WATER

India receives abundant rains. The average annual precipitation is estimated to be 4000 billion m^3. Only 1000 billion m^3/year is available as usable surface water and ground water. At present the water consumption in India is about 750 billion m^3/year for all the applications, viz. agricultural, industrial, domestic and commercial. Assuming a conservative figure of per capita water consumption of 1000 m^3/year, the water availability in the country is likely to get fully stretched by the year 2010 unless augmentation is planned right now. The consumption norm of 1000 m^3/year is only 10-20% of the per capita consumption in industrialized countries. Moreover, the geographical distribution and seasonal variation of rainfall are not uniform. There are pockets like Saurashtra and Kutch, the coastal areas of Tamil Nadu and land locked areas of Western Rajasthan and Marathwada in Maharashtra with scanty rainfall and perennial water scarcity. In addition, a large number of villages in various parts of the country are known to be suffering from excess salinity, fluoride, nitrate, iron, arsenic and microbial contaminations of ground water. These invariably lead to widespread water borne diseases and cause enormous hardships to the inhabitants. A holistic approach is therefore called for to cope with the fresh water needs of the country in the coming decades. These involve;

i) Large water supply schemes to meet the urban as well as rural needs of water for both irrigation and drinking, and piped water supply schemes for drinking water;

ii) Rain water harvesting and artificial recharge of ground water sources;

iii) Treatment of chemically and biologically contaminated ground water sources in rural areas for provision of safe potable water;

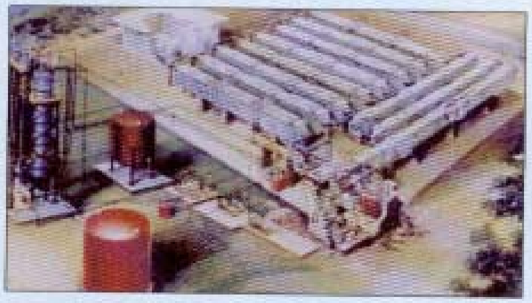
iv) Augmentation of water resources in coastal areas by large scale desalination of abundant sea water, and

v) Treatment of domestic/industrial effluents and recycling of usable water for irrigation and commercial purposes thereby diverting the water used in these areas for domestic consumption.

Government of India and concerned State Governments have launched a number of water supply schemes. These schemes invariably require huge capital expenditure and take long periods for completion. Desalination technology is a proven option to augment the water resources in the water scarcity areas. Bhabha Atomic Research Centre (BARC) has been engaged in R&D on desalination to develop indigenous technologies for providing fresh water from seawater in water scarce coastal areas and safe drinking water in salinity affected inland areas.

Technologies Developed

As a part of the programme for improving the quality of life of the large Indian population by systematic induction of nuclear energy, BARC has been engaged in R&D activities on desalination since 1970s. The development activities in the field of desalination were initially based on thermal processes. Later, the programme for development of membrane processes was also included in 1980s when this process showed sign of commercial viability. Over a period of time, BARC has successfully developed desalination technologies based on multi-stage flash (MSF) evaporation, reverse osmosis (RO) and low temperature evaporation (LTE). In the field of thermal desalination, efforts are directed towards utilizing the low grade heat and the waste heat as energy input for desalination. In membrane desalination, work is being carried out on newer pretreatment methods such as use of ultrafiltration, energy reduction and higher membrane life.



Artist's view of a Multistage Flash Plant

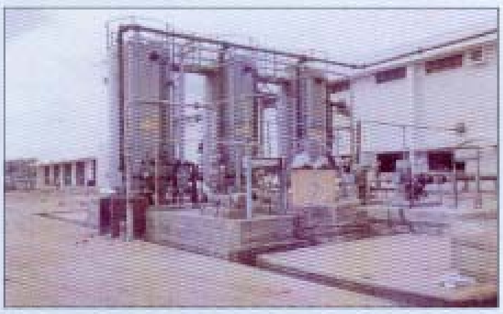
Reverse Osmosis Plant (Capacity : 30 cubic metre per day) set up at Sheelgan village, district Barmer, Rajasthan.

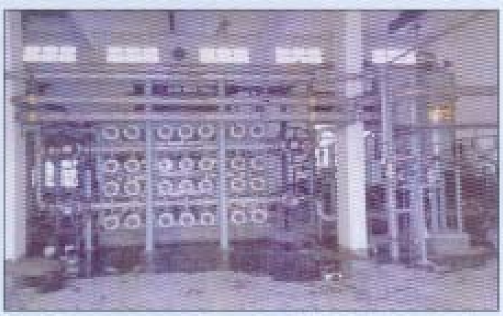
Based on these technologies, a number of desalination plants have been successfully demonstrated during the last few years. These include desalination plants for conversion of sea water into fresh potable water, providing safe drinking water in brackishness affected areas and for process applications (Table 1).

Table – 1: Pilot Plants set up by BARC	
Description	**Date of Commissioning**
I. Thermal	
1 15 m^3/d MSF experimental facility	1975
2 30 m^3/d low temperature evaporation unit	1985
3 425 m^3/d MSF plant	1990
II. Membrane	
1 2 x 30 m^3/d brackish water RO plants providing drinking water in villages of Andhra Pradesh & Gujarat	1984
2 50 m^3/d RO unit for industrial effluent treatment plant at RCF, Mumbai	1986
3 2 x 10 m^3/d RO units for treatment of radioactive liquid effluents at BARC, Mumbai	1990
4 15 m^3/d RO-DM plant at VECC, Kolkata for production of low conductivity water	1994
5 24 m^3/d nano-filteration plant for a pharmaceutical industry	1998
6 30 m^3/d brackish water RO plant providing drinking water in Sheelgan village,Barmer district, Rajasthan	1998
7 100 m^3/d sea water reverse osmosis (SWRO) plant at Trombay, Mumbai	1999
8 30 m^3/d RO plant providing drinking water in village Satlana village, Jodhpur district, Rajasthan	2003

Based on decades of operational experience of MSF and RO plants at Trombay, BARC has undertaken establishment of the Nuclear Desalination Demonstration Project (NDDP) at Kalpakkam, Tamil Nadu. NDDP consists of a hybrid MSF-RO desalination plant of 6300 m^3/d capacity (4500 m^3/d MSF and 1800 m^3/d SWRO) coupled to 2 x 170 MWe pressurised heavy water reactors at the Madras Atomic Power Station (MAPS), Kalpakkam. The requirements of seawater, steam and electrical power for the desalination plants are met from MAPS I & II which are around 1.5%, 1.0% and 0.5% of available at MAPS. The hybrid plant has provision for redundancy, utilization of streams from one to other and production of two qualities of products for their best utilization.

The sea water reverse osmosis (SWRO) plant which is already commissioned, operates at relatively lower pressure (51.5 bar during first year and 54 bar during third year) to save energy, employs lesser pre-treatment (because of relatively clean feed water from MAPS outflow) and aims for longer membrane life resulting in lower water cost. The MSF plant which is in advanced stage of completion is designed for higher top brine temperature with Gain to Output Ratio (GOR) of 9:1 and utilizes less pumping power (being of long tube design).





Sea Water Reverse Osmosis (SWRO) Plant building and membrane modules

The desalination plant can meet the fresh water needs of around 45,000 persons @ 140 lpcd (litres per capita per day) There is a provision of augmentation of product water capacity by blending the low TDS (total dissolved salt) product of MSF plant with brackish ground water/ moderate salinity permeate from SWRO plant. This will then serve the need of larger population. The overall water production cost for this plant is estimated to be 5 paise/litre. For large size plants it is likely to come down to about 4 paise/litre.

The Nuclear Power Corporation of India Limited (NPCIL) has recently put up two trains of SWRO plant, each of capacity 25 m^3/h (total capacity: 1200 m^3/d) at Kudankulam. The product water is primarily being utilized for construction and other water requirements at Kudankulam site. The SWRO plant includes pretreatment section, RO system along with energy recovery turbo unit.

Efforts at BARC are also directed towards the utilization of waste heat. The Centre has been studying the possibility of use of waste heat of nuclear reactors for seawater desalination using low temperature evaporation (LTE) technology. The know-how utilizing waste heat was developed and a 30 cubic metre/day pilot plant was installed. Such plants would be ideal for industries where waste heat is available in the form of flue gas and process heat. These plants can also produce fresh water from high salinity or sea water for the rural areas where waste heat from DG sets/ solar energy is available. The LTE plant has been connected to CIRUS reactor for demonstration of coupling to a nuclear research reactor. The product water from this plant after minor polishing will meet the make up water requirement of the research reactor .

Technologies under Development

Low Temperature Evaporation Plant at CIRUS

The desalination industry is witnessing numerous technological innovations so that these are available to the population in the water scarce areas. The X Plan project entitled **"Desalination Technology Studies and Development"** has been prepared to undertake some of these innovative features. These activities are planned to be taken up in mission mode to supplement the activities on desalination already carried out in the past. The successful completion of the project would lead to effective solutions for meeting the fresh water needs in the coastal as well as inland areas of the country. The main project entitled "Desalination Technology Studies and Development" consists of five sub projects:

Desalination by Centrifugal Reverse Osmosis

Centrifugal Reverse Osmosis (CRO) is a potential alternative to conventional reverse osmosis due to its energy efficiency and less maintenance requirement of the centrifuge. Compactness and energy efficiency even at smaller capacities makes it attractive proposition for small scale brackish water and seawater desalination units. The innovative idea to be carried out is the use of a rotor to achieve the required pressure across the RO module for desalination (10 m^3/d capacity). Enough expertise is available at BARC on rotor development that can be utilized for this purpose. This unit will not have high pressure pump which requires frequent maintenance leading to shutdowns of conventional RO plants.

Low Temperature Evaporation Desalination Plant with Cooling Tower

The project involves setting up of a 50 m^3/d low temperature evaporator using waste heat (hot water at around 65^{0}C). A cooling tower will be coupled to bring down the large cooling water requirements. Due to low operating temperature, this plant does not require any chemical pretreatment of the feed water. Such a unit can be installed in rural inland areas having high brackish water sources and coastal areas. It will produce high quality product water from high brackish water or seawater.

Multi-Effect Distillation Vapour Compression (MED-VC) Desalination Plants

The project involves setting up of a 50 m^3/d horizontal tube thin film (HTTF) evaporator unit. The unit will be coupled to vapour compressor to improve the performance. Such unit will not require large amount of cooling water that is normally needed for conventional thermal desalination plants. It produces very pure water.

Continuous Thin Film Composite (TFC) Membrane Casting Assembly

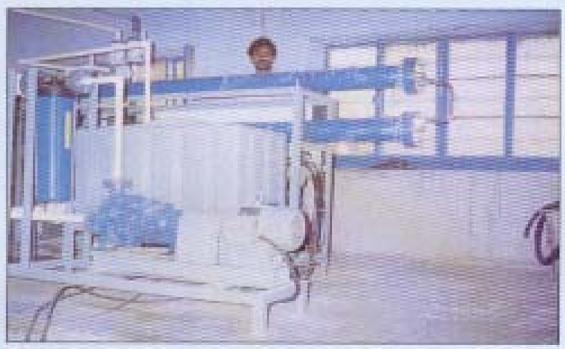
The membrane is the heart of a RO plant. Worldwide efforts are directed to synthesize membranes, which offer higher output without sacrificing the salt rejecting capablity. It is possible by making membranes with very thin rejecting barrier on a suitable porous support required for membrane integrity. These membranes are prepared by in situ interfacial condensation polymerization of suitable monomers. The casting of these membranes requires controlled casting parameters. A suitable continuous casting machine will be fabricated and used for this purpose.

Barge Mounted Reverse Osmosis Unit

It is proposed to develop and demonstrate the usefulness of barge mounted RO unit (Capacity: 50 m^3/d) for providing fresh potable water in isolated areas. The RO unit is installed on a barge. The high pressure pumps of RO unit are diesel operated.

Consultancy Services and Technology Transfer

BARC has actively participated in the Rajiv Gandhi National Drinking Water Mission (RGNDWM) and setup a number of small reverse osmosis plants in the villages during eighties. It also provided active support to the Mission in the water quality monitoring and analysed large number of water samples for the presence of brackishness, nitrate, fluoride, iron etc. from various affected districts of Andhra Pradesh, Karnataka, Maharastra, Gujarat and Rajasthan. In recent years, BARC has installed a RO plant at Sheelgan village, Barmer district, Rajasthan. In January 2003, the Centre has installed another plant at Satlana village, Jodhpur district, Rajasthan. This plant will also remove excess fluoride and nitrate alongwith the brackishness. The cost of such plants which provide drinking water to habitation of 1000 people is around 7 lakhs. The water cost comes out to about 3 paise/litre.



RO Plant at Satlana village, Jodhpur, Rajasthan

The knowhow of the RO technology has been transferred to a number of parties and they are manufacturing and supplying RO plants for various applications. The technology for on-line Domestic Water Purifier has also been developed and transferred to several parties. The technology for indigenous production of spiral membrane elements using sheet membranes has been developed. Commercial equivalents of elements have already been made. Efforts are in progress for standardizing and subsequent transfer of the technology for commercial exploitation.

Domestic water purifier

BARC has been interacting in recent years with the Government of Rajasthan, Government of Lakshadeep and Tamilnadu Water Board and will further expand this contact with Government of Gujarat, Maharastra, Andhra Pradesh and Karnataka. It has been providing consultancy services to several private parties and government undertakings. The mobile/ transportable desalination units based on RO & VC technology are in the advanced stage of development. Standardized modules both for RO (5-50 m^3/d) and small thermal desalination units (5-50 m^3/d) using waste heat (diesel or solar) specific to individual needs have been developed.

These technologies are available for deployment as soon as user and funding agency are ready. Deployment of X-Plan projects will further enhance the strength of BARC technologies to serve the societal cause.

Enough expertise is available for the design of large size MSF and RO plants for sea water desalination. Expertise is also available on utilization of low grade and waste heat for producing pure water from saline water. There is a serious interest in the country to put up a number of large size plants of million gallons per day capacity for brackish and sea water desalination, treatment of industrial effluents for water reuse as well as process stream concentrations.

The development work done at Trombay has generated capability to design, fabricate, commission and operate small and large size desalination plants indigenously. The technological innovations in desalination would lead to its large scale application and provide opportunities for the socioeconomic development of water scarcity areas and large coastal arid zones of the country.

Contact: *Head, Technology Transfer & Collaboration Division*
Bhabha Atomic Research Centre, Trombay

Phone : 022-25505337 Fax : 022-25505151