ATMOSPHERIC WATER HARVESTING - A REVIEW

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ABSTRACT

Nowadays, atmospheric water harvesting (AWH) became very essential to provide fresh potable water. Atmospheric water is a source of fresh water with 13000 trillion litres availability of water at any time and can be utilized in overcoming water shortage, especially in arid and rural areas. Mainly, the two most common methods have been used for the extraction of atmospheric water. First, the ambient air is cooled below the dew point temperature, and second in which the moisture in atmospheric air is adsorbed/absorbed using desiccant materials. The scope of this paper is to review different types of sustainable water harvesting methods from the atmospheric fogs and dew. In this paper, we report upon the water collection performance of various fog collectors around the world. The key target in all these approaches is the development of an atmospheric water collector that can produce water regardless of the humidity level and low in cost and can be made using local materials.

Keywords: *Atmospheric water harvesting, Bio-mimicry, Relative humidity, Water scarcity, Desiccant, Atmospheric water generator, condenser.*

1. INTRODUCTION

One sq.km of atmospheric air contains 10,000 to 30,000 m3 of pure water. Water is second to oxygen as being essential for life. People can survive days, weeks, or even longer without food, but only about four days without water. Globally, at least 2 billion people use a drinking water source contaminated with faeces. Microbial contamination of drinking-water as a result of contamination with faeces poses the greatest risk to drinking-water safety. Drinking water is never pure. Water naturally contains minerals and microorganisms from the rocks, soil, and air with which it comes in contact. Human activities can add many more substances to water. But drinking water does not need to be pure to be safe. In fact, some dissolved minerals in water can be beneficial to health. Four billion people almost two thirds of the world's population experience severe water scarcity for at least one month each year. Over two billion people live in countries where water supply is inadequate .Half of the world's population could be living in areas facing water scarcity by as early as 2025.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.

Globally, the number of people lacking access to water is 2.1 billion, while 4.5 billion people have inadequate sanitation and clean water source. The latter, has led to risk of infected by diseases, such as cholera and typhoid fever and other water-borne illnesses. As a result, the world has witnessed 340,000 children under five die each year from diarrheal diseases alone. Clearly, water scarcity is an issue requiring urgent action. The situation is exacerbated by climate change causing rainfall patterns to change with some areas already experiencing prolonged droughts.

Worldwide, many methods have been used to harvest water Such as through water desalination, ground water harvesting and rain water collection and storage. Obviously, for these to work liquid water must already be available, but when such supplies are limited, harvesting atmospheric water becomes essential. There- fore, not surprisingly, it is now receiving considerable attention from researchers worldwide. This paper reviews this work, discussing the various water harvesting technologies and their performance, both theoretical and experimental. Commercialized atmospheric water harvesting technologies are also described. We hope this review will help new workers wishing to enter this important field by providing introduction to state-of-the-art technologies and inspire them to develop their own ideas for innovative and sustainable atmospheric water harvesting technology. We believe that general readers, with an interest in the welfare of 'water poor' people, will also find this paper useful by showing how emerging water harvesting systems can contribute to improve living standards.

The first category is harvesting water from fog, i.e. a visible cloud water droplets or ice crystals that are suspended in the air at or near the Earth's surface .Next categories are extract water from the atmospheric air by hygroscopic materials like $CaCl_2$, Silica gel, MOF (Metal Organic Framework), Zeolite and Atmospheric water generator.

2. BIOMIMICRY: WATER-COLLECTION INSPIRED FROM NATURE

Nowadays, water shortage is a severe issue all over the world, especially in some arid and undeveloped areas. Interestingly, a variety of natural creatures can collect water from fog, which can provide a source of inspiration to develop novel and functional water-collecting materials.

2.1 Namib Desert Beetle (*Stenocara gracilipes*)

The Namibian desert beetle is a species of insect that lives in the Namib Desert (fig 1), which is coastal to the Atlantic Ocean in South Africa. Namib Desert is one of the most arid regions of the world. To survive in the arid wilderness of south western Africa, the Namib Desert beetle harvests water from thin air. The blueberry-size, long-legged insect leans its bumpy body into the wind, letting droplets of fog accumulate and drip down its wing case into its mouth. When the Namib Desert beetle (*Stenocara gracilipes*) "fog basks", water droplets hit its abdomen and roll down its body. The Namibian desert beetle drinks by separating water particles that are infrequently found in the system from air and wind. This water collection process can be carried out in the most basic principle thanks to the unique structure of the back. There are mounds and cavities scattered randomly and irregularly on the back of the beetle. These gaps extending between the toppings are covered with a material exhibiting similar properties with wax. The characteristic of this material is its effective transmission by pushing the water. On the other hand, the hills are covered with a material that is water-absorbing (hydrophilic). With this feature, water is collected in the most efficient way. The insect rises above the hind legs in the fog, turning the head in the direction in which the wind comes, and secures the body at forty-five degrees. Thanks to this posture, the water particles in the system hit the back of the beetle with the effect of the wind and stick to the hydrophilic hills. When the water grains adhered to the overheads reach a self-weight, they begin to slip towards the slopes and reach hydrophilic spaces. Water droplets descending into these cavities are being rolled towards the mouth of the beetle under the influence of hydrophobic structure and gravity so that the insect meets the water that is needed.

Fig 1 Namib Desert beetle

2.2 Thorny Lizard

Moloch horridus, also known as the thorny devil lizard (fig 2), is a species of lizard that lives in arid regions in Australia and has extraordinary ability to meet its water needs. This type of lizard can cope with thirst by acquiring the water in the air, water deposits and wet sand with superior techniques through its unique structure in arid climates .Moisture-harvesting lizards, such as the Australian thorny devil *Moloch horridus*, have remarkable adaptations for inhabiting arid regions. Their micro-structured skin surface, with channels in between overlapping scales, enables them to collect water by capillarity and passively transport it to the mouth for ingestion.

Fig 2 Thorny Lizard

ATMOSPHERIC FOG HARVESTING

Beetle-Inspired Bottle (Dew bank) [19] (fig 3) which is made of stainless steel metal is used for extracting water from the atmosphere because during the night time surface become colder than air. The metal is in the shape as hemisphere with uneven form creates more dewdrops by widening superficial area of air and also contain narrow gap with the size to permit only water drops prevents the contamination by foreign materials and protect waters from wildlife. The stainless steel gathers water from air which is rolled to the lower part along slope surface by generating dew drops. The dew bank bottle is inspired from the insect called African Namibian desert beetle which collects water from the atmospheric air by perching in an opportune position that allows dew droplets to collect in ridges on its back.

Fig 3 Dew Bank [19]

The collection of fog water [12] (fig 4) is a simple and sustainable technology to get hold of fresh water for various purposes. In areas where as substantial amount of fog can be obtained, it is feasible to set up a stainless steel as well as black double layer plastic mesh structure for fog water harvesting. The mesh structure is directly exposed to the weather and the fog containing air is pushed through the active mesh surface by the wind. Afterward fog droplets are deposited on the active mesh area which combines to form superior droplets and run down into a gutter to storage by gravity.

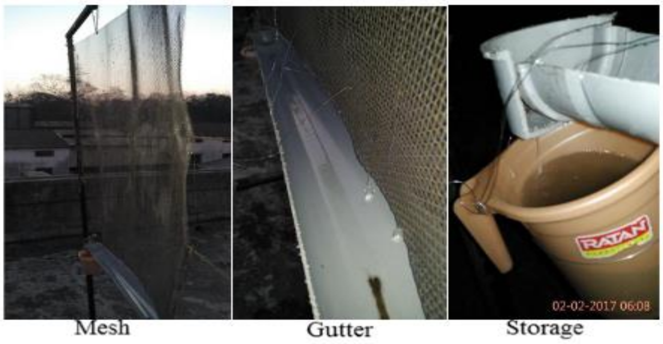


Fig 4 Fog Water Harvesting [12]

Pawar *et al.,* "Experimental Study Of Fog Water Harvesting By Stainless Steel Mesh" have been reported that The maximum water collected was 2.0 –3.70 L /m^2/day and average drinking water requirement for a human is 2.5 –3.0 L per day per person.

A design of fog collector has been designed by Choiniere-Shields [22] (fig 5). The concept of cloud harvester is based on a fog catcher that turn the condense fog into water droplet. The design of cloud harvester uses stainless steel mesh for the water collection. The Stainless steel mesh kept outside during night time, the metal surface becomes colder than air. The fog on the atmospheric air gathered on the stainless steel mesh collect on water storage container. The Fog harvester has a potential water harvesting output of one litre of fresh water per hour for each 10 square feet of mesh.

Fig 5 Fog Water Harvesting by Stainless Steel Mesh [22]

3. ATMOSPHERIC WATER HARVESTING

3.1 Review of $CaCl_2$ and its comparison materials

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.

3.1.1 Glass pyramid collector

A.E.Kabeel *et al.,* described a glass pyramid shape with a multi-shelf solar system to extract water from atmospheric air collector with desiccant beds [6] (fig 6) contain saw dust and 30% saturated concentrated calcium chloride cloth bed on shelves and a wall built of aluminium and glass faces the glass is 5mm thick which is slanting like pyramid and a collection cone at the top and a condenser section mounted on top of the pyramid, shading it from solar radiation. The height of the pyramid is 160cm, and the base is 100cm x 100cm. The covers over the beds are open overnight so the desiccant can absorb water vapour from the air. During the day, the covers are closed so the beds are heated by solar radiation driving off the absorbed water, which condenses on the sides and especially at the pyramid top, where it is collected by a central cone and flows through a tube to an external container. The reported water yield is 2.5 $l/day/m^3$; the cloth bed showed better performance than the sawdust bed system.

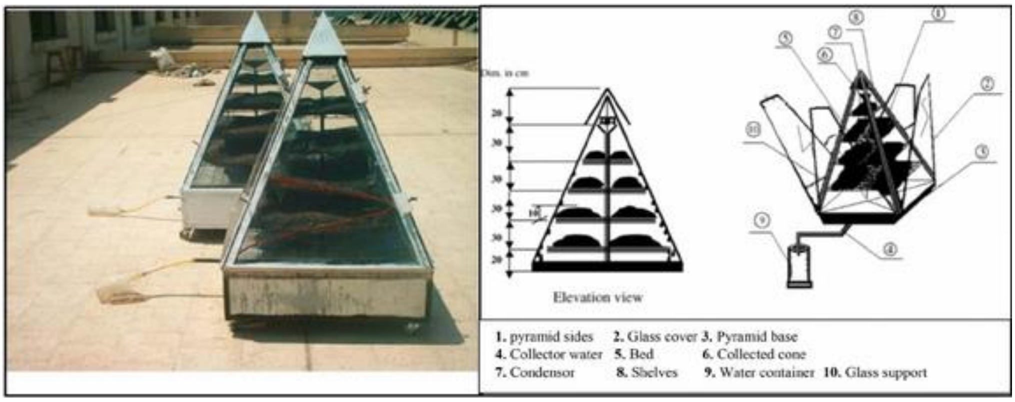


Fig 6 Glass Pyramid Shape with a Multi-Shelf Solar System [6]

3.1.2 Trapezoidal prism solar collector

William *et al*., designed a trapezoidal prism solar collector with four sides with $CaCl_2$ as the desiccant supported on sand and on dark cloth [17] (fig 7). The height of the collector is 1800 mm and the base dimensions of the test rig are 1000 mm × 1000 mm. The trapezoidal prism worked in essentially the same way as the pyramidal system described above in that moisture absorption occurred at night time and the solar radiation driving off the absorbed water during the day with the evaporated water forming water droplets that collected in the water tank. The fibre glass bolted to aluminium frames was used while the top of the prism was an opaque material that acted as a condenser and to facilitate collecting the condensate water. The efficiency was computed on day time by considering the total heat of evaporation to the total incident solar radiation. The results revealed that the total evaporated water for cloth and sand bed can reach 2.32 and 1.23 slit/days m^2 at initial saturation concentration (30%) of $cacl_2$. However, the system efficiency is 29.3 and 17.76% for cloth and sand bed, respectively.

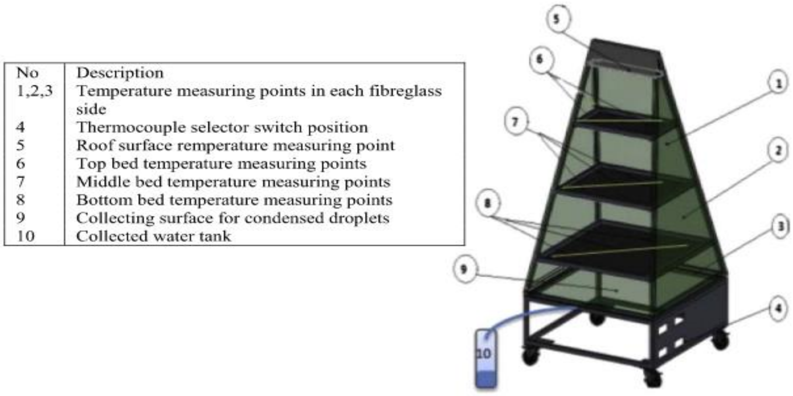


Fig 7 Trapezoidal prism solar collector [17]

3.1.3 Corrugated surface

Based on the principle of desiccant moisture absorption at night and simultaneous desorption and water vapour condensation during the day, Gad *et al*., introduced the use of an integrated desiccant/solar collector to harvest water from humid air [1] (fig 8). In their study, a small air circulation fan was used to force the ambient air to enter the glass-enclosed solar collector during the evening. In the collector, a thick layer of corrugated cloth was used as the desiccant bed. The use of corrugated surface was meant to increase the heat and mass transfer area during the absorption/desorption mechanism. During the day, water vapour condensation will occur on the inner surface of the glass enclosing the solar collector. According to the researchers, the solar driven system could produce 1.5 l of fresh water per square meter per day.

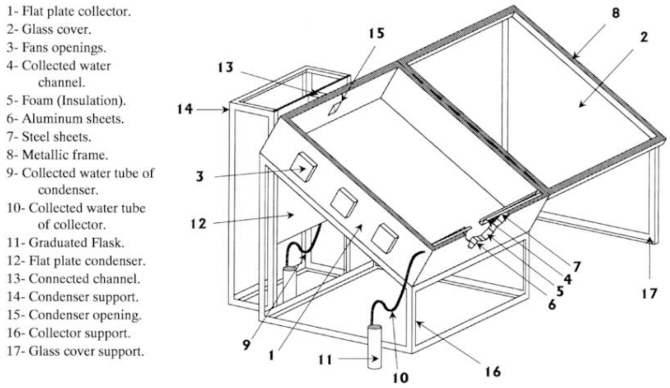


Fig 8 Corrugated surfaces [1]

3.1.4 Solar glass desiccant box type system

Kumar *et al* ., "Experimental investigation of solar powered water production from atmospheric air by using composite desiccant material "$CaCl_2$/saw wood" have been reported that newly designed solar glass desiccant box type system (SGDBS) having a capture area 0.36 m^2 [9] (fig 9) It is found that water production rate depends upon the concentration of $CaCl_2$ in the saw wood . The box was made of a 3 mm single glaze glass; the desiccant bed was fixed at 0.22 m at inclination of 30◦. The desiccant bed was a composite material using sawdust impregnated with CaCl2. Three boxes were tested under the Indian climatic conditions at NIT Kurukshetra, India [29◦58' (latitude) north and 76◦53' (longitude) east] in October. The researchers observed that the performance depend mainly on the concentration of $CaCl_2$, which generated 180 ml/kg/day at a loading of 60% on the sawdust.

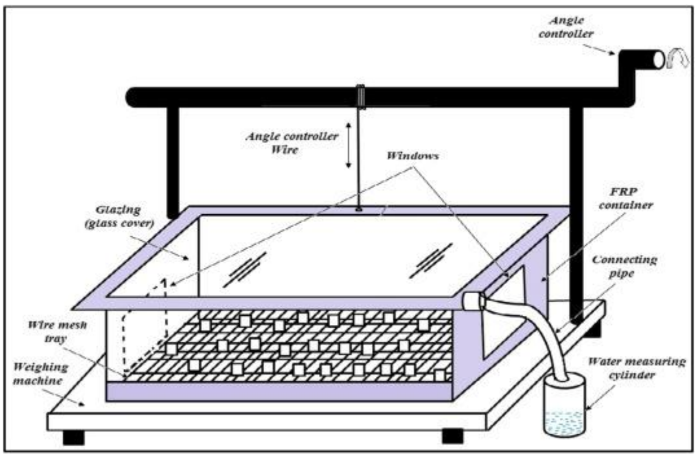


Fig 9 Solar glass desiccant box type system [9]

3.1.5 Solar Energy for Recovery of Water

Ahmed m mamed *et al.,* Experimental investigation on the application of solar energy to heat a sandy bed impregnated with calcium chloride for recovery of water from atmospheric air [4] (fig 10). An experimental unit has been designed and installed for this purpose in climatic conditions of Taif area, Saudi Arabia. The sandy layer impregnated with desiccant is subjected to ambient atmosphere to absorb water vapour in the night. During the sunshine period, the layer is covered with glass layer where desiccant is regenerated and water vapour is condensed on the glass surface. Experimental measurements show that about 1.0 litre per m^2 of pure water can be regenerated from the desiccant bed at the climatic conditions of Taif. Liquid desiccant with initial concentration of 30% can be regenerated to a final concentration of about 44%. This method for extracting water from atmospheric air is more suitable for Al-Hada region especially in the fall and winter.

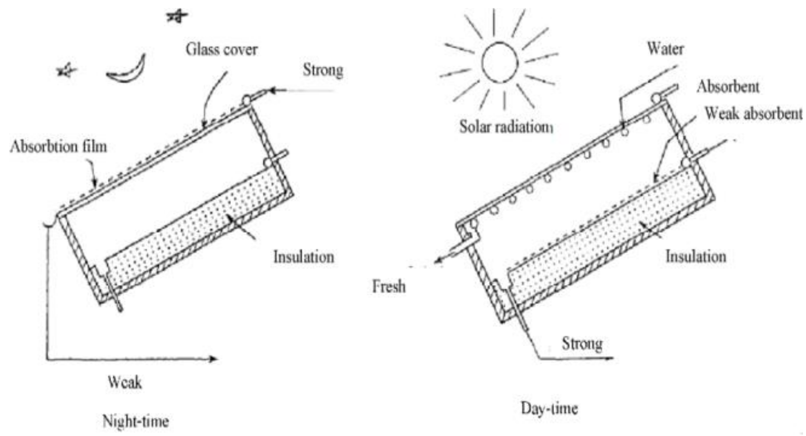


Fig 10 Solar Energy for Recovery of Water [4]

3.1.6 Atmospheric Water Generator on Motor Vehicle device

C. Dhandapani *et al.,* performed an Atmospheric Water Generator on Motor Vehicle device constantly provides drinkable water from atmospheric air [16] (fig 11). There are mainly two methods 1) cooling condensation method: a compressor circulates the refrigerant through a condenser and then an evaporator coil which cools the air surrounding it. This lowers the air temperature to its dew point, causing water to condense. 2) Desiccant method, desiccants absorb the water molecules in the air. Desiccants may absorb atmospheric moisture by several methods: by physical absorption, forming chemical bonds or adsorption. Desiccants are Calcium chloride, Lithium chloride, and Water gel crystals. Desiccation Technologies are superior over cooling condensation by water produced is clean of air contaminates and microorganisms, Solar heat can be used. Installed in a motor vehicle, the device constantly provides hot and cold drinkable water from atmospheric air and produce an unlimited supply of water without environmental pollution for the current water scarcity problem the device can be especially helpful for travellers and truck drivers who need water on long roads.

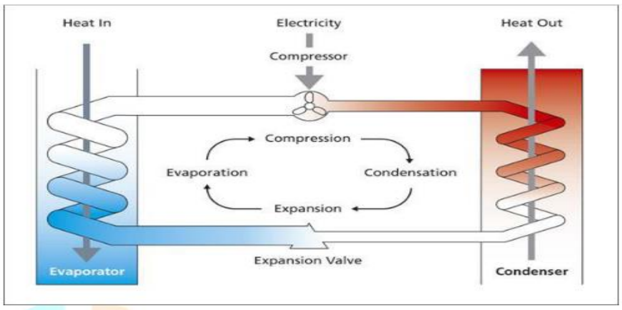


Fig 11 Atmospheric Water Generator on Motor Vehicle Device [16]

3.1.7 Extract water by using different composite materials

Shobhit Srivastava *et al.*, performed in order to generate water from atmospheric air by using different composite materials under atmospheric condition [13] (fig 12). In this analysis, three composite materials named LiCl/sand, $CaCl_2$/sand and LiBr/sand have been used as salt with 37% concentration and sand as a host material. The absorption process has been carried out at night in the open atmosphere whereas regeneration process took place during the day time by using newly designed 1.54 m^2 Schaffer reflector. The maximum water quantity generate from LiCl/sand is 90 ml/day, from $CaCl_2$/Sand it is 115 ml/day and from LiBr/Sand it is 73 ml/day in 330 min, 270 min and 270 min respectively through investigation.

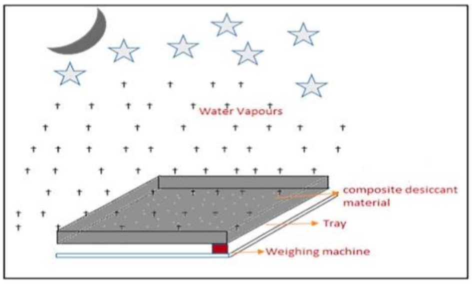


Fig 12 Extract water by using different composite materials [13]

3.2 Review of silica gel and its comparison materials

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.

Wang, J. Y *et al.*, "Water vapour sorption performance of ACF-CaCl2 and silica gel-CaCl2 composite adsorbents" reported that the host matrix is activated carbon fiber felts (ACF FELT) [14] (fig 13 a,b) fabricated by viscose-based fibers. Scanning electron micro-scope (SEM) and Micro meritics ASAP2020 were adopted to observe the micro characteristics of matrix. Inductive coupled plasma emission spectrometer (ICP) was used to test the quality of impregnation and water crystallization carried by calcium chloride in synthesis. The preparation processes, pore structures, quantities of crystallization water of calcium chloride and impregnated salt, as well as the non-equilibrium adsorption performances were studied, and the results were compared with the composite adsorbents with SC matrix. Research shows that ACF is more suitable as the matrix of composite adsorbents, and ACF30 has the best sorption performance of water uptake 1.7 g/g, which is three times more than silica gel-$CaCl_2$. Furthermore, ACF compound can be retested without rupture or carryover.

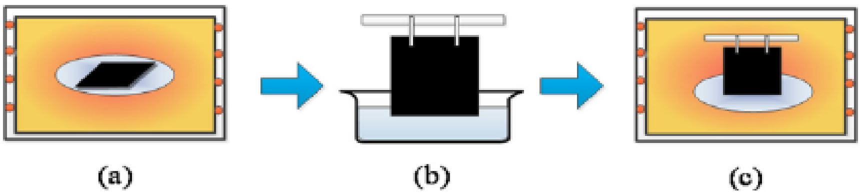


Fig 13 (a) Procedures of the Composite Adsorbents with ACF [14]

Developing procedures of the composite adsorbents with ACF as matrix. (a) The ACF is dried in the oven, (b) impregnation; (c) the ACF is dried in the oven after impregnation.

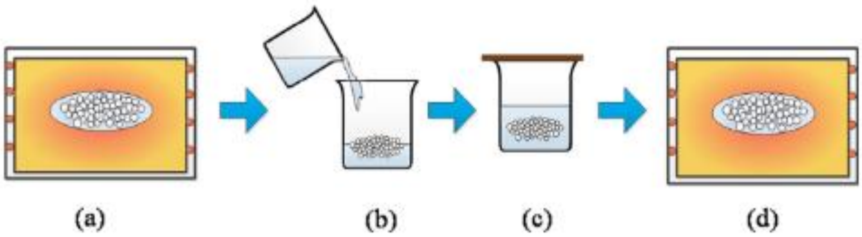


Fig 13 (b) Procedures of the Composite Adsorbents with ACF [14]

Developing procedures of the composite adsorbents with silica gel as matrix. (a) The SC is dried in the oven, (b) impregnation, (c) standing for 48 hours. (d) The SC is dried in the oven after impregnation.

The silica gel was immersed into calcium chloride aqueous solution with different mass concentrations of 10%, 20%, 30%, and 40% at room temperature for 48 hours, which were abbreviated to SC10, SC20, SC30, and SC40.

3.3 Review of MOF (metal organic framework) and zeolite.

Metal-organic frameworks (MOFs) (fig 14) due to their unique micro-structure, intrinsic porosity, and unprecedented functional and chemical control have a high potential to be used for harvesting water from air. The characteristic of Zeolite to adsorb and desorbs water makes them useful as desiccants. When the Zeolite powder is placed in an area of moisture, it will absorb the moisture up to the saturation point. Aero gel is also ideal material for liquid absorption and storage due to their porous nature.

Metal-organic frameworks (MOFs) offer a high potential for this application due to their structural versatility which permits scalable, facile modulations of structural and functional elements. Although MOFs are promising materials for water harvesting, little research has been done to address the microstructure-adsorbing characteristics relationship with respect to the dynamic adsorption-desorption process. In this article, we present a parametric study of nine hydrolytically stable MOFs with diverse structures for unravelling fundamental material properties that govern the kinetics of water sequestration in this class of materials as well as investigating overall uptake capacity gravimetrically. The effects of temperature, relative humidity, and powder bed thickness on the adsorption-desorption process are explored for achieving optimal operational parameters. They found that Zr-MOF-808 can produce up to 8.66 L_{H2O} $kg^{-1}{}_{MOF}$ day^{-1}, an extraordinary finding that outperforms any previously reported values for MOF-based systems. The presented findings help to deepen our understanding and guide the discovery of next-generation water harvesting materials.

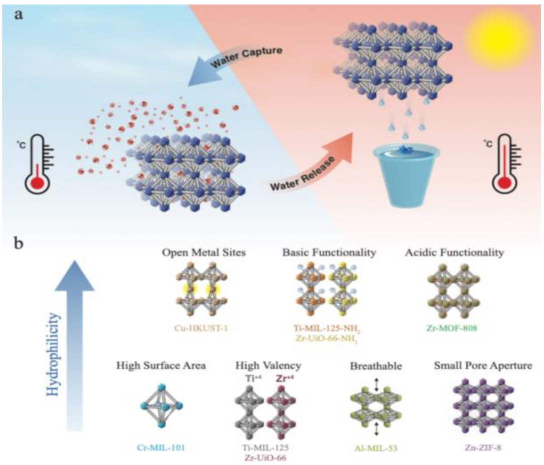


Fig 14 Metal-organic frameworks

Atmospheric water generators that utilise sorbents enable capture of vapour at low RH conditions and can be driven by the abundant source of solar-thermal energy with higher efficiency [8] (fig 15). Here, they demonstrate an air-cooled sorbent-based atmospheric water harvesting device using the metal–organic framework (MOF)-801 [Zr_6O_4 $(OH)_4$(fumarate)$_6$] operating in an exceptionally arid climate (10–40% RH) and sub-zero dew points in USA with a thermal efficiency (solar input to water conversion) of ~14%. We predict that this device delivered over 0.25 L of water per kg of MOF for a single daily cycle.

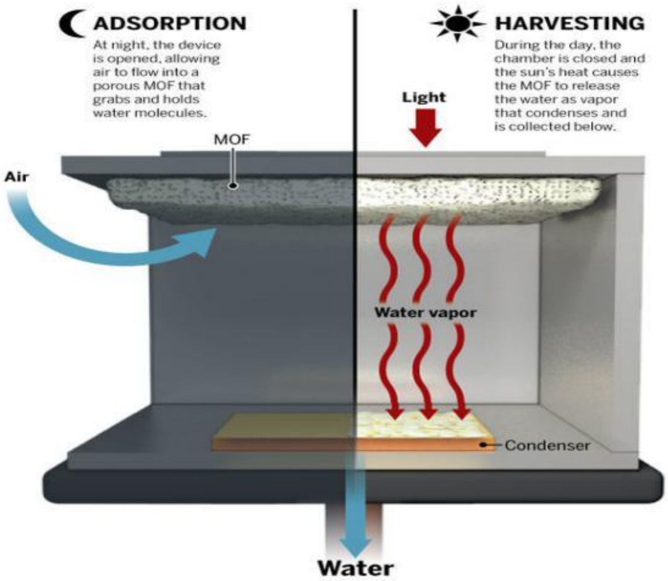
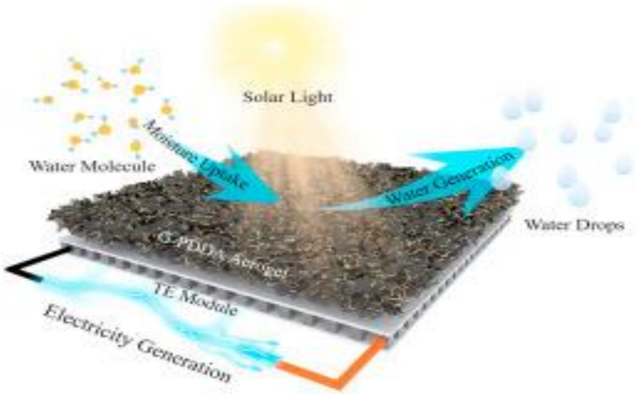


Fig 15 Water harvesting device using the metal–organic framework – 801 [8]

Kaijie Yang *et al.*, extract water from the atmosphere and also produce electricity using a hygroscopic (G-PDDA) aero gel [15] (fig 16), they design and fabricate a hygroscopic aero gel material that integrates a cationic polymer, poly(diallyl dimethyl ammonium chloride) (PDDA), and a negatively charged reduced graphene oxide (rGO), to produce a highly porous structure. In this aero gel (denoted as G-PDDA), the cationic polymer provides a large number of water harvesting sites, and the rGO acts as an effective solar thermal material. At the same time, the highly porous structure greatly facilitates the transfer of water and heat. The dual-function system achieves this by combining AWH with thermoelectric technology and using natural sunlight as the sole energy input. The model system can produce a maximum output power density of 6.6 mW/m^2 during the moisture capture process at the relative humidity of 60%, and 520 mW/m^2 during the water release process under 1 kW/m^2 solar irradiation.



Figs 16 Extract water from the atmosphere using (G-PDDA) aero gel [15]

Alina La Potin et al .,Dual-Stage Atmospheric Water Harvesting Device for Scalable Solar-Driven Water Production [10] (fig 17) reported that a dual-stage AWH device using commercial zeolite increased the productivity, and the latent heat of condensation was recycled from the top stage to assist in desorption of the bottom stage. The dual-stage framework can be used with high-performance adsorbent materials and in different AWH systems to improve thermal efficiency. This dual-stage device configuration is a promising design approach to achieve high performance, scalable, and low-cost solar-thermal AWH. The dual-stage device with daily water harvesting productivity of 0.77 L/m2/day

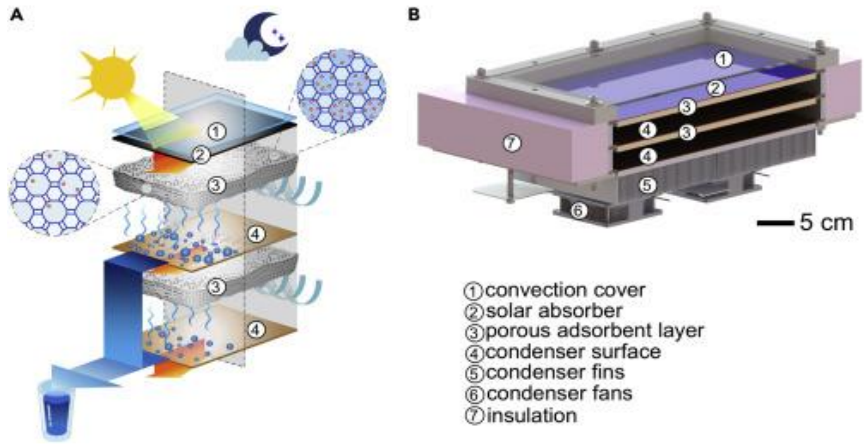


Fig 17 A Dual-Stage AWH Devices Using Commercial Zeolite [10]

3.4 Review of general atmospheric water generator

An atmospheric water generator (AWG) is a device that extracts water from humid ambient air, producing potable water. Water vapour in the air can be extracted by multiple techniques, including condensation - cooling the air below its dew point, exposing the air to desiccants, using membranes that only pass water vapour, collecting fog.

Emerging advancement of photo thermal nano-materials and the urgent demand for a green technology transition have reinvigorated the established solar distillation technology [2] (fig 18). The current development of photo thermal vaporization focuses on material innovation and interfacial heating, which largely emphasizes vapour generation efficiency, without considering pragmatic water collection. Moreover, salt accumulation is another critical issue of seawater solar-driven vaporization. The incorporation of photo thermal materials into a photo thermal membrane distillation (PMD) solar evaporator design harmoniously resolves these issues through combination of renewable energy and efficient interfacial distillation, to achieve the ultimate goal of practical saline water into freshwater conversion. At this juncture, it is imperative to review the recent opportunities and progresses of the PMD system. Here, the fundamental photo thermal processes, strategies for efficient evaporator design, evaluation of various criteria for photo thermal material incorporation with desired properties, discussions on desalination, water treatment, and energy generation applications are covered.

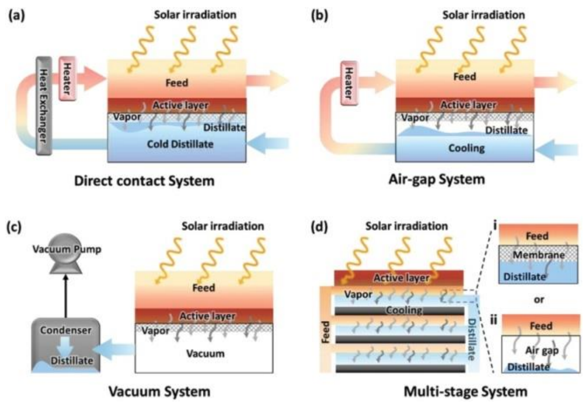


Fig 18 Photo-Thermal Membrane Distillation [2]

The Air Drop irrigation system designed by Edward Linacre is also very inspiring. Ed Linacre’s airdrop is a simple device that literally sucks water out of thin air [18] (fig 19). Airdrop consists of a mast-like tube with a wind-powered turbine that sucks air down into a coiled metal pipe. The air descends under the earth and cools until it hits 100% humidity and the water starts to drip out. Linacre installed one in his mother's back yard in Australia and it pulled out a litre of water in a day. The units also have storage tanks, from where they pump out the water into underground irrigation systems.

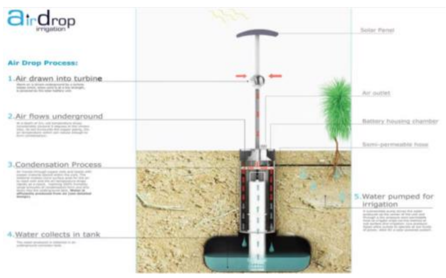


Fig 19 Air Drop irrigation system [18]

A billboard that condenses water from humidity [21] (fig 20). Atacama Desert is one of the driest places on earth, Lima, Peru. The desert receives almost no rainfall. Electricity from the city's power lines runs the condensers inside the billboard. When air contacts the cooled surfaces of the condensers, the air also cools, and the water vapour in the air condenses into liquid water. The billboard generates about 96 litres of water each day. Last December, they erected a billboard in the Bujama District of Lima that by early March had produced 9450 litres of water.

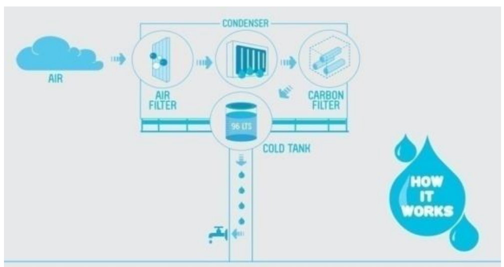


Fig 20 Billboard that condenses water from humidity [21]

Eole Water is a French company specialized in the design and manufacturing of drinking water production systems [20] (fig 21). The WMS 1000 is a unique technology able to supply fresh drinking water with no external power source and in due respect of the environment. Wind is the only power needed to operate the turbines. First it supplies the power needed to transform the humidity in the air into liquid water. Then, this energy is used to route the water to a storage tank.

Turbine operation – (Power production - Ambient air intake - Humid air condensation - Water production - Water filtration - Available fresh drinking water) with an electrical output of 30 kW, the WMS 1000 can produce up to 1000 l of drinking water per day and requires no additional external electrical input.

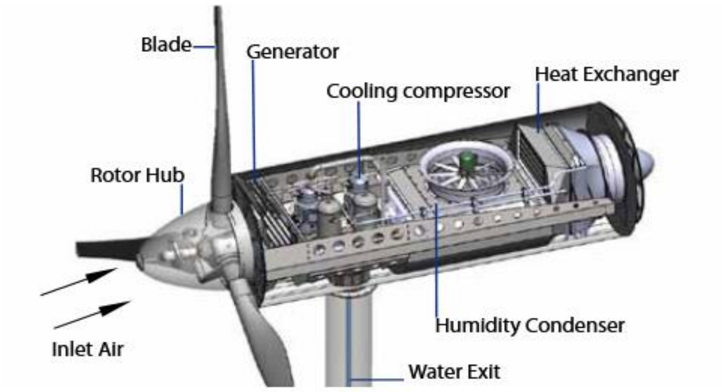


Fig 21 Eole Water (wind turbine) [20]

The atmospheric water generator (AWG) converts water vapour into liquid water and is a promising solution for water scarcity [5] (fig 22). We provide the first comprehensive analysis of the chemical profiles of water produced for several months by an AWG in Israel. Metals, inorganic ions, volatile organic compounds (VOCs), and semi-VOCs were analyzed in the dew water. The main elements found were ammonium, calcium, sulphate, and nitrate. Location of the sampling site in an urban residential area, between major traffic routes, likely affected the chemical composition of the produced dew water. Nevertheless, the produced water nearly always (day and night in different seasons) met the WHO and Israeli drinking water standards. Thus, even in a highly developed urban environment, the AWG offers an excellent alternative source of safe drinking water throughout the year.

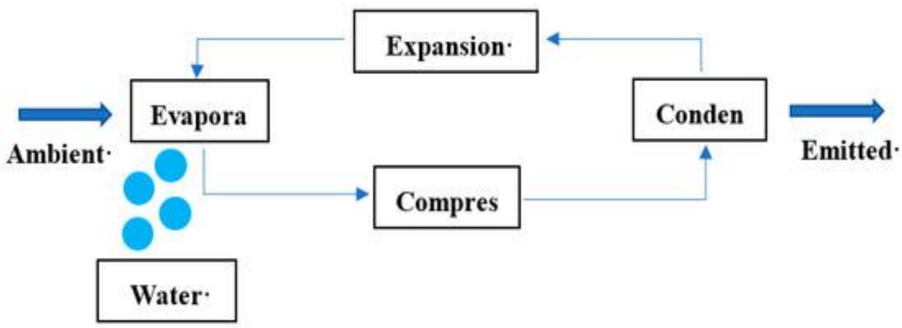


Fig 22 Atmospheric Water Generator Process [5]

Humid atmospheric air is passed through a direct expansion or chilled water cooling coils, moisture is condensed if the coil surface temperature is lower than the dew point of air [7]. For climatic conditions with high temperature and relative humidity such as those in UAE coastal regions, this cooling process, if optimized, can result in appreciable amounts of fresh water suitable for human consumption. In the present work, the cooling/dehumidification process is analyzed and the parameters controlling the heat and mass transfer rates are optimized for the climatic conditions in humid regions in the UAE.

4. DISCUSSIONS AND CONCLUSIONS:

About 4 billion people worldwide experience water scarcity. Water scarcity limits access to safe water for drinking and for practising basic hygiene at home, in schools and in health-care facilities. When water is scarce, sewage systems can fail and the threat of contracting diseases like cholera surges. Scarce water also becomes more expensive. Therefore extracting water from atmospheric air has received considerable attention from researchers world-wide. This review has described various technologies and we expect more to appear in future. Atmospheric water vapour is a world-wide resource and is available even in the driest place like desert and gulf countries etc.

Some hygroscopic materials can collect more water cheap materials can be fabricated from sawdust , silica gel, calcium chloride, recently developed modern metal organic framework (MOF) materials are able to operate with relative humidity as low as 20%, but will be more expensive. The maximum amount of water collected is 2.8 litres of water out of the air per day by metal organic framework. This research work will support further research on the extraction of water from atmospheric air.

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