I BET YOU DIDN'T KNOW...

Water can be harvested from the air in very dry climates

Dr Julia Nash, PSTT
College Fellow, links **cutting-edge research** with the **principles of primary science**

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One third of the Earth is 'water stressed' which means that the demand for water exceeds the amount of water available during a specific period (Figure 1). This could be due to a lack of water (e.g. no rainfall, dry rivers, or lakes), or because the only water supply is salty or contaminated. Over the past one hundred years the population on Earth has increased 3-fold, however, the demand on water has increased 6-fold. The United Nations predicts that by 2025, just 5 years' time, 48 countries throughout the world will experience water scarcity or stress.

There are many questions to be considered by scientists and governments that you could discuss in the classroom:

Which countries of the world are most likely to be 'water stressed'?

What could cause this water stress?

How do dry, desert habitats compare with other habitats?

What is the impact on the people who live in these areas of the world?

Designing economical and efficient ways to harvest fresh drinking water has become vital in many countries around the world because when water is limited (e.g. through drought), farmers struggle to grow crops to feed the population.

How could access to fresh water be increased?

To avoid a water crisis, the world needs to:

- use less fresh water
- reduce water pollution
- upgrade current water treatment centres and pipelines
- improve the technology used to generate fresh water.

A question for children to consider:

Can you think of ways to reduce the use of fresh water and to avoid wasting water?

Children could investigate water wastage from dripping taps (details are described in the Teacher Guide).

Figure 1. People travelling to collect water in Uganda, Africa.

One source of water that has interested scientists in recent years has been water vapour and liquid droplets of water found in the atmosphere. Water vapour (the gaseous form of water) is always present in the air but how much there is changes from place to place and at different times of the day. Although water vapour contributes to just 0.001% of the atmosphere, this atmospheric water is a resource equivalent to approximately 10% of all fresh water in lakes on Earth (equivalent to 12,800 trillion litres of renewable water). Atmospheric water, therefore, could become a significant resource for the future and a potential solution to solve the problem of water shortage in some areas.

Atmospheric Water Harvesting

To design and create a process to harvest atmospheric water efficiently and economically in dry, arid areas of the world has taken a long time. In 2017, scientists Kim *et al.*, reported on a new device they had created: a box that could capture water vapour from desert air and turn it into drinkable water, just utilising the energy from the Sun.

The most important part of the scientists' device is a chemical called a *metal-organic framework* (MOF) composed of organic molecules (mostly carbon and hydrogen) and a metal. This particular MOF has the name MOF-801 and contains the metal zirconium $[Zr_6O_4(OH)_4(fumarate)_6]$.

Questions for children:

Do you know anything about these molecules (carbon and hydrogen)?

Can you find familiar examples of them (e.g. the graphite in pencils)?

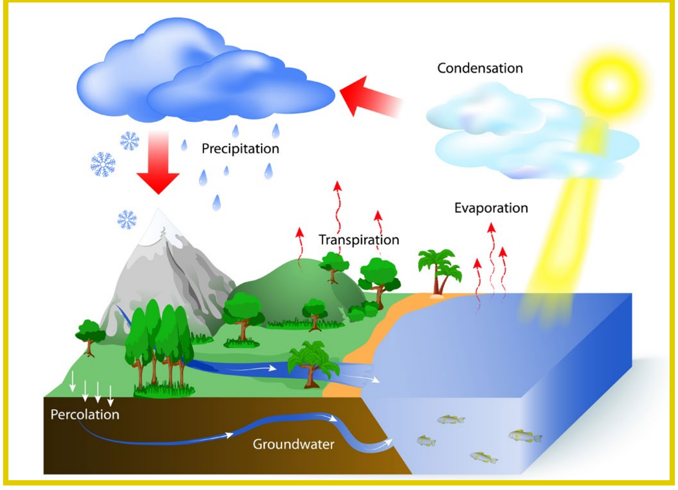
MOF-801 molecules have a structure (a way that the atoms that make up the molecules are arranged) that contains spaces into which water vapour molecules can be captured. In other words, it is a *porous* material (a bit like a sponge). MOF-801 takes up water vapour from the air at *ambient* temperatures even when there is very little water vapour in the air. We say that when there is very little water vapour in the air, there is *low humidity*.

The MOF-801 powder is put in a box with a lid on. During the night when it is cool, atmospheric water vapour 'sticks' to the MOF and stays there because bonds are formed between the water molecules and the MOF. The next day, heat from the Sun warms the MOF powder and the water molecules come out of the MOF as water vapour. The Sun's energy is needed to release the water molecules (break the bonds) sticking it to the MOF. Enough water vapour molecules are released to fill (*saturate*) the trapped air and so some water vapour must *condense* as liquid water, even at the temperatures near that of the surrounding area. The scientists managed to harvest 2.8 litres of water in every kilogramme of MOF each day in the very dry climate (at *low humidity*). It is important that none of the molecules from the MOF powder are found in the harvested water, but the scientists say that the water is 100% clean and can be drunk straight away.

The science inside the water harvesting box

One area of science that would have been referred to extensively in this research is the water cycle (Figure 2). Scientists often reflect on the knowledge they already have to answer new questions.

Figure 2. Schematic diagram showing how water vapour and liquid water are part of the water cycle. The Sun heats water in oceans and seas and the water evaporates as water vapour into the air. Higher in the sky, the temperature is cooler and water vapour condenses into water droplets (clouds). When the droplets join and become larger, they precipitate (rain).



Using some household materials, it is possible to investigate these processes. It is possible to see how water vapour is released back into the atmosphere over time from shaving gel, hydrogel extracted from nappies or florist beads, and to explore how water vapour *condenses* onto cold surfaces. These two concepts can be brought together to explain the water harvesting box. Details of these activities and investigations can be found in the Teacher Guide.

How did the scientists improve their water harvester?

The researchers have spent many years designing the perfect MOF powder. These chemists have designed and tested MOFs with different proportions of specific molecules and changed how the molecules position themselves within the compound. They did this to see if changing the structure of the MOF could improve the amount of water that the MOF harvests from the atmosphere. An analogous investigation which children could carry out in the classroom would be to compare how different sizes/types of sponge can hold different amounts of water.

The scientists then trialled their water harvesting box in the desert and investigated how much water could be harvested when they changed the structure of the box, the size of the box, and how the MOF is placed in the box. By using more powder, or a bigger box, more water could be harvested. This enabled them to build the best water harvester possible.

Many scientists were involved in this research project based in the USA and in Saudi Arabia. They all had something to bring to the table and share.

A question for children to consider:

Why do you think these two countries shared their ideas and why do you think it is important to develop atmospheric water harvesting?

Think about group work carried out in the classroom. Does everyone in the group always know the same things? Also, consider where these scientists come from, the different habitats in their countries, the types of populations, the types of industries and also climate change.

What will the future hold for water harvesting?

The necessity for this type of water harvesting/generating technology, especially atmospheric water harvesting, is growing as the human world population grows. It will become more important as the world looks to avoid some of the effects of droughts, food shortages and major catastrophes in the future. Climate change will have a profound effect on accessible water in the coming decades and so it is imperative that this type of research continues in order to ensure that clean, drinking water can be sourced even in the arid areas. The scientists are already working on a new MOF material that will be cheaper and more effective than the ones currently used. Maybe this is a field of science you would like to work in?

GLOSSARY

Ambient
the temperature of the surrounding environment.

Condense
change from a gaseous state (vapour) to a liquid.

Evaporate
change from a liquid into gas (vapour).

Humidity
a measure of the mass (g) of water vapour in one cubic metre (m^3) of air.

Porous
having small spaces (pores) that can hold a gas or liquid or that will allow these to pass through.

Saturate
hold as much water or moisture as possible.

The research paper that inspired this work was:

Water harvesting from air with metal-organic frameworks powered by natural sunlight.

By Hyunho Kim,[1] Sungwoo Yang,[1] Sameer R Rao,[1] Shankar Narayanan,[1] Eugen A Kapustin,[2,3] Hiroyasu Furukawa,[2,3] Ari S.Umans,[1] Omar M. Yaghi,[2,3,4] Evelyn N Wang[1]

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