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EXPERIMENTAL STUDY OF ATMOSPHERIC WATER HARVESTING BY SINGLE SHELF STAINLESS STEEL PYRAMID SYSTEM

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ABSTRACT

In recent decades, as a result of climate change and mismanagement, water scarcity and drought have become more frequent, affecting both humans and biodiversity drastically. Alternative, new technologies were urgently needed to overcome the rapidly increasing global water scarcity. Atmospheric dew water is a potential source of potable water, as the earth's atmosphere contains thirteen thousand trillion litres of fresh water (98% in a vapour state). The stainless steel single-shelf solar pyramid system was here to extract water from the atmospheric air by using different types of hygroscopic materials placed on the shelf. The hygroscopic materials are silica gel, calcium chloride, and rice. The pyramid sides were opened at night to allow the moist air inside from the atmosphere and closed during the day to extract the moisture from the material by solar radiation. The experimental study was investigated to study the effect of the stainless steel pyramid shape on the absorption and regeneration processes. Preliminary results have shown that the calcium chloride absorbs more water from the atmosphere as compared to the silica gel and rice.

Keywords: Dew point, Hygroscopy, Deliquescence, Condensation, Dew harvesting, Regeneration.

1. INTRODUCTION

Water is one of the natural resources, which are found in an adequate amount. It is an essential source for the existence of life on the planet earth. It is widely used for various purposes such as drinking, washing, bathing, cleaning, cooking, irrigation, and other industrial and domestic uses. Water is a precious natural resource. All living things need water for their survival. We cannot imagine life without water. Let it be animals or plants they require water to complete their daily metabolic activities. Plants require water to synthesize their food from the process of photosynthesis. We all can live without food for days together but cannot even imagine surviving without water; even plants become dry and shed their leaves without water.

Water covers about 2/3 of the Earth's surface, but most of it is too salty to be used by humans for food or agricultural. Water covers about 71% of the earth's surface. About 97% of the earth's water is found in the oceans.3% of the earth's water is fresh. 2.5% of the earth's fresh water is unavailable (locked up in glaciers, polar ice caps, atmosphere, and soil; highly polluted; or lies too far under the earth's surface to be extracted at an affordable cost). If the world's water supply were only 100 litres, our usable water supply of fresh water would be only about 0.003 litre. Water plays an important role in the world economy. Approximately 70% of the freshwater used by humans goes to agriculture. Fishing in salt and fresh water bodies has been a major source of food for many parts of the world, providing 6.5% of global protein. The presence of water on earth is essential for the development and sustenance of life. Water is important because it is the basis of all forms of life and without this valuable resource the Earth would not exist. The daily life itself and conduct of the simplest actions require the use of water; just think of the use made of it in the field of agriculture and industry. Around 60 percent of our body is made up of water and we can only live three to five days without fluids. Water plays many important roles in the body including flushing waste from the body, regulating body temperature, transportation of nutrients and is necessary for digestion.

The global demand for clean water has been on the increase, and the shortage of drinking water, especially in arid regions, is a major global challenge, threatening sustainable development and human health. In its last report, the World Economic Forum listed water crises as one of the top five global risks to man worldwide. Water scarcity has become a serious global issue which may lead to severe consequences on both natural environment and human society such as crop production reduction, drinking water shortage and water quality degradation. Water scarcity is an increasing problem on every continent, with poorer communities most badly affected. By 2025, two-thirds of the world’s population may face water shortages. Water scarcity is not only about human demand. When freshwater is in short supply, entire ecosystems suffer. Solutions for water scarcity are based on various water-saving strategies, reclaiming of used water, and water production. Four billion people almost two thirds of the world’s population experience severe water scarcity for at least one month each year. Some 700 million people could be displaced by intense water scarcity by 2030. By 2040, roughly 1 in 4 children worldwide will be living in areas of extremely high water stress.

Humidity is the concentration of water vapour present in the air. Water vapour, the gaseous state of water, is generally invisible to the human eye. Humidity indicates the likelihood for precipitation, dew, or fog to be present. Absolute humidity is the actual amount of water vapour present in the air. It does not take temperature into consideration. The relative humidity is a percentage of amounts of moisture the air could possibly hold, if the temperature goes up the relative humidity goes down and vice-versa.

The dew point is the temperature the air needs to be cooled to (at constant pressure) in order to achieve a relative humidity (RH) of 100%. At this point the air cannot hold more water in the gas form. Colder air is less able to hold water vapour than warm air .This forces water vapour in the air around cooling objects to condense. When condensation happens, small water droplets form dew. The temperature at which dew forms is called the dew point. The earth’s atmosphere is a huge and renewable water resource, containing approximately 12,900 billion tons of fresh water 98% vapour and the rest in a condensed state (clouds and fog).

The term hygroscopic refers to a matter's ability to hold, adsorb and attract water from the surrounding environment. Typically, this process occurs near ambient or room temperature. Hygroscopy is the ability to attract and hold the water. Deliquescence is the process by which a substance absorbs moisture from the atmosphere until it dissolves in the absorbed water and forms a solution. If a hydroscopic substance absorbs so much of moisture that an aqueous solution is formed then the substance becomes deliquescent. Hygroscopic absorbs water and becomes clumpy. Deliquescent absorbs water and dissolves into it (becomes liquid) Almost all soluble salts are deliquescent. Hygroscopic substances include rice, straw, silica gel, calcium chloride, saw dust, metal organic framework (MOF), ethanol, methanol, sulphuric acid and wood.

In nature, in the same way as the plants, insects learned to adapt and survive in arid and semi-arid areas of the planet. Few examples of such animals and insects

Beetles in Namib Desert: One of the best examples of fog and dew harvesting in nature can be found in some beetle species living in the Namib Desert in Africa. In both cases of beetles either collecting dew or fog, they use their body surfaces which consists of complex nano and micro structure with different hydrophobic and hydrophilic properties for condensing and transporting the water to their mouth.

2. MATERIALS

- **Stainless Steel**

Stainless steel is really easy to clean and sanitize. Stainless steel is an alloy of iron that is resistant to rusting and corrosion. Grade 304 stainless steel is generally regarded as the most common austenitic stainless steel. The high amounts of chromium and nickel give 304 stainless steel excellent corrosion resistances. Stainless steel keep your cold region cold and also hot region hot for hours, making them the perfect choice for any season or environment.

- **Hygroscopic materials:**
  - **Rice**

Rice is a hygroscopic grain which adsorbs or desorbs moisture depending on its ambient environment. Moisture desorption is associated with rice drying. Besides its rich nutritional value, there is a common conception that rice can also be used as a moisture absorber and drying agent. If after accidentally soaking your cell phone, camera, or charger in water, there is a good chance that you will find someone, family member, friend or someone on the web, recommending putting the device in a bowl of uncooked rice and leaving it there for at least 24 hours.

  - **Calcium Chloride**

Calcium chloride is an inorganic compound – a salt with the chemical formula $CaCl_2$. It is white flakes or pellets at room temperature, and is highly soluble in water. Calcium chloride desiccant absorbs more moisture when the relative humidity (RH) of the surrounding air is higher and its absorption increases exponentially as RH rises, which is a remarkable result compared to other desiccants like silica gel and clay. Calcium chloride is applied as the working desiccant in this investigation.

- **Silica Gel**

Silica gel is made of sodium silicate, comes in bead or granular form and attracts and removes moisture from the air. Most often sold in small packets .Silica gel is a hygroscopic material used for maintaining dryness. For manufacturers, the purpose of silica gel is to be used as a desiccant. Silica gel also serves to keep the relative humidity inside a system of satellite transmission wave guide as low as possible. In compressed air systems of any industry, silica gel is also used to dry the air. The silica gel beads are used for adsorbing the amount of moisture present in the air and preventing it from damaging at the point of use of the compressed air due to condensation. A similar kind of system is used for drying the compressed air on railway locomotives. Silica gel has water absorption properties because of this property; it is used in domestic water filters. Some minerals that are dissolved in water can be absorbed by the surface structure of silica gel.

- **Condenser Material**

Most condenser and evaporator coils used today are made of copper tubes and aluminium fins. The condenser coil can be made of copper tubing with aluminium fins or all-aluminium tubing so heat can be rapidly transferred.

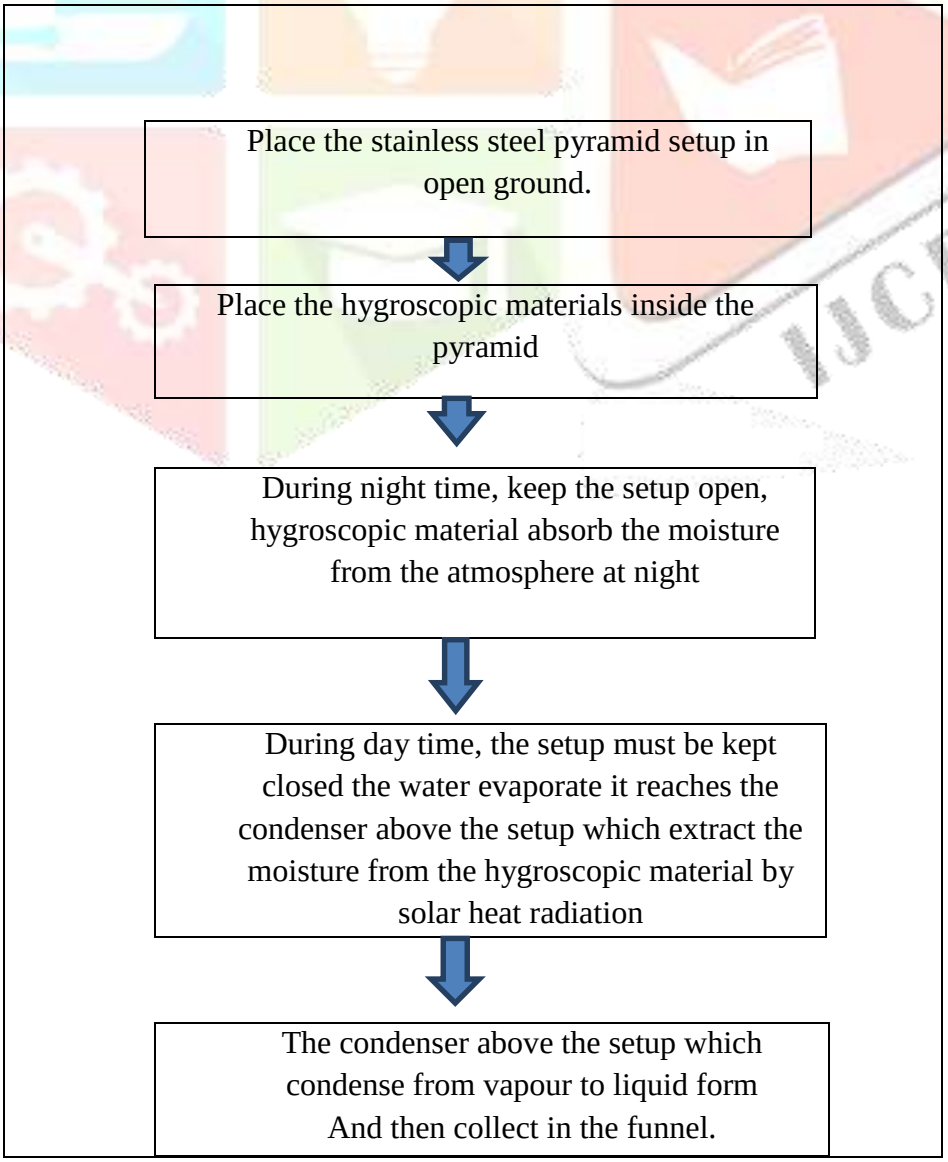
- **Copper**

It means copper both heats up and cools down faster than other heavy metals. Hence, in terms of actual usage, copper condenser air conditioners provide faster cooling. Fortunately, almost all big brands have AC models that have a copper condenser. Copper has better heat transfer efficiency, and durability, and is easy to maintain. It ensures faster cooling and longer life of the air conditioner.

- **Aluminum**

Aluminium offers better bending abilities and you can bend it easily in your desired shapes. In terms of money, copper is a bit costlier than aluminium. While making an AC, the amount of copper required to make a condenser coil is thrice of that required to make aluminium coils of the same size and shape. This has a direct impact on the overall cost of the air conditioner. Hence, ACs with copper coils is costlier than the ones with aluminium coils.

3. Experimental Setup & Methodology



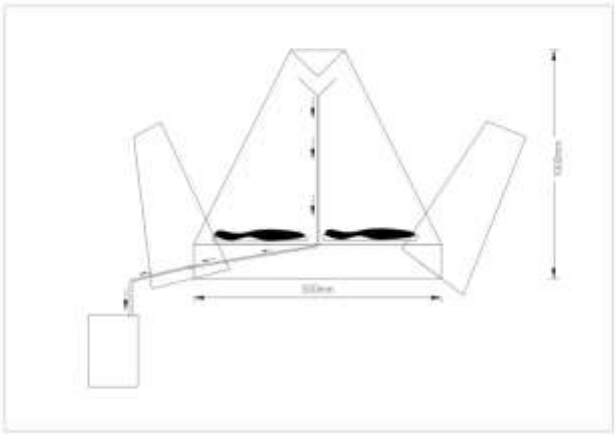


Fig 1 Experimental setup

Fig 2 Single shelf stainless steel pyramid system (closed)

Fig 3 Single shelf stainless steel pyramid system (opened)

The main concept is precipitation process. A pyramid quadratic shape solar system with four faces and square base is used in our experimental work. The pyramid structure is built of stainless steel faces. The sides of the pyramids are covered with stainless steel. Inside the pyramid, there is a perpendicular pipe in the middle to collect water. Also, the shelves are folded on the steel corners inside. A preparation of steel sheet and bolts is made to fix precisely. Also, a piece of rubber is inserted between the Stainless steel faces and steel frame of the pyramid to prevent vapour leak. The height of the pyramid is 100 cm. The base of the pyramid is 50 cm * 50 cm. Single shelf inside the pyramid, where the hygroscopic material will be placed. The arrangement will be provided to the whole pyramid assembly for easy mobility. At night, the sides of the pyramids are opened and the hygroscopic material which is placed on the shelf absorbs the moisture from atmospheric air. After sunrise, as the day becomes warm, the sides will be closed again. The solar radiation passes through the pyramid raising the internal temperature and causing the moisture that was absorbed in the material to evaporate. The vapour rises to the top of the pyramids, where it condensates into droplets. Also some of this vapour will condense at the inside surface of the pyramid sides. The collection of atmospheric water from inside of the hygroscopic material and the amount of water harvested from the atmosphere will be measured and compared with different hygroscopic material such as silica gel, calcium chloride and rice.

4. Results and discussions

The objective was to study the performance of the Single shelf stainless steel pyramid system, i.e. the effect of this single shelf stainless steel pyramid system extract water from the atmospheric air. The proposed system has a higher productivity for the following reasons:

1. Higher effective shape area,

2. Employed higher regeneration and absorption system area due to the Single shelf used,

3. Four sides moisture extracting at night compared to other systems one-sided moisture extraction.

The temperature difference between the four sides of the stainless steel pyramid is small. Here the hygroscopic materials used for this experimental work are rice, calcium chloride and silica gel. These results are recorded in a typical experimental day.

The below two graph represents the all hygroscopic materials experimentally tested for 30 days, 10 days each material which as 5 days tested weigh of 500 grams and 5 days tested for 1 kilogram of hygroscopic materials.

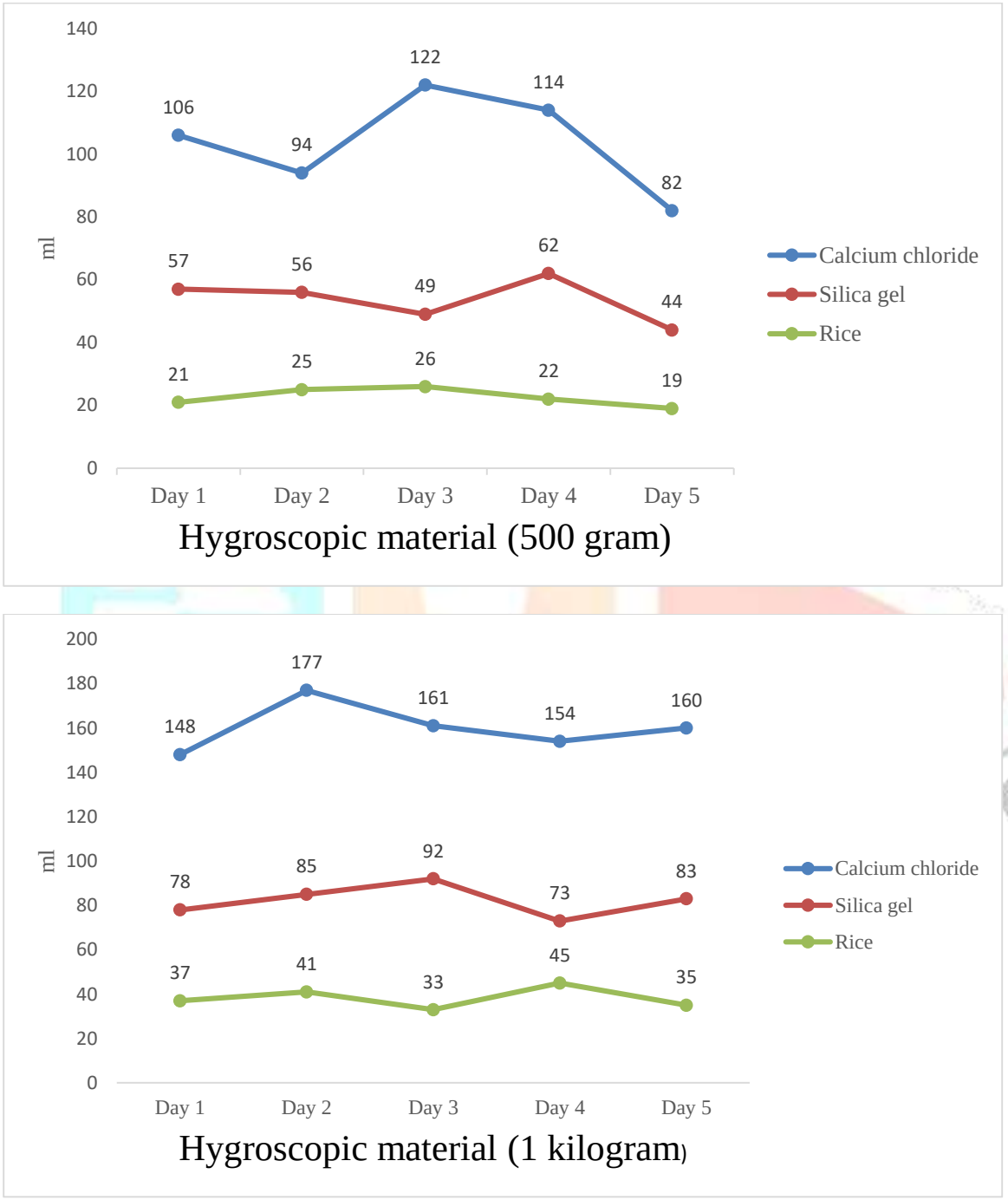


Fig 4 (a) & (b) Hygroscopic material for 500 gram and hygroscopic material for 1 kilogram

5. Conclusions

Experimental study of atmospheric water harvesting by single shelf stainless steel pyramid system has been designed, constructed and experimentally tested. Silica gel, Calcium chloride, rice which are the materials applied as the hygroscopic material in this experiment. The calcium chloride is a Deliquescence which means when it absorb water from the atmosphere it formed as a solution (it change its physical state) the rice and silica gel are hygroscopy means it does not formed as a solution (it does not change its physical state). The average results for the experimental work of hygroscopic materials silica gel, calcium chloride and rice was 53.6 ml/day, 103.6 ml/day and 22.6 ml/day for 500 gram of material and 82.2 ml/day, 160 ml/day and 38.2 ml/day respectively. When compare to silica gel and rice, the calcium chloride absorb more atmospheric water. The outdoors experimental results during sunny day's highest amount of water produce from the calcium chloride reached the average about 101.6 ml/day for 500 grams and 160 ml/day for 1 kilogram.

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