# An Underground Model Atmospheric Water Generator Designed for South African Rural Communities

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## Abstract

Water is a major component of all living matter, which when pure is an odourless, tasteless, only slightly compressible liquid that appears bluish in dense layers, freezes at 0 ° C and boils at 100 ° C. This design intends to address the problem of water scarcity in the rural area of South Africa with KwaZulu-Natal as case study, by designing an atmospheric water generator that will obtain water from the atmosphere. The atmosphere has about 0% to 4% of water available as water vapor. The present technologies of harvesting water from the atmosphere are differentiated into three: the cooling condensing type, wet desiccant type and Peltier effect type. Concept were generated and a final design was developed that works using a fan and solar power, with the aid of the temperature difference in the soil and the atmosphere to condense the water vapour into water. Under favoarable conditions the atmospheric water generator is able to produce 23 l/day of water.

**Keywords** Atmospheric water generator, Water vapour, Humidity, Atmospheric vapor condensation, Water scarcity, Underground condensation.

## 1. Introduction

Water is a liquid that when pure is an odourless, tasteless, only slightly compressible liquid that appears bluish in dense layers, freezes at 0 ° C and boils at 100 ° C (AR Controls, 2020). Water is a precious resource with only 3% available as fresh water. Of which only 1% is easily accessible, the remainder 2% is inaccessible. Water is a scarce resource with 2.2 billion people having limited access (UN-Water, 2015). Many rivers, streams, and aquifers have dried up or have become too toxic to be used. Today more than half of wetlands (lakes) have gone missing. The increasing population, agriculture activities and pollution (UN-Water, 2015) mostly cause scarcity of water. Sub-Saharan Africa has the most water stressed countries of any area (WWF, 2020). This design seeks to address the problem of water scarcity in the rural area of of South Africa using KwaZulu-Natal as case study, by designing an atmospheric water generator that will obtain water from the atmosphere. The atmosphere has about 0% to 4% of water available as water vapor. The system of condensing water from the atmosphere dates to the sixth century, were ancient Greeks used the system to build large dew condenser to harvest water vapor. The present technologies of harvesting water from the atmosphere are differentiated into many types but only three will be considered in this project that is: cooling condensing type, wet desiccant type and Peltier effect type (Thisani, 2018). The three types differ by the way they condense water vapor to water, that is the cooling condensation type of AWG uses refrigeration technology (Thisani et al, 2017). The cooling condenser type is the most available in the market as a commercial solution to the scarcity of water (Bruce, et al., 2008). The wet desiccant type uses a chemical substance to absorb water vapor from the atmosphere, while the Peltier effect type is the least known design as it is being tested (Thisani et al, 2019). The Peltier effect type uses thermoelectric systems to condense water vapor into water and is still being investigated. The wet desiccant type is less available to the commercial market (Nandy, et al., 2014).

## 2. Existing Models

The technology that exist in the market right now is of good quality and uses different innovation. Some of the models available in the market are reviewed herein:

### 2.1 Airdrop irrigation

The idea of Airdrop irrigation is a low-tech system that allows use of the basic condensation cycle to extract water from soil. Using a turbine intake device, air is channeled underground through a piping network which quickly cools the air to soil temperature. This process creates a 100 per cent humidity environment from which water is then harvested. The collected water is stored in an underground tank, ready to be pumped out via an irrigation host sub-surface drip. The Airdrop architecture also features an LCD screen showing water rates, intensity of the strain, existence of the solar battery and safety of the device, Figure 1 (Borgobello, 2011).

Figure 1: AirDrop irrigation system (Borgobello, 2011).

### 2.2 Ecoloblue 30ME AWG

The Ecoloblue (Figure 2) is a cooling condensation type of Atmospheric Water Generator that can produce 33 liters of water a day that uses a Panasonic variable compressor (Talisa Water, 2019). The Ecoloblue uses 11 step filtrations system, produces 99.9 % pure water, has 18-liter storage tank, has an advance leak detection system, and has reduced noise at only 52 decibels. The price of the system cost approximately R11 999.00. the drawback of the system to this proposal is that the device is very advance and requires a lot of maintenance (Talisa Water, 2019).

Figure 2: Picture of the Ecoloblue 30ME (Talis, 2019).

## 3. **Atmospheric Water Generator Model**

The design incorporates a tank, copper coils, solar panel, a battery, and a hand pump. The design incorporates an oval tank that is able to withstand the pressures that will be associated with being placed underground. Water tanks can last approximately 15 years, but that depends on factors such as where the tank is placed, tank ocnsruction material, and the type of tank (Saidul, 2018). The tank will be placed underground since underground tanks last longer because they are not affected by the harsh environment. The material also has an effect on the longevity of the tank which is made of plastic such as high-density polyethylene (Saidul, 2018). The tank is made of polyethylene or polyurethane which has a life span of over 20 years. The design incorporates copper coils that coil around a PVC pipe that is used to build outlet pipes of water and air. Type K copper pipe will is used in this project as it is better suited to transfer heat from air to the soil at low the temperature (Sutton, 2017). Type K is mostly recommended in underground work as it will be in contact with the soil, therefore it will have to stand erosion or the chemicals that are found in the soil. The air enters the fan that is powered by a battery recharged by solar panels.

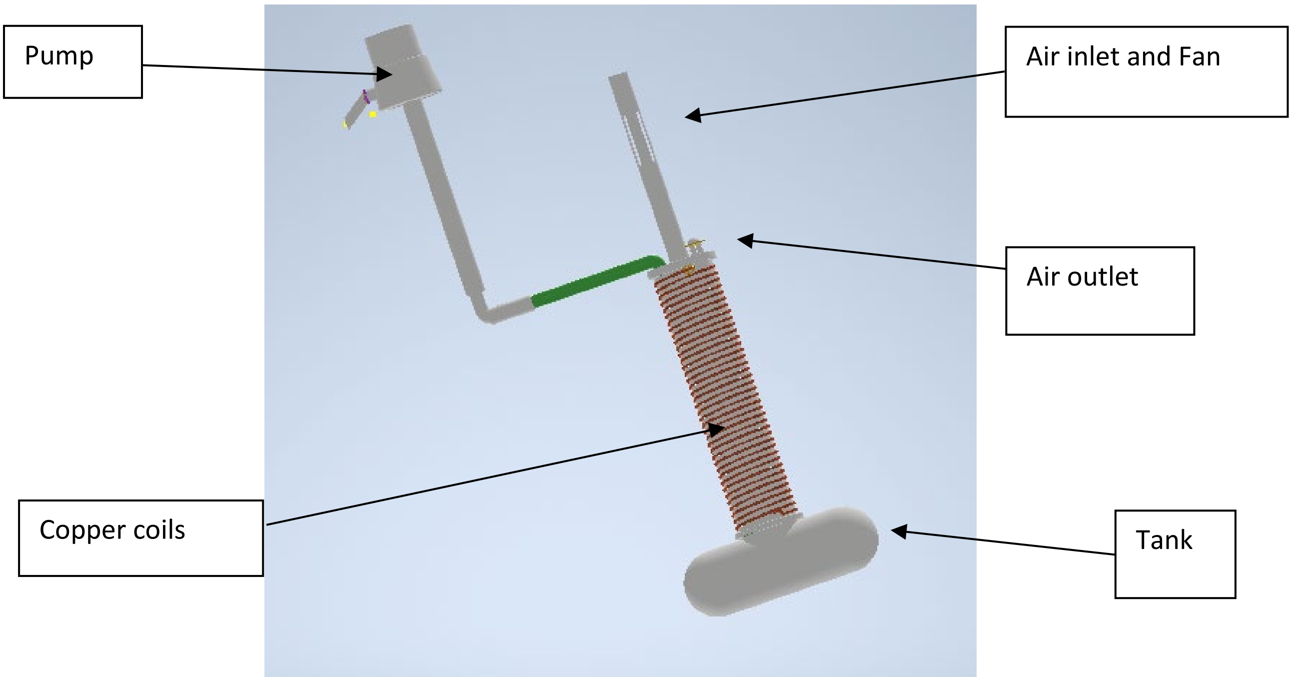


Figure 3: Model of the atmospheric water generator.

## 4. Model Testing

Conservation of mass:

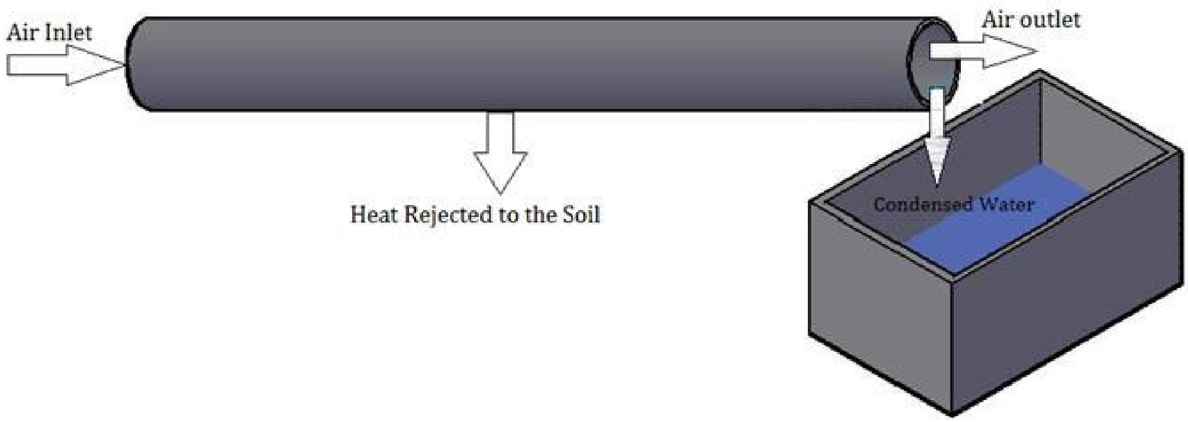


Figure 4: Air inlet and outlet of the copper pipe system underground.

$$\dot{m}_{a,i} = \dot{m}_{a,o} + \dot{m}_{w,o} \qquad (1)$$

But

$$\dot{m}_{a,i} = \dot{m}_{da,i} + \dot{m}_{v,i}$$

$$\dot{m}_{a,o} = \dot{m}_{da,o} + \dot{m}_{v,o}$$

$$\dot{m}_{a,i} = \dot{m}_{da,o}$$

$$\dot{m}_{v,i} = \dot{m}_{da,i}\omega_i$$

$$\dot{m}_{v,o} = \dot{m}_{da,o}\omega_o$$

$$\therefore \dot{m}_{w,o} = \dot{m}_{da}(\omega_i - \omega_o) \qquad (2)$$

The assumptions made are as following:

- Pipe diameter is set to be 0.05 m.
- Inlet velocity is set to be 5m/s.

Volume of air delivered by the fan:

$$v_a = C \times A_c$$

$$\therefore v_a = 5 \times \pi(0.025)^2 \times 3600$$

$$\therefore v_a = 35.34\ m^3/hr$$

Table 1: Mass of water produced in favourable conditions and unfavourable conditions.

| Temperature | Humidity (%) | Humidity ratio (g/kg) | Humidity ratio (kg/kg) | Volume | Mass of air | Mass of water |
|---|---|---|---|---|---|---|
| 10 | 60 | 4,5 | 0,00450 | 0,809 | 43,68355995 | 0,00 |
| 15 | 65 | 7 | 0,00700 | 0,825 | 42,83636364 | 0,00 |
| 20 | 70 | 10,25 | 0,01025 | 0,843 | 41,92170819 | 0,0419 |
| 25 | 75 | 15 | 0,01500 | 0,865 | 40,85549133 | 0,2349 |
| 30 | 80 | 21,7 | 0,02170 | 0,905 | 39,04972376 | 0,4862 |

Litres of water produced:

$$\rho = \frac{m}{V} \qquad (3)$$

The density of water was taken as 1000 kg/m$^3$ to calculate the volume of water produced from the mass of water produced. The atmospheric water generator was found to be able produce 23.3 litters per day in favourable conditions while it cannot produce water at very unfavourable conditions (Thisani, 2018; Thisani et al, 2019).

Table 2: Volume of water in litres produce in optimal conditions and unfavourable conditions

| Mass of water | Volume of water produced | Volume of water produced | Volume of water produced |
|---|---|---|---|
| 0,00 | 0 | 0 | 0 |
| 0,0000 | 0 | 0 | 0 |
| 0,0839 | 0,000084 | 0,08385528 | 2,012527 |
| 0,4699 | 0,000470 | 0,46990462 | 11,27771 |
| 0,9725 | 0,000972 | 0,97247569 | 23,33942 |

## 5. Cost Analysis

After the atmospheric water generator was designed the components prices were then listed in table 3 and the number of quantity needed also shown. The completely assembled product has an estimated cost of R9417, which is less than the Ecoloblue 30ME.

Table 3: Cost of the components selected.

| Component | Description | Quantity | Price | |
|---|---|---|---|---|
| Tank | Underground tank | 1 | R1500.00 | R1500.00 |
| Copper Pipes | Coiled copper pipes | 2 | R1400.00 | R2800.00 |
| PVC pipes | 50 mm | 2 | R478.00 | R956.00 |
| | 25 mm | 1 | R30.00 | R30 |
| Pipe | LDPE pipes | 1 | R410.00 | R410 |
| Pump | Plastic pump | 1 | R173.00 | R173.00 |
| Solar | 100 watts | 1 | R850.00 | R850.00 |
| Fan | 60 mm | 1 | R199.00 | R199.00 |
| Battery | Solar deep cycle gel | 1 | R2499.00 | R2499.00 |
| **Total** | | | ? | **R9417** |

## 6. Other Design Considerations

### 6.1 Specifications

The average temperature and humidity in the town of Ulundi in KwaZulu-Natal ranges from 10ºC to 30ºC and 60% to 75% humidity, therefore, the temperature and humidity are considered constrained in the inlet air that can be drawn by the Atmospheric water generator to be condensed (World Weather Online, 2020).

Table 4: Technical Specifications for the Atmospheric water generator

| Parameter Description | Considered | Allowable Deviation |
|---|---|---|
| Working Temperature | 10ºC - 30ºC | 5ºC |
| Humidity | 60% - 75% | 5% |
| Production | 0 – 10 litters | Less than 5 litters |

### 6.2 Materials and Components Selected

Components are selected from the many components that are available, that is the battery, fan and solar panel are all selected from the market. The fan that is needed must be a fan that can produce 0.5 m/s speed of air and that can operate from a DC battery. The solar panel that is need is panel that can produce at least 1000 watts of power at average cloud cover. The battery that is selected is a solar deep cycle gel battery that is 24 V. The atmospheric water generator is made of plastic tank and PVC pipes that separate the coils and in pipes of air leaving the atmospheric water generator.

### 6.3 Safety

The water produced with the designed atmospheric water generator is safe to consume as it is filtered and purified so that it meets the WHO (World Health Organisation) standards in South Africa such that it meets the SANS 241-1 standards. The device is easy to disassemble such that when foreign debris falls in the device it can be easily removed.

### 6.4 Social Impact

Water scarcity has become a problem as water demand is increasing with the increase of populations. The design will solve the problem of water scarcity and will impact the livelihood of communities. The water produced is of good quality with low mineralisation without biological contaminants. Water produced can be used for different needs such as food preparation, human consumption and agriculture.

### 6.5 Health impact

The water produced by the atmospheric water generator is of high quality that will improve the health of individuals that use the product. Water in most South African rural communities is not pure water or purified water but water that is contaminated that needs to be purified further. This often leads to diseases such as cholera in the townships. The use of the design will greatly reduce spread of such disease. Cholera is a disease that causes diarrhoea, dehydration, and may lead to death if treatment is not carried out.

### 6.6 Environment Impact

Atmospheric water generation is a source of renewable source of clean, pure water. The humidity in the air is water contained in the atmosphere as water vapour which is a natural source. The design uses renewable energy in the form of solar energy therefore does not impact the environment in a negative manner. Atmospheric water generator is design in such a way that less energy is used, the construction of the water generator will only use non-renewable energy which affects the environment.

## 7. Conclusion

Water is a basic need, water scarcity in the world is a problem as pollution keep on increasing at an exponential rate. The water scarcity in South Africa is caused by a lot of factors including climate change. All provinces are affected including KwaZulu-Natal. Rural KwaZulu-Natal is facing a major problem in water scarcity and a problem in clean water that is safe to drink and irrigate crops (Thisani et al, 2017). The objective of this paper is to develop a solution to address this problem. The solutions thus investigated are of two types were the air is dehumidified and filtrated above ground level using electricity and another were air is dehumidified below ground level, using solar power during the day and battery stored energy at night. The cost of the product is estimated to be less than R10 000.00. The final solution to the problem was the dehumidify below ground level type of atmospheric water generator, that can produce water from water vapor. The atmospheric water generator is able to produce 23 l/day of water, but under unfavorable conditions, that is when temperature is below 15$^{o}$C combined with a relative humidity ratio of 65% or less, no water is produced.

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