1.3 Fog harvesting

This innovative technology is based on the fact that water can be collected from fogs under favorable climatic conditions. Fogs are defined as a mass of water vapor condensed into small water droplets at, or just above, the Earth's surface. The small water droplets present in the fog precipitate when they come in contact with objects. The frequent fogs that occur in the arid coastal areas of Peru and Chile are traditionally known as *camanchacas.* These fogs have the potential to provide an alternative source of freshwater in this otherwise dry region if harvested through the use of simple and low-cost collection systems known as fog collectors. Present research suggests that fog collectors work best in coastal areas where the water can be harvested as the fog moves inland driven by the wind. However, the technology could also potentially supply water for multiple uses in mountainous areas should the water present in stratocumulus clouds, at altitudes of approximately 400 m to 1 200 m, be harvested.

Technical Description

Full-scale fog collectors are simple, flat, rectangular nets of nylon supported by a post at either end and arranged perpendicular to the direction of the prevailing wind. The one used in a pilot-scale project in the El Tofo region of Chile consisted of a single 2 m by 24 m panel with a surface area of 48 m^2. Alternatively, the collectors may be more complex structures, made up of a series of such collection panels joined together. The number and size of the modules chosen will depend on local topography and the quality of the materials used in the panels. Multiple-unit systems have the advantage of a lower cost per unit of water produced, and the number of panels in use can be changed as climatic conditions and demand for water vary.

The surface of fog collectors is usually made of fine-mesh nylon or polypropylene netting, e.g., "shade cloth," locally available in Chile under the brand name Raschel. Raschel netting (made of flat, black polypropylene filaments, 1.0 mm wide and 0.1 mm thick, in a triangular weave) can be produced in varying mesh densities. After testing the efficiency of various mesh densities, the fog collectors used at El Tofo were equipped with Raschel netting providing 35% coverage, mounted in double layers. This proportion of polypropylene-surface-to-opening extracts about 30% of the water from the fog passing through the nets.

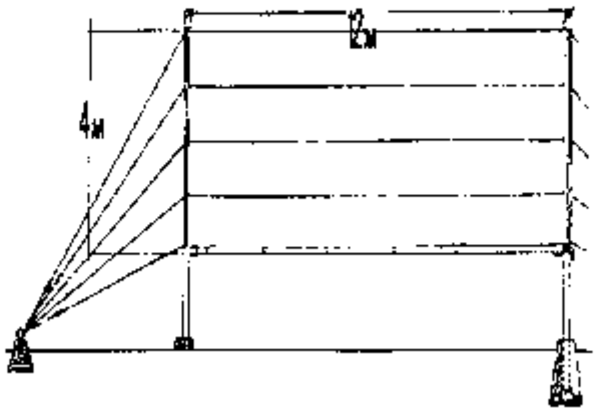
As water collects on the net, the droplets join to form larger drops that fall under the influence of gravity into a trough or gutter at the bottom of the panel, from which it is conveyed to a storage tank or cistern. The collector itself is completely passive, and the water is conveyed to the storage system by gravity. If site topography permits, the stored water can also be conveyed by gravity to the point of use. The storage and distribution system usually consists of a plastic channel or PVC pipe approximately 110 mm in diameter which can be connected to a 20 nun to 25 nun diameter water hose for conveyance to the storage site/point of use. Storage is usually in a closed concrete cistern. A 30 m^3 underground cistern is used in the zone of Antofagasta in northern Chile. The most common type of fog collector is shown in Figure 6.

Storage facilities should be provided for at least 50% of the expected maximum daily volume of water consumed. However, because the fog phenomenon is not perfectly regular from day to day, it may be necessary to store additional water to meet demands on days when no fog water is collected. Chlorination of storage tanks may be necessary if the water is used for drinking or cooking purposes.

Extent of Use

Fog harvesting has been investigated for more than thirty years and has been implemented successfully in the mountainous coastal areas of Chile (see case study in Part C, Chapter 5), Ecuador, Mexico, and Peru. Because of a similar climate and mountainous conditions, this technology also can be implemented in other regions as shown in Figure 7.

Figure 6: Section of a Typical Flat, Rectangular Nylon Mesh Fog Collector. The water is collected in a 200 l drum.



Source: *G.* Soto Alvarez, National Forestry Corporation (CONAF), Antofagasta, Chile.

In Chile, the National Forestry Corporation (CONAF), the Catholic University of the North, and the Catholic University of Chile are implementing the technology in several regions, including El Toro, Los Nidos, Cerro Moreno, Travesía, San Jorge, and Pan de Azúcar. The results of the several experiments conducted in the northern coastal mountain region indicate the feasibility and applicability of this technology for supplying good-quality water for a variety of purposes, including potable water and water for commercial, industrial, agricultural, and environmental uses. These experiments were conducted between 1967 and 1988 at altitudes ranging from 530 m to 948 m using different types of fog water collectors. The different types of neblinometers and fog collectors resulted in different water yields under the same climatic conditions and geographic location. A neblinometer or fog collector with a screen containing a double Raschel (30%) mesh was the most successful and the one that is currently recommended.

In Peru, the National Meteorological and Hydrological Service (SENAMHI) has been cooperating with the Estratus Company since the 1960s in implementing the technology in the following areas: Lachay, Pasamayo, Cerro Campana, Atiquipa, Cerro Orara (Ventinilla-Ancón), Cerro Colorado (Villa María de Triunfo), and Cahuide Recreational Park (Ate-Vitarte), and in southern Ecuador the Center for Alternative Social Research (CISA) is beginning to work in the National Park of Machalilla on Cerro La Gotera using the Chilean installations as models.

Operation and Maintenance

Operating this technology is very simple after once the fog collection system and associated facilities are properly installed. Training of personnel to operate the system might not be necessary if the users participate in the development and installation of the required equipment. A very important factor in the successful use of this technology is the establishment of a routine quality control program. This program should address both the fog collection system and the possible contamination of the harvested water, and include the following tasks:

· Inspection of cable tensions. Loss of proper cable tension can result in water loss by failing to capture the harvested water in the receiving system. It can also cause structural damage to the collector panels.

· Inspection of cable fasteners. Loose fasteners in the collection structure can cause the system to collapse and/or be destroyed.

· *Inspection of horizontal mesh net tensions.* Loose nets will lead to a loss of harvesting efficiency and can also break easily.

· *Maintenance of mesh nets.* After prolonged use, the nets may tear. Tears should be repaired immediately to avoid having to replace the entire panel. Algae can also grow on the surface of the mesh net after one or two years of use, accumulating dust, which will cloud the collected water and cause offensive taste and odor problems. The mesh net should be cleaned with a soft plastic brush as soon as algal growth is detected.

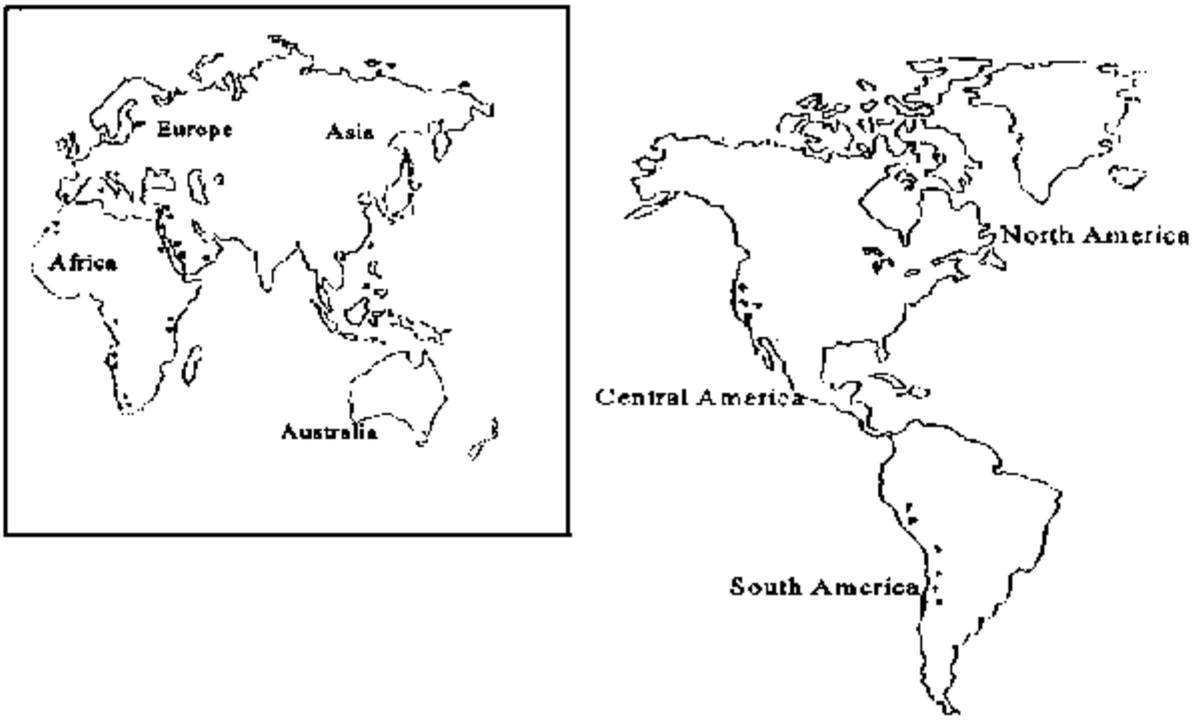
· *Maintenance of collector drains.* A screen should be installed at the end of the receiving trough to trap undesirable materials (insects, plants, and other debris) and prevent contamination of water in the storage tank. This screen should be inspected and cleaned periodically.

· *Maintenance of pipelines and pressure outlets.* Pipelines should be kept as clean as possible to prevent accumulation of sediments and decomposition of organic matter. Openings along the pipes should be built to facilitate flushing or partial cleaning of the system. Likewise, pressure outlets should be inspected and cleaned frequently to avoid accumulation of sediments. Openings in the system must be protected against possible entry of insects and other contaminants.

· *Maintenance of cisterns and storage tanks.* Tanks must be cleaned periodically with a solution of concentrated calcium chloride to prevent the accumulation of fungi and bacteria on the walls.

· *Monitoring of dissolved chlorine. A* decrease in the concentration of chlorine in potable water is a good indicator of possible growth of microorganisms. Monitoring of the dissolved chlorine will help to prevent the development of bacterial problems.

Figure 7: Locations Where Fog Harvesting Has Been or Can Be Implemented.



Source: W. Canto Vera, et al. 1993. *Fog Water Collection System.* IDRC, Ottawa, Canada.

Level of Involvement

In applying this technology, it is strongly recommended that the end users folly participate in the construction of the project. Community participation will help to reduce the labor cost of building the fog harvesting system, provide the community with operation and maintenance experience, and develop a sense of community ownership and responsibility for the success of the project. Government subsidies, particularly in the initial stages, might be necessary to reduce the cost of constructing and installing the facilities. A cost-sharing approach could be adopted so that the end users will pay for the pipeline and operating costs, with the government or an external agency assuming the cost of providing storage and distribution to homes.

Costs

Actual costs of fog harvesting systems vary from location to location. In a project in the region of Antofagasta, Chile, the installation cost of a fog collector was estimated to be $90/m^2 of mesh, while, in another project in northern Chile, the cost of a 48 m^2 fog collector was approximately $378 ($225 in materials, $63 in labor, and $39 in incidentals). This latter system produced a yield of 3.0 l/m^2 of mesh/day. The cost of a fog harvesting project constructed in the village of Chungungo, Chile, is shown in Table 2. The most expensive item in this system is the pipeline that carries the water from the fog collection panel to the storage tank located in the village.

Maintenance and operating costs are relatively low compared to other technologies. In the project in Antofagasta, the operation and maintenance cost was estimated at $600/year. This cost is significantly less than that of the Chungungo project: operating costs in that project were estimated at $4 740, and maintenance costs at $7 590 (resulting in a total cost of $12 330/year).

Both the capital costs and the operating and maintenance costs are affected by the efficiency of the collection system, the length of the pipeline that carries the water from the collection panels to the storage areas, and the size of the storage tank. For example, the unit cost for a system with an efficiency of 2.0 l/n^/day was estimated to be $4.80/1 0001. If the efficiency was improved to 5.0 l/m^2/day, then the unit cost would be reduced to $1.90/1 0001. In the Antofagasta project, the unit cost of production was estimated at $1.41/1000 l with a production of 2.5 l/m^2/day.

Table 2 Capital Investment Cost and Life Span of Fog Water Collection System Components

Component	Cost ($)	%of Total Cost	Life Span (Years)
Collection	27680	22.7	12
Main pipeline	43787	35.9	20
Storage (100m^3 tank)	15632	12.8	20
Treatment	2037	1.7	10
Distribution	32806	26.9	20
TOTAL	121 942	100.0	

Source: Soto Alvarez, Q. National Forestry Corporation, Antofagasta, Chile.

Effectiveness of the Technology

Experimental projects conducted in Chile indicate that it is possible to harvest between 5.3 l/m^2/day and 13.4 l/m^2/day depending on the location, season, and type of collection system used. At El Tofo, Chile, during the period between 1987 and 1990, an average fog harvest of 3.0 l/n^/day was obtained using 50 fog collectors made with Raschel mesh netting. Fog harvesting efficiencies were found to be highest during the spring and summer months, and lowest during the winter months. The average water collection rates during the fog seasons in Chile and Peru were 3.0 and 9.0 l/m^2/day, respectively; the lengths of the fog seasons were 365 and 210 days, respectively. While this seems to indicate that higher rates are obtained during shorter fog seasons, the practical implications are that a shorter fog season will require large storage facilities in order to ensure a supply of water during non-fog periods. Thus, a minimum fog season duration of half a year might serve as a guideline when considering the feasibility of using this technology for water supply purposes; however, a detailed economic analysis to determine the minimum duration of the fog season that would make this technology cost-effective should be made. In general, fog harvesting has been found more efficient and more cost-effective in arid regions than other conventional systems.

Suitability

In order to implement a fog harvesting program, the potential for extracting water from fogs first must be investigated. The following factors affect the volume of water that can be extracted from fogs and the frequency with which the water can be harvested:

· **Frequency of fog occurrence,** which is a function of atmospheric pressure and circulation, oceanic water temperature, and the presence of thermal inversions.

· **Fog water content,** which is a function of altitude, seasons and terrain features.

· **Design of fog water collection system,** which is a function of wind velocity and direction, topographic conditions, and the materials used in the construction of the fog collector.

The occurrence of fogs can be assessed from reports compiled by government meteorological agencies. To be successful, this technology should be located in regions where favorable climatic conditions exist. Since fogs/clouds are carried to the harvesting site by the wind, the interaction of the topography and the wind will be influential in determining the success of the site chosen. The following factors should be considered in selecting an appropriate site for fog harvesting:

Global Wind Patterns: Persistent winds from one direction are ideal for fog collection. The high-pressure area in the eastern part of the South Pacific Ocean produces onshore, southwest winds in northern Chile for most of the year and southerly winds along the coast of Peru.

Topography: It is necessary to have sufficient topographic relief to intercept the fogs/clouds; examples, on a continental scale, include the coastal mountains of Chile, Peru, and Ecuador, and, on a local scale, isolated hills or coastal dunes.

Relief in the surrounding areas*:* It is important that there be no major obstacle to the wind within a few kilometers upwind of the site. In arid coastal regions, the presence of an inland depression or basin that heats up during the day can be advantageous, as the localized low pressure area thus created can enhance the sea breeze and increase the wind speed at which marine cloud decks flow over the collection devices.

Altitude: The thickness of the stratocumulus clouds and the height of their bases will vary with location. A desirable working altitude is at two-thirds of the cloud thickness above the base. This portion of the cloud will normally have the highest liquid water content. In Chile and Peru, the working altitudes range from 400 m to 1 000 m above sea level.

Orientation of the topographic features: It is important that the longitudinal axis of the mountain range, hills, or dune system be approximately perpendicular to the direction of the wind bringing the clouds from the ocean. The clouds will flow over the ridge lines and through passes, with the fog often dissipating on the downwind side.

Distance from the coastline: There are many high-elevation continental locations with frequent fog cover resulting from either the transport of upwind clouds or the formation of orographic clouds. In these cases, the distance to the coastline is irrelevant. However, areas of high relief near the coastline are generally preferred sites for fog harvesting.

Space for collectors: Ridge lines and the upwind edges of flat-topped mountains are good fog harvesting sites. When long fog water collectors are used, they should be placed at intervals of about 4.0 m to allow the wind to blow around the collectors.

Crestline and upwind locations: Slightly lower-altitude upwind locations are acceptable, as are constant-altitude locations on a flat terrain. But locations behind a ridge or hill, especially where the wind is flowing downslope, should be avoided.

Prior to implementing a fog water harvesting program, a pilot-scale assessment of the collection system proposed for use and the water content of the fog at the proposed harvesting site should be undertaken. Low cost and low maintenance measurement devices to measure the liquid water content of fog, called neblinometers, have been developed at the Catholic University of Chile (Carvajal, 1982). Figure 8 illustrates four different types of neblinometers: (a) a pluviograph with a perforated cylinder; (b) a cylinder with a nylon mesh screen; (c) multiple mesh screens made of nylon or polypropylene mesh; and (d) a single mesh screen made of nylon or polypropylene mesh. The devices capture water droplets present in the fog on nylon filaments that are mounted in an iron frame. The original neblinometer had an area of 0.25 m^2 made up of a panel with a length and width of 0.5 m, and fitted with a screen having a warp of 180 nylon threads 0.4 mm in diameter. The iron frame was 1.0 cm in diameter and was supported on a 2.0 m iron pole. These simple devices can be left in the field for more than a year without maintenance and can be easily modified to collect fog water samples for chemical analysis.

In pilot projects, use of a neblinometer with single or multiple panels having a width and length of one meter, fitted with fine-mesh nylon or polypropylene netting is recommended. It should be equipped with an anemometer to measure wind velocity and a vane to measure wind direction. The neblinometer can be connected to a data logger so that data can be made available in computer-compatible formats.

Advantages

· A fog collection system can be easily built or assembled on site. Installation and connection of the collection panels is quick and simple. Assembly is not labor intensive and requires little skill.

· No energy is needed to operate the system or transport the water.

· Maintenance and repair requirements are generally minimal.

· Capital investment and other costs are low in comparison with those of conventional sources of potable water supply used, especially in mountainous regions.

· The technology can provide environmental benefits when used in national parks in mountainous areas, or as an inexpensive source of water supply for reforestation projects.

· It has the potential to create viable communities in inhospitable environments and to improve the quality of life for people in mountainous rural communities.

· The water quality is better than from existing water sources used for agriculture and domestic purposes.

Disadvantages

· This technology might represent a significant investment risk unless a pilot project is first carried out to quantify the potential rate and yield that can be anticipated from the fog harvesting rate and the seasonably of the fog of the area under consideration.

· Community participation in the process of developing and operating the technology in order to reduce installation and operating and maintenance costs is necessary.

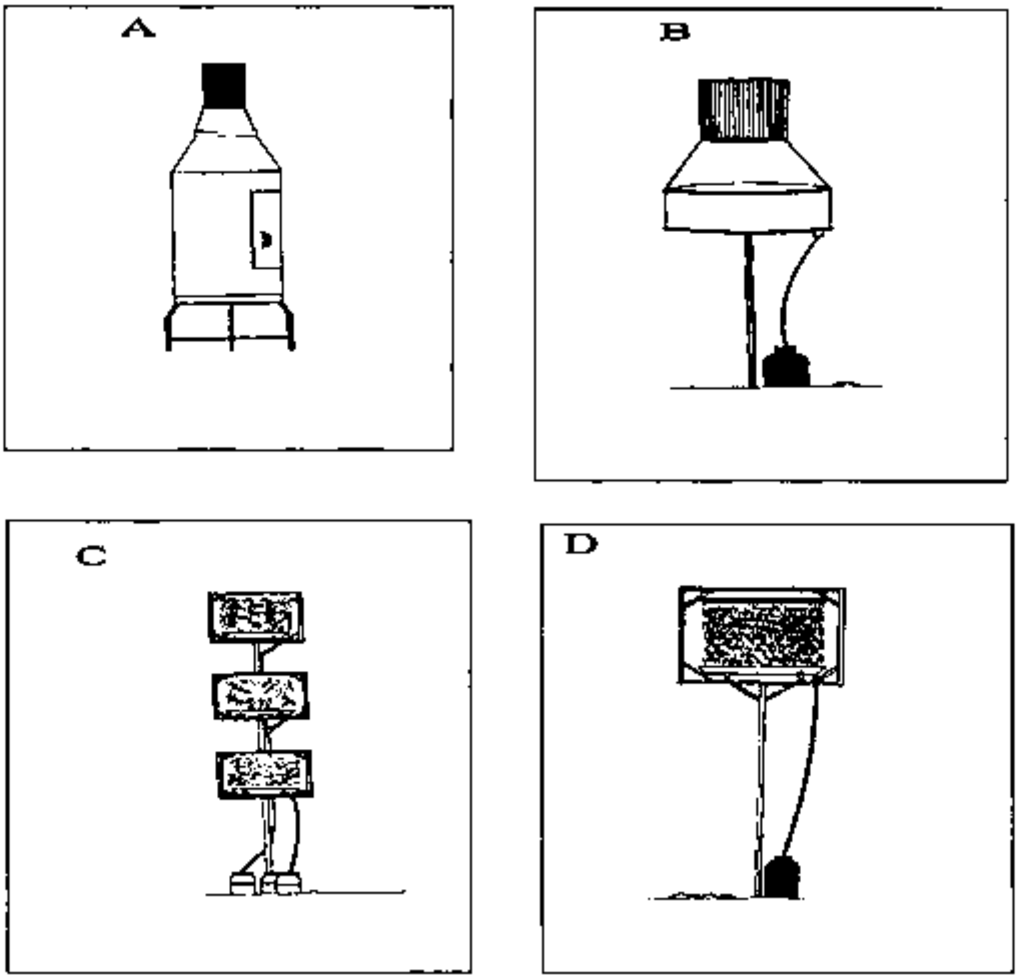
· If the harvesting area is not close to the point of use, the installation of the pipeline needed to deliver the water can be very costly in areas of high topographic relief.

· The technology is very sensitive to changes in climatic conditions which could affect the water content and frequency of occurrence of fogs; a backup water supply to be used during periods of unfavorable climatic conditions is recommended.

· In some coastal regions (e.g., in Paposo, Chile), fog water has failed to meet drinking water quality standards because of concentrations of chlorine, nitrate, and some minerals.

· Caution is required to minimize impacts on the landscape and the flora and fauna of the region during the construction of the fog harvesting equipment and the storage and distribution facilities.

Figure 8: Types of Neblinometers.



Source: G. Soto Alvarez, National Forestry Corporation, Antofagasta, Chile.

Cultural Acceptability

This technology has been accepted by communities in the mountainous areas of Chile and Peru. However, some skepticism has been expressed regarding its applicability to other regions. It remains a localized water supply option, dependent on local climatic conditions.

Future Development of the Technology

To improve fog harvesting technology, design improvements are necessary to increase the efficiency of the fog collectors. New, more durable materials should be developed. The storage and distribution systems needs to be made more cost-effective. An information and community education program should be established prior to the implementation of this technology.

Information Sources

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Bibliography

Acosta Baladón, A. 1992. "Niebla potable." *Conciencia Planetaria,* 12. pp. 50-55.

----, and A. Gioda. 1991. "L'importance des précipitations occultes sous les tropiques secs," *Sécheresse,* 2(2), pp. 132-135.

Canto Vera, W. 1989. *Proyecto Camanchacas-Chile (Construcción de Captadores en el Sector El Tofo): Informe Final de la Primera Fase.* Antofagasta, Chile, CIID/Environment Service of Canada, Universidad de Chile, and Universidad Católica de Chile.

----, et al. 1993. *Fog Water Collection System.* Ottawa, IDRC.

Carlson, P.J., and R.M. Añazco. 1990. *Establecimiento y Manejo de Prácticas Agroforestales en la Sierra Ecuatoriana.* Quito, Red Agro-Forestal Ecuatoriana.

Cavelier, J., and G. Goldstein. 1989. "Mist and Fog Interception in Elfin Cloud Forests in Colombia and Venezuela,." *Journal of Tropical Ecology,* 5, pp. 309-322.

Cereceda, P. 1983. *Factores Geográficos que Determinan el Comportamiento Espacial y Temporal de la Camanchaca, Informe Final.* Santiago, Dirección de Investigación de la Pontificia Universidad Católica de Chile.

----, and H. Larraín. 1981. *Pure Water Flowing from the Clouds.* Montevideo, UNESCO/ROSTLAC.

----, R.S. Schemenauer, and M. Suit. 1992. "Alternative Water Supply for Chilean Coastal Desert Villages," *Water Resources Development,* 8(1), pp. 53-59.

----, ----, and R. Valencia. 1992. "Posibilidades de Abastecimento de Agua de Niebla en la Región de Antofagasta, Chile," *Revista de Geografia Norte*

Grande, 19, pp. 3-14.

----, et al. 1993. "El árbol fuente." *Mundo Científico,* 13(132), pp. 126-134.

----,Z. Hernández Martin, and E. Gonzales Garcia. 1993. *Observatoires, Brouillards et arbres fontaines awe Canaries.* Veille Climatique Satellitaire. (In press)

----, et al. 1993. "The Fountain Tree of Canary Islands and Others Fog Collectors." In *Proceedings of the International Symposium on Tropical Mountain Cloud Forests, San Juan.* Lawrence, Kan. U.S.A., Association for Tropical Biology. (In press)

Gischler, C. 1977. *Camanchaca as a Potential Renewable Water Resource for Vegetation and Coastal Springs along the Pacific in South America.* Cairo, Egypt, UNESCO/ROSTAS.

----. 1979. *Reunión para Evaluación Preliminar de la Camanchaca (Neblinas Costeras) como Recurso Renovable no Convencional a lo largo de la Costa Desértica del Pacifico en Sudamérica (Tacna, Peru).* Montevideo, UNESCO/ROSTLAC.

----. 1981. *Informe sobre las Acciones Realizadas para la Formulación del Proyecto "Aprovechamiento de las Nieblas Costeras (Camanchacas) en la Zona Arida del Pacífico Sur".* Montevideo, UNESCO/ROSTLAC.

----. 1981. *Atrapanieblas para Fertilizar el Desierto.* Paris, UNESCO. (Perspectivas de la UNESCO, No. 766)

----- -. 1991. *The Missing Link in a Product! on Chain: Vertical Obstacles to Catch Camanchaca.* Montevideo, UNESCO/ROSTLAC.

King, W.D., D.A. Parkin, and R.J. Handsworth. 1978. "A Hot-Wire Water Device Having Fully Calculable Response Characteristics," *J. Appl. Meteor.,* 17, pp. 1809-1813.

Knollenberg, RG. 1972. "Comparative Liquid Water Content Measurements of Conventional Instruments with an Optical Array Spectrometer," *J. Appl. Meteor.,* 11, pp. 501-508.

Larraín Barros, H. 1981. "Cosechando Camanchaca en El Tofo (IV Region, Chile)," *CRECES,* 2(10).

----.1982. "Hurgando en el Pasado Climático de Paposo," *CRECES,* 2.

----, et al. 1983. "Aprovechamiento de la Camanchaca, IV Region, Chile." In *Informe Final de Actividades en 1982-1983 para la Intendencia Regional de Coquimbo, Chile.* Santiago.

Lopez, J.M., W.V. Cantos, and R.R. Meneses. 1989. "Construcción de Atrapanieblas," *Revista La Platina,* 56, pp. 41-47.

López Ocaña, C. 1986. *Estudio de las Condiciones Climáticas y de la Niebla en la Costa Norte de Lima.* Lima, Universidad Nacional Agraria La Molina. (Tesis de grado)

Mejía E., S. 1993. "Cazadores de Niebla," *Hoy Domingo* (Quito), mayo 23, 184, pp. 2-3.

Mooney, M.J. 1995. "Come the Camanchaca," *Américas,* 47(4), pp. 30-37.

Nagel, J. F. 1959. "Fog Precipitation on Table Mountain," *Quart. J. Roy. Meteor. Soc.,* 82, pp. 452-460.

Ramirez Fernández, J. 1982. "Cálculo del Potencial Hídrico de las Nubes Rasantes en el Desierto Costero Chileno," *Revista Geográfica de Chile "Tierra Australia,"* 26.

Santana Pérez, L. 1990. "La Importancia Hidrológica de las Nieblas en las Cumbres del Parque Nacional de Garojonay." In P.L. Pérez de Paz, *Parque Nacional de Garojonay,* Madrid, ICONA. pp. 67-71.

Schemenauer, R.S. n.d. "Acidic Deposition to Forests: The 1985 Chemistry of High Elevation Fog (CHEF) Project," *Atmos. Ocean.,* 24, pp. 452 -460.

----. 1988. "Agua de la Niebla para Humedecer un Desierto Sediento." *Boletín de la OMM (Geneva),* 37(4).

----, and P. Cereceda. 1991. "Fog-Water Collection in Arid Coastal Locations." *Ambio,* 20(7), pp. 303-308.

----,and ----. 1992. "Water from Fog-Covered Mountains," *Waterlines,* 10(4), pp. 10-13.

----, and ----. 1992. "The Quality of Fog Water Collected for Domestic and Agricultural use in Chile." *Journal of Applied Meteorology,* 31(3), pp. 275-290.

----, ----,and N. Carvajal. 1987. "Measurement of Fog Water Deposition and their Relationships to Terrain Features," *Journal of Climate and Applied Meteorology,* 26(9), pp. 1285-1291.

----, -----, H. Fuenzalida, and P. Cereceda. 1988. "A Neglected Water Resource: The Camanchaca of South America." *Bulletin of the American Meteorological Society,* 69(2).

Soto A., G. 1992. *Camanchaca: Alternativas de Utilización y Selección de Lugares en el Norte de Chile (El Tofo-Chungungo).* La Serena, Chile, Corporación Nacional Forestal, IV Región.

Torres, G. J., and C. Lopez Ocaña. 1981. "Productividad Primaria en las Lomas de la Costa Central del Perú," *Boletín de Lima,* 14.

UNESCO. 1988. *Final Report: II Meeting of the Major Regional Project (MRP) on Use and Conservation of Water Resources in Rural Areas of Latin America and the Caribbean, La Serena, Chile.* Montevideo, UNESCO/ROSTLAC.

Universidad del Norte, Departamento de Ciencias Físicas. 1981. *Datos Meteorológicos de la Ciudad de Antofagasta (ano 1980).* Antofagasta, Chile.

Valvidia Ponce, J. 1972. *Obtención de Agua Atmosférica en Lomas de Lachay.* Lima, SENAMHI.

Zúñiga, I.J. 1977. "Un Relicto Boscoso Natural de Probable Origen Terciario en el Norte Chico de Chile." *Atenea,* 440.