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Alternative Water Source: Concept of Atmospheric Water Generator using Wet Desiccation Method

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Abstract

An atmospheric water generator is a device which generates water from humid air. This project includes a wet desiccation method of atmospheric water generation. The wet desiccation method uses the desiccant to absorb water from the ambient air. The desiccant used was $CaCl_2$ salt which absorbs moisture from the atmosphere and gets converted into the brine solution. The water was extracted from the solution by the distillation process. From an experiment performed at the Chemistry Lab of Pashchimanchal Campus, it was found that 1.11 grams of $CaCl_2$ were able to absorb 1.37 grams of water. This report includes two experiments. The pH range of water collected in the first experiment is 3 to 4 and the pH, TDS and hardness of water collected by partial distillation in the second experiment are 7.41, 61 ppm and 26 ppm respectively whereas the pH of water collected after complete crystallization of salt in second experimentation was 5.65. It was found to be the presence of HCl acid in the solution, which was partially removed by evaporating it in an open atmosphere. It was concluded that the calculated amount of $NaHCO_3$ can completely neutralize it.

Keywords: Atmospheric Water Generator; Crystallization; Distillation; Wet Desiccation

1. Introduction

Many countries are facing a water crisis currently due to inefficient use of water in different fields such as agriculture, industries and domestic activities [1]. Since the water vapour of volume 14,000 km^3 is presented in the atmosphere, enormous attempts have been done for extracting water from the air [1]. It was studied that the production of freshwater by the liquid desiccant method was possible to obtain 1.90 kg/m^2 of water at a given set of operating conditions [2]. The atmospheric water generator (AWG) is a potential solution for water scarcity and is becoming popular [3]. Among various types of atmospheric water generators, in the wet desiccation method, a desiccant is exposed to atmospheric air during the night where it absorbs the water vapour present in the atmosphere and water can be extracted by heating [4].

The minimum relative humidity for higher efficiency of the thermoelectric method, compression refrigeration method and wet desiccation method at which water can be generated are 50%, 40% and 20% respectively [5-6].

2. Methodology

There are different steps involved in the design and fabrication of atmospheric water generators which are shown in figure 1.

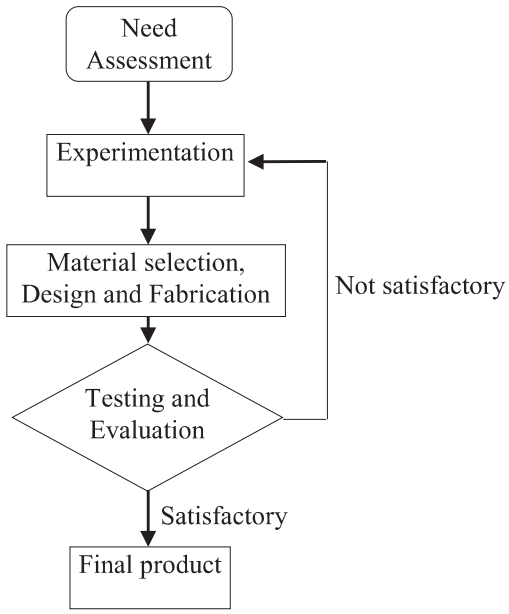

Figure 1: Steps involved in mechanical system design

2.1 Need Assessment

Today, more than 1.7 billion people live in river basins where depletion from use exceeds natural renewable capacity, a trend that will leave two-thirds of the world's population living in struggling countries [7]. In the case of Nepal, according to the Department of Water Supply and Sewerage, although about 80% of the total population has access to safe drinking water, it is not safe. One reason for this is that surface water

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and groundwater in cities are degraded by natural and human pollution [8].

2.2 Experimentation

In order to extract water from the atmosphere, we have performed two experiments to know the water-absorbing capacity of calcium chloride crystals at the chemistry lab of IOE, Pashchimanchal Campus, Pokhara. The chemical equations involved in experimentation are as follows:

$$CaCl_2 + 6H_2O \longrightarrow CaCl_2.6H_2O \quad (1)$$

$$CaCl_2 + H_2O \longrightarrow CaO + 2HCl \quad (2)$$

$$CaO + H_2O \longrightarrow Ca(OH)_2 \quad (3)$$

Theoretically, 111 grams of 100% pure $CaCl_2$ absorbs 6 molecules of H_2O. It reacts with absorbed water to form 56 grams of CaO which further absorbs 1 molecule of H_2O.

2.3 Material Selection, Design and Fabrication

The design of the prototype consists of the base plate, dome, insulation disc, condensing pipe, heater and collecting beaker. The base plate is made up of borosilicate glass which does not react with brine solution, polypropylene plastic is chosen for the dome. and an insulation disc of wood and galvanized sheet is placed between the electric heater and plastic dome. Copper is used for condensing pipes and GI sheet fins are attached to the condensing pipe to enhance the condensation rate, as shown in figure 2.

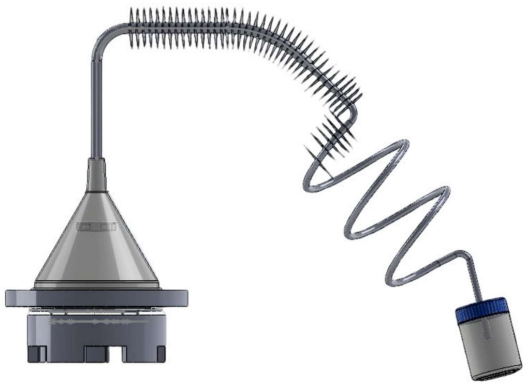

Figure 2: 3D model of AWG prototype

3. Results and Discussion

After experimentation, it was found that 1.11 grams of 90% pure anhydrous $CaCl_2$ absorb 1.37 grams of water with a 20.8% error due to impurities from the surrounding. After complete distillation, out of 23.27 grams of solution, only 11.37 grams of water was obtained. It means only 0.2578% was lost in the complete process and if total losses were neglected, 81.17% of the weight of $CaCl_2$ was recovered. On testing pH value, the extracted water was found to be acidic with a pH range between 3 and 4. The extracted acidic water was neutralized by adding a calculated amount of $NaHCO_3$. The collected water by partial distillation from the second experimentation was found to have a pH value of 7.41 i.e neutral in nature, TDS of 61 ppm and hardness of 26 ppm. The water obtained from complete distillation was found to have a pH value of 5.65.

4. Conclusions

The overall conclusions are:

1. Wet desiccation method is best suited for a relative humidity of 20% and above.
2. 90% anhydrous $CaCl_2$ can absorb up to seven molecules of water i.e 102.16% of its weight but by experiment, it was found that desiccant is able to absorb 123.42% of its weight and such a high error percentage was due to impurities present in the atmosphere and a small amount of salt taken for the experiment.
3. According to National Drinking Water Quality Standards (NDWQS), 2062, the range for pH is 6.5 to 8.5, TDS is <1000 ppm, and total hardness is <500 ppm. Hence, the water collected from partial distillation satisfied the NDWQS parameters of pH, TDS and hardness.

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