Water from fog-covered mountains

by Robert S. Schemenauer and Pilar Cereceda

Supplying fresh water to rural locations is always a challenge, but this innovative idea is the kind we'll need to see more of if water supply goals are to be reached.

HIDDEN IN THE MOST arid deserts of the world is an untapped water resource that has the potential to change village life. The same combination of meteorology, ocean currents, and topography that generates the deserts also produces fog-covered coastal mountains. That fog water can be collected in large quantities for domestic and agricultural use.

The village of Chungungo on the northern coast of Chile is beside the now unused mining port of Cruz Grande. Up until 20 years ago, Chungungo received water from the El Tofo mine, which was on a ridge 6km inland. From that time until today water has been trucked to the 330 villagers from a well 40km away. The sole source of income in Chungungo is fishing, primarily for shellfish, in the cold coastal waters. A 1988 survey of all the households in the village found that the water usage was only 14 litres/person/day and that, at a cost of US$2/m^3, this represented 10 per cent of their total family income. Even this cost is heavily subsidized by the municipality, the true cost being US$8/m^3. The purchase of water at this latter rate would be an impossible burden for the villagers. As it is, the cost is one of the main factors limiting consumption, the other being the unreliability of delivery. The last 22km of road to the village are in very bad shape and problems, with both the truck and the road, limit the volume of water that can be supplied. The water problems of Chungungo are typical of many other isolated villages in the coastal deserts of Chile and Peru.

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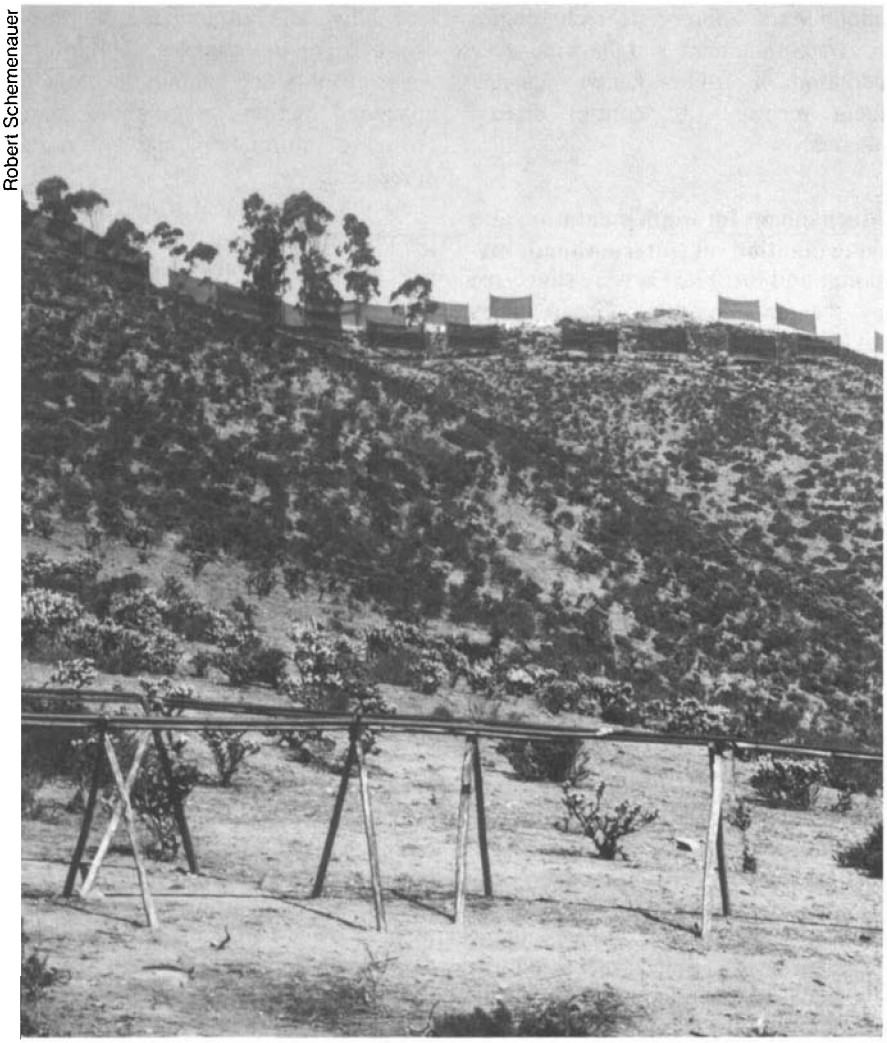


The ridge at El Tofo, Chile, showing some of the fifty 48m^2 collectors that have been installed.

Collecting fog

Along the northern section of the Chilean coast, the mountains rise rapidly, reaching altitudes of up to 1200m within 5km of the shoreline. Slightly further inland is usually found a hot dry intermediate valley, before elevations rise rapidly to 5000 or 6000m in the Andes.

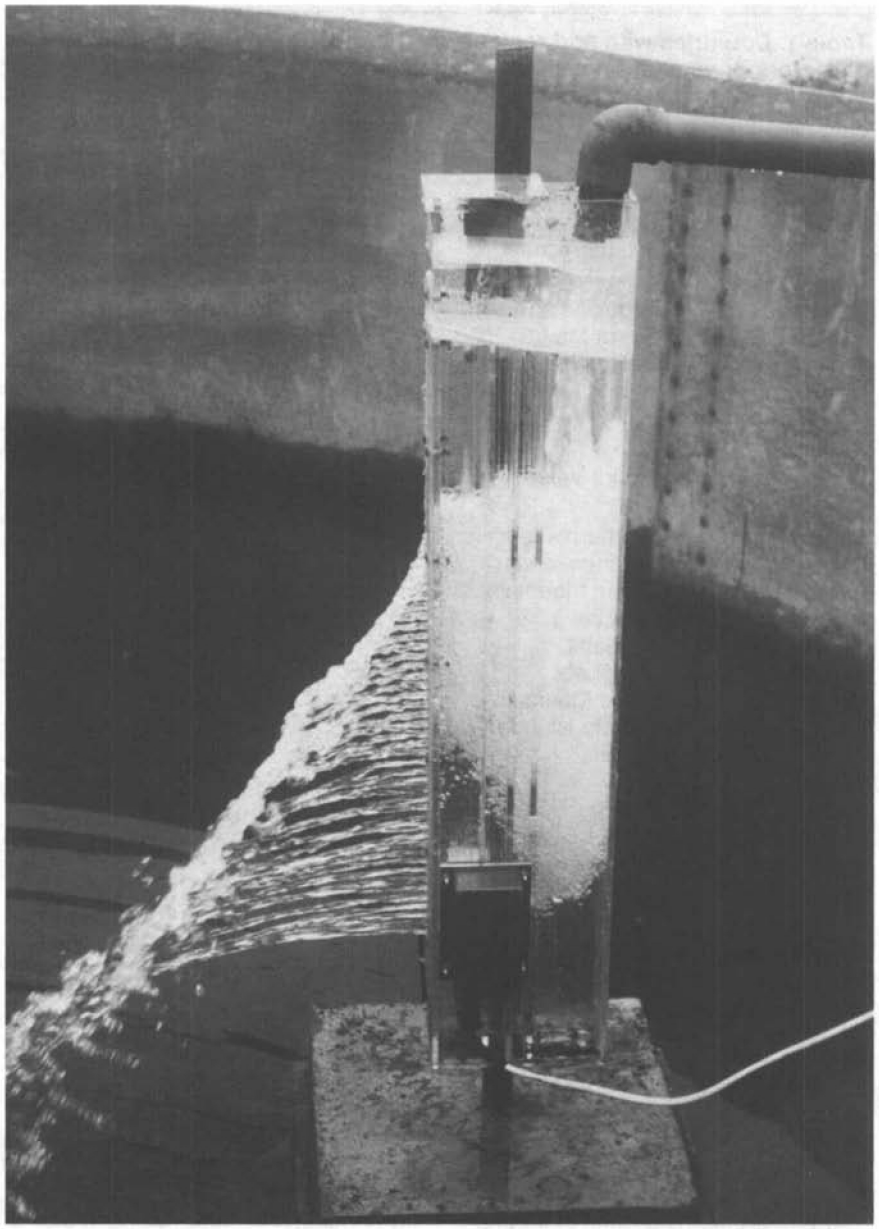
The coastal ridge-line (780m elevation) at El Tofo is frequently covered in fog, which is produced as low decks of marine stratocumulus are blown onshore. The cloud layers are thin, 100 to 300m, and rarely produce drizzle or rain. They vary in altitude from perhaps 500 to 1200m depending on the height of the temperature inversion that persists throughout the year. Since 1987, El Tofo has been the site of a large pilot project to evaluate the potential for using high elevation fog as a water supply in the arid north.

Fog is simply a cloud that is touching the ground. It is composed of hundreds of tiny liquid droplets in each cubic centimetre of air. The droplets typically range from 1 to 30μm in diameter, with the larger droplets being collected more efficiently by narrow fibres or vegetation.[1] At the El Tofo site, 50 large fog collectors, each consisting of 48m^2 of a double layer of polypropylene mesh, were constructed by the Corporación Nacional Forestal in late 1987 with funding from the International Development Research Centre (IDRC, Ottawa). They are constructed of treated eucalyptus posts mounted in cement and supported by galvanized-steel wires. The ultraviolet-protected meshes (to ensure a long life when exposed to sunshine) are suspended on galvanized-steel wires that are coated in plastic. The fog water beads up on the meshes and then drips into polyvinyl chloride (PVC) or fibreglass troughs. It is then moved through PVC pipes to a 25 000-litre reservoir and to a 3ha tree plantation.

The average water production from the El Tofo collectors has been approximately 3 litres per square metre of collecting surface per day from November 1987 through to February 1991. This is an average production of 7200 litres per day from the array,

and this occurred during three drought years when precipitation averaged 10, 50, and 10mm as opposed to the normal of 70mm. Production rates vary with conditions, from 0 on clear days to a maximum of about 85 000 litres per day. There is a seasonal minimum in the winter (June-July). The production has been sufficient to justify the construction of a pipeline to the village of Chungungo, 6.5km away. The pipeline was completed in March 1992 and is taking water to a 100 000-litre reservoir, funded by the Canadian Embassy in Santiago, and then into the homes in the village. With the current array size, each of the 330 villagers should receive about 22 litres of water per day. A further 25 collectors will be constructed in 1992 to supply additional water to the village. Both the terrain and the pipeline can accommodate several hundred more collectors, and the system may be expanded depending on the results of the current project.

Water from the fog collectors can be expected to be of good quality. It will contain some marine salts and soil dust, but little contamination from anthropogenic sources because of the remote locations of most of the proposed sites. The ion and trace element concentrations at the El Tofo site have been studied in detail[2] and found to meet Chilean and WHO drinking-water standards. A similar study in the Dhofar Region of the Sultanate of Oman also found the water to be completely acceptable. These studies did not address the question of bacterial concentrations, but work by the University of Chile (unpublished) has



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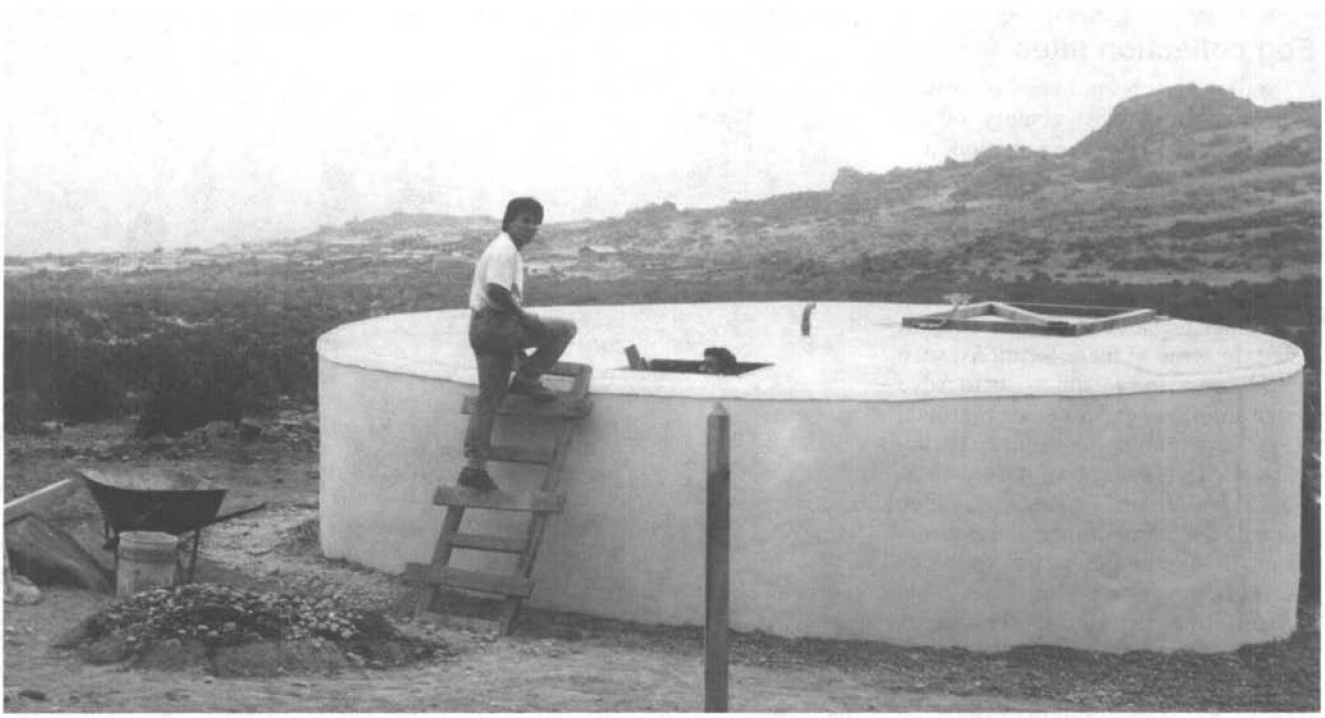
A flow meter at the El Tofo site which is receiving 1 litre per second of fog water from the collectors.



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The 100 000-litre fog water storage tank near the village of Chungungo on the northern coast of Chile.

Table 1. Countries with arid regions where fog collection by artificial collectors or vegetation has been documented.

Country	*Region*	*Latitude range*	*Altitude range (m)*
South America			
Chile	Northern coast	23°S-30°S	500-800
Peru	Central and southern coast	11°S-16°S	350-700
North America			
Honduras	Tegucigalpa	14°N	2000
Mexico	Sierra Madre Or.	19°N	15-2400
USA	California	34°N-40°N	50-1200
USA	Hawaii	21°N	225-3400
Europe			
Gibraltar		36°N	300
Yugoslavia	Mount Velebit	44°N	1600
Africa			
Angola	Northern interior	6°S	50-900
Angola	Southern coast	13°S	1600-2000
Ascension Is.	Green Mountain	8°S	850
Cape Verde Is.	Isla Brava	15°N	980
Kenya	Marsabit	2°N-4°N	200-1700
Namibia	Gobabeb	23°S	10-400
South Africa	Table Mountain	34°S	750-1050
Spain	Canary Islands	28°N	600-2350
Sudan	Erkwit	19°S	1150
Middle East			
Israel	Menara	31°N-33°N	600-900
Jordan	Kefar Etsyon	32°N	600
Oman	Dhofar Jebel	17°N	100-1000
Saudi Arabia	Hejaz Mountains	20°N	1200
Yemen	Al-Mahwit Province	15°N	1500
Asia			
India	Cheerapunji	25°N	1300
Australia			
Australia	Mount Wellington	43°S	1270

Adapted from Schemenauer and Cereceda[2] where references can be found.

shown the absence of faecal coliforms, as would be expected. Other bacteria will be eliminated by the small chlorination plant that is required by law for domestic water supplies in Chile.

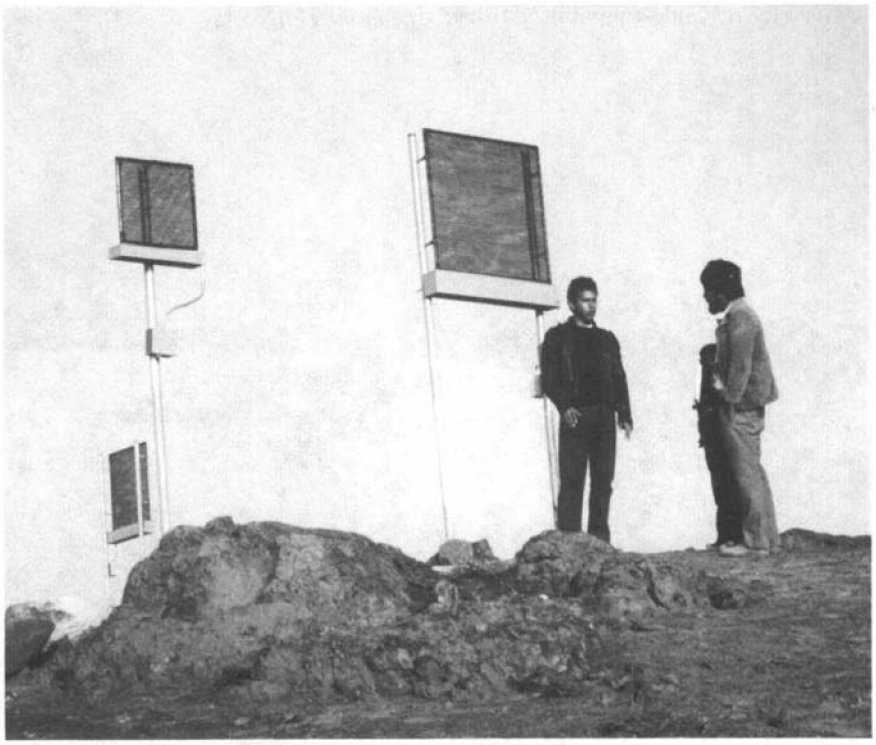
Fog collection sites

A review has been made of observations over the last century of the collection of fog by vegetation and small collectors[3] in semi-arid and arid lands. The results are summarized in Table 1.

In 47 locations in 22 countries on six continents there are indications that fog as a water resource should be investigated. In some of these locations, such as California, the wealth exists to solve water shortages in more conventional ways. But in other locations, particularly in developing countries such as the Cape Verde Islands, Namibia, Yemen, and Peru, fog collection deserves to be considered. Care must be taken in choosing a productive site but the collectors themselves are simple, require no energy, and deliver their water by gravity flow. Generally the area of the collector array would be fenced off but, if necessary, grazing animals could simply pass underneath the collectors. The cloud decks bring an essentially unlimited amount of water to the mountain sites, so in principle the amount of water that can be collected is limited only by the number of collectors that one chooses to install. It is important to realize though, that no matter how much water one might collect, the amount will be very small compared to the total water in the fogs, and there should be no detrimental environmental impacts because of the collection and management of some of the water.

Cerro Orara, Peru

In 1990 the Canadian International Development Agency (CIDA, Ottawa) was approached for funding to carry out an assessment project near Lima. With the assistance of the Canadian Embassy and the Servicio Nacional de Meterología e Hidrología, a site at an altitude of 430m was selected just north of the city using previously established criteria. It was 3.5km from the coast and above a *pueblo joven* (squatter settlement) of 6000 people. The water usage of the people of Los Rosales was not measured, but since the entire supply was from one illegal connection to a nearby pipeline, it is unlikely that it exceeded 10 litres/person/day. Fog and drizzle were frequent at the site during June and July, while the site and the instrumentation were being prepared. Field measurements using a set of standard 1m^2 collectors began in July and continued well into December when the fog, though less frequent, was still present. A continuously recording me-



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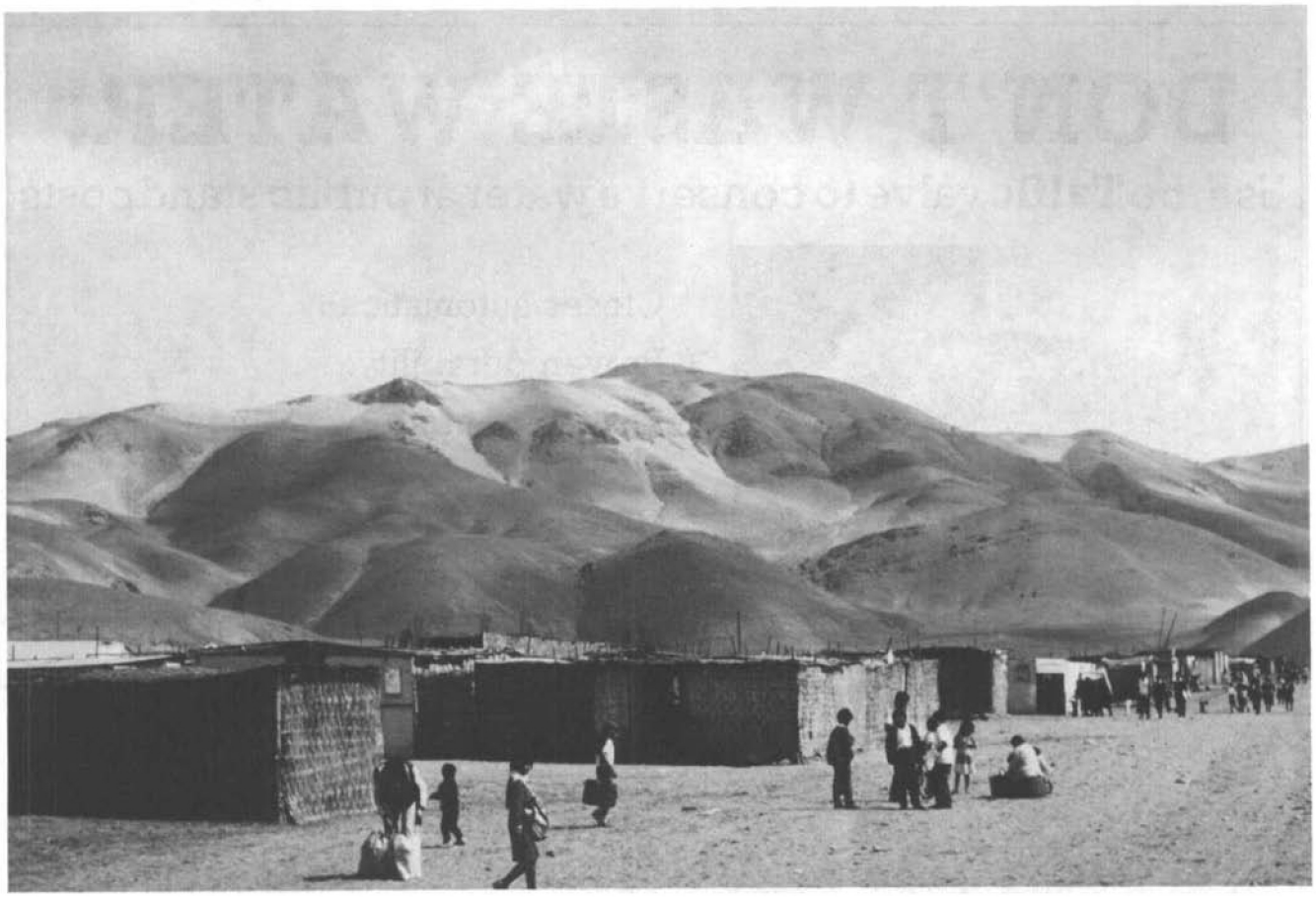
Small fog collectors built to a standard size measuring the fog collection rates at the site in Cerra Orara, Peru.



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The Cerra Orara fog collection site in Peru is located 3.5km from the coast, just above the settlement of Los Rosales.

teorological station operated throughout the period. The results showed that at this site a collection rate of 8.5 litres/m^2/day could be expected for at least seven months of the year. On an annual basis, the site may have a greater productivity than the El Tofo site in Chile. This results in part from higher wind speeds and in part from the drizzle which falls from the thicker cloud decks.

Dhofar, Oman

A major fog collection experiment was undertaken in the Sultanate of Oman in 1989 and 1990, based on the work in Chile. The project was funded initially by the United Nations Development Programme, the World Meteorological Organization, and the Government of Oman through the Planning Committee for Development and Environment in the Southern Region (PCDESR). In the second year work was carried out under the auspices of PCDESR. During the southwestern monsoon (*khareef*), the mountains (*jebel*) of Dhofar are covered in a thick deck of fog with frequent drizzle. The maximum duration of the *khareef* is from mid-June to mid-September, and it is often some weeks shorter. Data were collected with both standard $1m^2$, as well as much larger collectors. In the upper elevations, from 900 to 1000m, average collection rates of 30 litres/m^2/day were obtained for a three-month period. Because of the extended dry period between collection seasons, and because of the other options available in Dhofar (boreholes, desalination), a private sector evaluation is presently underway to determine if fog water collector arrays should be included in the next five-year plan for the region. If they are, the most likely application will be the reforestation of the *jebel*.

Discussion

High elevation fogs are important for many reasons. In central Europe and in eastern North America forest-covered mountains have experienced considerable damage, and this is at least in part because of the deposition of fog water containing high concentrations of pollutants. Extensive studies have measured fog frequencies, the amount of water collected by the forests, and the chemical composition of the water.

In the humid tropics, cloud forests owe their existence to the input of water from both precipitation and fog. But few quantitative measurements exist of the amount of water these forests collect from the fog. It is clear, however, that deforestation on tropical mountains will lead to reduced water inputs, which will result in less water in acquifers and the streams which these acquifers feed. This, coupled with the erosion that deforestation generates, may result in both seasonal aridity and semi-arid highlands.

In the present instance it is the potential application of water produced by artificial collectors in arid lands that is so fascinating. The small-scale applications discussed here may ultimately lead to fog collection sites being established in many countries where there are demands for safe and reliable water supplies. The pressures for increased water supply as a result of increased demand and the contamination of traditional sources means that non-conventional water supplies such as this must be explored. ●

References

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2. Schemenauer, R.S., and Cereceda, P., 'The quality of fog water collected for domestic and agricultural use in Chile', *Journal of Applied Metereology*, Vol.31, pp.275-90.
3. Schemenauer, R.S., and Cereceda, P., 'Fog water collection in arid coastal locations', *Ambio*, Vol.20, pp.303-8.

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