WIOA KWATYE (WATER) PRIZE 2008

The Water Harvester

Investigations into harvesting water from atmospheric humidity

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The Water Supply Problem

In the current environment of climate change and inequity in supply and demand, there is great pressure for governments and communities to secure their water sources. It has become clear that existing sources are often unable to cope under the more extreme weather conditions we are beginning to experience more routinely. These conditions not only reduce water availability but can also have a large negative impact on the quality of existing sources. Such supply issues are suffered particularly in small and remote communities, where other alternatives are extremely expensive due to their isolation and lack of infrastructure.

Current water sources are not only increasingly insufficient and of inconsistent quality, but also impact negatively on the environment in a number of ways.

- Diversion of surface water puts pressure on the natural ecosystem and can affect soil salinity. Quality can be quite variable with pathogenic bacteria, pesticides, turbidity and colour issues.
- Increased groundwater use in recent times has caused serious depletion of resources in some areas, reducing its availability and increasing bore costs. The wide range of contaminants present in groundwater such as arsenic, and many salts, limits its value and is often used untested at the risk of the consumer and environment.
- Removal of contaminants often requires high-pressure filtration or distillation, both very expensive operations.

More recently, the use of water from the ocean after desalination has received much attention. While it does not interrupt the natural water cycle, it is known to be extremely energy intensive, thus a considerable emitter of carbon dioxide and very expensive. State of the art techniques reduce energy consumption but fundamentally the processes of distillation or membrane filtration will always be energy hungry.

In addition to the broader problem of lack of available water, treatment and distribution costs are common to all current sources. Depending on the water source, treatment of drinking water to guidelines and regulations can be costly and difficult. Disinfection and removal of colour and turbidity represent the main costs for most treatment plants, through the use of power, treatment chemicals and operational resources. Piping water requires extensive infrastructure and pumping, and in emergency situations trucking of water is utilised at very high cost to communities and landholders in both urban and rural areas.

To sum up, these are the key issues relating to the water supply problem:

- Availability
- Quality
- Distribution

An Alternate Approach to Solving Water Supply & Quality Issues

Having discussed the three main issues above with respect to our fundamental water sources (surface, ground and ocean), it is apparent that water from the ocean is the only source whose availability may be relied upon. The availability from all other sources can be highly variable and cannot be controlled.

Distillation and reverse osmosis have been proven to be extremely effective in treating and purifying seawater, but are known for their high financial and environmental costs. Distillation requires huge quantities of energy to raise water temperature to boiling and then to convert from liquid to vapour. Reverse osmosis demands similar amounts of energy to force the water molecules through extremely fine membranes. Such energy requirements represent high costs for the water produced.

An effective way to drastically reduce these costs is to take advantage of the natural water cycle that continually extracts pure water from the ocean into the atmosphere. It costs nothing and provides high quality water in the form of vapour. All that is needed is to re-condense the water vapour into liquid like when it rains. This fundamentally requires much smaller amounts of energy, as energy is removed from water vapour when it is condensed. In addition, water removed from this point of the cycle is readily replenished by natural processes of equilibrium and therefore has negligible effect on the natural water cycle and the environment.

When air is cooled, it progressively loses its ability to hold water vapour, to the point where air at or below 0ºC contains none. As the air temperature is reduced, more and more of its water vapour is condensed as liquid water. This is why rain occurs, and also why condensation can form in your bathroom when you take a shower.

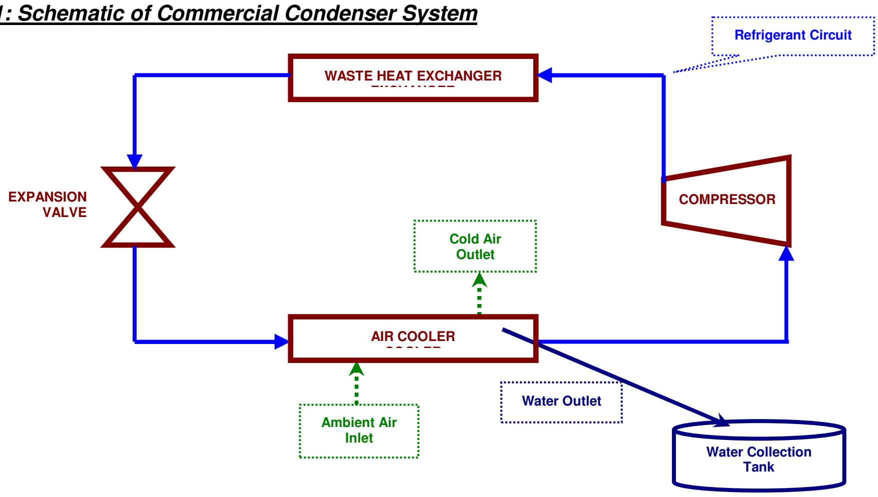
The idea of condensing and collecting pure water from the atmosphere is not new. It is the process used by desert flora to survive in water-starved conditions. The ancient Egyptians used it to generate drinking water, even in very hot and dry environments. It is still in use by communities living in coastal regions of South America in areas known to be among the driest on Earth, with no requirement for man made energy.

Over recent years these natural processes have been exploited by a growing number of manufacturers of atmospheric water condensers. Essentially, by cooling the air, the water vapour it contains is condensed and collected as a liquid (this is explained further in the next section). There are electric units available the size of an office water cooler, designed for domestic use, right through to large-scale industrial units capable of producing up to 10,000 litres per day. The U.S. military for example use a mobile diesel powered unit to produce water when conducting operations under desert conditions.

The other main issue for water supply is the cost of distribution. In some cases, desalination plants can take advantage of existing infrastructure with little modification. However in many cases substantial investment in infrastructure is required to deliver water to consumers most in need. If the natural water cycle is utilised to convert water into pure vapour, it may also be used to transport that vapour directly to the end user, whether that be a small community, landholder or irrigator. A condenser directly at the point of use can then harvest water hence minimising distribution costs.

Using simple technology, the effectiveness of this natural system is greatly enhanced. As shown schematically in Figure 1 overleaf, a closed refrigeration loop is used to cool ambient air to below its dew point, the temperature at which its water vapour begins to condense and precipitate as liquid. All currently available atmospheric water collectors are designed on the basis of this principle. The greater the temperature difference between the condenser and its surrounds, the more water is produced, which is also the case in conditions of higher humidity.

Figure 1: Schematic of Commercial Condenser System



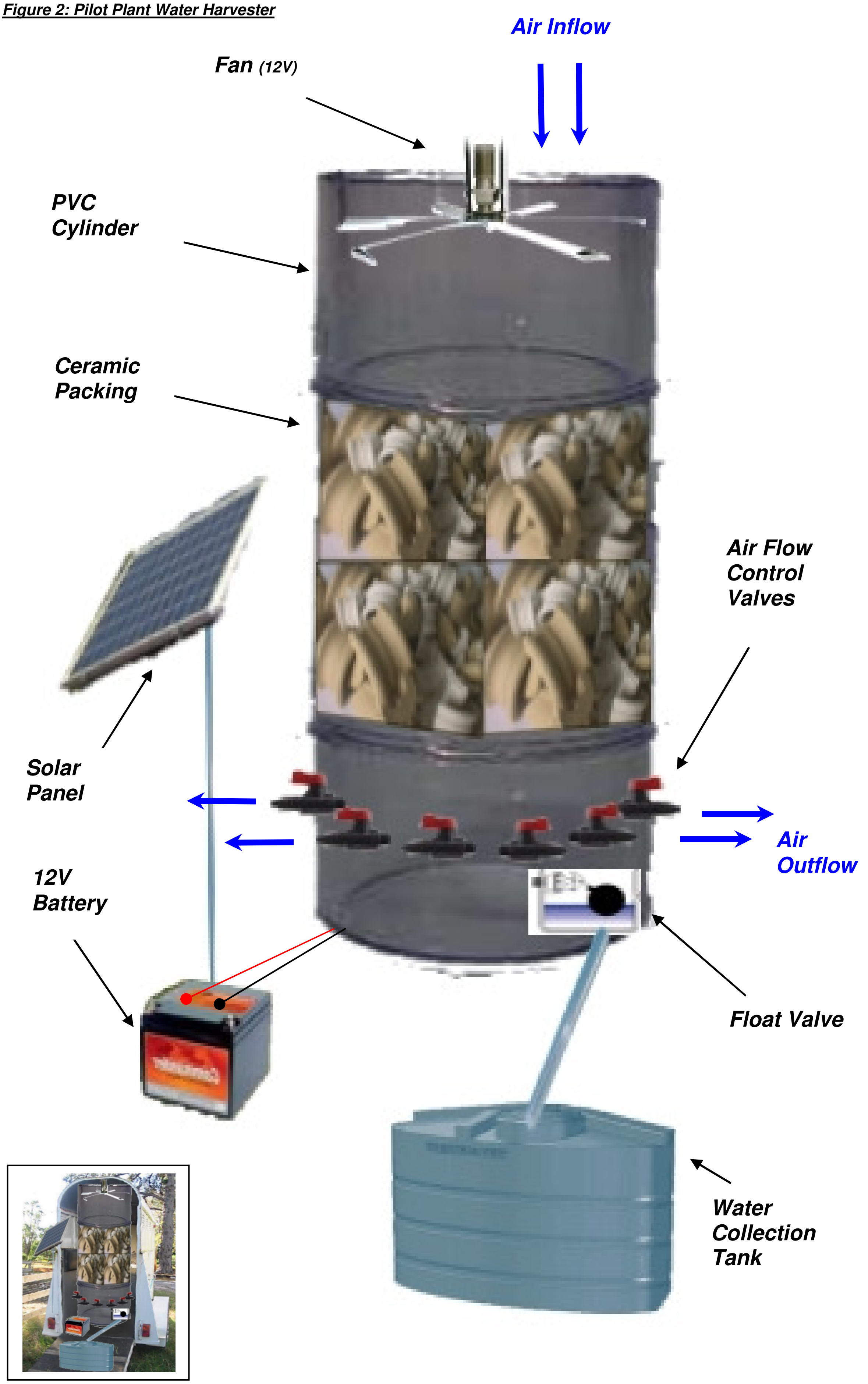
Currently available office or residential units can generate up to 24 litres per day depending on atmospheric conditions with operating costs of around 5 cents per litre. While this cost is very high, the large-scale industrial version can produce water at a fraction of the cost. However even on a large scale, there are still two key factors that could be improved on to make this type of water source commercially viable within a few years. The first is that as more research and effort is put into design improvements the operating costs will come down. Secondly, the trend of water prices over recent years suggests that within the next decade the cost of water will continue to increase. In fact, in some circumstances, such as a remote inland community, it may be commercially viable now.

Building a Pilot Plant Water Harvester

The authors' submission from the previous year is similar in subject matter, but this year is less ambitious. We plan to build a simple pilot plant (refer to Figure 2) capable of assessing the relative viability of atmospheric water harvesting under a variety of ambient conditions and environments. The system will not use powered cooling, instead we plan to utilise overnight temperatures to cool a condenser made from ceramic "packing" materials. This type of material is currently used in separation columns in the chemical, petroleum, and pharmaceutical industries. It is available in a variety of shapes with different properties such as surface area, and a few will be assessed to select that which is most effective. The packing material will be held in a 300mm diameter PVC or polycarbonate cylinder with a fan mounted at the top to draw in moist warm air. Valves will be fitted underneath the packing section to control airflow and pressure. Temperature, pressure, and humidity sensors will be installed at key positions and data logged during testing periods. These will record ambient conditions as well as conditions in the test rig itself. It is estimated that the unit will not have the cooling capacity to operate for more than 1-2 hours per day, so the energy for the fan and monitoring equipment will be minimal and supplied by a deep cycle battery connected to a solar panel. The whole unit will be mounted on a trailer to allow the mobility to test in a variety of environments and conditions.

Data collected will be used to create a profile of the most effective conditions for the use of atmospheric water condensers. While the unit to be built is not powered, the data used in this way is equally applicable to the powered units commercially available. It is important to create such a profile due to the relatively high cost of water produced in this way. It will not only be useful to any parties considering the viability of this type of equipment in a particular location, but it will also serve as a guide of the most cost effective time of day and year to operate.

Figure 2: Pilot Plant Water Harvester



Project Expenses

Item	Description	Estimated Price	Supplier
Trailer with Cover	Horse float, 2.1m (H) x 2.7m (L) x 0.9 (W)	$1500	Various
Solar Panel	Kyocera KC85, 1007 x 652 x 58, 12V, 85W, 5A	$900	Going Solar
Battery	Exide 12RP20, deep cycle, 12V, 200A	$500	Going Solar
Fan	12V thermo radiator fan	$200	Various
Ceramic Packing	Berl saddles, cascade rings, pall rings, conjugate rings (Vol 0.07m^3)	$400	AceChemPack
Plumbing Components	Pipes, valves, reducers, adapters, teflon, etc	$600	PPS
Water Tank	200L tank for water collection	$300	PPS
Measuring Sensors	Internal and external temperature, pressure and humidity	$600	Datataker
Data Loggers	Data capture of temperature, pressure, humidity	$1000	Datataker
Travel Expenses	Testing at different locations. Petrol, accommodation, etc		
Research Expenses	Investigate commercial units, site visits etc (Optional)		
Misc Expenses			

Project Summary

The potential of this atmospheric water harvesting technology is very high. It can deliver high quality water to those most in need and is likely to be commercially viable for commonplace use within a matter of years. As such, some investigation is warranted. We will focus on the fundamental technology with a view to understanding the overall efficiency and cost implications of operation in a variety of environments and conditions. This will be achieved by constructing a pilot plant and recording data as it is operated in different environments and conditions. In addition, if feasible, we would also like to investigate commercially available units (ideally some that are actually in use).

Personal Profiles

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Qualifications:

- Bachelor of Engineering (Chem), Honours, RMIT University

Affiliations:

- Member, Water Industry Operators Association (WIOA)
- Golden Key Honour Society

Industry Experience:

- Grundfos Pumps Australia, Contracts & Applications Engineer (2007 to current)
- Technicolor Pty Ltd, Process Engineer, 2004 - 2007
- Manildra Starches, Chemical Engineer, 2003
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Qualifications:

- Bachelor of Applied Science (Chem), RMIT 1993
- Post Graduate Certificate IV in Environmental Engineering, Deakin 2001
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Affiliations:

- Member, Australian Water Association (AWA)
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Industry Experience:

- Goulburn Valley Water Authority, 2004 to Current – Water Quality Chemist, Water Treatment Operator, Water Treatment Works Coordinator.
- Ecowise Environmental (formerly WSL Consultants), 1994 to 2004 – Analytical Chemist, Manager of Chemistry Laboratory, Manager of Client Services, Manager of Quality Assurance.
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