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RESEARCHARTICLE OPENACCESS

Development of a Low-Cost Atmospheric Water Generator from Thin-Air Using Forced Convection System

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Abstract: On a global scale, water scarcity impacts 1.2 billion people or roughly a fifth of the world's population. Current water sources are depleting faster than they are being replenished in some areas, with the majority of this loss being used for irrigation and agricultural reasons. The atmosphere contains about 12870 litresof water vapour at any given time, enough to cover the entire Earth with one inch of water. Universal mechanical energy has gained much interest as a new sustainable energy source, and it has been successfully harnessed for a variety of technical uses.This Atmospheric Water Generator (AWG), as it is usually called, will convert water vapour into liquid water and is intended for use in agricultural and irrigation applications in areas where water is scarce. The concept is thatan air extractor, condensation device, and a heat exchanger are matched as a synchronous system to convert water vapour in the air into water. The machine cools and condenses the surrounding air using a forced convection electricity system to create a temperature gradient. By cycling a coolant that is cooled by a lower ground temperature, the heat exchanger principle operates.Theatmospheric water harvesting system's development process and working mechanism from thin air using forced convectionare tested. We then discuss different applications of the water harvesting machine. We conclude with the challenges and potential research directions in this emerging field.The major challenge is to design a cost-effective all-in-one solar or wind-powered that can capture water from the air, even when outdoor conditions are excellent, dry, and with low-intensity nature sunlight.

Keywords: Water Harvesting, Thin-Air, Forced Convention,Atmospheric water harvesting, AWG

1. Introduction

The long-term viability of future water supplies is critical because it is influenced by various factors such as population, affluence, and climate. The atmosphere contains roughly 13 thousand trillion litres of water in the form of vapour and droplets. [1] However, due to the low-density distribution of water molecules in the air, this vast amount of resource cannot be exploited directly as liquid water. Collection atmospheric water is an innovative and practical strategy for obtaining clean water in water-scarce areas [2]; functional materials and processes are essential for atmospheric water harvesting (AWH).[2]On a global scale, water scarcity is a crisis. Only 3% of the world's water is fresh, and two-thirds of that is frozen in glaciers or otherwise unavailable [4]. As a result, about 2.7 billion people have limited access to water for at least one month of the year [4]. If present water consumption rates continue, two-thirds of the world's population could suffer water shortages by 2025 [4]. Water shortages are frequently caused by a lack of humidity in the air (resulting in little rainfall) or by human activity disrupting the water cycle.

Some areas with high water stress are depleting present water sources faster than they are replenished, with agriculture accounting for most of this depletion. Seventy percent of the world's freshwater is anticipated to be utilised for irrigation [5]. The most severely affected regions are Africa, the Middle East, and Asia; nonetheless, even regions near the Midwest United States experience water shortages regularly [6]. To help solve the problem, an innovative solution must be created to ensure that enough water is delivered to the affected communities.The resolution of this dilemma contributes to one of the UN's eight Millennium Development Goals (MDGs), which were established during the Millennium Summit in 2000. The Millennium Development Goals (MDGs) were established to help people in the world's poorest regions improve their lives. Goal 7 focuses on maintaining environmental sustainability through the integration of sustainable principles, reversing environmental resource loss, and reducing the number of people without access to a sustainable water source [4]. The desire to aid in the eradication of global water scarcity necessitated the use of a renewable, long-term resource, and the answer was found in the atmosphere.

The atmosphere holds 3400 trillion gallons (12870 litres) of water vapour [1,5]. By developing a technology known as an atmospheric water generator, this replenishing resource provides the sustainable and inventive solution needed to help address this worldwide catastrophe. This system converts water vapour into a usable liquid form. At an example test environment of 75% relative humidity and 92°F with an average wind speed of 6 km/h, this prototype design is expected to produce enough water daily to cultivate vegetables and feed three households with water. The prototype building is intended to be scaled up for commercial use to produce more water. The device's efficiency is determined by the air conditions in the implementation region (in this case, Auchi, Nigeria, and day-to-day weather fluctuations. The end product is a working prototype that can take moisture from the air and convert it to valuable liquid water.The AWG was developed using the engineering design approach defined by Pahl and Beitz, which is discussed in greater depth later in this research [6].
The partial pressure of the vapour must equal the pressure of the liquid molecules on the water's surface for water vapour and liquid water to coexist under the same atmospheric circumstances [7]. If the partial pressure of liquid water is higher than the partial pressure of water vapour, the liquid water will begin to evaporate until the pressures are equal. When the partial pressures of the vapours are higher than the partial pressures of the liquid water, the vapour will begin to condense into liquid water until the pressures are equal.Temperature, specific volume, and pressure all influence the equilibrium points at different sites. These dynamic elements have a direct impact on air humidity in any location. For example, at a greater temperature, the air holds more moisture, affecting the humidity level in the area [8]. To extract water vapour from the atmosphere, various ways are used, including changing the pressure, volume, or temperature to force condensation within the system. Condensation is a forced natural phenomenon found in a variety of gadgets now on the market.

Condensation of air is incorporated into the design technology of air conditioners, freezers, and dehumidifiers. Some plants and animals, such as the Namibian Desert Beetle, use patterns of hydrophobic and hydrophilic surfaces to condense water on their own[1]. AWGs (atmospheric water generators) remove water from humid air by lowering the temperature below the dew point. AWG water vapour extraction uses passive methods (i.e., independent energy sources), although some of its processes demand significant energy input.AWG technology has been developed for either drinking or agricultural uses by companies like Skywater, Gr8water, and Airdrop Irrigation [9][10][11]. With only 416 watts of power, the Skywater design can create 1,135 litres of water each day [12]. The Skywater technology generates water by an adiabatic distillation process that collects water from the air using an electrical current [12,13]. Airdrop Irrigation, which is utilised only for agricultural reasons, is powered by solar and wind energy and pumps water collected through a semi-permeable hose to neighbouring plant roots [11,14,15,16].AWGs are often expensive, ranging from $300 to $16,000 on the market, and require additional operating costs because of the electrical power required [9][11]. Compared to other benchmarked devices, the AWG's goals are to minimise energy usage while maximising energy and a viable competitive option for consumers.

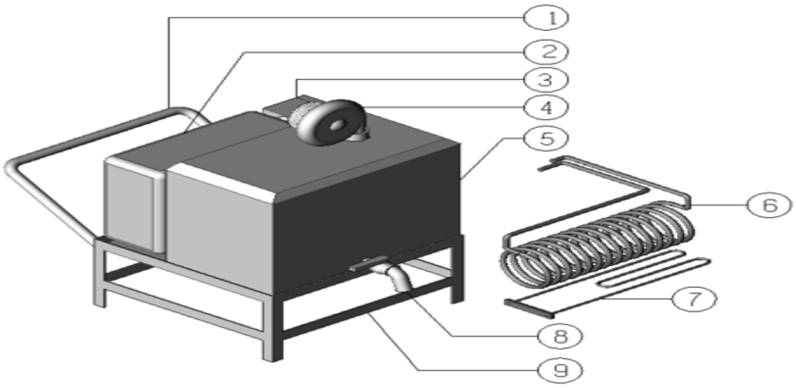
2. Materials and Methods

2.1 Design Concepts

The methodology adopted included:

a. Design and fabrication of the AWG system conceptconsisted of a fan, heat exchanger, air-cooling condenser and a blower.A mains supply powered the water harvesting system, and all the materials were locally gathered before the AWG was fabricated.The air-collector system help collect air from the atmosphere and transfer it to an interconnected fan and steel pipes partly attached to the tankadjacent to it by forced convection. The water harvesting device has a heat exchanger that aids the condensation process. A blower is attached at the top of the water collection tank to aid the rate of condensation. Figure 1 depicts the system's operation.

b. The theoretical design was then translated into a real-world design for the pilot-scale AWG system. The air collection and heat exchanger design utilise the natural colder temperature underground to cool moving air below the dew point and force condensation. The ground temperature acts as a constant colder passive source, lowering the design's energy consumption.



1	HANDLE
2	AIR UNIT
3	CONTROL PANNEL
4	BLOWER
5	WATER COLLECTOR UNIT
6	CONDENSER
7	HEATING ELEMENT
8	DISCHARGE OUTLET
9	FRAME SUPPPORT
ITEMS	**DESCRIPTION**

Figure 1: Isometric projectionof the AWG

2.1.1 Fabrication and Installation of the AWG System

This included: (a) allocating a fabricator to construct the AWG chambers and accessories; and (b)Some of the selected materials for the construction and fabrication of the water harvesting system, would comprise: Stainless Steel plates, stainless steel Pipes, PVC Pipes, Blower, mild Steel plates, Copper pipes, pressure hoses(flexible) and pressure pumps.

c:**Testing the System**

1. Evaluation of theair temperature, RH and waterharvestingefficiency were monitored and evaluated throughout the trial and testing periods.
2. Assessment of water quality and their characterisationwere obtained from the Oyo State Water Corporation and compared to other water samples controlled by conventional means.
3. The fabricated AWG system was installed at the MechanicalEngineering Technology Fluid Mechanics laboratory at Auchi Polytechnic for performance evaluation.

The main goals of testing were to determine how wellthe AWG met the system requirements, determine howadjustments made to the system affected the device's waterproducing capabilities, and better understand the processby which water is condensed from the atmosphere. Somerefinements using a blower over the heat exchanger were made to the device to createa larger volume of water at the same atmospheric conditions.The two significant refinements that were made throughout testing were changing the orientation of the AWG insidethe water collection chamber and adding a fan to the hot side of the device to remove hot air from the immediate area around the water tank.

2.2 Design process

The proposed solution to combat this global water crisis hasled to the testing of a prototype AWG. The concept uses a flow heat exchanger placed around condenser cooling to condense thewater vapour from the ambient air. The heat exchanger cyclesa coolant that is cooled by the internal temperatureof the system. Ambient air isdrawn down into a chamber containing the heat exchangerusing a fan. As the humid ambientair passes over the chilled heat exchanger, the water vapourwill condense to its liquid form to be used for variousapplications, such as agriculture.Figure 2 shows the projections of the water harvesting system and other parts. In future evaluations of the AWG, mathematical models will be used to determine the mostinfluential variables that would impact the quantity ofcollected usable water. The models were also used tocalculate an expected quantity of water that could becollected at various environmental conditions.

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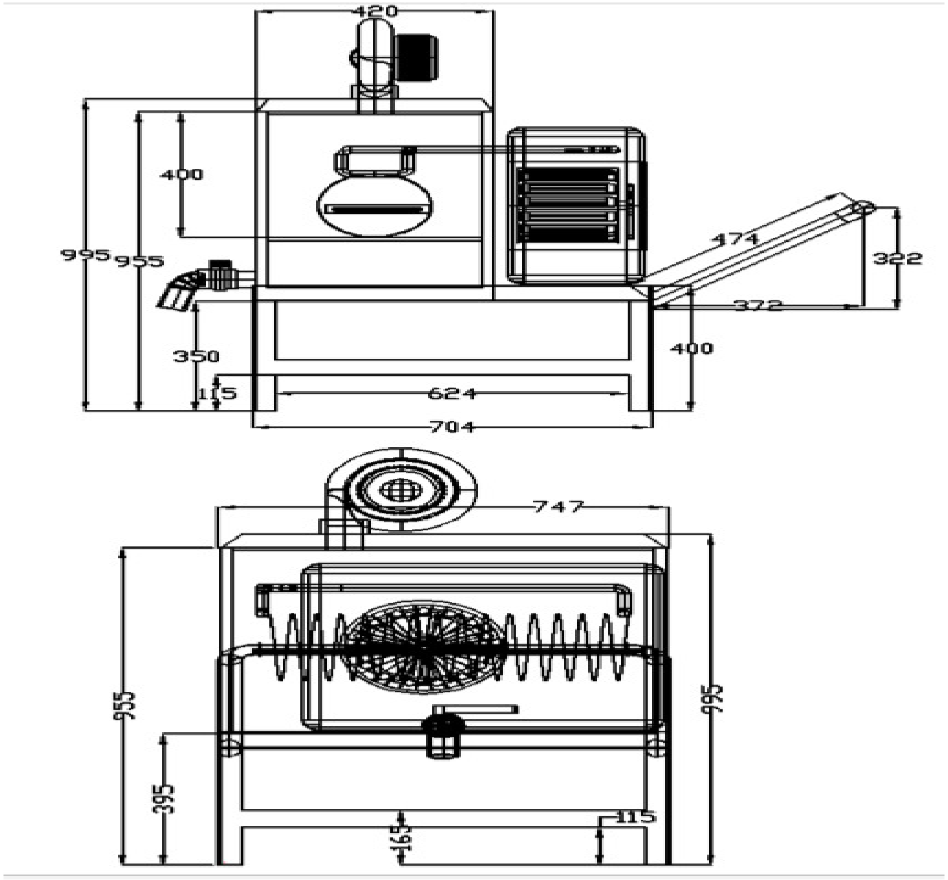

Figure 2. Diagram of the Pilot-Scale -AWG

3.0 **Results and Discussion**

3.1. **Performance Test**

The AWG using the heat exchanger concept was produced much later than anticipated. The higher relativehumidity indicates that more water was present on the heatexchanger side to be extracted than on the outside[16,17]. Further analysis on the concepts mustbe done to determine how well the AWG device performs.From the testing results, as shown in Tabe 1, the performance was measured of the AWG system.

TABLE I
EXAMPLE TRIAL: AVERAGE TEMPERATURE, HUMIDITY, AND VOLUME OF WATER COLLECTED FROM THE AWG

Testing Time	3 Hours	
Flow Rate	0.0065 m^3/s	
Inlet/Outlet	Inlet	outlet
Average Temperature (F)	92	149
Average RH (%RH)	89.9	144
Wate Collected (mL)	106.5	

As shown in Figures 1 and 2, the CAD drawings were necessary to test the fabrication concept to be adopted. Further tests and performance evaluations need to be carried out to compare and validate the quantity and quality of water generated.Further analysis of water harvesting technology need to be performed as a function of local requirements (electricity, water), available resources (solar irradiation, wind speed, air temperature, water quality) and techno-economic parameters (plant configuration, investment and operation cost, back-up fuel cost and other examples.) using annual yield simulations with hourly time steps. We intend to run our calculations based on the field test and data we gather from the selected sites. The levelized cost of electricity would be evaluated, and parametric tests carried out. The statistical tools proposed the is ANOVA and R.

4. **Conclusion**

In this work, we built an atmospheric water generator with a large capacity for capturing atmospheric water. The concept of a blower-heat exchanger allows for rapid moisture absorption kinetics. The AWG can quickly absorb atmospheric water, even in harsh, dry conditions; it has a large water storage capacity and uses very little electricity from the main supply. On the other hand, there is the need for Solar-driven vapour evaporation, which will necessitate the use of natural sunshine. At the open area beside the Fluid Mechanics Laboratory in Mechanical Engineering at the Auchi Polytechnic, AWG was successfully tested, and water was harvested from the air with the mains supply.Because following the rigorous project, the teamwill propose a fully functional andmanufactural design. The design is recommended wouldhave been pursued further given more allotted time.

5. **Recommendation**

Cost analysis, Failure Modes Effects Analysis (FMEA), Life Cycle Assessment (LCA), and performance assessment will all be covered in future works. Modifying the AWG prototype to enhance water output will also be part of the plan. Hydrophobic and hydrophilic surface patterns may boost water output efficiency without increasing energy consumption. Scaling up the designs has a more dramatic effect, but it may increase the water produced. The scaled model might have a bigger and better influence on communities than the existing prototype.

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