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Design of an all-weather water extraction system based on solar energy and diurnal temperature difference

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Abstract. According to the survey, the water content in the air is as high as 14,000 km^3. To make full use of the moisture retained in the air, we designed this all-weather water extraction system based on solar energy and the temperature difference between day and night. The system uses solar power panels to supply power to the micro-suction fan during the daytime, builds a condensation structure of "air-ground", and uses the natural temperature difference between day and night to condense water at night and store it in the buried water reservoir. Semi-arid areas have water demand and have the advantages of all-weather use, fast water extraction, low cost, and ease of promotion.

1. Background of the work

Water resources, the foundation of human development, are becoming scarce, and the increasing global scarcity of fresh water is not only a serious constraint on social and economic development but also an unprecedented challenge to human survival. Water resources exist on Earth in three forms: solid, liquid, and gas, and it is the liquid freshwater resources that are widely used by us. The amount of fresh water on the earth is only 2.53% of the total global water, of which 68.7% is solid glaciers, which are located in high mountains and polar regions that are difficult to use, and some of the freshwaters are buried deep underground and difficult to extract. With the deteriorating environment, these freshwater resources are becoming more and more scarce, especially in arid and island areas[1,2].

The atmosphere is rich in fresh water and is not limited by geographical area. It is estimated that the atmosphere contains about 14,000 km^3 of water vapor and the total amount of fresh water on the surface is only 1,200 km^3, but the utilization rate of fresh water in the air has been almost zero so far. The dry and early areas are suffering from water shortage due to too little surface and shallow groundwater, while the islands and coastal areas are suffering from insufficient freshwater resources due to excessive surrounding seawater and high salinity of surrounding waters[3,4]. The traditional methods to solve the freshwater supply problem in these areas include the transportation of freshwater and desalination of seawater. Transportation is costly and slow, while desalination technology and equipment are demanding and costly, which are not suitable for most poor and backward areas.

To solve the above problems of expensive transportation, slow speed, and high gloss, this system introduces a solar power supply module under the premise of ensuring low cost and good effect, and creatively uses the temperature difference generated by day and night for all-weather air-water extraction.

2. Design scheme

The system contains three major parts: air introduction, cold junction into the water, and water storage. The air introduction part includes solar panels, power transmission lines, micro-suction fans, anti-particle filters, etc[5]. The cold junction into water mainly contains the structure of the external soil layer in close contact with the cup, and the water storage depends on the structure of the cup with the design, as shown in Figure 1 below, and the schematic diagram is shown in Figure 2 below.

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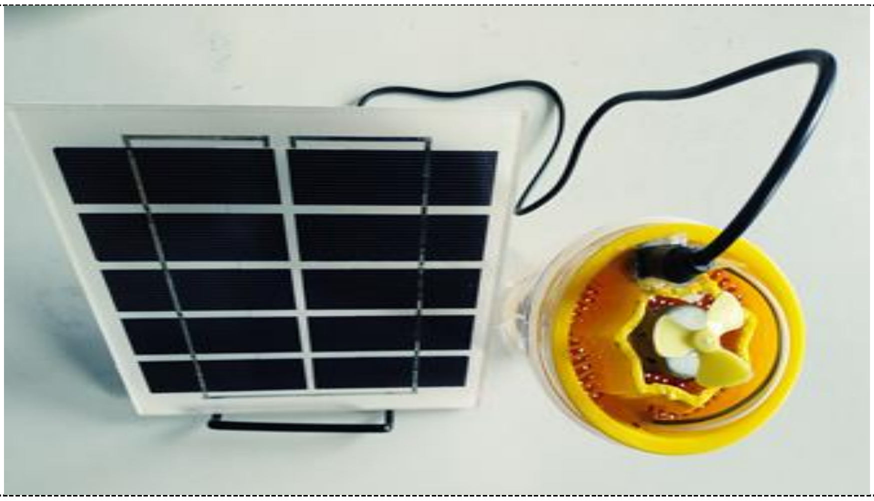

Figure 1. Physical diagram of the device.

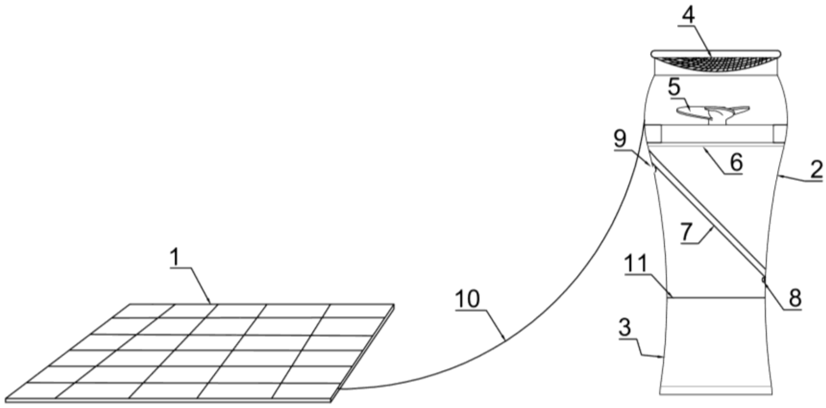

Figure 2. Schematic diagram of the device model.

3. System principle

This system combines two natural energy sources, solar energy, and temperature difference generated by day and night, to achieve all-weather air condensation into water. During the daytime, the system uses solar power panels to supply power to the micro-suction fan, and at night it uses the natural temperature difference generated by day and night to condense and take water and store it in the water reservoir. When the air is sucked into the system devised by the micro-suction fan, the larger ash particles entrained in the device are intercepted by the anti-particle filter at the top of the device and cannot enter the inside of the water cup, ensuring the cleanliness of the water source[6,7]. After contact with the cup wall, the temperature difference between the ground and the air will make the temperature of the air entering the cup drop quickly to the dew point temperature, and in the state of constant air pressure, the water vapor becomes dew droplets attached to the cup wall. As the air continues to inhale and discharge cycle, the water molecules collect more and more and eventually converge at the bottom of the cup to form a usable water source.

Before the system works, it is necessary to consider the size of the device and determine the horizontal diameter of the shaft, which can be dug into the ground to a depth of 1.5 meters. In fact, according to the literature survey and experiments, about 1.8 meters is the most suitable, when the shaft is not too deep, also conducive to the user to excavate, but also to ensure the basic temperature difference conditions for the condensation of moisture in the air. By constructing the "air-ground" condensation structure and keeping the shaft evenly up and down and in close integrated contact with the system device, the best water extraction effect can be guaranteed.

4. Experimental tests and analysis

4.1. Diurnal water production test

The water production experiments were also carried out for a week-long period during two time periods from 1.15 to 1.20, from 14:00 to 17:00 during daytime and from 20:00 to 8:00 on the following day, with the shaft depth set at 1.8m, for quantitative analysis in the spatial and temporal range, and the water extraction experimental data are shown in Figures 3 and 4 below.

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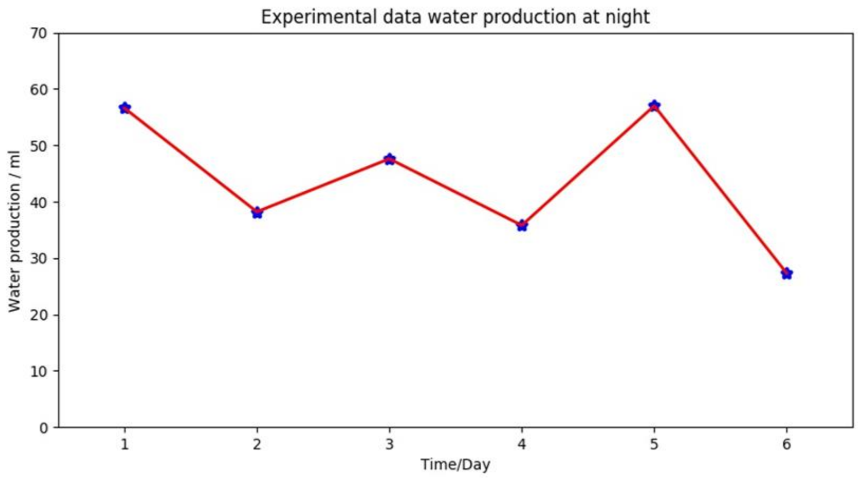

Figure 3. Data table of daytime water extraction experiment.

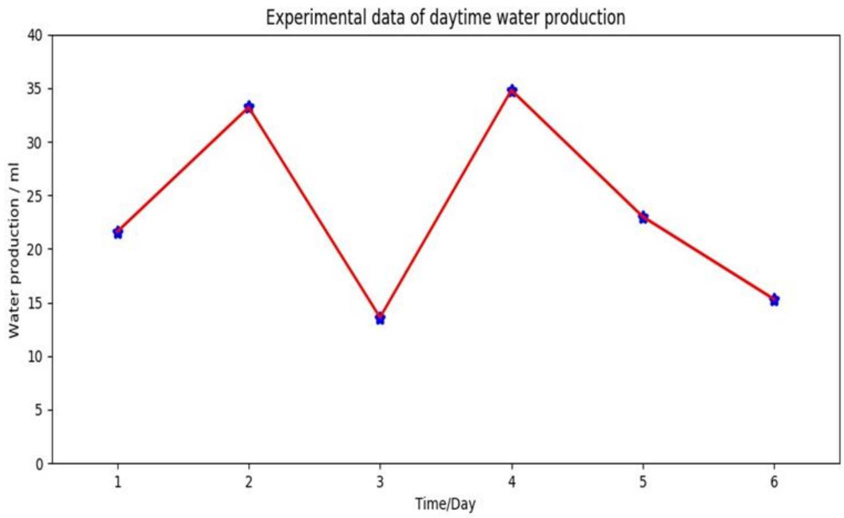

Figure 4. Experimental data table of water extraction at night.

4.2. Shaft depth test

Before assembling the complete system device, the principle was verified, the device model was constructed, and the water production results are shown in Figure 5 below, while trying to ensure that other conditions are the same, the vertical well depth gradient test (1 hour) at different depths was conducted in the experimental field in the new area of Southwest University of Science and Technology, and different water extraction amounts were obtained.

We analyzed the collected sample data to obtain the relationship between water extraction and shaft depth, as shown in Figure 8 below. The data was found to be quadratically distributed. Therefore, we further calculate the data, where we use the least squares method to fit and optimize by minimizing the squared difference loss, and the whole process is iteratively calculated by the unconstrained optimizer, which finally achieves a better fitting effect. Since this effect was achieved using only a two-function fit, there was no possibility of overfitting, so we were able to determine the correctness of the function, and the fitted image and equation are shown in (1) below, where Y represents the water production in milliliters and X represents the depth of the shaft in meters.

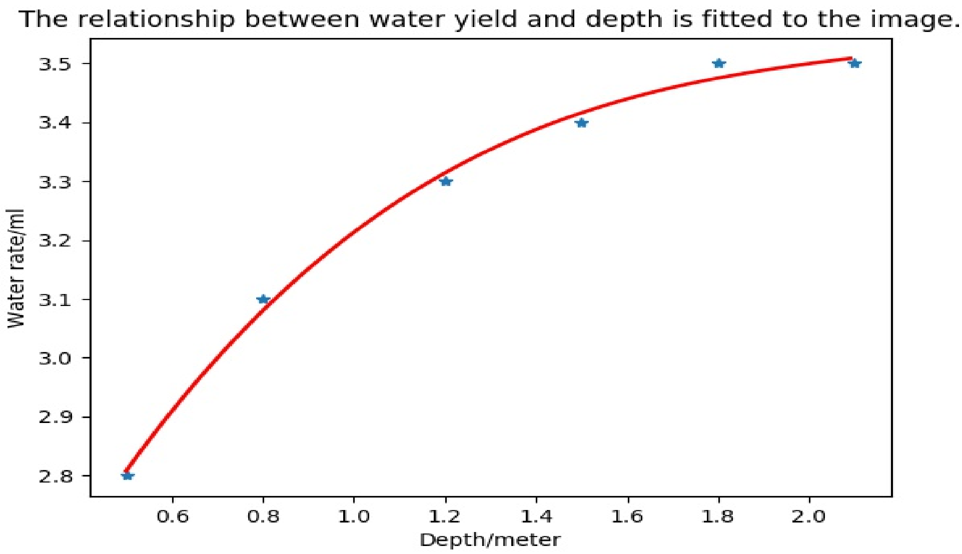

Figure 5. Relationship between vertical shaft depth and water production.

$$Y = 0.2221 * X^3 - 1.476 * X^2 + 3.445 * X + 4.234 \quad (1)$$

4.3. Social and economic analysis

It should be noted that the water extraction system is affected by the local weather, humidity, the size of the diurnal temperature difference, and other related factors, and is a typical multiple linear regression model problem, so the daily water production is not yet the same. It has been experimentally verified that the greater the diurnal temperature difference, the lower the degree of barometric pressure variation, and the higher the humidity at the location of the system installation, the higher the water production and storage efficiency[8,9].

From the social and economic point of view, the device can reduce the economic losses and energy losses in the process of inter-basin water transfer implemented in China to solve water resources problems, including the cost of transportation and use of energy, time costs, water supply costs, etc. If 1% of the population of Xinjiang uses the device in a year, for example, according to the research results of the average level of one day and night (24 hours) can produce 60ml of water to calculate: the device can achieve the production of water 6716000 liters, with fifteen years as a fixed depreciation period, so we can find that the device can be an average of 15% reduction of drinking water expenses for users. At the same time, the device for the macroeconomic and ecological environment is easy to foresee the great benefits. After promotion, it is conservatively estimated that it can reduce the burden of national environmental protection by about 8% and the high cost of construction and implementation of some inter-basin water transfer projects[10].

At the same time, the minimum daily water intake for travelers in a long-term water shortage environment is 300ml, while 80ml is sufficient to sustain life under extreme water shortage. It can be seen that the device also has greater value for travelers[11].

5. Innovations and Applications

5.1. Innovation points

- This system and its device have been strictly experimented with and rigorously analyzed by data modeling to prove its stability and feasibility. This system has been assembled and tested through many experiments and can work normally in long-term use to achieve good results in air-water extraction in arid and semi-arid areas, etc. After the end of the water extraction, after testing the water quality, it is found that the water quality is good and worthy of guarantee.
- Air for water, green energy. The combination of solar energy and day and night temperature difference two types of continuous natural energy, to achieve all-weather non-stop air-water production, fully saving manpower and material resources.
- Cold junction of the ground, gathered into water. Creative construction of "air-ground" condensation structure, the use of the difference between the ground temperature and air temperature, the air temperature transition to the dew point temperature, so that water condensation, environmental protection, no pollution, and no labor costs.
- Lightweight structure, easy to promote. The system contains a simple structure of the device, low cost, low weight, easy to assemble, gets rid of the traditional air water extraction device is

bulky and heavy, not easy to transport, and other problems.

5.2. conclusion

Air water technology for the lack of fresh water in the region to provide a new solution, current international air water technology has shown a product trend, the United States, Germany, Canada, Israel, and other countries have developed high humidity in the air used in areas of water extraction equipment, large, large-capacity water extraction equipment technology is rapidly developing, but also presents a system clumsy, bulky, unsuitable for carrying and promotion difficulties and other disadvantages.

This system and its device have been rigorously experimented with and rigorously analyzed by data modeling to prove its stability and feasibility. Meanwhile, this system has been assembled and tested through many experiments and can work normally in long-term use to achieve good results in air-water extraction in arid and semi-arid areas, etc. After the end of the water extraction, after testing the water quality, it is found that the water quality is good and worthy of guarantee.

The arid zone accounts for about 30% of China's land area, and its climate is characterized by low precipitation and high variability, generally large daily and annual temperature differences, evaporation greater than precipitation, low cloudiness, and strong sunshine. The all-weather water collection system based on solar energy and diurnal temperature difference developed by the project team is precisely for the arid and semi-arid regions of China, and creatively combines the above-mentioned climatic characteristics of sufficient daytime light and large diurnal temperature difference in these regions, and wonderfully uses the "air-ground" condensation structure to realize sustainable air-based water collection. The system is compact, low-cost, easy to assemble, and easy to promote and develop.

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