolers and air conditioners When the refrigerant leaves the condenser and enters the capillary tube its pressure drops down suddenly due to very small diameter of the capillary. In capillary the fall in pressure of the refrigerant takes place not due to the orifice but due to the small opening of the capillary.

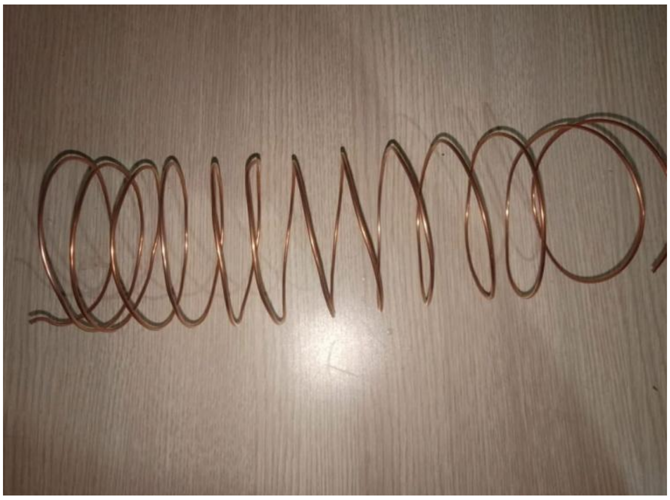

Figure 5: Capillary Tube

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The decrease in pressure of the refrigerant through the capillary depends on the diameter of the capillary and the length of the capillary. Smaller is the diameter and more is the length of the capillary more is the drop in pressure of the refrigerant as it passes through it.

In the normal working conditions of the refrigeration plant there is drop in pressure of the refrigerant across the capillary but when the plant stops the refrigerant pressure across the two sides of the capillary equalize. Due to this reason when the compressor restarts there won't be much load on it. Also, due to this reason one cannot over-charge the refrigeration system with the refrigerant and no receiver is used. The capillary tube is non- adjustable device that means one cannot control the flow of the refrigerant through it as one can do in the automatic throttling valve. Due to this the flow of the refrigerant through the capillary changes as the surrounding conditions changes. For instance, as the condenser pressure increases due to high atmospheric pressure and the evaporator pressure reduces due to lesser refrigeration load the flow of the refrigerant through the capillary changes. Thus, the capillary tube is designed for certain ambient conditions. However, if it is selected properly, it can work reasonably well over a wide range of conditions.

1.2.5 Refrigerant

R134a is also known as Tetrafluoro ethane (CF3CH2F) from the family of HFC refrigerant. With the discovery of the damaging effect of CFCs and HCFCs refrigerants to the ozone layer, the HFC family of refrigerant has been widely used as their replacement. It is now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors. It is safe for normal handling as it is non-toxic, non-flammable and non-corrosive.

It exists in gas form when expose to the environment as the boiling temperature is - 14.9°F or -26.1°C. This refrigerant is not 100% compatible with the lubricants and mineral-based refrigerant currently used in R-12. Design changes to the condenser and evaporator need to be done to use this refrigerant. The use of smaller hoses and 30% increase in control pressure regulations also have to be done to the system.

Figure 6: Refrigerant

1.2.6 Fan

Specifications:

i. Speed – 1200 rpm

Figure 7: Fan

Fans are used for circulating air in rooms and buildings; for cooling motors and transmissions; for cooling and drying people, materials, or products; for exhausting dust and noxious fumes; for conveying light materials; for forced draft in steam boilers; and in heating, ventilating, and air-conditioning systems.

1.2.7 Water filter

This basically means water is filtered through normal gravity process, from the higher point to a lower point, without the help of any external force and biggest advantage is gravity-based water purifiers woks without electricity.The water flows from the top compartment to the bottom compartment, naturally. Usually for filtering, they depend upon micro fiber mesh, activated carbon filtering and some kind of polisher which removes residual chemicals.

Specifications:

i. Material- Plastic
ii. Free Flow Type

Figure 8 : Water filter

1.2.8 Thermostat

Thermostat is a device used to detect temperature changes for the purpose of maintaining the temperature of an enclosed area essentially constant. In a system including relays, valves, switches, etc., the thermostat generates signals, usually electrical, when the temperature exceeds or falls below the desired value. It usually is used to control the flowof fuel to a burner, of electric current to a heating or cooling unit, or of a heated or cooled gas or liquid into the area it serves. The thermostat is also an element in some types of fire-detection warning systems.

Figure 9 :Thermostat

An adjustable thermostat is used to cut the power supply if the evaporator ever gets below a set threshold (3 degree Celsius in our case), which avoids the over freezing of evaporator coils and saves energy

1.2.9 Refrigerant filter drier

Filter-driers are a key component in any refrigeration or air conditioning system. This article offers acr technicians a description of the basic function of these devices and differences between the various types currently available. A filter-drier in a refrigeration or air conditioning system has two essential functions: one, to adsorb system contaminants, such as water, which can create acids, and two, to provide physical filtration. Evaluation of each factor is necessary to ensure proper and economical drier design

Figure 10: Refrigerant filter drier

The ability to remove water from a refrigeration system is the most important function of a drier. Water can come from many sources, such as trapped air from improper evacuation, system leaks, and motor windings, to name a few.

Another source is due to improper handling of polyolester (POE) lubricants, which are hygroscopic; that is, they readily absorb moisture. POEs can pick up more moisture from their surroundings and hold it much tighter than the previously used mineral oils. This water can cause freeze-ups and corrosion of metallic components.Water in the system can also cause a reaction with POEs called hydrolysis, forming organic acids. To prevent the formation of these acids, the water within the system must be minimized. This is accomplished by the use of desiccants within the filter-drier. The three most commonly used desiccants are molecular sieve, activated alumina, and silica gel.

1.2.10 Expansion valve

The expansion valve is the regulator through which the refrigerant passes from the high-pressure side of the system to the low-pressure side. The pressure drop causes the evaporating temperature of the refrigerant to fall below that of the evaporator.

Figure 11: Expansion valve

Thus, forexample, the refrigerant can be boiled off by an evaporator temperature of — 18 deg C because the pressure drop brings the evaporating temperature of the refrigerant down to say — 24 deg C The liquid refrigerant leaves the condenser with a temperature just above that of the sea-water inlet, say 15 deg C. As it passes through the expansion valve the evaporating temperature decreases to — 24 deg C and some of the liquid boils off taking its latent heat from the remainder of the liquid and reducing its temperature to below that of the evaporator.

1.2.11 Main frame

For the main body frame, we used a refrigerator housing that is cleared inside out because of the insulated covering on every sides. The rear section is mounted with the compressor which is connected to the inside via a hole Also the fan is mounted on the rear side, which sucks the air from the atmosphere to the evaporator coil. The compressor, evaporator, and the water filter are placed inside the main body frame. The front and top section of the body frame is covered by using PVC laminate, along with an air passage to exit the remaining air

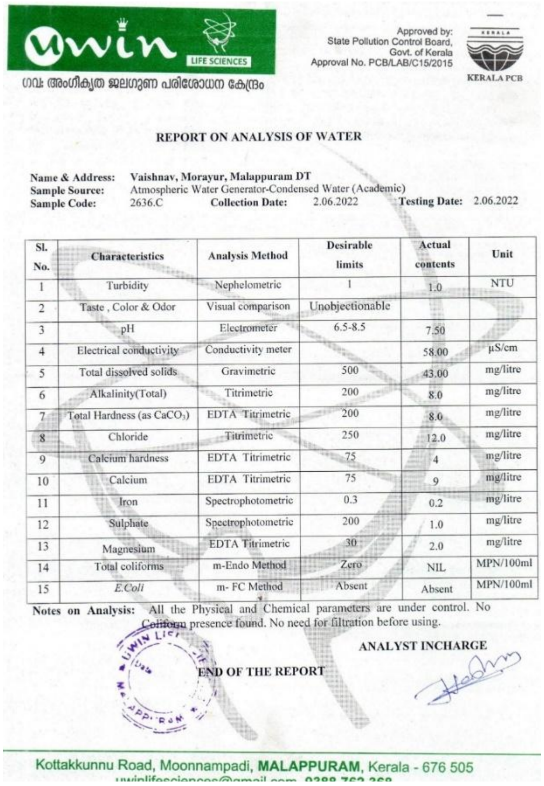
Figure12 : Front section of Body Frame

Figure 13: Rear section of Body Frame

Then the body frame was spray painted in blue colour complete the finished look after the corroded parts are cleaned up, and for a pleasing aesthetic look.

II. EVALUATION AND ANALYSIS

As per the carried-out experiments, we got a satisfying result. After operation of one hour, we got 100ml of water, which was passed through a gravity-based water filter after generation, which filters out unwanted dust, viruses and bacteria and gives filtered water from its output tap. The filter can store 1 litres of water, so it also acts as a storage tank. After working of multiple hours, adequate quantity of water has been collected and sent to a government authorised water testing centre to test its purity and usability. And it was tested that the pH value of water is 7.5, which is under the limits (6.5-8.5). And after further testing, it was tested pure. The Figure 14 shows the water test.



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Approved by:
State Pollution Control Board,
Govt. of Kerala
Approval No. PCB/LAB/C15/2015

KERALA PCB

REPORT ON ANALYSIS OF WATER

Name & Address: Vaishnav, Morayur, Malappuram DT
Sample Source: Atmospheric Water Generator-Condensed Water (Academic)
Sample Code: 2636.C **Collection Date:** 2.06.2022 **Testing Date:** 2.06.2022

Sl. No.	Characteristics	Analysis Method	Desirable limits	Actual contents	Unit
1	Turbidity	Nephelometric	1	1.0	NTU
2	Taste , Color & Odor	Visual comparison	Unobjectionable		
3	pH	Electrometer	6.5-8.5	7.50	
4	Electrical conductivity	Conductivity meter		58.00	µS/cm
5	Total dissolved solids	Gravimetric	500	43.00	mg/litre
6	Alkalinity(Total)	Titrimetric	200	8.0	mg/litre
7	Total Hardness (as $CaCO_3$)	EDTA Titrimetric	200	8.0	mg/litre
8	Chloride	Titrimetric	250	12.0	mg/litre
9	Calcium hardness	EDTA Titrimetric	75	4	mg/litre
10	Calcium	EDTA Titrimetric	75	9	mg/litre
11	Iron	Spectrophotometric	0.3	0.2	mg/litre
12	Sulphate	Spectrophotometric	200	1.0	mg/litre
13	Magnesium	EDTA Titrimetric	30	2.0	mg/litre
14	Total coliforms	m-Endo Method	Zero	NIL	MPN/100ml
15	*E.Coli*	m- FC Method	Absent	Absent	MPN/100ml

Notes on Analysis: All the Physical and Chemical parameters are under control. No Coliform presence found. No need for filtration before using.

ANALYST INCHARGE

END OF THE REPORT

Kottakkunnu Road, Moonnampadi, **MALAPPURAM**, Kerala - 676 505

Figure 14: Water test report

2.1 Cost evaluation and testing

The working cost of the atmospheric water generator has been calculated by using the rated power input of the compressor and using the price slab of electricity under 50 units a month. It has been calculated by letting the atmospheric water generator for some hours until it produces a required amount of water quantity, say 100ml or 1 litre. The time required to produce this quantity has been noted and further electricity consumption is calculated using available data.

Specifications:

i. 200 Litres Compressor
ii. Model name: MA57LLJJG
iii. Brand name: LG
iv. Maximum wattage= 130W
v. Temperature of evaporator =220K
vi. Room temperature =280K
vii. Working time=1 hrs
viii. amount of water produced in 1hrs =100ml
ix. Power consumed for 1 hr =0.130 kwH
x. Electricity charge for slab 0-50 =3.90 rupees per unit
xi. Cost for producing 1 litres of water =0.130 × 3.90×10 hours =5.07 rupees
xii. Total cost=cost of one hour=approx. 0.507 rupees

III. ADVANTAGES & DISADVANTAGES

The implementation of atmospheric water generator comes with several notable advantages, disadvantages and future scopes. Out of them, the positive side or the advantages are pointed out as below:

3.1 Advantages

i. **Can produce water from air**
It's unique in that no other water supply source does this

ii. **Can help address water scarcity issues**
Being able to generate water from another source: the atmosphere, helps address water quantity problems in some areas.

iii. **Can provide direct drinking water**
When used with purification and filtration technology (and UV treatment). Some AWGs also produce ice in addition to drinkable water.

iv. **Rate of water production can be increased**
Depending on variables such as the ambient air temperature, relative humidity, the volume of air passing over the coil, and the machine's capacity to cool the coil or the size of the compressor

v. **Provides water independence, & accommodates off grid living**
Independent from other water sources, and public utilities. Facilitates off grid living in some ways.

vi. **Diversifies water supply**
Can be used alongside other water sources like rain water harvesting, desalination, water recycling, ground water and surface water withdrawal, and so on. Can be used as part of a diversified water strategy to prevent one of a number of water issues.

vii. **Can Be Portable**
In this case of smaller AWG units, it can be transported easily to work in a wide variety of locations

Apart from being a usable and portable machine that can generate water from out of atmosphere, this machine also comes with some flaws or disadvantages as pointed out below.

3.2 Disadvantages

i. **Can require a lot of energy**

ii. **It takes a lot of time to produce the quantity of water required**

iii. **Can have a high carbon footprint**
When coal is used as an energy source for electricity. Some estimates say it exceeds reverse osmosis seawater desalination by three times. It can be one of the worst water sources environmentally in this instance.

iv. **Cost effectiveness can be an issue**
Cost-effectiveness of an AWG depends on the capacity of the machine, local humidity and temperature conditions and the cost to power the unit [or, the cost of electricity/power in a city or town]. The upfront cost of an AWG machine and the alternative cost of water from other sources can also play a part.

v. **Can be inefficient (input to output)**
It demands more than four times as much water up the supply chain than it delivers to the user

vi. **Largest quantities/scales of water generation can be an issue**
AWG technology may not be suitable for uses like agriculture due to the sheer quantity of water required for irrigation and other uses. It might only produce enough water for activities like drinking, cooking, cleaning, and general human use and consumption.

vii. **Might not work effectively in some environments**
AWG technology might work better when relative humidity and air temperature is higher. It might not work efficiently when temperature is below 18.3°c (65°f) or the relative humidity drops below 30%. AWG technology may also not be good in region and countries with very dry climates and dry air (as there is no moisture to extract in the air)

viii. **Cleanliness, healthiness & safety of collected water can be an issue**

In the case of passive 'water harvesting from air' methods that don't rely on patented technology that come with water purification and filtration devices. Even in the case of AWG units, you have to consider factors such as purification of the air (which might be poor quality), and the final mineral content of the water.

IV. FUTURE SCOPES

i. Usage of Peltier module in an AWG has proven to increase the overall efficiency of the atmospheric water generator at the cost of minor electricity increase

ii. Usage of solar energy is possible. If adequate energy for running the compressor and fan can be availed from solar energy alone, it can be used as a power source and can be stored in battery and supplied to compressor. This will increase the cost of AWG by a big margin, but it is still possible

iii. If the AWGs are placed in open areas, it can be used for rainwater harvesting as well. The collected water can be purified using inbuilt water filter

iv. Incorporating Liquid Desiccant method to extract humidity from air and convert it into drinking water. Wet desiccation is a process where abrine solution is exposed to humid air in order to absorb water vapour from that air. This method is efficient and can be incorporated with renewable energy such as solar

V. RESULT AND CONCLUSIONS

The Project implemented is an idea on a refrigeration method. This refrigeration method is found to be having higher productivity when relative humidity is high, enhancing the productivity of the prototype. Also, we have done some test on the product and obtained satisfactory results for the same. In the initial stage, we have successfully obtained 100 ml of water in 1 hour with relative humidity of 70%. Within this period, it consumed 0.130 kilowatt-hours of energy per litre of water generated using refrigeration process. Resulting around 5 Rupees for producing 1 litre. The aim would be extracting humidity from the air and then purifying it into the highest quality drinking water by sending the collected condensation through a water filter that purifies and kills all germs, bacteria and viruses that could be present in the water. The end result is the clean drinking water. The water is absolutely pure, safe and clean.

The Project was completed within the limited time successfully. The ‘ATMOSPHERIC WATER GENERATOR’is working with satisfactory conditions. also, able to understand the difficulties in maintaining the tolerance and also quality. The project is done while making maximum use of available facilities.

As conclusion remarks of project work, this developed “ATMOSHERIC WATER GENERATOR”is a method to achieve low-cost automation in water generation. By using more techniques. They can be modified and developed according to the applications.

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