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5.4 Seawater/brackish water desalination by reverse osmosis in the British Virgin Islands

Technical Description

Desalination by reverse osmosis for public water supply is carried out in the British Virgin Islands on the islands of Tortola and Virgin Gorda. The operations on the island of Tortola may be classified into two different types, based on the source of the feedwater, which is brackish water either from shoreline wells or from alluvial well fields. Of the three plants on the island, the main plant is operated by Ocean Conversion (BVI) Ltd. and obtains its feedwater from wells sunk at the shoreline to a depth of roughly 75 feet. A sanitary seal from ground level to a depth of about 40 feet has been installed. Water is pumped by submersible pumps to the intake of the plant. The two other plants, operated by Aqua Design (BVI) Ltd., obtain their feedwater from either shallow wells dug in the alluvial deposits of the nearby valleys or wells drilled at the shoreline (in the case of the westernmost plant). The two plants operated by Aqua Design (BVI) Ltd. on Virgin Gorda obtain their feedwater from an open-sea intake system. In each case, however, the process of desalination at the plants is generally the same and can be divided into the following stages:

- Pre-filtration of the raw water using disposable 5-10 micron polypropylene cartridge filter elements.

- Pressurization of the raw water to a pressure of about 1 000 psi, utilizing either positive-displacement or multistage centrifugal pumps.

- Separation of the raw water (approximately 40% of the seawater and 73% of the brackish water) into product water and brine, utilizing spiral-wound membrane elements contained in FRP pressure vessels.

- Recovery of the pressure in the brine, by means of a work-exchanger energy recovery system that significantly reduces energy use.

- Disposal of the spent brine.

- Post-treatment of the product water by chlorination, pH adjustment, and corrosion inhibition so that the final water meets the WHO standards for drinking water supply.

- Distribution of the product water, including metering at the exit of the plant and monitoring of the production process through instrumentation and control of automated plant operations.

This technology is described in Part B, Chapter 2, "Water Quality Improvement Technologies."

Extent of Use

All of the public water supply on Tortola, and approximately 90% on Virgin Gorda, is desalinated water. The distribution system covers all areas on the islands below the 300 ft. contour. On Tortola, most of the southern side of the island, from East End, including Beef Island, to Pockwood Pond, is supplied. In the northwest, at Cappoons Bay, desalination plants cover the West End, Carrot Bay, and Cane Garden Bay areas. There are about 4 000 water connections on Tortola, serving a population of 13 500 residents and approximately 256 000 visitors annually. In 1994, the government bought 260.6 million gallons of desalinated water from the two private companies for distribution on Tortola.

On Virgin Gorda, the two plants have open-sea water intakes extending about 1 500 feet from the shoreline: One is in the Valley, and the other is in the North Sound. These plants serve a resident population of 2 500 and a visitor population of 49 000 annually. There are 675 connections to the public water supply system. In 1994, the government purchased 20.8 million gallons of water for distribution in Virgin Gorda.

Operation and Maintenance

On both seawater and brackish water reverse osmosis plants the major maintenance work consists of the following:

- Maintaining and repairing the equipment, which, in the case of the High School Plant located in Road Town, where the wells and well pumps are operated by the Water and Sewerage Department, consists of weekly routine maintenance to ensure a continuous and adequate flow of water to the plant, and general maintenance (e.g., cleaning, painting, leak repair, cleaning around wells).

- Backwashing and flushing of the media filters.

- Replacing cartridge filter elements (approximately every 8 weeks).

- Cleaning the membrane elements (approximately every 4 months).

- Repairing and calibrating instruments.

- Replenishing the pre- and post-treatment chemicals.

- Controlling inventories and ordering spare parts.

The staff required is approximately 1 person for a 200 m^3/day plant, and 3 persons for a 4 000 m^3/day plant.

Level of Involvement

Currently, all plants are operated on a BOOT (build, own, operate, transfer) basis by private (generally foreign) companies which finance, operate, and maintain the plants for a fixed period. The price of the product water is fixed for me period of the agreement, although provision is made for adjustment for inflation, and there are penalties for non-performance. The contracts prescribe a minimum quantity of water which the government is obligated to buy.

At two of the five plants operating on the islands, the government, through the Water and Sewerage Department (WSD), is responsible for the disinfection of the final product water. On Tortola, the WSD is also responsible for the operation and maintenance of the product water pumps at the exit of the plants, and it owns and operates the well fields that serve the westernmost plant. At the Ocean Conversion plant, located close to the Water and Sewerage Department head office, two technicians from the Department have been involved in the operation of the plant from the time of its commissioning. They are paid a monthly stipend as part of the contractual arrangement, and are called in to assist with repair work as and when required. The government also provides the land, tax relief and custom exemptions; buys the bulk water; and monitors the product water quality. The WSD distributes the water.

Costs

The unit cost of production of desalinated water decreases as the plant capacity increases. The turnkey capital cost of a plant of 20 000 gpd is approximately $200 000. For a plant of 1.0 mgd, the cost is approximately $4 500 000. The major operating costs consist of energy (primarily), labor, replacement membranes, and spare parts. Energy consumption ranges from 3 to 6 kWh/m^3 of potable water produced, depending on the size of the plant and the technology employed.

Under the current purchase agreements, the companies maintain and operate the plants at their own cost and sell water in bulk to the government at the following rates per 1 000 gallons:

Tortola

Aqua Design (BVI) Ltd.

- Desalinated seawater = $ 16.50.
- Desalinated brackish water = $9.10

Ocean Conversion (BVI) Ltd.

- Desalinated seawater = $ 15.80

Virgin Gorda

Aqua Design (BVI) Ltd.

- Desalinated seawater = $ 13.10

In 1994, the Government of the BVI bought 260.6 million gallons of water from the desalination companies for distribution on the island of Tortola at a cost of $3 611 000. On Virgin Gorda, after desalinated water became available to the public during February 1994, the Government of the BVI bought 20.8 million gallons at a cost of $485 000.

Effectiveness of the Technology

The seawater/brackish water reverse osmosis technology is very effective at converting Caribbean Sea water to potable water, meeting the WHO standards for drinking water, with a total dissolved solids level of less than 500 mg/l.

Suitability

The technology is suitable for use throughout the Caribbean Basin, provided there is a source of clean raw water, either from boreholes or from open-sea water intakes. The technology is particularly suitable for use in areas where the freshwater resources are inadequate to meet growing demands and the centers of population are concentrated close to the coast. In considering the use of seawater in desalination, the seawater should be free from pollutants, especially from land-based industries, and the intake should be located in an area with little chance of pollution by ocean-going vessels. The disposal of the brine effluent should be carefully considered as this can have adverse effects on sea life.

Advantages

- Desalinated water is a reliable source of water that is not subjected to seasonal changes in, or locally extreme, weather events.

- There is generally minimal usage of chemicals in the process.

- There is minimal environmental impact.

- The plants can be modular in design and easily expanded to meet changing demands.

- Delivery times for modular units and spares are short, typically 3 to 12 months, depending on the location and size of plant.

- If private contractors are used to supply the water, minimal capital investment by the government is required.

- Water price can be fixed and/or linked to inflation for the duration of the agreement.

Disadvantages

- Great care and staff expertise is required to minimize the rate of membrane replacement.

- In the case of open-sea intakes, there is the chance of interruptions during stormy weather.

- The sophistication of plant and the high pressures involved require materials and equipment of a very high standard, not usually available locally, which may result in high importation costs.

- There is usually a need for foreign expertise, with a concomitant commitment of foreign exchange.

- There are many dissimilar components used in the plants, so a highly varied spare parts inventory is required.

Further Development of the Technology

The seawater/brackish water reverse osmosis technology would be further improved by the development of membrane elements that are less prone to fouling, operate at lower pressures, and require less pre-filtration, and by the introduction of highly efficient energy recovery technologies that are simpler to operate than the existing work-exchanger technologies.

Information Sources

Contacts

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Dean Bedford, General Manager, Aqua Design (BVI) Limited, Post Office Box 845, Road Town, Tortola, British Virgin Islands.

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5.5 Recycling of industrial effluent in Jamaica

Technical description

Recycling of industrial effluent is now being practiced by several industries to reduce the demands on freshwater resources and to reduce pollution of the environment. The recycling of industrial effluent was spearheaded by the bauxite/alumina companies operating in Jamaica, and they are the largest recyclers at the present time. The bauxite/alumina industry produces a waste product known locally as "red mud," which consists of over 70% water, enriched with caustic soda and organics.

The waste is thickened to 28% solids and sprayed on a sloping drying bed in a layer 8 to 10 cm thick. The liquid fraction is collected at the toe of the drying bed and is channeled via pipelines to a sealed holding pond. Pumps move the effluent from the holding pond back to the plant via a pipeline where it is recycled through the process. The system consists of:

- Deep mud thickeners (conical vessels).
- High pressure pumps and pipelines to the drying beds.
- Drying beds, sealed to prevent infiltration of the effluent to the groundwater.

- An effluent holding pond, also sealed to prevent infiltration of the effluent to the groundwater.

- Recycling pumps and pipelines to the plant.

This technology is described in Part B, Chapter 3, "Wastewater Treatment Technologies and Reuse."

Extent of Use

This technology is used at four bauxite/alumina plants in Jamaica. Efforts are under way to encourage other industries to follow suit and recycle process and waste waters.

Operation and Maintenance

Problems encountered in the operation and maintenance of the system include mechanical breakdowns of the pumps; ruptures of the pipelines, necessitating a total shutdown of the system; and heavy rains that overload the system, resulting in spillage to the environment. The bauxite/alumina companies, all being multinational corporations, have few problems in replacing parts or equipment, and generally maintain a large equipment inventory. Each bauxite company has a preventive maintenance program, which also reduces downtime.

The skills needed to operate the system are varied. Overall direction is provided by the senior production engineer. However, skill levels range from laborers, who turn valves on and off, to chemical engineers, who manage the system.

Level of Involvement

The private sector and the government are involved in the implementation of this technology and in certain facets of the operation. The bauxite/alumina companies provide the capital and the engineering designs, and construct the systems. The government, through several specialized agencies, reviews the engineering designs and grant the permits for construction to proceed. Part of the permitting process involves the conduct of an environmental impact assessment. After the permit is granted, construction of the systems is monitored by the government to ensure that design specifications are adhered to. The relationship between the public and private sectors is cooperative and complementary.

Costs

Initial capital costs vary and are dependent on the volume of work to be done in preparing the site, resettling persons living on or near the site, and making the necessary changes in the plant infrastructure. The minimum investment to date in any one system has been $50 million. Operation and maintenance costs are not available as this information is confidential and proprietary to the bauxite companies.

Effectiveness of the Technology

The system, as designed and operated, is very effective in reducing contamination of groundwater resources. Because it is completely sealed, it does not allow infiltration of liquid effluents, and recycling this fraction reduces the risk of contamination of groundwater resources from effluent disposal. The use of this system has reduced groundwater contamination in one area by 44% since 1985, as reported by the Water Resources Authority. Despite some disadvantages, due predominantly to the large land areas consumed by the drying beds and holding ponds, the application of this technology, in all cases, has proved to be advantageous.

Suitability

The technology is suitable for application in areas where large tracts of non-agricultural land - i.e., in excess of 200 ha

- are available. In addition, the land should not be steeply sloped, and a supply of nondispersive clay should be available in close proximity to provide impermeable material for sealing the bottom and sides of the drying beds and holding ponds. The technology can be, and is being, adapted for other situations.

Advantages

- Use of this technology reduces the rate of freshwater withdrawal from aquifers; savings of 4 to 5 Mm^3/year of freshwater have been recorded.

- Recycling of process water reduces the volume of caustic soda solution needed, as the caustic soda is recycled with the effluent.

- The use of energy, to pump freshwater from depths greater than 100 m, is reduced, thereby saving on the import bill (foreign exchange) for oil.

- Contamination of groundwater is reduced by removing and recycling the liquid fraction of the waste stream that is a risk to groundwater quality; likewise, the retention of a high percentage of the caustic soda in the thickened mud (solid fraction) and in the recycled process water makes this contaminant less available for migration to the groundwater.

- The bauxite/alumina companies are better able to meet the ISO 9000 and ISO 14000 certifications and thereby gain a competitive advantage in the marketplace.

- The decreased input costs reduce operational costs, resulting in higher profit margins for the companies and more tax revenue for the government, increasing both the level of investment in the country and the GDP.

- Better environmental management by the corporate sector results in fewer governmental regulations; other multinational corporations are likely to see such conditions as favorable and invest in Jamaica.

- The incidence of water pollution is reduced, increasing the availability of freshwater for domestic and irrigation uses and reducing the cost of water to citizens; this increases the standard of living and governmental popularity.

Disadvantages

- There is an increased risk of pollution of surface water resources, due to the large size of the holding ponds and the possibility of spillages.

- Technical problems within the plants may be experienced, reducing the level of production and affecting the volume of recycled effluent; hence, storage volumes can increase to the point where overflows occur, affecting the environment.

- The quality of effluent may vary significantly, affecting the degree of treatment provided by this technology and thus, potentially, the level of production at the plants.

- The technology is capital-intensive, not labor-intensive, and provides few spin-offs for nearby communities where unemployment may be high.

- As a result of the land-intensive nature of this technology, its implementation may result in the relocation of residents, disrupting their lives and causing great inconvenience; for farmers and other small businesspeople, a new location may be less suitable and/or create the need to seek other employment.

- Agricultural land may be lost in some cases, decreasing food production.

Further Development of the Technology

This technology can be more effective if overflows and spills from the system are managed better. Design parameters, especially relating to the effects of rainfall/runoff and the rate at which the plants can accept recycled effluent to prevent negative environmental impacts, need to be better refined.

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Contacts

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5.6 Treated wastewater reuse scheme in Barbados

Sam Lord's Castle Hotel is located on the southeastern coast of Barbados, in the parish of St. Philip. It lies within the coral-covered portion of the island, with a coral cap thickness of about 80 ft. With an average annual rainfall of 45 inches, this is one of the driest areas of the island (the average annual rainfall for the whole island is 60 inches). In this area, except for 4 months of the year (August to November), the average evapotranspiration rate, 4.5 inches/month, exceeds the monthly rainfall figures. The groundwater resources in this area consist of a thin freshwater lens floating on top of saline water.

The hotel was formerly supplied with freshwater from a groundwater well, but because of the high water demand, especially for the irrigation of large expanses of lawns and garden plants, saline groundwater intruded into it to the point where the freshwater supply was virtually exhausted. A decision was made then to abandon the use of the well and the hotel sent an application to the Ministry of Health and Environment seeking permission to use the treated effluent from its extended aeration sewage treatment plant for irrigating lawns and garden plants. Permission for wastewater reuse was granted and treated wastewater was diverted to irrigation use from its former disposal site in four deep suckwells.

This technology is described in Part B, Chapter 3, "Wastewater Treatment Technologies and Reuse."

Technical Description

Effluent consisting of kitchen, laundry, and domestic sewage is conveyed to a collection chamber, from which it is pumped through a comminutor to an aeration chamber. No primary sedimentation is provided. The aerated mixed liquor then flows out of the aeration chamber through a rectangular opening at one end into a clarifier for gravity separation of solids. The effluent from the clarifier chamber is then passed through a 16-foot-deep chlorine disinfection chamber and pumped to an automatic sprinkler irrigation system. The irrigated areas are sub-divided into 16 zones with 12 sprinklers each. Some areas also have a drip irrigation system. This process is illustrated in Figure 46.

Sludge with a high water content is pumped from the sludge chamber to the suckwells for disposal without thickening. Previously this sludge was pumped to the Bridgetown Sewage Treatment Plant for further treatment and additional desludging. This pumping incurred additional transportation costs.

The packaged wastewater treatment plant was designed abroad and constructed using local contractors. The drip and sprinkler irrigation systems were designed and installed in part by a local irrigation system consulting company and in part by the hotel's maintenance personnel. The Environmental Engineering Division (EED) of the Ministry of Health and Environment was responsible for approving, monitoring, and controlling the operation of the packaged plant. Thus, despite the absence of effluent standards enacted into law, some conditions were placed on the system before permission was granted for irrigation reuse. The approval process involved consultations with the Town and Country Planning Offices and the Barbados Water Authority (BWA).

Extent of Use

At present, there are twelve wastewater treatment facilities in use in Barbados, ranging in size from 2 860 gpd to 37 400 gpd for hotel facilities and to 594 000 gpd for the Barbados

Water Authority plant. The combined total treatment capacity amounts to 786 280 gpd. Eight of these plants are extended aeration plants, three are rotating biological contactor plants, and one, the Barbados Water Authority plant, is a contact stabilization plant. Two more BWA sewerage systems are planned for the south and west coasts, with the intention of reusing their wastewater effluents.

Reuse of treated wastewater for the irrigation of garden plants and lawn grass is limited at present to Sam Lord's Castle Hotel. Another, the Almond Beach Village Hotel, formerly Heywoods Hotel, in St. Peter on the west coast, is almost ready to start irrigating a 9-hole golf course. Other applications for the reuse of wastewater on golf courses (Westmoreland, Kingsland, and Bushy Park are pending, and a number of major hotels have indicated their interest in applying for permission to reuse their effluent. In addition, plans are in place to reuse some of the treated effluent from the BWA Bridgetown Sewage Treatment Plant for flushing sewer lines.

Operation and Maintenance

According to the report of a survey on the Operational Aspects of Wastewater Treatment Plants in Barbados undertaken by A. Vlugman of PAHO in 1990, the operational status of the Sam Lord's Castle Hotel plant was considered to be moderate. The plant is about twelve years old and the operator reports few problems; those that have occurred are considered minimal (due to grease). There does not seem to be any problem with obtaining spare parts. However, no design or construction drawings are available to help with the operation and maintenance of the plant, and the basic skills required to operate and maintain the plant, such as some knowledge of microbiology, some electrical/mechanical skills to repair the equipment, and some understanding of the treatment process and the impact of poor performance on the whole scheme, are generally lacking.

Considering the small size of most packaged wastewater treatment plants, it may not be cost-effective for each hotel to employ a qualified operator. However, it might be possible for a number of hotels to employ collectively one qualified operator to look after a number of plants. Alternatively, the Barbados Hotels and Tourism Association (BHTA) could employ an environmental officer or sanitary engineer to oversee or advise the various hotels on wastewater treatment and effluent reuse.

The operation and maintenance required consists of turning the pumps that do not run continuously (such as the sludge pumps) on and off, and checking to ensure that all systems are running smoothly without any blockages. There are no flow meters installed and no laboratory facilities of any kind are provided to document the technical performance of the plant. Any operational monitoring of plant and process by the operator is limited to visual inspections. Plant performance is evaluated by the operator on the basis of the color of the mixed liquor in the aeration chamber; a brownish color is an indicator of good performance. Nevertheless, BOD and TSS analyses are done monthly during inspections by the EED.

Level of Involvement

The only government involvement in this program is licensing, monitoring and administrative control, exercised through the EDD, which is charged with the responsibility of approving and monitoring the performance of packaged wastewater treatment plants. The Sam Lord's Castle Hotel plant is entirely privately owned and operated, except for the monthly inspections and sampling for BOD and TSS conducted by the EED.

Costs

As this plant is privately owned and operated, cost figures are not available.

Effectiveness of the Technology

Based on 1989 and 1990 results, BOD and TSS removal efficiencies of 86%, and of 98% and 83%, respectively, are achievable. Data on the microbiological quality of the effluent are not available; two chlorine tablets are put into the chlorination chamber each week, regardless of effluent quality or quantity. Hence there is need to evaluate in detail the effectiveness of the disinfection before the effluent is used for irrigation. However, from an aesthetic point of view, the irrigation of lawns and plants seems to be very successful, as evidenced by the lush greenery surrounding the hotel. This is a great improvement compared to the period before the effluent reuse program was put into place.

Figure 46. Wastewater Treatment Process for Sam Lord's Castle.

Source: John Bwalya Mwansa, Project Manager, Barbados Water Resources Management & Water Loss Studies, Barbados Water Authority.

Suitability

The applicability of this technology depends on the nature of the land. In Barbados, owing to the karstic nature and topography of the coral rock aquifer system, groundwater contamination by reused wastewater can be avoided only if the wastewater is properly treated. At present, there are very few facilities with a suitable effluent quality. However, the hotels in the belt along the south and west coast, downgradient from the line of public water supply wells, would be obvious candidates for application of this reuse technology, posing the least danger of contamination to the groundwater. The hotel belt also has the advantage of being situated next to the BWA wastewater treatment plants.

Advantages

- The use of the treated effluent results in substantial savings in irrigation water costs and reduces the likelihood of water pollution, assuming that the effluents would otherwise have been disposed of through sea outfalls.

- This technology eliminates the need to use potable water supplied by the BWA public domestic supply system for irrigation and makes it available for other uses.

Disadvantages

- Inadequate operation and maintenance may pose some health risks.

- The WHO criteria on wastewater reuse for recreational purposes with possible human contact may not be fully met in this case. These criteria (effluents should not contain more than 100 coliform organisms/100 ml in 80% of samples, and should not contain chemical contaminants that lead to the irritation of mucous membranes and skin) require primary and secondary treatment and sand filtration, or the equivalent. Provision of such treatment would significantly increase the cost of this technology.

- The potential environmental impacts associated with this technology are contamination of groundwater, human skin irritations caused by bacteria or viruses in inadequately disinfected effluent sprayed on lawns or gardens, and mineral buildup (salination) in the soil, none of which are currently monitored on an adequate and continuous basis. (Because of the proximity of the application area to the coast, there is little risk to the domestic groundwater supply from the Sam Lord's Castle Hotel reuse scheme; however, the flow to the sea could still adversely affect the coastal marine ecosystem. In this case, the irrigation is timed to minimize the health risk to the hotel guests.)

Further Development of the Technology

The technology is well developed; however, local engineers and scientists need to familiarize themselves with it and evaluate its suitability for use elsewhere in Barbados, with any necessary modifications. There is also a need to evaluate the effectiveness of the disinfection process (chlorination by gas or chlorine tablets) in eliminating bacteria and viruses. It is very probable that, in future, more hotels will want to reuse effluent from the packaged treatment plants, especially in the light of proposals to change the domestic water tariff structure. Special training programs, in association with the BWA wastewater treatment facilities, should be developed to improve plant performance and monitoring.

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5.7 Clay pot and porous capsule irrigation in Brazil

Subsistence farmers in the tropical, semi-arid parts of Brazil depend on rainfall to provide water for the growth of most of their crops. In years of low rainfall, agricultural production is severely affected. To make matters worse, most agricultural plots in this region cannot be served by conventional systems of irrigation because of the huge volume of water that would be required. To overcome these difficulties, Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) introduced the use of porous or clay pot irrigation systems in Brazil in 1978. These systems have contributed to ensuring steady or even higher agricultural output owing to the highly efficient and economical use of water. A system of this kind was used centuries ago by the Romans, and initial experience in Brazil suggests that different varieties of plants can thrive in normal, saline, and saline-sodic soils on small amounts of water using the clay pot technology. Water use is roughly equivalent to 17 mm/ha/800 pots over a period of 70 days (Modal, 1978). This technology is described in Part B, Chapter 4, "Water Conservation."

Technical Description

- Clay Pot Irrigation

The clay pot system of irrigation, which consists of individual pots or a series of pots connected with plastic tubing, is easy to install, operate, and maintain. The main components of the system are shown in Figure 37.

A main supply line connects the raw water source (a reservoir, tank, pit, dam, etc.), by way of a storage tank and sand filter, to the series of clay pots, which are joined together with ½″ diameter polyethylene tubing. The water level in the pots is kept steady by a system of float valves. The pots, similar to the tanks used to store drinking water in the home, are generally conical in shape and can hold 10 to 121 of water. They are typically made of clay and baked in home ovens by individual craftsmen. Because each is handmade, they will not all have the same volume. These pots, in turn, may be connected to a row of secondary storage pots which are connected to load pots in the main row. The secondary pots are installed in curved lines and are used to grow different crops.

Before the pots are set up, the soil must be prepared enough to mark out the curved lines where the pots in the secondary line of supply are to be placed. Holes are dug at the desired distance apart to accommodate the pots in the main and secondary lines. Manure from the farm is added at this time, if necessary. Then one pot is placed in each hole and the tubing is attached with an epoxy glue. The tubing is aligned in a small furrow, about 8 cm deep, so that it can be fully covered with soil. It is essential that the pots in the second row be aligned parallel to the gradient so that the water in each pot is kept at the same level.

The clay pot method of irrigation should only be used on small plots of up to one hectare because the pots do not usually release the same volume of water. The system is recommended for home vegetable gardens (10 to 20 pots) and for small orchards in rural communities. The steps involved in setting up a family vegetable garden include:

- Choosing an area with regular to clayey soils to a depth of more than 1 m situated near a water source with a good supply of clean water (without clay particles in suspension).

- Marking out one or two 10 m x 1 m beds in the area selected and digging circular holes 80 cm in diameter and 60 cm deep, about 1 m apart from center point to center point. This will be large enough for 10 clay pots to be placed in each bed. The soil removed should be left beside the hole. Likewise, the soil in the 40 cm strip running from the edge of one hole to the edge of the next and in a 20 cm strip around the borders of the beds should be removed to a depth of 30 cm to take the "wet bulbs" of the clay pots, and left beside the bed.

- Breaking up the soil that has been dug up into pieces of less than 1 cm in diameter, and mixing it with at least 50 kg of manure for each bed.

- Placing the soil-manure mixture in the bottom of each hole to a depth of 30 cm.

- Inserting a porous clay pot 30 cm in diameter and 50 cm high, with a 10 to 12 l capacity, into the center of each hole and filling the rest of the hole with the soil-manure mixture, leaving just the neck of the pot protruding. In the case of heavy clay soils, a fine layer of sand should be placed around the pot.

- Filling the pots with clean water; muddy water or water with clay particles should never be used as the silt particles will interfere with the porosity of the clay vessels.

- Planting vegetable seeds in the bed in the same way as in traditional vegetable gardens. The seeds should be irrigated two or three times a day until germination, which usually takes about 6 days, depending on climatic conditions.

Three days after the pots are initially filled with water, six to eight holes are dug about 2 m to 4 m from the side of each pot for the final planting of the seedlings. The hole should be covered with dry soil and irrigated daily. The pots are refilled with water every day until the seeds or seedlings are able to survive on their own using just the regular release from the clay pots. The same procedure is used for seedlings that are planted directly.

The clay pots should release, on average, at least 3.5 l/day of water each day, although, to start with, as much as 20 l of water may be released. (The important thing is for the pots to be able to release a minimum of 3.5 l/day during the period when the need for water is greatest.) In areas where the clay pots are not baked in closed ovens, sand should be added to the clay mixture to make them more porous.

- Porous Capsule Irrigation

This method is technologically a little more sophisticated than the previous method. It has the advantage of a standard volume for each capsule. Each capsule is also more porous and releases more water. As in the clay pot technology, the capsules are made from a clay mixture. They are reddish brown and conical, with sides about 60 mm thick.

The Center for Research in Tropical Semi-Arid Regions (CPATSA) of Brazil has conducted comparative studies of the capsules used in this technology and has found that Mexican pots have four openings: two at the top and two at the bottom. They are made of pure, nonexpandable clay and are baked in ovens at 850°C. They can hold 600 cm^3 of water and have a porosity of 18% (Santos, 1977). In contrast, the capsules currently in use in Brazil have a 700 cm^3 capacity with a mechanical resistance of 5 kg/cm^2, a porosity of 21%, and two connector spouts at the top. They are commercially made from a mixture of plastic and elastic materials, and baked in closed tunnel ovens at 1120°C. These units can accommodate higher volumes of water and release an average of 5 l/day. They are set in 100 m rows, making them easy to join together. This makes the system economical to install and eliminates the need for a hose (Silva et al., 1981).

The basic components of this system are shown in Figure 38. The storage area of the system consists of a receptacle (a home-made clay pot will do) that can hold 10 to 12 l. A float keeps the water level inside the pot constant. This level then creates the pressure head, which is the difference between the surface level of the water in the reservoir and the average level in each porous pot. The main supply line, consisting of

1" polyethylene tubing, connects the porous pots to this storage reservoir. The porous pots are placed in a series joined together in a curve parallel to the contour, or at a slight incline when the lines exceed 100 m in length, and are connected to the main supply line. This method of irrigation does not require a conventional motor to pump the water; it is distributed automatically and continuously, in direct proportion to the difference in potential between the water level in the pot and the soil surface and inversely proportional to the resistance created by the porosity of the pot.

Extent of Use

Given their limitations in terms of area served and volume of water, irrigation systems of this kind ought to be used mainly on small family farms. The technology is used at present for irrigating small farm plots, small orchards, and small-scale horticultural operations.

Operation and Maintenance

Water is automatically and continuously released owing to the difference in potential (head) between the water level in each unit and the dry soil. As the plants take in water from the soil, the potential between the soil and the irrigation pots increases, causing water to flow directly to the soil and supply the needs of the crop. This system is easy to operate and maintain.

If the required volume of water is not released, this can be corrected by drilling four small (1.5 mm-diameter) drainage holes at regular intervals in the side of the pot, about 10 cm to 15 cm below the soil level. In any case, the pot gradually loses its original capacity to release water after long periods of use. When this occurs, the user has two alternatives: the pot's original capacity to release water can be restored by baking it once more in the oven, or it can be replaced with a new one.

Level of Involvement

The government of the state of Pernambuco recently established a porous pot manufacturing plant, and capsule set up irrigation units on a number of small farms using this system to irrigate the main food crops such as maize and beans. Most clay pot/porous capsule irrigation systems are constructed privately by individual landowners.

Costs

The average cost of an irrigation system is approximately $1 300/ha for an orchard and $1 800/ha for a vegetable garden. Representative costs are shown in Tables 24 and 25 for the two technologies.

Effectiveness of the Technology

Water is released automatically from both the clay pots and porous capsules, as the process of evapotranspiration occurs. As a result, water is not lost through percolation or surface runoff as is the case with conventional irrigation systems. Hence, the system is extremely effective. However, it is limited to small-scale operations at present.

Suitability

This system can be used on agricultural plots that do not have access to water for conventional irrigation methods. It has been well accepted in the semi-arid regions of northeastern Brazil. EMBRAPA reports that the systems have also been well received in other parts of Latin America.

Table 24 Installation Costs of a Clay Pot Irrigation System on a 0.2 ha Plot

Item	Quantity	Total cost ($)
Clay pots	166	73.78

½" diameter plastic tubing	800 m	118.52
Tailpiece	0.8 kg	11.85
Float	7	5.19
Labor (digging)	12 person-days	35.56
Other		22.52
Total		267.42

Table 25 Installation Cost of a Porous Capsule Irrigation System on a 1 ha Plot

Item	Quantity	Total cost ($)
Porous pots	2500	745.00
½" diameter plastic tubing	2500 m	815.00
1" diameter plastic tubing	100 m	23.00
Tailpiece	4 kg	60.00

Tailpiece	4 kg	60.00
Labor	50 person-days	150.00
Total		1793.00

Advantages

- This technology results in an economical use of water, since losses due to percolation and surface runoff are eliminated.

- Water is distributed evenly through the soil, which is highly conducive to plant growth.

Disadvantages

- With the clay pot system, water may not be released at the same rate from all the pots; since they are handmade by individual craftsmen, there is little control over the proportions of materials used.

- In the case of porous capsules, even though the proportions of materials used can be better monitored, the amount of water released gradually diminishes over time. This problem can be minimized by ensuring that clean water is used at all times, so that water with particles in suspension does not pass through the sides of the pot.

Further Development of the Technology

Research is being carried out to increase the useful life of the system for producers in rural areas, and to develop economical variations of this technology that can be used commercially.

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Annex 2 List of participants in the Lima and Barbados workshop

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Annex 3 Contributions by workshop participants

B. Workshop on alternative technologies for freshwater augmentation in the Caribbean

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A. Workshop on alternative technologies for freshwater augmentation in Latin America

Lima, Peru, 19-22 September 1995

CONTRIBUTIONS PRESENTED BY THE PARTICIPANTS

Country	Participant	Technology Profiles	Case Studies
Argentina	Nicolás Ciancaglini	- Artificial recharge of aquifers	Irrigation using clay pots in Mendoza
		- Desalination using reverse osmosis	
		- Irrigation using clay pots	
	Valeria	- Artificial recharge of	Reuse of

	Valeria Mendoza	- Artificial recharge of aquifers	Reuse of domestic effluents for irrigation in Mendoza
		- Water management model using conservation	
		- Reuse of domestic effluents for irrigation	
		- Optimization of water resources	
		- Management of potable water systems	
		- Utilization of surface water in dams	
	Eduardo Torres	- Rainwater harvesting roofs/cisterns	Natural and artificial recharge of underground
		- Rainwater harvesting (natural low areas)	

		- Use of well buckets in groundwater extraction	reservoirs in Mendoza
		- Artificial recharge of aquifers	
	Alberto Vich	- Rainwater harvesting (paved roads)	Water traps for runoff diversion, rainwater harvesting, and recharge of aquifers in mountain areas
		- Rainwater harvesting and aquifer recharge	
	Adrián Vargas	- Utilization of river beds	Utilization of river beds in Santiago del Estero
Bolivia	Freddy	- Hand pumps	Use of hand

	Camacho V.	- Use of desalination in irrigation	pumps in the high plateau of Bolivia
		- *Totora* as a water quality treatment agent	
		- Use of native products in clarifying water	
		- Irrigation using clay pots	
Brazil	Everaldo R Porto	- Rainwater harvesting (roofs/cisterns)	Use of rural cisterns in northeastern Brazil
		- Rainwater harvesting (paved and unpaved roads)	
		- Irrigation with clay	

	pots and porous capsules	
Luiza T. de L. Brito	- Rainwater harvesting (in situ)	Underground dams in northeastern Brazil
	- Runoff collection and storage (dams/dikes)	
	- Underground dams	
Pedro C.S. Mancuso	- Use of continuous vertical reactors for wastewater treatment and reuse	Continuous vertical reactors
Marco Antonio Palermo	- Runoff collection and storage	Optimization of runoff storage and distribution in the state of Sao Paulo
	- Water basin diversion and reuse	
	- Reuse and utilization of saline waters	
Claudison	- Desalination using	Desalination of

	Rodrigues	reverse osmosis	well water in northeastern Brazil using reverse osmosis
		- Desalination using solar distillation	
		- Desalination using electrodialysis	
	Gertjan B. Beekman	- VLF-WADI method to locate fractures in crystalline rocks	Small systems of dams in river basins of Paraiba
Chile	Roberto Espejo Guasp	- Fog harvesting (Camanchacas)	Water supply using fog harvesting in Poposo, Chile
		- Desalination using reverse osmosis	
		- Desalination using distillation	
		- Treatment and	

		recycling of non-potable water	
	Johannes Wrann	- Fog harvesting (camanchacas)	Rainwater harvesting and utilization of surface water runoff from sloping watersheds for forestation in Chile
		- Rainwater harvesting	
Colombia	Guillermo Sarmiento	- Wastewater treatment technologies	Biological treatment of domestic wastewater using hydroponic cultivation and

			comparison with other wastewater treatment technologies in Colombia
Costa Rica	Jorge Faustino Manco	- Rainwater harvesting (roofs/cistems)	Runoff storage in irrigation ditches in various regions of Central America
		- Water conservation agricultural practices	
		- Runoff storage in irrigation ditches	
		- Use of lagoons for runoff collection and storage	
	William Murillo	- Comprehensive utilization of water	Comprehensive use of surface

	Montero	resources (basin transfer)	water resources in Costa Rica (water transfer from the Arenal to the Tempisque river basin)
		- Sustainable use of aquifers	
		- Efficient use of irrigation methods in small areas (use of pressurized systems)	
Dominican Republic	Milagros Martinez Esquea	- Rainwater harvesting using house roofs	Irrigation with interconnected clay pots in Dominican Republic
		- Irrigation with clay pots	
	José O. Payero	- Artificial lagoons	Home water purification systems in Dominican Republic
		- Rainwater harvesting using collection pipes	
		- Cloud seeding	
		- Water distribution by	

		cistern trucks	
		- Bottling of water	
		- Development of small watersheds	
		- Water storage in homes	
		- Water purification systems	
		- Wastewater treatment technologies	
Ecuador	Felipe Cisneros Espinoza	- Rainwater harvesting	Rainwater harvesting through runoff storage in reservoirs in the southern region of
		- Distribution of potable water	
		- Water transfer by pumping	
		-	

		Disinfection/purification - Use of clay pots in irrigation	Ecuador
El Salvador	Saul Rodríguez	- Cyclic rope pump - Chlorine production *in situ* - Home made artesian filters - Potable water by filtration using slow sand dripping filters	Utilization of cisterns for rainwater harvesting in El Salvador
Guatemala	Luis Alfredo Ochoa	- Rainwater harvesting - Water purification using sodium hypochlorite in rural areas - Stabilization lagoons	Use of potable water from rainwater harvesting in Guatemala

		(Jacintos)	
		- Water quality treatment using seeds *of Monringa oleifera*	
		- Pilot project on the use of pre-filters	
		- Irrigation with treated water	
Honduras	Emesto Bondy Reyes	- Rainwater harvesting (roofs, cisterns, and lagoons)	Rainwater harvesting using roofs, cisterns, and lagoons in Honduras
		- Rope and bucket homemade wells	
		- Use of mulch to control soil humidity and sediments	
		- Photovoltaic energy	

		for pumping systems	
		- Alternative pumping systems	
Mexico	Polioptro F Martinez	- Fog harvesting	Non-conventional devices for use in intermittent irrigation in Mexico
		- Quarry filters	
		- Gravitational tank irrigation system	
		- Device for intermittent irrigation in furrows	
	Carlos Solís Morelos	- Stabilization lagoons	Modified stabilization lagoon system for municipal wastewater treatment in the Lerma

			River basin in Mexico
Nicaragua	Javier García Romano	- Microbasin management	Microbasin management in Nicaragua
Panama	Icela Márquez de Rojas	- Mini-dams - Irrigation with clay pots - Agriculture and aquaculture water use	Utilization of spring waters for rural aqueducts in Panama
	María Concepción Donoso	- Water recycling in rice cultivation and aquaculture system - Drip irrigation - Use of wind energy for pumping systems - Aqueducts	Utilization of wind energy to augment water supply in the central provinces of Panama

Paraguay	Eugenio Godoy Valdovinos	- Rainwater harvesting using roofs and cisterns	Artificial recharge ofgroundwater in Central Chaco in Paraguay
		- Rainwater harvesting using cultivation	
		- Artificial recharge of groundwater	
Peru	Hugo Rodríguez	- Harvesting use and storage of water with raised beds (Waru Waru) cultivation	The agro-ecosystem of Waru Waru: an alternative technology for agricultural development in the plateau of Puno
	Juan Ocola	- Wastewater	Treatment in

	Salazar	treatment using native plants *(totora)*	oxidation lagoons using native plants (Totora) in Puno
	Pablo Sánchez		Poncho Verde project in Cajamarca
	Miguel Hadzich Marín		Pumping systems in Peru
Uruguay	Lourdes Batista	- Utilization and regulation of watersheds	Regulation, water use, and development plan for the region of Rocha in

			Uruguay
Venezuela	Carmen Fermín Regardiz	- RunotF collection and storage using road dikes	Use of road dikes in the state of Nueva Esparta
		- Artificial lagoons	
		- Storage tanks with galvanized plates	
		- *Toroba*	
	Hernán López Herrera	- River basin rehabilitation	Rehabilitation of the Moron River basin in Venezuela
CEPIS/OPS	Julio Moscoso		Use of effluents from stabilization lagoons in aquaculture

			and agriculture in San Juan, Peru

B. Workshop on alternative technologies for freshwater augmentation in the Caribbean

Barbados, October 24-27,1995

CONTRIBUTIONS PRESENTED BY THE PARTICIPANTS

Country	Participant	Profiles of Technology	Case Study
Antigua and Barbuda	Vincent Sweeney	- Transportation of water by barges - Desalination: reverse osmosis and distillation	
Aruba	Theofilo	- Desalination:	Rainwater

Aruba	Theofilo Damian	- Desalination: multistage flash evaporation system - Wastewater treatment	Rainwater harvesting in dams for agricultural purposes in Aruba
Bahamas	Cadrington Coleby	- Desalination: reverse osmosis - Trench wells for groundwater extraction - Barging	Barging/tanking water from neighboring islands in the Bahamas
Barbados	John Bwalya Mwansa	- Rainwater harvesting - Surface runoff impoundments - Artificial	Sam Lord's Castle Hotel's treated wastewater reuse scheme, Barbados

		recharge of groundwater	
		- Wastewater treatment and reuse	
British Virgin Islands	Rajkumar Roopchand*	- Rainwater harvesting	Implementation of seawater desalination on the island of Virgin Gorda
		- Seawater/brackish water desalination by reverse osmosis	
Haiti	Bernardine Georges*	- Rainwater harvesting	Rainwater cistern in Miragoane, Haiti
		- Hand pumps	
		- Winch	
	Michael		Photovoltaic

	Merisier		system to pump water in St. Jean du Sud, Haiti
Jamaica	Basil Fernandez	- Rainwater harvesting	Artificial groundwater recharge of a karstic limestone aquifer using sinkholes as injection points in Jamaica
		- Transportation of water by pipeline; interbasin transfer	
		- Artificial recharge of groundwater	
		- Wastewater treatment and reuse	
		- Recycling of	

		industrial effluent	
Montserrat	Margaret Dyer-Howe	- Rainwater harvesting	Floating chlorinator and gas chlorinator in Montserrat
Netherlands Antilles	Martha Pinedo-Medina	- Rainwater harvesting - Artificial recharge of groundwater - Wastewater treatment	Water desalination by distillation in Curaçao (multistage flash evaporation system)
Saint Lucia	Vincent Sweeney	- Rainwater harvesting - Root zone wastewater treatment	Root zone wastewater treatment in Saint Lucia

		- Dual distribution system	
	Martin Satney	- Rainwater harvesting - Runoff harvesting - Wastewater reuse	Transportation of water by canal/pipeline for irrigation in Saint Lucia
Suriname	Moekiran Amatali	- Rainwater harvesting - Storage in natural wetlands - Storage in dammed-up feat lands	The use of the manmade Lake Brokopondo in Suriname
Turks and Caicos	Joseph Williams	- Rainwater harvesting	Rainwater harvesting in

Islands		- Desalination; reverse osmosis	the Turks and Caicos Islands
		- Dual distribution systems	
		- Groundwater exploration	
U.S. Virgin Islands	Henry Smith	- Rainwater harvesting	Mandatory rainwater harvesting for residential use in the U.S. Virgin Islands
		- Dual distribution system	
		- Desalination	

* Mr. Rajkimar Roopchand and Ms. Bernardine Georges were not able to participate in the workshop, but sent their contributions.

Annex 4 Table of conversion factors for metric and english units

This water-quantity equivalents and conversion factor list is for those interested in converting units. The right-hand column includes units expressed in two systems - U.S. Customary and International System (metric). Units, which are written in abbreviated form below, are spelled out in parentheses the first time they appear. To convert from the unit in the left-hand column to that in the right, multiply by the number in the right-hand column. Most of the quantities listed were rounded to five significant figures. However, for many purposes, the first two or three significant figures are adequate for determining many water-quantity relations, such as general comparisons of water availability with water use or calculations in which the accuracy of the original data itself does not justify more than three significant figures. Quantities shown in italics are exact equivalents - no rounding was necessary. Regarding length of time, each calendar year is assumed (for this list) to consist of 365 days.

U.S. Customary	U.S. Customary or Metric
Length	
1 in (inch)	= *25.4 mm (millimeters)*
1 ft (foot)	*0.3048 m (meter)*
1 mi (mile, statute)	= *5 280 ft*
	= *1609.344 m*
	= *1.609344 km (kilometers)*

	= 1.609344 km (kilometers)
Area	
1 ft^2 (square foot)	= *0.09290304 m^2 (square meter)*
1 acre	= *43 560 ft^2*
	= *0.0015625 mi^2*
	= *0.40469 ha (hectare)*
1 mi^2	= *640 acres*
	= *259 ha*
	= *2.59 km^2 (square kilometers)*
Volume or Capacity (liquid measure)	
1 qt (quart, U.S.)	*0.94635 l (liter)*
1 gal (gallon, U.S.)	
	= 231 in^3 (cubic inches)

	= *0.13368* ft^3 *(cubic foot)*
	= *3.78541*
	= *0.0037854* m^3 *(cubic meter)*
1 Mgal (million gallon)	= *0.13368* Mft^3 *(million cubic feet)*
1 Mgal	= *3.0689 acre-ft (acre-feet)*
	= *3.785.4* m^3
1 ft^3	= *1.728* in^3
	= *7.4805 gal*
	= *28.317 l*
	= *0.028317* m_3
1 Mft^2	= *28,317* m^3
1 acre-ft (volume of water,	
	= *43,560* ft^3

1 ft deep, covering an area of 1 acre)	= *0.32585 Mgal*
	= *1,233.5 m^3*
1 mi_3 (cubic mile)	= *1,101.1 billion gal*
	= *147.20 billion ft^3*
	= *3.3792 million acre-ft*
	= *4.1682 km_3 (cubic kilometers)*
Speed (or, when used In a vector sense, velocity)	
1 ft/s (foot per second)	= *0.3048 m/s (meter per second)*
	= *0.68182 mi/hour (mile per hour)*
1 mi/hr	= *1.4667 ft/s*
	= *0.44704 m/s*
Volume per Unit of Time (discharge, water supply	

Volume per Unit of Time (discharge, water supply, water use, and so forth)	
1 gpm (gallon per minute)	*= 0.00144 mgd (million gallons per day)*
	= 0.0022280 ft^3/s (cubic foot per second)
	= 0.0044192 acre-ft/d (acre-fool per day)
	= 3.7854 l/min (liters per minute)
	= 0.063090 l/s (liters per second)
1 mgd	*= 694.44 gal/min*
	= 1.5472 ft^3/s
	= 3.0689 acre-ft/d
	= 1.120.0 acre-ft/d (acre-feet

	per year)
	= 0.043813 m^3/s (cubic meter per second)
	= 3.785.4 m^3/d (cubic meters per day)
1 billion gal/yr (billion gallons per year)	= 0.0013817 km^3/yr (cubic kilometer per year)
1 ft^3/s	= 2.73 97 mgd
	= 448.83 gal/min
	= 0.6463 2 mgd
	= 1.9835 acre-ft/d
	= 723.97 acre-ft/yr
	= 28.317 l/s
	= 0.028317 m^3/d

	= 2.446.6 m^3/d
	= 0.00089300 km^3/yr
1 acre-ft/yr	= 892.74 gal/d (gallons per day)
	= 0.61996 gal/min
	= 0.0013813 ft^3/s
	= 3.3794 m^3/d
1 acre-ft/d	= 0.50417 ft^3/s
Volume, Discharge, or Use per Unit of Area	
1 in of rain or runoff	= 17.379 Mgal/mi^2
	= 27.154 gal/acre (gallons per acre)
	= 25 400 m^3/km^2 (cubic

	[illegible] (cubic meters per square kilometer)
1 in/yr	= 047613 (Mgal/d)/mi^2
	= 073668 (ft/s)/mi^2
1 (Mgal/d)mi^2	*=21.003 in/yr (inches of rain or runoff per year)*
1 (ft^3/s)/mi^2	*= 13.574 in/yr*
	= 0.010933 (m'/s)/km^2 (cubic meter per second per square kilometer)
Mass (pure water in dry air)	
1 gal at 15° Celsius (59° Fahrenheit)	*= 8.3290 lb (pounds avoirdupois)*
1 gal at 4° Celsius (39.2° Fahrenheit)	*= 8.3359 lb*
1 lb	*= 0.45359 kg (kilogram)*
[illegible]	[illegible]

1 ton, short (2,000 lb)	= *0.90718 Mg (megagram) or ton, metric*

Prepared by John C. Krammer, U.S. Geological Survey (National Water Summary 1990-1991).

THE ORGANIZATION OF AMERICAN STATES

The Organization of American States (OAS) is the world's oldest regional organization, dating back to the First International Conference of American States, held in Washington, D.C., on April 14, 1890, This meeting approved the establishment of the International Union of American Republics. The Charter of the OAS was signed in Bogota in 1948 and entered into force on December 13, 1951. The Charter was subsequently amended by the Protocol of Buenos Aires signed in 1967, which entered into force on February 27, 1970, and by the Protocol of Cartagena de Indias, signed in 1985, which entered into force on November

16, 1988. The OAS currently has 35 Member States, In addition, the Organization has granted Permanent Observer status to 25 States in Europe, Africa and Asia, as well as to the Holy See and the European Economic Community.

The basic purposes of the OAS are as follows: to strengthen the peace and security of the continent; to promote and consolidate representative democracy, with due respect for the principle of nonintervention; to prevent possible causes of difficulties and to ensure the pacific settlement of disputes that may arise among the Member Slates, to provide for common action on the pan of those Stales in the event of aggression: to seek the solution of political, juridical and economic problems that may arise among them; to promote, by cooperative action, their economic, social and cultural development, and to achieve an effective limitation of conventional weapons that will make it possible to devote the largest amount of resources to the economic and social development of the Member States.

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The General Assembly holds regular sessions once a year. Under special circumstances it meets in special session. The Meeting of Consultation is convened to consider urgent matters of common interest and to serve as Organ of Consultation under the Inter-American Treaty of Reciprocal Assistance (Rio Treaty), the main instrument for joint action in the event of aggression. The Permanent Council takes cognizance of such matters as are entrusted by the General

Assembly or the Meeting of Consultation and implements the decisions of both organs when their implementation has not been assigned to any other body, it monitors the maintenance of friendly relations among the Member States and the observance of the standards governing General Secretariat operations and also acts provisionally as Organ of Consultation under the Rio Treaty. The purpose of the other two Councils is to promote cooperation among the Member States in their respective areas of competence, These Councils hold one annual meeting and meet in special sessions when convoked in accordance with the procedures provided for in the Charter. The General Secretariat is the central and permanent organ of the OAS. The headquarters of both the Permanent Council and the General Secretariat is in Washington, D.C.

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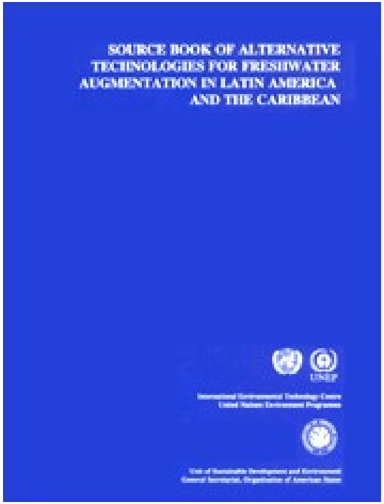
Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean



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Unit of Sustainable Development and Environment
General Secretariat, Organization of American States
Washington, D.C., 1997

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